8th 2022 INTERNATIONAL CONFERENCE ON HIGH STRENGTH LOW ALLOY STEELS

NOVEMBER 9-11, 2022 | CHINA

HSLA STEELS 2022

TECHNICAL PROGRAM

Organized by
The Chinese Society for Metals

Co-organized by
Ansteel Group

Supported by
CBMM | Niobium, CITIC Metal
Vanitec Limited
Vanadium Application Technology Promotion Center, CISRI
Nanjing Iron & Steel Co., Ltd.

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Technical Program Timetable

WEDNESDAY, 9 NOVEMBER 2022, GMT+8 (Beijing)

Plenary Sessions	Room A, Zoom Link: TBD
Plenary Session 1 8:30-12:05	Chairs: Aimin Guo, Caifu Yang
Plenary Session 2 14:00-17:15	Chairs: Chengjia Shang, Zhongzhu Liu

THURSDAY, 10 NOVEMBER 2022, GMT+8 (Beijing)

Room: B Zoom Link: TBD	Room: C Zoom Link: TBD	Room: D Zoom Link: TBD	Room: E Zoom Link: TBD
B1 8:30-11:20 **Physical Metallurgy and Properties** Chairs: Zhinan Yang Zhongwu Zhang	**C1** 8:30-12:10 **Niobium Microalloyed Steels Helping the Dematerialization in Civil Construction** Chairs: Marcos Stuart Caihua Cheng Weibiao Yang Alexandre Magnus Jordão	**D1** 8:30-11:45 **Shipbuilding, Offshore Engineering and Vessel Steels** Chair: Xuehui Chen	**E1** 8:30-11:40 **Automotive and Special Steels** Chairs: Hai-wen Luo Li Wang
B2 14:00-17:15 **Physical Metallurgy and Properties** Chairs: Hardy Mohrbacher Xuemin Wang	**C2 14:00-17:20** **Construction Steels** Chairs: Houxin Wang Yongqing Zhang	**D2 14:00-16:55** **Shipbuilding, Offshore Engineering and Vessel Steels** Chairs: Zhenjia Xie Linxiu Du	**E2 14:00-17:35** **Automotive and Special Steels** Chair: Hongzhou Lu

FRIDAY, 11NOVEMBER 2022, GMT+8 (Beijing)

Room: B Zoom Link: TBD	Room: C Zoom Link: TBD	Room: D Zoom Link: TBD	Room: E Zoom Link: TBD
B3 8:30-11:35 **Physical Metallurgy and Properties** Chairs: Jianchun Cao Jingliang Wang	**C3** 8:30-11:50 **Low Temperature Steels** Chairs: Shan Gao Zhenyu Liu	**D3 8:30-11:25** **Pipeline Steels and Welding** Chairs: Marcos A. Stuart Nogueira Chunyong Huo	**E3 8:30-11:20** **Automotive and Special Steels** Chair: Wenjun Wang
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Plenary Session I

WEDNESDAY, 9 NOVEMBER 2022, GMT+8 (BEIJING) 8:30-12:05 ROOM A, ZOOM LINK: TBD		
Chairs: Aimin Guo, CITIC Metal Co.,Ltd., China Caifu Yang, Central Iron & Steel Research Institute, China		
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8:50-9:25	Advance of HSLA Steels in China **Zhiling Tian**, The Chinese Society for Metals, China	P24
9:25-10:00	Recent Developments in the Science and Technology of Zinc-Coated HSLA Steels **Frank E. Goodwin**, Ana P. Domingos, International Zinc Association, Durham, NC USA	P24
10:00-10:20 Break		
10:20-10:55	Niobium Microalloyed Steels – an Enabling Solution towards a Sustainable Future for the Built Environment **Ricardo Fonseca de Mendonça Lima**[1], Marcos Alexandre Stuart Nogueira[2], Jitendra Patel[3] 1. CEO - CBMM, Brazil; 2. Consultant - CBMM, Brazil; 3. Consultant - CBMM Technology Suisse S.A., Switzerland	P24
10:55-11:30	Revisit TWIP and TRIP in Steel **Mingxin Huang**, The University of Hong Kong, Hong Kong, China	P24
11:30-12:05	A Half-Century of Innovation in Niobium-Containing Automotive Sheet Steels **J.G. Speer**[1], E. De Moor[1], K.O. Findley[1], L. Wang[2] 1. Colorado School of Mines, USA; 2. Baosteel R&D Center, China	P24

Plenary Session 2

WEDNESDAY, 9 NOVEMBER 2022, GMT+8 (BEIJING) 14:00-17:15 ROOM A, ZOOM LINK: TBD		
	Chairs: Chengjia Shang, University of Science & Technology Beijing, China **Zhongzhu Liu, CITIC Metal Co., Ltd., China**	
14:00-14:35	**Role of Niobium Microalloying for Hydrogen Trapping in Steels: An Atomic-Scale Investigation** **Julie Cairney**[1,2], Yisheng Chen[1,2], Hongzhou Lu[3], Aimin Guo[3] 1. Australian Centre for Microscopy and Microanalysis, The University of Sydney, Sydney, NSW, Australia; 2. School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, Sydney, NSW, Australia; 3. CITIC Metal, Beijing, China	P25
14:35-15:10	**Current Status of Development of High-Strength Steel Sheets and Application Technologies Contributing to Automobile Weight Reduction** **Yasunobu Nagataki**, JFE Steel Corporation, Japan	P25
15:10-15:45	**Eco-friendly Steel Products for a Low-carbon Society** **Seok Jong Seo**, POSCO, China	P25
	15:45-16:05 Break	
16:05-16:40	**Assessing the Role of Vanadium Technologies in Decarbonizing the Construction Industry** **Sarbajit Banerjee**, Texas A&M University, USA	P25
16:40-17:15	**The Use of Vanadium in High Strength Low Alloy Steels** **David Crowther**, Yu Li, Vanitec	P26

B1 Physical Metallurgy and Properties

THURSDAY, 10 NOVEMBER 2022, GMT+8 (BEIJING) 8:30-11:20 ROOM B, ZOOM LINK: TBD		
	Chairs: Zhinan Yang, Yanshan University, China Zhongwu Zhang, Harbin Engineering University, China	
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8:55-9:20	*Invited* **Study on Gradient Microstructure and Properties of Low Density Steels** **Xuemin Wang**[1], Dan Liu[2], Xiangyu Xu[3] 1. University of Science and Technology Beijing, Beijing, China; 2. NCS Testing Technology Co., Ltd., Beijing, China; 3. Shanghai University, Shanghai, China	P27
9:20-9:40	**Contribution of grain boundary misorientation to intragranular globular austenite reversion and resultant in grain refinement in a high-strength low-alloy steel** **Xuelin Wang**[1,2], Zhiquan Wang[1], Anran Huang[1], Sundaresa Subramanian[3], Chengjia Shang[1,2], Zhenjia Xie[1] 1. Collaborative Innovation Center of Steel Technology, University of Science and Technology Beijing, China; 2. Yangjiang Branch, Guangdong Laboratory for Materials Science and Technology (Yangjiang Advanced Alloys Laboratory), China; 3. Department of Materials Science and Engineering, McMaster University, Canada	P27
9:40-10:00	**Study of Decarburization and Oxidation of Surface Crack during Reheating of Billet for Super Strength Cord Steel** **Dayong Guo**, Yang Pan, Hang Gao, Wenzhu Li, Bingxi Wang, Bo Zhang, Liguo Ma, Ansteel Iron and Steel Research Institute, China	P27
	10:00-10:20 Break	
10:20-10:40	**Effects of Induction Heating Process on the Precipitates and Microstructure of the Nb-bearing Steel in the Multi-mode Continuous Casting & Rolling Plant Production Lines** **Jia Guo**[1], Zhihong Tian[1], Zhongzhu Liu[2], Xiaolin Li[1], Quhan Li[1], Guodong Zhang[2] 1. Shougang Research Institute of Technology, Beijing, China; 2. CITIC Metal Co., Ltd., Beijing, China	P28
10:40-11:00	**Constitutive Relationship of Flow Stress during Hot Deformation of Cu-bearing Ultra-high-strength Steel** **Liye Kan**[1], Tan Zhao[2], Xiaolan Gong[1], Zhaodong Wang[1] 1. Northeastern University, China; 2. State Key Laboratory of Metal Material for Marine Equipment and Application, China	P28
11:00-11:20	**Investigation of Improving Surface and Internal Quality of the Spring Steel Billet** **Shuming Huang**[1], Wei Deng[1], Shuai Niu[1], Zhixiang Xu[2] 1. Special Steel Business Unit, Nanjing Iron and Steel Co., Ltd., China; 2. Research Institute, Nanjing Iron and Steel Co., Ltd., China	P29

C1 Niobium Microalloyed Steels Helping the Dematerialization in Civil Construction

THURSDAY, 10 NOVEMBER 2022, GMT+8 (BEIJING)
8:30-12:10
ROOM C, ZOOM LINK: TBD

Session 1 Reinforced Concrete		
Chairs: Marcos Stuart, ST3 Consulting, Brazil Caihua Cheng, China Academy of Building Research Co., Ltd., China		
8:30-8:35	Opening Address	
8:35-8:55	*Invited* **The Benefits of Using 500MPa as the Yield Strength of Reinforcement Bars for Civil Construction** **Marcos A. Stuart Nogueira**[1], Carlos J. Massucato[2], Alexandre Magnus Jordão[3] 1. ST3 Consulting. Consultant for Niobium Technology at CBMM; 2. Massucato Consulting. Consultant for Niobium Technology at CBMM; 3. Market Development of CBMM	P34
8:55-9:15	*Invited* **Case Study on Optimal Structural Design and Economic Analysis of 500MPa Rebar in Building Structures** Dewen Chu[1], **Mingzhe Cui**[1], Hongrui Ma[1], Jirui Shi[1], Yuxin Jiang[1], Alexandre Jordão[2] 1. China Academy of Building Research Co., Ltd., China; 2. CBMM Niobium, São Paulo, Brazil	P35
9:15-9:35	*Invited* **Development, Promotion and Application of HRB500E in China** **Yongqing Zhang**[1], Aimin Guo[1], Marcos A. Stuart Nogueira[2], Rafael A. Mesquita[2] 1. CITIC Metal Co., Ltd., China; 2. CBMM, Brazil	P35
9:35-9:55	Q&A	
9:55-10:20 Break		
Session 2 Structural Steels		
Chairs: Weibiao Yang, Beijing Institute of Architectural Design, China Alexandre Magnus Jordão, CBMM, Brazil		
10:20-10:40	*Invited* **Stronger Steels in the Built Environment: Structural Response and Application of S460 to S700 Hot Rolled and Fabricated Sections** **Nancy Baddoo**[1], Jitendra Patel[2,3] 1. Associate Director – Steel Construction Institute, Ascot, UK; 2. Director – International Metallurgy Ltd., Oxford, UK; 3. Consultant – CBMM Technology Suisse S.A., Geneva, Switzerland	P36
10:40-11:00	*Invited* **Application and Research of High Strength Steel Structure in Super High-rise Buildings in China** **Honglei Wu**[1,2], Shiyu Wang[1], Jiemin Ding[1,2] 1. Tongji Architectural Design (Group) Co., Ltd., China; 2. College of Civil Engineering, Tongji University, China	P36
11:00-11:20	*Invited* **Case Study on High Strength Steel Grades Used in High Rising Structure CITIC Tower** **Weibiao Yang**, Beijing Institute of Architectural Design, China	P37
11:20-11:40	**Recent Developments of the Use of Advanced Niobium HSLA Flat Steels for Stadiums and High-rise Buildings** **Houxin Wang**, Aimin Guo, CITIC Metal Co., Ltd., China	P37
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D1 Shipbuilding, Offshore Engineering and Vessel Steels

THURSDAY, 10 NOVEMBER 2022, GMT+8 (BEIJING) 8:30-11:45 ROOM D, ZOOM LINK: TBD		
Chair: Xuehui Chen, Central Iron & Steel Research Institute, China		
8:30-8:55	*Invited* **Multi-phase Microstructure Design of High-performance Crack Arresting Heavy Plate Steel and its Industry Practices** **Hua Wang**[1,3], Chengjia Shang[2,3], Ling Yan[1,3], Peng Zhang[1], Xiucheng Li[2], Longhao Zhu[1,3] 1. Iron & Steel Research Institutes of ANSTEEL Group Corporation; 2. Collaborative Innovation Center of Steel Technology of USTB; 3. State Key Laboratory of Metal Materials for Marine Equipment and Application	P42
8:55-9:20	*Invited* **Research on the Application of High-strength Steel Plates on the Towers of Wind Turbines** **Xudong Cao**, Ziping Zhang, Gela Ji, Beijing Goldwind Science & Creation Windpower Equipment Co., Ltd., China	P43
9:20-9:40	**Comparative Study on Interface Microstructure and Properties of Al-Al-steel and Al-Ti-steel Clad Plates** **Xiyang Chai**, Xiaobiao Mu, Tao Pan, Xiaobing Luo, Feng Chai, Central Iron and Steel Research Institute, China	P43
9:40-10:00	**Effect of Ni Content on Copper Aging Weldable Steel Corrosion Behavior in Simulated Tropical Marine Atmosphere** **Haifeng Yang**[1], Zhizhong Yuan[1], Jian Li[2], Naipeng Zhou[2], Feng Gao[2] 1. Jiangsu University, China 2. Central Iron & Steel Research Institute, China	P43
10:00-10:20 Break		
10:20-10:45	*Invited* **Study on QLT Heat Treatment of 1000MPa Ship Hull Steel** **Xiaobing Luo**[1], Tianyang Guo[2], Feng Cha[1], Tao Pan[1] 1. Institute for Structural Steel, Central Iron and Steel Research Institute, China; 2. School of Iron and Steel, Soochow University, China	P43
10:45-11:05	**Research on Microstructure and Mechanical properties of Hot-Rolling TRIP Wear-Resistant Steel NM400 Under Different Cooling Process** **Haotian Chen**[1], Renbo Song[1], Kunpeng Che[1], Yan Huang[1], Guannan Li[2] 1. School of Materials Science and Engineering, University of Science and Technology Beijing, China; 2. Technology Center of HBIS Group Hansteel Company, China	P44
11:05-11:25	**Effect of H_2S Partial Pressure on Sulfide Stress Corrosion Behavior of SA387M Gr.11CL2 Anti-hydrogen Steel** **Fangfang Ai**[1,2], Yiqing Chen[1,2], Chu Wang[1,2], Peng Gao[1,2], Lin Li[1,2], Bin Zhong[1,2], Xiandong Su[1,2], Hongyu Shan[1,2] 1. State Key Laboratory of Material for Marine Equipment and Application, China; 2. Ansteel Iron & Research Institute, China	P44
11:25-11:45	**The Development of Large Thickness Marine Structure Steel Plate with Strength of 490MPa** **Xiaoshu Wang**[1], Peng Zhang[2], Weijun Zhang[2], Baojun Zhao[1], Jie Long[2] 1. Jiangxi University of Science and Technology, China; 2. Wuyang Iron and Steel Co., Ltd., HBIS, China	P44

E1 Automotive and Special Steels

THURSDAY, 10 NOVEMBER 2022, GMT+8 (BEIJING) 8:30-11:40 ROOM E, ZOOM LINK: TBD		
	Chairs: Haiwen Luo, University of Science and Technology Beijing, China Li Wang, Baoshan Iron & Steel Co., Ltd., China	
8:30-8:55	*Invited* **The Influence of Vanadium Additions on Hot Rolled Carbide-Free Bainite Microstructure** **Irina Pushkareva**[1], Juan Macchi[2], Babak Shalchi-Amirkhiz[1], Fateh Fazeli[1], Guillaume Geandier[2], Frederic Danoix[3], Julien Da Costa Teixeira[2], Sébastien Yves Pierre Allain[2], Colin Scott[1] 1. Canmet Materials, Natural Resources Canada, Canada; 2. Institut Jean Lamour, France; 3. Normandie Université, UNIROUEN, INSA Rouen, CNRS, Groupe de Physique des Matériaux, France	P52
8:55-9:20	*Invited* **High-throughput Design of Vanadium Microalloyed Lightweight Steels** **Weisen Zheng**, Shanghai University, China	P52
9:20-9:45	*Invited* **The Hydrogen Embrittlement Mechanism and Effect of Nb for Minimizing Hydrogen Embrittlement in Press Hardening Steel** **Hongzhou Lu**[1,2], F. D'Aiuto[3], Yi Feng[4], Yan Zhao[5], Jiangtao Liang[6], Yisheng Chen[7], Wei Li[8], Wenjun Wang[1,2], Aimin Guo[1,2], Zhengzhi Zhao[9], Mingtu Ma[4] 1. CITIC Metal Co., Ltd., China; 2. CITIC-CBMM Microalloying Technical Center, China; 3. CBMM Europe, Netherlands; 4. China Automotive Engineering Research Institute Co., Ltd., China; 5. New Materials Technology Laboratory, Beijing Institute of Technology Chongqing Innovation Center, China; 6. Shougang Group Co., Ltd., China; 7. The University of Sydney, Australia; 8. School of Materials Science and Engineering, Shanghai Jiao Tong University, China; 9. University of Science and Technology Beijing, China	P52
9:45-10:05	**Coating Free Press Hardening Steel and the Effect of Microalloying Elements** **Xiao Zhang**[1], Jun Hu[1], Lingyu Wang[1], Yanxin[1] Song, David san Martin[2], Wei Xu[1] 1. The State Key Laboratory of Rolling and Automation, Northeastern University, China; 2. Materalia Research Group, Centro Nacional de Investigaciones Metalurgicas (CENIM-CSIC), Spain	P53
	10:05-10:20 Break	
10:20-10:40	**Effect of Finishing Rolling Temperature and Cooling Rate after Rolling on Microstructure and Properties of Non-quenched and Tempered Steel** **Liu Lei**, Lei Zhou, Xueyi Peng, Qinglong Wang, Qunfeng Hou, Nanjing Iron & Steel Co., Ltd., China	P53
10:40-11:00	**Enhanced Mechanical Properties by Retained Austenite in Medium–C Si-rich V-Nb Microalloyed Spring Steel Treated by Different Heat Treatment Processes** **Kui Chen**[1], Zhouhua Jiang[1,2], Fubin Liu[1], Congpeng Kang[1], Junzhe Gao[1], Xiaodong Ma[3], Baojun Zhao[3], Yang Li[1] 1. School of Metallurgy, Northeastern University, China; 2. State Key Laboratory of Rolling and Automation, Northeastern University, China; 3. School of Chemical Engineering, University of Queensland, Australia	P54

11:00-11:20	**Galvanizing Process Optimization of High Strength Low Alloy Steel over 3.0mm Thickness** **Yan Li**[1,2], Tiejun Li[3], Guangrui Jiang[1,2], Huaxiang Teng[1,2], Haiquan Wang[1,2], Chengliang Xu[1,2] 1. Shougang Research Institute of Technology, China; 2. Beijing Key Laboratory of Green Recyclable Process for Iron & steel Production Technology, China; 3. Shougang Institute of Technology, China	P54
11:20-11:40	**Study on the Feasibility of the Q&P Steel Produced by TSCR Process** **Cheng Wang**[1], Jinping He[1], Chao Zhang[1], Jinping Wang[1], Yongkun Zhang[1], Chunfeng Wang[1], Bo Li[1], Yang Liu[2] 1. CSP Branch of Long Product Plant of Wuhan Iron & Steel Co., Ltd., China; 2. Wuhan Branch of Baosteel Central Research Institute, China	P54

B2 Physical Metallurgy and Properties

THURSDAY, 10 NOVEMBER 2022, GMT+8 (BEIJING) 14:00-17:15 ROOM B, ZOOM LINK: TBD		
	Chairs: Hardy Mohrbacher, NiobelCon BV, Belgium **Xuemin Wang, University of Science & Technology Beijing, China**	
14:00-14:25	*Invited* **Microstructural Evolution Modelling under Endless Rolling Conditions with Nb Microalloyed Steels** **Pello Uranga**[1], Jia Guo[2], Guodong Zhang[3], Jose Maria Rodriguez-Ibabe[1], Zhihong Tian2, Unai Mayo[1], Zhongzhu Liu[3], Chunzheng Yang[4] 1. CEIT and University of Navarra-Tecnun, Spain; 2. Shougang Research Institute of Technology, China; 3. CITIC Metal Co., Ltd., China; 4. Shougang Jingtang Iron & Steel United Co., Ltd., China	P29
14:25-14:50	*Invited* **Thermomechanical Processing of V-N Structural Plate Steels - a Modelling Perspective** **Kevin Banks**, Rorisang Maubane, University of Pretoria, South Africa	P29
14:50-15:10	**Flash Annealing Enables 1GPa Nanoprecipitate-strengthened Ferritic Steel with Heterogeneous Microstructure** **Shichun Liu**[1], Haokai Dong[2], Hao Chen[1] 1. Tsinghua University, China; 2. South China University of Technology, China	P30
15:10-15:30	**Deformation Induced Ferrite in A FH500 Steel** **Li Liu**, Xiangdou Qin, Baowen Qiu, Nanjing Iron & Steel Co., Ltd., China	P30
	15:30-15:50 Break	
15:50-16:15	*Invited* **Mechanisms of Hydrogen Embrittlement in Ultra-high Strength Steels and Possible Countermeasures** **Hardy Mohrbacher**, NiobelCon BV, Belgium	P30
16:15-16:35	**Influence of Aluminium on Grain Refinement in As-Rolled Vanadium-Microalloyed Steels** **Dannis Rorisang Nkarapa Maubane**, Kevin Mark Banks, Carel Coetzee, University of Pretoria, South Africa	P31
16:35-16:55	**In Situ Observation of Acicular Ferrite Formation in Ti-Zr Combined** Deoxidized **Low Carbon Steel** **Yongkun Yang**1, Dongping Zhan[1], Yuli Li[1], Hong Lei[1], Zhouhua Jiang[1], Huishu Zhang[2] 1. Northeasten University, China; 2. Liaoning Institute of Science and Technology, Chian	P31
16:55-17:15	**Microstructure and Properties of High Titanium Low Carbon Steel** **Zhimin Zhang**[1], Quanli Wang[2], Haoyu Wang[3], Yun Han[1] 1. Shougang Group Co., Ltd., Research Institute of Technology, China; 2. Shougang Group Co., Ltd., China; 3. Shougang Jingtang United Iron & Steel Co., Ltd., China	P31

C2 Construction Steels

THURSDAY, 10 NOVEMBER 2022, GMT+8 (BEIJING) 14:00-17:20 ROOM C, ZOOM LINK: TBD		
	Chairs: Houxin Wang, CITIC Metal Co., Ltd., China Yongqing Zhang, CITIC Metal Co., Ltd., China	
14:00-14:25	*Invited* **Metallurgical Aspects of Nb Application in Rebar Production** F. Bastos[1], Y. Zhang[2], B. Pereda[3], B. Lopez[3], **J.M. Rodriguez-Ibabe**[3] 1. CBMM, Brazil; 2. CITIC Metal Co., Ltd., China; 3. CEIT and University of Navarra-Tecnun, Spain	P37
14:25-14:50	*Invited* **Strengthening of High-strength Rebars** **Jingliang Wang**, University of Science & Technology Beijing, China	P37
14:50-15:10	**Development of HRB400E Rebars with Nb Microalloyed for High Speed Bar Production Lines** **Yi Luo**[1,2], Yongqing Zhang[1,2], Bastos Felipe[3,4], Siqian Bao[5], Xuehai Qian[6] 1. CITIC Metal Co., Ltd., China; 2. CITIC-CBMM Microalloying Technology Center, China; 3. Universidad de Navarra, Spain; 4. CBMM, Brazil; 5. Wuhan University of Science and Technology, China; 6. Guangxi Liuzhou Iron and Steel Group Co., Ltd., China	P38
15:10-15:35	**Overview of Application of Nb Microalloyed- and Micro Nb Treated Hot Rolled Value-added Sections in China** **Houxin Wang**, CITIC Metal Co., Ltd., China	P38
	15:35-15:50 Break	
15:50-16:15	*Invited* **Industrial Trials and Role of Nb Microalloying for Hyper-eutectoid Wire Rod Products** **Yongqing Zhang**[1,2], Maoqiu Wang[2], Qilong Yong[2] 1. CITIC Metal Co., Ltd., China; 2. China Iron & Steel Research Institute Group, China	P38
16:15-16:35	**Effects of Reheating Temperature and Time on Grain Boundary Cementite Dissolution in Wire Rods for Super High Strength Steel Cord** **Dayong Guo**[1], Bo Zhang[1], Junfeng Zhang[2], Hang Gao[1], Liguo Ma[1], Yang Pan[1], Bingxi Wang[1], Wenzu Li[1] 1. Ansteel Iron and Steel Research Institute, China; 2. Wire rod Plant of Ansteel, China	P39
16:35-17:00	*Invited* **Ultra-low Niobium (ULNb): Reducing Cost and GWPe in S275 & S355 Commodity Grade Structural Steels** **Jitendra Patel**, International Metallurgy Ltd., Oxford, UK	P39
17:00-17:20	**Effects of Finishing Temperature on Mechanical Properties of the Economical Fire-resistant Steel Q390FRE** **Lingming Meng**[1], Qiang Cui[1], Zhaodong Li[2], Xin Wang[2] 1. Nanjing Iron and Steel Group Co., Ltd., China; 2. Department of Structural Steels, Central Iron and Steel Research Institute, China	P39

D2 Shipbuilding, Offshore Engineering and Vessel Steels

THURSDAY, 10 NOVEMBER 2022, GMT+8 (BEIJING) 14:00-16:55 ROOM D, ZOOM LINK: TBD		
	Chairs: Linxiu Du, Plate Business Unit of Nanjing Iron & Steel Co., Ltd., China **Zhenjia Xie, University of Science & Technology Beijing, China**	
14:00-14:25	*Invited* **Influence of Band Microstructure on Carbides Precipitation and Toughness of a 1 GPa Grade Ultra-heavy Gauge Low Alloy Steel** **Zhenjia Xie**[1], Zhipeng Liu[1], Peng Han[1,2], Yaohui Jin[2], Xuelin Wang[1,3], Chengjia Shang[1,3] 1. Collaborative Innovation Center of Steel Technology, University of Science and Technology Beijing, China; 2. State Key Laboratory of Metal Material for Marine Equipment and Application, China; 3. Yangjiang Branch, Guangdong Laboratory for Materials Science and Technology (Yangjiang Advanced Alloys Laboratory), China	P45
14:25-14:50	*Invited* **A Production Process of V-N Microalloyed HSLA Steel without vacuum degassing and the Mechanism of Controlling Hydrogen Induced Defects of Steel Plates** **Linxiu Du**[1], Heng Ma[2], Hongqian Huang[3], Xiuhua Gao[3], Hongyan Wu[3], Xiaoxin Huo[2], Cairu Gao[3], Zhongxue Wang[2] 1. Northeastern University, China; 2. Technical center of Laiwu Branch of Shandong Iron and Steel Co., Ltd., China; 3. State Key Laboratory of Rolling and Automation, Northeastern University, China	P45
14:50-15:10	**Effect of Al Content on Seawater Corrosion Resistance of B Steel Plate for Shipbuilding** **Jian Li**, Feng Chai, Xiaobing Luo, Naipeng Zhou, Feng Zhang, Central Iron and Steel Research Institute, China	P46
15:10-15:30	**Effect of Ni on the Micro-substructure, Strength and Toughness of HSLA Steel** **Zhengyan Zhang**[1], Feng Chai[1], Xiaobing Luo[1], Sencai Wang[1,2], Caifu Yang[1] 1. Central Iron and Steel Research Institute, China; 2. China University of Petroleum, China	P46
	15:30-15:50 Break	
15:50-16:15	*Invited* **Effect of Nb Microalloying on Microstructure and Low Temperature Toughness of 630MPa Mobile Pressure Vessel Steel** Wenbin Liu[1,3], **Liqin Zhang**[2], Zhongzhu Liu[4], Fangzhong Li[5], Baozhu Liang[6] 1. The School of Materials and Metallurgy (SMM) of WUST (Wuhan University of Science and Technology), China; 2. Department of Applied Physics, Wuhan University of Science and Technology, China; 3. Baosteel Central Research Institute, China; 4. CITIC Metal Co., Ltd., China; 5. Shenzhen Qianhai Tongchuang New Metal Materials Co., Ltd., China; 6. Echeng Iron & Steel Co., Ltd., of China Baowu Steel Group, China	P46
16:15-16:35	**Study on Core Impact Performance for API 2W Offshore Structural Steel** **Xing Jin**, Plate Business Unit of Nanjing Iron & Steel Co., Ltd., China	P47
16:35-16:55	**Quantitative Analysis for the Cross-Section Effect of Quenched and Tempered Ni-Cr-Mo Ultra-heavy Steel** **Kaihao Guo**, Tao Pan, Ning Zhang, Li Meng, Feng Chai, Xiaobing Luo, Central Iron and Steel Research Institute, China	P47

E2 Automotive and Special Steels

THURSDAY, 10 NOVEMBER 2022, GMT+8 (BEIJING) 14:00-17:35 ROOM E, ZOOM LINK: TBD		
Chair: Hongzhou Lu, CITIC Metal Co., Ltd., China		
14:00-14:25	*Invited* **Computational Design and Processing Simulation of V containing ultra-high Strength Automotive Steels** **David Martin**[1], Erik Claesson[1], Arron Middleton[2], Rolf Schmidt[2] 1. Swerim A B, Sweden; 2. East Metals A G, Switzerland	P55
14:25-14:50	*Invited* **A Shrinkage-based Criterion for Evaluating Resistance Spot Weldability of Alloyed Steels** **Shuoshuo Li**[1,2], Yanjun Wang[3], Bin Hua[2], Wu Tao[3], Shanglu Yang[3,4], Haiwen Luo[1,2] 1. State Key Laboratory of Advanced Metallurgy, University of Science and Technology Beijing, China; 2. Department of Ferrous Metallurgy, University of Science and Technology Beijing, China; 3. Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, China; 4. Center of Materials Science and Optoelectronics Engineering, University of Chinese Academy of Sciences, China	P55
14:50-15:15	*Invited* **Development and Application of Microalloyed Steel for Commercial Vehicles** **Wenjun Wang**, CITIC Metal Co., Ltd., China	P56
15:15-15:35	**The Fracture Behavior Analysis of Nb-bearing and Nb-free Press Hardened Steel under Different Stress States** **Jifu Fan**[1], Zihan Jiang[1], Hongzhou Lu[2], Yazhou Jiang[3], Xiaoyong Geng[4], Yan Zhao[1] 1. Chongqing Innovation Center, Beijing Institute of Technology, China; 2. CITIC Metal Co., Ltd., China; 3. Chongqing Changan Automobile Co., Ltd., China; 4. Central Research Institute, Lingyun Industrial Co., Ltd., China	P56
15:35-15:50 Break		
15:50-16:10	**Research on the Microstructure, Tensile Properties and Formability of 1180MPa Grade Cold Rolled Complex Phase Steel** **Musheng Qiu**[1], Yun Han[1], Huasai Liu[2], Longshuai Han[2], Huaxiang Teng[1] 1. Sheet Metal Research Institute, Shougang Group Co.,Ltd., Research Institute of Technology, China; 2. Jingtang Technology Center, Shougang Group Co., Ltd., Research Institute of Technology, China	P56
16:10-16:30	**Effect of Segregation on the Microstructure and Mechanical Properties of Multiphase Automotive Steels** **Jingliang Wang**, University of Science and Technology Beijing, China	P57
16:30-16:50	**Revealing Tensile Fracture Mechanisms of Al Added Multiple Phase Steel with Membrane Like δ-ferrite** **Hao Wu**, Xiangtao Deng, Tianliang Fu, Northeast University, China	P57

16:50-17:10	**Study on the Composite Toughening Mechanism of 1800-2000MPa Strength Hot Stamped Steel Based on Alloy Optimization Design** **Yi Feng**, Materials Department, China Automotive Engineering Research Institute Co., Ltd., China	P58
17:10-17:35	*Invited* **A Route for Production of Elevated-Strength Cold-Rolled HSLA Steel** C. Matthew Enloe[1], Fabio D'Aiuto[2], **Hardy Mohrbacher**[3] 1. CBMM North America, USA; 2. CBMM Europe, Netherlands; 3. NiobelCon bvba, Belgium	P58

B3 Physical Metallurgy and Properties

FRIDAY, 11 NOVEMBER 2022, GMT+8 (BEIJING) 8:30-11:35 ROOM B, ZOOM LINK: TBD		
Chairs: Jianchun Cao, Kunming University of Science and Technology, China Jingliang Wang, University of Science and Technology Beijing, China		
8:30-8:55	*Invited* **Vanadium Effects on Recovery in Bainitic and Martensitic Microstructures** **K.O Findley**, J. Benz, J. Klemm-Toole, S.W. Thompson, J.G. Speer, A. Carley-Clopton, G.S. Ansell Department of Metallurgical and Materials Engineering, Advanced Steel Processing and Products Research Center, Colorado School of Mines, USA	P32
8:55-9:15	**Regulation Effect of Nb Content on Microstructure Evolution of 2000MPa Martensitic Ultra-high Strength Steel** **Hongyan Liu**[1,2], Zigang Chen[2], Xiangtao Deng[1], Zhaodong Wang[1] 1. State Key Laboratory of Rolling and Automation, Northeastern University, China; 2. Handan Iron & Steel Company of Hebei Iron & Steel Group Co., Ltd., China	P32
9:15-9:35	**Physical Metallurgy of Steel—Titanium Microalloyed High Strength Steel** **Liejun Li**[1], Xiangdong Huo[2], Jixiang Gao[3], Zhengwu Peng[1], Songjun Chen[1] 1. South China University of Technology, China; 2. Jiangsu University, China; 3. Guangdong Polytechnic Normal University, China	P32
9:35-9:55	**A New Cooling Strategy in Curved Continuous Casting Process of Vanadium Micro-alloyed YQ450NQR1 Steel Bloom Combining Experimental and Modelling Approach** **Kun Dou**[1], Qing Liu[2], Wanlin Wang[1] 1. School of Metallurgy and Environment, Central South University, China; 2. State Key Laboratory of Advanced Metallurgy, University of Science and Technology Beijing, China	P33
9:55-10:20 Break		
10:20-10:45	*Invited* **The Optimization of Slab Microstructure and Effect on Silicon steel Magnetic Property** **Jian Gong**, Maolin Sun, Xianhui Wang, Weiguang Pang, Beijing Shougang Co., Ltd., China	P33
10:45-11:10	*Invited* **Strength and Toughness Mechanisms of 700 MPa Grade High Strength Ti-Zr Composite Microalloyed Steel** **Hanyu Luo**[1], Jianchun Cao[1], Juncai Wang[1], Fanlin Zhang[1], Shubiao Yin[2], Chuangwei Wang[3], Xiaoyu Ye[3], Qinchun Liu[3] 1. School of Materials and Engineering, Kunming University of Science and Technology, China; 2. Faculty of Metallurgy and Energy Engineering Kunming University of Science and Technology, China; 3. Panzhihua Iron and Steel Research Institute Co., Ltd., China	P34
11:10-11:35	*Invited* **Evolution of Prior-austenite Grain Structure during Reheating of As-cast Microalloyed Steels** **Debalay Chakrabarti**[1], Kumar Aniket Anand[2], Vinod Kumar[2] 1. Dept. of Metallurgy & Materials, Indian Institute of Technology Kharagpur, India; 2. Research & Development Centre for Iron & Steel, Steel Authority of India Limited, India	P34

C3 Low Temperature Steels

FRIDAY, 11 NOVEMBER 2022, GMT+8 (BEIJING) **8:30-11:50** **ROOM C, ZOOM LINK: TBD**		
Chairs: Shan Gao, Baoshan Iron & Steel Co., Ltd., China **Zhenyu Liu, Northeastern University, China**		
8:30-8:55	*Invited* **Development of High-Mn Austenitic Steels for Cryogenic Applications and their Deformation Performances in Liquid Helium** **Zhenyu Liu**, Jiakuan Ren, Pengjie Wang, Jun Chen, Weina Zhang, Northeastern University, China	P40
8:55-9:15	**Cryogenic Fracture Behavior of High-manganese Austenitic Steel with TWIP/TRIP Effect** **Yangwen Wang**, Honghong Wang, Wuhan University of Science and Technology, China	P40
9:15-9:35	**Mechanical Properties of Welded Joints of Novel High Manganese Austenitic Steel for Cryogenic Application** **Shuchang Zhang**, Honghong Wang, Wuhan University of Science and Technology, China	P40
9:35-10:00	*Invited* **Development of 7Ni Steel Plate for Cryogenic Storage Tanks and Transportation Vessels** **Zhanglong Xie**, Nanjing Iron & Steel United Co., Ltd., China	P41
10:00-10:20 Break		
10:20-10:45	*Invited* **Study on Hydrogen Embrittlement Susceptibility of WHAZ in 9Ni Steel** **Zhaoxia Liu**, Yun Bai, Buqiang Han, Xin Zhang, Jun Liu, Jiangyin Xingcheng Special Steel Works Co., Ltd., China	P41
10:45-11:05	**Comparative Study of the Weldability for 5Ni and 9Ni Steels** **Huibin Liu**[1], Liqian Xia[1], Jinhua Huang[2], Zhaoxia Qu[1], Hanqian Zhang[1] 1. Central Research Institute of Baosteel, China; 2. Manufacturing Management Department of Baosteel, China	P41
11:05-11:30	*Invited* **Development and Application of High-Performance Plate for Polar Icebreaker** **Shan Gao**, Caiyi Zhang, Xiao-hui Lu, Central Research Institute of Baoshan Iron & Steel Co., Ltd., China	P41
11:30-11:50	**Study on the Effect of Surface Oxides on the Friction Mechanism of Polar Marine Steel** **Chaoyi Wang**[1,2], Xueting Chang[3], Tao An2, Ling Yan[1] 1. State Key Laboratory of Metal Materials for Marine Equipment and Application, China; 2. Ansteel Beijing Research Institute Co., Ltd., China; 3. Shanghai Maritime University, China	P42

D3 Pipeline Steels and Welding

FRIDAY, 11 NOVEMBER 2022, GMT+8 (BEIJING) 8:30-11:25 ROOM D, ZOOM LINK: TBD		
	Chairs: Marcos A. Stuart Nogueira, CBMM, Brazil **Chunyong Huo, Tubular Goods Research Institute, CNPC, China**	
8:30-8:55	*Invited* **Improved API X80 Heavy Gauge Pipe Body and Weld Mechanical Property Stability by Optimized Niobium Metallurgical Processing** **Stalheim Douglas**[1], Jinxing Jiang[2], Chunyong Hou[3], Han David[4], Yongqing Zhang[5], Bacalhau Jose[6], Litschewski Aaron[7] 1. DGS Metallurgical Solutions, Inc., USA; 2. Nanjing Iron and Steel Company, Ltd., China; 3. Tubular Goods Research Institute, China; 4. International Welding Technology Institute, China; 5. CITIC Metal, China; 6. CBMM, Brazil; 7. CBMM NA, USA	P47
8:55-9:20	*Invited* **Effect of Nitrogen Content on the Microstructures and Mechanical Properties in Simulated Properties in Simulated CGHAZ of Normalized Vanadium Microalloyed Steel** **Feng Chai**, Zhongran Shi, Xuehui Chen, Research Institute of Structural Steels, Central Iron and Steel Research Institute, China	P48
9:20-9:40	**Influence of Heat Input on Microstructure and Toughness Properties in Simulated CGHAZ of High Niobium X80 Steel Manufactured Using High Temperature Processing** **Jian Han**[1], Frank Barbaro[1,2], Jose Britti Bacalhau[2], Lihua Qi[3], Xiaodong He[3], Meijuan Hu[3] 1. School of Mechanical, Materials, Mechatronic and Biomedical Engineering, University of Wollongong, Australia; 2. CBMM, Brazil; 3. Tubular Goods Research Institute of CNPC, China	P48
9:40-10:00	**The Effect of Heating Speed on Phase Transformation and Properties Of Pipeline Steel** **Meijuan Hu**, Tubular Goods Research Institute of CNPC, China	P48
	10:00-10:20 Break	
10:20-10:45	*Invited* **Cheyenne Plains X80 with Low Carbon and 0.10% Nb: The Best Example of High Quality and Cost Competitive Steel for Pipelines** **Marcos A. Stuart Nogueira**, ST3 Consulting Consultant for Niobium Technology of CBMM, Brazil	P49
10:45-11:05	**Research on Manufacturing Technology of Steel for Low Alloy Drill Pipe Joint with High Strength and Resistance to Hydrogen Sulfide Stress Corrosion** **Yaze Tan, Hui Wen**, Nanjing Iron and Steel Co., Ltd., China	P49
11:05-11:25	**Effect of Different Strength Matching on Properties of High Nb X80 Pipeline Girth Weld Joint** **Xiaodong He**[1,3], Xiongxiong Gao[1], Jian Han[2,3], Qiang Chi[1,3], Chunyong Huo[1,3], Lihua Qi[1,3] 1. Tubular Goods Research Institute of CNPC, China; 2. University of Wollongong, Australia; 3. International Welding Technology Center, China	P50

E3 Automotive and Special Steels

FRIDAY, 11 NOVEMBER 2022, GMT+8 (BEIJING) 8:30-11:20 ROOM E, ZOOM LINK: TBD		
Chair: Wenjun Wang, CITIC Metal Co., Ltd., China		
8:30-8:55	*Invited* **Development and Prospect of High Strength Steel for Automobile in China** **Li Wang**, Baoshan Iron & Steel Co., Ltd., China	P58
8:55-9:20	*Invited* **Influence of Annealing Temperatures on Initial Austenite Grain Size of 2GPa Hot Stamping Steel** **Rui Wang**, Bo Yang, Pengfei Liu, Yu Chen, Chongtao Su, R&D Institute of Benxi Steel Plates Co., Ltd., China	P58
9:20-9:40	**Development and Application of Nb-microalloyed Isotropic High Strength Uni-FISH Steel** **Jiandong Guan**[1], Jiaji Ma[1], quanli Wang[3], Dong Wei[2], Lei Jin[2], Tao Niu[2], Nai Wu[1] 1. Beijing Shougang Co., Ltd., China; 2. Shougang Research Institute of Technology, China; 3. Beijing Shougang Co., Ltd., China	P59
9:40-10:00	**Effect of Continous Annealing Process on Microstructure and Properties of 2000MPa Grade Hot Stamping Steel** **Xinghan Chen**[1], Renbo Song[1], Weifeng Huo[1], Shuai Zhao[1], Xinwei Wang[1], Yu Zhang[2], Zhiyu Geng[2], Mingguang Yu[3] 1. University of Science and Technology Beijing, China; 2. Ansteel Beijing Research Institute Co., Ltd., China; 3. Ansteel Iron & Steel Research Institute, China	P59
10:00-10:20 Break		
10:20-10:40	**Research on Strengthening Mechanism of 1800MPa Ultra-high Strength Hot Stamping Steel** **Xinwei Wang**[1], Renbo Song[1], Weifeng Huo[1], Shuai Zhao[1], Xinghan Chen[1], Yu Zhang[2], Zhiyu Geng[2], Mingguang Yu[3] 1. School of materials science and Engineering, China; 2. Ansteel Beijing Research Institute Co., Ltd., China; 3. Ansteel Iron & Steel Research Institute, China	P60
10:40-11:00	**Step-cooling Process for Strength and Toughness Matching Coordination of Vanadium Containing Railway Wheel: Effect of Intragranular Ferrite** **Sancheng Yao**[1], Xuehua Liu[1], Hai Zhao[1], Bo Jiang[1], Gang Chen[2], Kang Xu[2] 1. Technology Center, Ma'anshan Iron and Steel Co., Ltd., China; 2. Technology Center, Baowu Group Masteel Rail Transit Materials Techhnology Co., Ltd., China	P60
11:00-11:20	**Research and Application of Key Technology of High Wear Resistance Rail** **Gangtie Hou**, Chaojun Guo, Dongning Chen, Bo Lian, HBIS HanSteel, China	P60

C4 中文分会场

2022 年 11 月 11 日（周五） 14:00-16:55 ROOM D，ZOOM LINK: TBD	
分会主持人：张俊粉，河钢集团承德钒钛新材料公司	
14:00-14:25	（特邀）大型 LNG 储罐用 7%Ni 钢性能及工程应用 李宏斌，中石化广州（洛阳）工程有限公司
14:25-14:50	（特邀）钒在高强、超高强钢筋中的应用 张俊粉，河钢集团承德钒钛新材料公司
14:50-15:15	（特邀）VN 微合金化在热轧 H 型钢中析出强化应用研究 汪杰，马钢股份有限公司
15:15-15:40	（特邀）钒微合金化高强汽车结构用钢开发及应用 李正荣，攀钢集团研究院有限公司
15:40-16:05	（特邀）鞍钢耐候桥梁钢的研制与应用 杨颖，鞍钢集团
16:05-16:30	（特邀）基于元素扩散控制制备更高强塑性复合钢 杨志南，燕山大学
16:30-16:55	（特邀）LP 钢板在风力发电机组塔架应用分析和验证 吉格拉，北京金风科创风电设备有限公司

D4 Pipeline Steels and Welding

FRIDAY, 11 NOVEMBER 2022, GMT+8 (BEIJING) 14:00-16:00 ROOM D, ZOOM LINK: TBD		
	Chair: Xiaobing Luo, Central Iron and Steel Research Institute, China	
14:00-14:25	*Invited* **The International Welding Technology Center in China: Advancing Technology for Pipeline Welding** **Chunyong Huo**[1], Lihua Qi[1,2], Marcos A. Stuart Nogueira[3], José B. Bacalhau[3], Frank J. Barbaro[4], David Han[2] 1. Tubular Goods Research Institute, CNPC, China; 2. International Welding Technology Center (IWTC), China; 3. CBMM, Brazil; 4. School of Mechanical, Materials, Mechatronic and Biomedical Engineering, University of Wollongong, Australia	P50
14:25-14:50	*Invited* **Development of Steel Plates with Excellent HAZ Toughness after HHIW With Mg Deoxidation** **Jian Yang**, Xiaoqian Pan, Longyun Xu, Yinhui Zhang, Dekun Liu, School of Materials Science and Engineering, Shanghai University, China	P51
14:50-15:15	*Invited* **Research and Development of Strain Based Design L485 offshore Linepipe** **Chuanguo Zhang**, Long Li, Leilei Sun, Bo Wang, Shiqiang Xie, Baoshan Iron & Steel Co., Ltd., China	P51
15:15-15:40	*Invited* **Metallurgical Characteristics for Ductile Fracture Resistance in High Strength Pipeline Steels** **Alexey Gervasyev**[1], Frank Barbaro[2], Chunyong Huo[3], Igor Pyshmintsev[4], Roumen Petrov[1,5] 1. Ghent University, Belgium; 2. University of Wollongong, Austrialia; 3. Tubular Goods Research Institute of CNPC, China; 4. R&D Center TMK, Russia; 5. Delft University of Technology, Netherlands	P51
15:40-16:00	**Microstructural Features of X100 Plate and Pipe Production with Increased Impact Toughness and Cold Resistance** **Dmitrii Ringinen**, Andrei Chastukhin, Leonid Efron, Sergey Golovin, OMK Vyksa Steel Works, Russia	P52

Poster Session

P-1	**Effect of Peak Temperature and t8/5 on Mechanical Properties of Heat Affected Zone in Super High-strength Marine Steel** **Tianyi Li**[1,2], Wenyue Liu[1,2], Yan Zang[1,2], Chaoyi Wang[1,2], Chuanjun Wang[1,2], Tao An[1,2], Zhiyu Geng[1,2] 1. State Key Laboratory of Metal Material for Marine Equipment and Application, China; 2. Ansteel Beijing Research Institute, China
P-2	**The Influence of Corrosion Behaviors about XCS-Iode Steel and 30CrNi3Mo Steel in Simulated Marine Atmospheric Environment** **Jianpeng Wu**, Yao Li, HaiLong Xu, Feng Cao, PeiRong Zhou, Jiangyin Xingcheng Special Steel Works Co., Ltd., China
P-3	**Effect of Heat Treatment on Microstructures, Mechanical Properties and Corrosion Behavior of SA-387Gr.11 Cl2 Steel** **Chu Wang**[1,2], Fangfang Ai[1,2] ,Xin Ouyang[1,2], Xinming Hu[1,2], Yong Wang[1,2], Mengnan Xing[1,2] 1. State Key Laboratory of Metal Material for Marine Equipment and Application, China; 2. Ansteel Iron & Research Institute, China
P-4	**Analysis of Unqualified Flaw Detection on Ansteel 12MnNiVR Steel Plate for Low Alloy High Strength Pressure Vessel** **Xin Ouyang**, Ansteel Iron & Research Institute, China
P-5	**Development of Cr Alloyed Steel Wire Rod for High-Strength Direct-Drawing Bead Wire** **Xiangkun Yuan**, Luofang Guo, Maimai Li, Yongbin Gao, Jie Zhang, Qingdao Special Iron And Steel Co., Ltd., China
P-6	**Effect of Cooling Process of NM300 Hot-rolled Wear Resistant Steel on Microstructure and Properties** **Yan Huang**[1], Renbo Song[1], Kunpeng Che[1], Haotian Chen[1], Guannan Li[2] 1. University of Science and Technology Beijing, China; 2. Technology Center of HBIS Handan Iron and Steel Group Co., Ltd.
P-7	**Effect of H_2S Concentration on Corrosion Behavior of 304L Stainless Steel in CO_2 Injection Well Annulus Environment** **Fangfang Ai**[1,2], Chu Wang[1,2], Yiqing Chen[1,2], Peng Gao[1,2], Bin Zhong[1,2], Lin Li[1,2], Hongyu Shan[1,2], Xiandong Su[1,2] 1. State Key Laboratory of Material for Marine Equipment and Application, China; 2. Ansteel Iron & Research Institute, China
P-8	**A 690MPa High Strength Low Carbon Microalloyed Steel with Fine High Heat Input Coarse-grained HAZ Toughness** **Yulong Yang**[1], Xiao Jia[2], Ping Wang[1,] Fuxian Zhu[2], Bingxing Wang[2] 1. Key Laboratory of Electromagnetic Processing of Materials, Ministry of Education, Northeastern University, China; 2. State Key Laboratory of Rolling and Automation, Northeastern University, China

P-9	**Development of HIC-resistant X80 Pipeline Steel Based on Oxide Metallurgy Process** **Xiao Jia**[1], Yulong Yang[2], Yaxin Ma[1], Bingxing Wang[1] 1. State Key Laboratory of Rolling and Automation, Northeastern University, China; 2. Key Laboratory of Electromagnetic Processing of Materials Ministry of Education, Northeastern University, China
P-10	**Research on Welding Technology of T-joint Hardness of C-Mn Low Temperature Section Steel** **Junming Wu**, Xiaobin Wang, Wei Li, Xuqiang Yan , Nanjing Iron and Steel Co., Ltd., China
P-11	**Hydrogen Trapping Characteristics of Low Transformation Temperature Weld Material** **Fengya Hu**[1], Jiaji Wang[1], Ye Yuan[1], Yumin Wu[1], Bo Fu1, Steve Ooi[2] 1. State Key Laboratory of Metal Material for Marine Equipment and Application, China; 2. Ovako, Cambridge, UK
P-12	**Development of Three-dimensional Mathematical Model for High Speed Wire Rod Stelmor Cooling Line** **Jingwei Yang**[1], Zhenli Mi[2], Lan Su[3] 1. Nanjing Iron and Steel Co., Ltd., China; 2. Collaborative Innovation Center of Steel Technology, University of Science and Technology Beijing, China; 3. Institute of Engineering Technology, University of Science and Technology Beijing, China
P-13	**Qualitative Analysis of the Surface Defects of Rolled High Strength Low Alloy Structural Steel Bar** **Xiangtian Gu**, Yufeng Wang, Jiaxiang Ke, Hu Zhang, Qingdao Special Iron and Steel Co., Ltd., China
P-14	**Process Practice of Sulphide Form Control in Sulphide Automobile Steel** **Jian Liu**[1], Weiji Zhou[2] 1. Nan Jing Iron& Steel Co., Ltd., China; 2. Dongbei Special Steel Group Co., Ltd., China
P-15	**Study on the High-Efficiency Air-Jet Quenching Technology of Ultra-Thin High-Strength Steel Sheets** **Yanqi Ye**, Tianliang Fu, Guanghao Liu, Zhaodong Wang, State Key Laboratory of Rolling and Automation, Northeastern University, China
P-16	**Flow Behavior and Dynamic Recrystallization of a Low Carbon Vanadium Nitrogen Microalloyed Steel** **Baochun Zhao**[1,2], Tan Zhao[1,2], Lei Huang[1,2], Junsheng Wang[1,2] 1. Key Laboratory of Metal Materials for Marine Equipment and Application, China; 2. Iron and Steel Research Institute of AnGang Group, China

Plenary Session 1

Wednesday, 9 November 2022, GMT+8 (Beijing)
Room A, Zoom Link: TBD

8:30-8:50 Opening Address

8:50-9:25

Advance of HSLA Steels in China

Zhiling Tian, The Chinese Society for Metals, China

9:25-10:00

Recent Developments in the Science and Technology of Zinc-Coated HSLA Steels

Frank E. Goodwin, Ana P. Domingos, International Zinc Association, Durham, NC USA

Recent developments in continuous galvanized HSLA steel sheet are reviewed. These include the advancement of galvanizing process technology for cold and hot rolled conditions that depended on improved knowledge of the effect of processing on microstructure and mechanical properties. Also reviewed are recent advances in resistance spot welding and laser welding, mechanical properties of tailor welded blanks that include galvanized HSLA and forming of ZnAlMg-coated HSLA.

10:20-10:55

Niobium Microalloyed Steels – an Enabling Solution towards a Sustainable Future for the Built Environment

Ricardo Fonseca de Mendonça Lima[1], Marcos Alexandre Stuart Nogueira[2], Jitendra Patel[3]

1. CEO - CBMM, Brazil;

2. Consultant - CBMM, Brazil;

3. Consultant - CBMM Technology Suisse S.A., Switzerland

As global crude steel production steadily increases towards the two billion tonnes mark, it remains one of the most widely used materials on the planet. According to the World Steel Association, the construction sector remains one of the most important industries accounting for more than 50% of world steel demand. When coupled with a growing world population, projected to reach 8.6 billion in 2030 (an increase of 0.7 billion from 2022) and 9.8 billion in 2050, greater levels of urbanization, increased demands on infrastructure, limited availability of habitable landmass and other impacts related to climate change will be more and more critical to the well-being of humanity. Under these circumstances, steel will continue to play an important pivotal role especially in the built environment to reduce overall material consumption and towards a net-zero future.

Structural steels cover a wide range of product types, from rolled plates, fabricated I-sections, H-beams, pilings, through to concrete reinforcement bar, and formed products from strip such as hollow sections. This paper highlights some recent examples where the development of high strength niobium microalloyed steels of such products have been successfully applied in a variety of structures enabling savings on material use, lower embodied carbon and savings on material and construction costs. Examples are given for a tall building, bridge, stadium, and an office complex.

Perspectives in the application of high strength steels for the construction sector are given in relation to China's 14th Five-Year Plan and environmental targets; with environmental protection being one of the more important requirements. The strong demand in China for buildings and modern infrastructure must be fully supported by the steel and construction sectors whilst always saving land, energy, water, and materials. Thus, making the use of niobium microalloyed steels of paramount importance to achieve these objectives. In concluding, the paper highlights the actions of CBMM's Global Technology Program that is supporting this pathway towards a more sustainable future for the built environment.

10:55-11:30

Revisit TWIP and TRIP in Steel

Mingxin Huang, The University of Hong Kong, Hong Kong, China

High strength steels are widely used in various industries. Understanding the strain hardening mechanism of high strength steel plays a key role on the development of new class of high strength steel. The first part of the present work revisit the twinning-induced plasticity (TWIP) effect on the strain hardening mechanism of TWIP steel. It is found that TWIP effect has trivial effect on the strain hardening of TWIP steel. Instead, carbon-induced high dislocation in TWIP steel is the major mechanism responsible for the high strain hardening of TWIP steels. The second part revisit the TRIP effect on strain hardening of TRIP-assisted steels at high-strain-rate deformation. During high-strain-rate deformation, martensitic transformation does occur, but the strain hardening rate is still low, indicating that TRIP effect does not provide strain hardening behaviour at high-strain rate. Further investigation indicates that the reason for this abnormal TRIP effect at high strain rate could be attribute to the critical role of interstitial carbon played in the TRIP effect.

11:30-12:05

A Half-Century of Innovation in Niobium-Containing Automotive Sheet Steels

J.G. Speer[1], E. De Moor[1], K.O. Findley[1], L. Wang[2]

1. Colorado School of Mines, USA;

2. Baosteel R&D Center, China

The development of new automotive sheet steels has progressed substantially over the past 5 or 6 decades, and here the progression of some of these innovations is highlighted, including the role that niobium microalloying has played in these developments across a broad spectrum of new steel concepts. The background physical metallurgy fundamentals are reviewed briefly, as these fundamentals related to Nb solute and Nb carbonitride precipitation control the mechanisms that influence microstructure and properties. Microalloyed HSLA steels were developed around the 1960s and already deployed for sheet steel applications in the 1970s. Later developments employed microalloying to enable or enhance interstitial-free and bake-hardening steels. More recent developments have focused on advanced high-strength sheet steels (AHSS) employing bainite, martensite and retained austenite, including the more recent "3rd Generation" AHSS. Other important developments include press-hardening steels and high strength microalloyed ferritic hot-rolled steels for "stretch-flanging" applications. This development history is reviewed, with a focus on the role and opportunity of microalloying, and Nb-microalloying in particular.

Plenary Session 2

Wednesday, 9 November 2022, GMT+8 (Beijing)
Room A, Zoom Link: TBD

14:00-14:35

Role of Niobium Microalloying for Hydrogen Trapping in Steels: An Atomic-Scale Investigation

Julie Cairney[1,2], Yisheng Chen[1,2], Hongzhou Lu[3], Aimin Guo[3]

1. Australian Centre for Microscopy and Microanalysis, The University of Sydney, Sydney, NSW, Australia;

2. School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, Sydney, NSW, Australia;

3. CITIC Metal, Beijing, China

Hydrogen embrittlement (HE) in steels involves complex interactions of hydrogen with defects and second phase precipitates. Understanding these interactions is essential to design material for reduced HE susceptibility. Niobium microalloying is effective for introducing niobium carbides (NbCs) and fine grains. However, it is necessary to understand how these features relate to HE. We have used the state-of-the-art cryogenic atom probe tomography to directly observe hydrogen at NbCs and grain boundaries (GBs) in steels. We provided the first direct maps of hydrogen trapping at certain microstructural features at a relevant scale, validating models of hydrogen trapping for the prevention of hydrogen embrittlement.

14:35-15:10

Current Status of Development of High-Strength Steel Sheets and Application Technologies Contributing to Automobile Weight Reduction

Yasunobu Nagataki, JFE Steel Corporation, Japan

Demand for weight reduction of automobile body has been getting stronger toward the coming carbon neutral society. The latest status of the development of high-strength steel sheets and application technologies in JFE Steel contributing to automobile weight reduction will be shown.

15:10-15:45

Eco-friendly Steel Products for a Low-carbon Society

Seok Jong Seo, POSCO, China

Environmental issues are global and must be addressed for future generations. Countries have declared carbon-neutral goals and are making various efforts to achieve them. In particular, the steel industry, a representative CO2 emissions industry, is actively researching the steel manufacturing process using eco-friendly energy to reduce CO2 emissions in the production stage. Recently, efforts to reduce CO2 emissions have been extended to the entire value chain of the steel industry. Eco-friendly steel products are being developed to reduce CO2 emissions generated during the processing or use of steel materials, which is called the avoided greenhouse gas (GHG) emissions. These eco-friendly steel products can be divided into several types as follows. First, they are products used in eco-friendly energy industries such as wind power and solar power. Second, products that save energy through weight reduction or high efficiency. Third, products that can be used for a long time with improved durability. Lastly, there are products that can omit or increase efficiency in heat treatment or processing processes. In this presentation, POSCO's efforts to develop eco-friendly products for the avoided GHG emissions will be introduced.

16:05-16:40

Assessing the Role of Vanadium Technologies in Decarbonizing the Construction Industry

Sarbajit Banerjee, Texas A&M University, USA

The decarbonization of heavy industry and the emergence of renewable energy technologies are inextricably linked to access to mineral resources. As such, there is an urgent need to develop benchmarked assessments of the role of critical elements in reducing greenhouse gas emissions. Here, we explore the role

of vanadium in decarbonizing construction by serving as a microalloying element and enabling the energy transition as the primary component of flow batteries used for grid-level storage. We estimate that vanadium has enabled an avoided environmental burden totaling 185 million metric tons of CO2 on an annual basis. In particular, policy changes implemented after the Sichuan Earthquake have mandated an increased use of vanadium steel in China giving rise to an unintended (but welcome) benefit of substantial decarbonization of a major sector. A granular analysis estimates savings for China and the European Union at 1.15% and 0.18% of their respective emissions, respectively. Our results highlight the role of critical metals in developing low-carbon infrastructure while underscoring the need for holistic assessments to inform policy interventions that mitigate supply chain risks.

16:40-17:15

The Use of Vanadium in High Strength Low Alloy Steels

David Crowther, Yu Li, Vanitec

The microalloying elements vanadium, niobium and titanium are commonly used to improve the properties of HSLA steels. Of these three microalloying elements, the carbides and nitrides of vanadium have the highest solubility, and this influences the steel types in which vanadium is used, and how they are processed. This paper will review the use of vanadium in HSLA steels and give recent examples of how the high solubility of vanadium carbides and nitrides is utilised in a range of steel types. Vanadium additions are well suited to medium and high carbon steels, as the high solubility of vanadium carbo-nitrides, V(C,N), enables the formation of the fine precipitates necessary for precipitation strengthening. In concrete reinforcing bar, V(CN) precipitation strengthening allows high strengths to be obtained combined with weldability and high ductility for use in seismic zones. In direct forging steels, vanadium additions enable costly quench and temper heat treatments to be eliminated, and in bainitic forgings, increased hardenability allows improved properties to be achieved over a wider section size. Vanadium additions to rail steels have been shown to significantly increase rail life, and in wire rod steels, vanadium not only increases strength, but decreases the formation of coarse grain boundary cementite which is detrimental to ductility. In low carbon steels, increased vanadium additions allow significant volume fractions of fine precipitates to be produced, giving exceptionally high precipitation strengthening. This allows high strength single phase ferritic steels to be produced with excellent edge ductility for the automotive sector. At low processing temperatures such as those used for hot forming of structural hollow sections or the annealing of cold rolled dual phase steels, V(CN) still has sufficient solubility to produce useful precipitation strengthening, and also significant grain refinement. Finally the high solubility of V(CN) allows reduced reheating and equalisation temperatures to be used prior to rolling, and limits precipitation in austenite. This results in reduced cracking during continuous casting, and gives a minimal increase in rolling loads which allows increased rolling rates and the production of wider material.

B1 Physical Metallurgy and Properties

Thursday, 10 November 2022, GMT+8 (Beijing)
Room B, Zoom Link: TBD

8:30-8:55

Mechanisms of Strengthening, Plasticity and Toughening of nanoscale precipitation-strengthened HSLA

Zhong-wu Zhang, Harbin Engineering University, China

For traditional high strength steels, the yield strength is mainly improved by obtaining high carbon microstructure. This may scarify the toughness and welding properties of materials, limiting severely the application range. Therefore, exploring methods to improve the comprehensive mechanical properties and weldability for various applications attracts more and more attention. Here we present some research results on nanoscale precipitation and its influence on the mechanisms of strengthening, plasticity and toughening of nanoscale precipitation-strengthened high strength low alloy steels. Cu-enriched and Ni(Mn, Al)-enriched nanoscale precipitates were applied to design a serial of high strength low alloy steels with yield strengths up to 1800MPa. The precipitation of nanoscale clusters and the effect of alloying elements on their precipitations are studied. Our study provides compelling experimental evidence that the precipitates consist of a duplex structures with a Cu-enriched bcc core partially encased by a B2-ordered Ni(Mn,Al) phase provide a more complex obstacle for dislocation movement due to atomic ordering together with interphases, resulting in a high yield strength alloy without sacrificing alloy ductility. Nanoscale precipitation strengthening can contribute a yield strengthen increment greater than 800MPa. The precipitation strengthening mechanisms, including both the shearing mechanisms and the Orowan mechanism, are quantitatively analyzed based on the mechanical properties and precipitate properties determined by small-angle neutron scattering, and atom probe tomography (APT). Until the peak aging, precipitation strengthening mainly arises from shearing mechanisms, among which the order and modulus strengthening mechanisms play the most significant role. Beyond peak aging, the shearing mechanisms are not valid and the Orowan mechanism is the dominant contributor to the increase in yield strength as the nanoscale precipitates grow coarse.

The effects of the matrix microstructure and nanoscale pectinates on strength, plasticity and toughening are also addressed and discussed in detail. The matrix microstructure of granular ferrite, polygonal ferrite and lath martensite can be obtained by controlling thermomechanical treatment and solid solution treatment. Copper-rich nano-precipitation strengthened steels with lath martensitic structure exhibit better low temperature impact toughness than the polygonal ferrite steels. The expansion of lath martensite structure with crack stable stage can inhibit the occurrence of crack instability propagation. While for the polygonal ferrite structure, once the cracks initiate, they rapidly spread in an unstable propagation way. As a result, despite of their similar crack initiation work, the lath martensite structure showed higher crack propagation work when compared to the polygonal ferrite. Meanwhile, lath martensite structure contains a higher content of high angle grain boundaries and smaller effective grain size, where the high angle grain boundary can effectively deflect crack propagation angle and consume crack extension energy, thus significantly preventing crack propagation.

8:55-9:20

Study on Gradient Microstructure and Properties of Low Density Steels

Xuemin Wang1, Dan Liu2, Xiangyu Xu3

1. University of Science and Technology Beijing, Beijing, China;

2. NCS Testing Technology Co., Ltd., Beijing, China;

3. Shanghai University, Shanghai, China

It has been found that with the increase of Al content in the steel, the low-carbon steel with high-aluminum will occur a serious decarburization phenomenon during the reheating before rolling and heat treatment, which leads to the decrease of the carbon content at the surface of the low density dual-phase steel. The dual-phase structure in the surface is transformed into single-phase ferrite, therefore the gradient microstructure along the depth is formed. The corrosion behavior of the experimental steel with gradient microstructure was evaluated by the dry-wet cycle corrosion test, and the rust layer was analyzed by XRD, SEM. The results show that corrosion resistance of steel with gradient microstructure is significantly improved when compared with the dual phase low density steel and Corten-A. It has been found that the enrichment of Al and Ni in the gradient microstructure acceleates the formation of α-FeOOH.The XRD analysis results of the rust layer show that the rust layer products of the steel with gradient microstructure have more stable products such as α-FeOOH and Fe3O4.

9:20-9:40

Contribution of grain boundary misorientation to intragranular globular austenite reversion and resultant in grain refinement in a high-strength low-alloy steel

Xuelin Wang[1,2], Zhiquan Wang[1], Anran Huang[1], Sundaresa Subramanian[3], Chengjia Shang[1,2], Zhenjia Xie[1]

1. Collaborative Innovation Center of Steel Technology, University of Science and Technology Beijing, China;

2. Yangjiang Branch, Guangdong Laboratory for Materials Science and Technology (Yangjiang Advanced Alloys Laboratory), China;

3. Department of Materials Science and Engineering, McMaster University, Canada

This paper elucidates the determining role of grain boundary types/misorientations on formation of intragranular globular austenite, which has random orientation or large deviation from the parent austenite, in a high-strength low-alloy bainitic steel during reaustenitization. Results revealed that within the parent austenite with lath bainite, reverted austenite with random orientation or large deviation from the parent austenite can nucleate at the packet and block boundaries with high misorientations, and rapidly evolve to become globular austenite with increase of temperature, making a significant contribution in final austenite grain refinement. While in granular bainite, the low misoriented boundaries belonging to the same Bain group are the preferred nucleation sites for the reverted austenite, which is detrimental to the formation of intragranular globular austenite. In addition, the precipitation mode of cementite is different in the reverse process, that is, cementite is precipitated from the matrix of lath bainite, but it is precipitated from retained austenite or martensite/austenite (M/A) particles in granular bainite, which will also lead to the different or consistent variant orientation of reverted austenite and matrix. Therefore, the final austenite grain refinement in initial granular bainite was mainly due to the formation of intergranular globular reverted austenite, and the refining effect is much lower than that of lath bainite.

9:40-10:00

Study of Decarburization and Oxidation of Surface Crack during Reheating of Billet for Super Strength Cord Steel

Dayong Guo, Yang Pan, Hang Gao, Wenzhu Li, Bingxi Wang, Bo Zhang, Liguo Ma, Ansteel Iron and Steel Research Institute, China

Surface quality is one of the important properties of wire rods for steel cords. Severe surface defects usually cause breakage during wire rod drawing. The surface quality requirement for high carbon steel wire rod used to produce super high strength steel cords is more stringent because the breakage in the process of the wire rod drawing is more sensitive to surface defect. The reheating of high carbon billet is a complex process.

The furnace atmosphere causes decarburization and oxidation of billet surface as well as surface cracks. The investigation of oxidation and decarburization of the cracks on the surface of high carbon billets in the reheating process will provide guide for the finding of the causes of wire rod defects, and give useful aid for the early detection and elimination of possible defects. In this paper, the oxidation and decarburization of the cracks on the surface of high carbon steel billet for super strength cord steel were studied. It is found that decarburization and oxidation layers on are enhanced by the increases in both soaking time and heating temperature. The compression of the sample vertical to the direction of crack, which decreases the width of crack, delays the diffusion of oxygen into the internal part of the crack and largely decreases the depth of surface defect. The oxidation flank along the crack disappears and the decarburization becomes main characteristic of the surface crack. When the soaking time of the high carbon steel becomes shorter, the compression of the crack also reduces the decarburization of the crack. It is concluded that the width of crack is a dominant factor to control the oxidation and decarburization of high carbon steel wire rods. The present finding provides direct insight into the causes of the different surface defects of high carbon steel wire rods.

10:20-10:40

Effects of Induction Heating Process on the Precipitates and Microstructure of the Nb-bearing Steel in the Multi-mode Continuous Casting & Rolling Plant Production Lines

Jia Guo[1], Zhihong Tian[1], Zhongzhu Liu[2], Xiaolin Li[1], Quhan Li[1], Guodong Zhang[2]

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2. CITIC Metal Co., Ltd., Beijing, China

The Multi-mode Continuous Casting & Rolling plant (MCCR) was built in Shougang in 2019. Compared to the traditional hot rolling production lines, induction heating(IH) was equipped between rough rolling and finish rolling. In this work, GLEEBLE-2000 thermal simulator was used to study the effects of IH temperature on the dynamic recrystallization, strain-induced precipitation and microstructure coarsening of Nb-bearing steels.The microstructure and precipitates of Nb-bearing steels were observed by SEM, EBSD and TEM. The results show that Nb-bearing steel containing 0.034%Nb are difficult to undergo dynamic recrystallization when the steel was heated by IH to the various temperatures ranging from 1000 °C to 1230 °C ,which is advantage to improve the stability of rolling and the uniformity of microstructure. Moreover, amounts of precipitates generated during continuous casting can be dissolved by IH at the high temperature of around 1100 °C,Which is beneficial to the producing of new fine precipitates during finish rolling at around 860 °C.However,the microstructure of the steel containing 0.034%Nb will not coarse when the IH temperature lower than 1150 °C, even if the finish rolling temperature reaches 900 °C.

10:40-11:00

Constitutive Relationship of Flow Stress during Hot Deformation of Cu-bearing Ultra-high-strength Steel

Liye Kan[1], Tan Zhao[2], Xiaolan Gong[1], Zhaodong Wang[1]

1. Northeastern University, China;

2. State Key Laboratory of Metal Material for Marine Equipment and Application, China

The constitutive relationship of Cu-bearing ultra-high-strength steel was investigated by the Arrhenius equation and back-propagation artificial neural network (BP-ANN). The Arrhenius equation was modified by considering the effect of strain rate and adiabatic temperature rise. The experimental true stress-true strain data was obtained from the hot compression tests on the MMS-200 thermomechanical simulator in the temperature range of 850 °C-1150 °C and the strain rate range of 0.01-10 s−1. The accuracy and reliability of the models were quantified through the statistical parameters such as the correlation coefficient (Rc), root mean square error (RMSE), and relative error (δ). The results showed that there was a complex nonlinear relationship between flow stress and the processing variables, strain, strain rate, and temperature in the experimental steel. The reason for this phenomenon is the hardening of the work and the dynamic softening, including the DRX and the dynamic recovery during hot deformation. In the construction of the Arrhenius equation, a fifth-order polynomial was used to fit the relationship between strain and material constant (α,n,Q,lnA), which had a good correlation and generalization. For the modification of the Arrhenius equation to predict the flow stress under higher deformation temperatures (1050 °C-1150 °C) and lower strain rates (0.1 s−1 and 0.01 s−1), the exponent of strain rate in the Z parameter was determined to be 3/4. For the modification of the Arrhenius equation to predict the flow stress under lower deformation temperatures (850 °C-950 °C) and higher strain rates (1 s−1 and 10 s−1), the exponent of strain rate in the Z parameter was changed to 0.7, and the effect of adiabatic temperature rise (ΔT=20 °C) during deformation was also taken into account. The Rc, AARE and RMSE are 0.99361, 4.92% and 6.05 MPa, respectively for the improved Arrhenius equation, while their values for the Arrhenius equation are 0.98417, 9.95% and 12.47 MPa, respectively. The Rc, AARE and RMSE of predicted flow stress data points of testing set of the network are 0.99977, 1.02 and 0.88, respectively. And, 98.0% of the test data set possesses δ within ±10%. Comparing with the statistical results of the improved Arrhenius equation, the BP-ANN model is more efficient to predict the flow stress.

11:00-11:20

Investigation of Improving Surface and Internal Quality of the Spring Steel Billet

Shuming Huang[1], Wei Deng[1], Shuai Niu[1], Zhixiang Xu[2]

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2. Research Institute, Nanjing Iron and Steel Co., Ltd., China

It is necessary to increase the allowable stress of the spring to meet its lightweight requirements. This will bring more challenging of improving the surface and internal quality of the spring steel billet. The present paper investigated the effects of casting flux properties and billet heating process on the surface and internal quality of the spring steel billet. By testing four types of casting flux during production, the optimal physical and chemical properties of the casting flux was determined, which has the viscosity range of 0.10-0.36 Pa·s and the melting temperature range of 1080-1105 °C. The billet surface defects such as slag-pit and notch were successfully eliminated by using the optimized casting flux. It was also found when increasing the temperature of the soaking stage in the heating furnace up to 1100-1180 °C, the internal quality of the billet regarding center segregation could be effectively improved and the band degree of the central region of the spring bar could be reduced to less than 2.0 after quenching and tempering. Overall, an engineering machinery spring steel which has achieved a weight reduction of about 25% and also has an allowable stress of over 1550 MPa was successfully developed in NISCO (Nanjing Iron and Steel Co., LTD) by improving the surface and internal quality of its billet, and this spring steel was also widely recognized by the spring industry.

B2 Physical Metallurgy and Properties

Thursday, 10 November 2022, GMT+8 (Beijing)
Room B, Zoom Link: TBD

14:00-14:25

Microstructural Evolution Modelling under Endless Rolling Conditions with Nb Microalloyed Steels

Pello Uranga[1], Jia Guo[2], Guodong Zhang[3], Jose Maria Rodriguez-Ibabe[1], Zhihong Tian[2], Unai Mayo[1], Zhongzhu Liu[3], Chunzheng Yang[4]

1. CEIT and University of Navarra-Tecnun, Spain;

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4. Shougang Jingtang Iron & Steel United Co., Ltd., China

During the last years, compact mini-mill production lines have evolved critically when compared to the initial thin slab CSP® type of configurations. On one side, initial thickness of the slab has been continuously increased to amid-thickness slab ranges, compact finishing stands have been expanded to separate roughing and finishing configurations and, in some cases, endless production operations have been designed to improve productivity, reduce energy consumption and environmental impact. Indirectly, these changes have modified the metallurgical mechanisms acting during hot rolling and, for successfully designed rolling strategies, overcome some metallurgical challenges, such as, the improvement of the initial as-cast microstructure refinement, the ability to produce high property product with thicker final gauges, and extend the steel grade portfolio for a given mill.

In order to understand the mechanisms acting under these new conditions and optimize the rolling sequences, this manuscript describes a detailed analysis run by combining laboratory hot torsion tests with microstructural modelling. Different rolling strategies modifying reheating peak temperatures were applied with several steel grades (CMn, low Nb, high Nb, Nb-Ti combinations). A new MicroSimDSP® version customized for the multi-mode full continuous casting-rolling production line (MCCR-DUE), endless rolling conditions has been developed and applied to predict final austenite grain size distributions. This tool will be used to optimize rolling conditions and improve final homogeneity in the hot-rolled coils.

14:25-14:50

Thermomechanical Processing of V-N Structural Plate Steels - a Modelling Perspective

Kevin Banks, Rorisang Maubane, University of Pretoria, South Africa

Thermomechanical (TM) rolling schedules were developed for typical vanadium-microalloyed structural steels to optimize grain refinement and thus yield strength in the as-rolled and air-cooled condition. Relevant equations describing austenite grain size evolution during rolling and V-precipitation strengthening during cooling were fitted to laboratory and industrial data to compile an integrated plate temperature-microstructure-strength model. Multi-pass hot rolling simulations were performed on V and C-Mn steels to compare the recrystallisation behaviour in various temperature regions. The weak influence of V on dynamic recovery and recrystallisation allowed the use of a C-Mn model to adequately describe austenite evolution in typical V-microalloyed structural steels. The model showed that static recrystallisation, SRX, is the dominant softening mode during plate rolling in both steel types. Significant grain refinement was achieved when finishing was performed predominantly in the lower austenite. When temperature is sufficiently decreased after roughing, recrystallisation is severely suppressed in the first finishing pass

followed by partial to full recrystallisation due to limited strain accumulation. The moderate retardation of SRX in V steels below 850°C - either through solute drag or precipitation - increased the flow stress slightly. Industrially, the key to enhanced strength via grain refinement is complete SRX during roughing followed by low temperature finishing at temperatures as close to the Ar3 as possible to maximize the ferrite nucleation site density. Yield strengths approaching 500MPa can be achieved in V structural steels with moderate nitrogen contents without altering the chemistry by applying optimized TM rolling. Whilst finishing temperature was the dominant process parameter influencing strength for a specific plate thickness, the amount of deformation passes applied and the reduction ratio during finishing were both negligible and allow flexibility in roll schedule design. Predicted plate rolling temperatures and yield strength were in good agreement with industrial measurements made over a range of C-Mn and V-microalloyed steels.

14:50-15:10

Flash Annealing Enables 1GPa Nanoprecipitate-strengthened Ferritic Steel with Heterogeneous Microstructure

Shichun Liu[1], Haokai Dong[2], Hao Chen[1]

1. Tsinghua University, China;

2. South China University of Technology, China

Heterogeneous ultrafine-grained materials have become a new class of materials with superior mechanical properties, whose fabrication method often requires severe plastic deformation followed by proper annealing. In this study, we utilize a cost-effective approach, i.e. flash annealing (FA), to a simple starting microstructure with cold-rolled ferritic matrix embedded by nanosized Ti/Mo alloy carbides. It reveals that FA enables the explosive nucleation of recrystallized ferrite grains and reversion austenite while carbides act as effective obstacles to inhibit their growth, both eventually leading to a heterostructured matrix composed of recrystallized/transformed and non-recrystallized/transformed domains. As compared with the as-received steel, FA-treated steel exhibits a much higher strength level (1GPa) but with a slight loss in ductility, which to our knowledge has not yet been achieved in IF steels and other low carbon ferritic steels. FA method combined with dense nanoprecipitates may open a new route to tailor the microstructure of high-performance uniform materials.

15:10-15:30

Deformation Induced Ferrite in A FH500 Steel

Li Liu, Xiangdou Qin, Baowen Qiu, Nanjing Iron & Steel Co., Ltd., China

Thermomechanical processing (TMP) using single pass hot compression experiments on a low carbon Nb–Ti microalloyed FH500 steel have been carried out to investigate the effects of strain and compression pass on deformation induced ferrite (DIF) production at two temperature 760 °C and 730 °C just above Ar3, and the effect of starting cooling temperature falling into two phase region (γ+α) on DIF growth. The result shows that higher volume fractions of DIF are obtained with increasing strain from 0.357 to 0.693. Deformation temperature of undercooling austenite had little effect on DIF production. At the same strain, one single compression pass enhanced more DIF production than two compression pass. Prior DIF grew very slowly even in two phase region. The hardness values of the various microstructures are consistent with each other.

15:50-16:15

Mechanisms of Hydrogen Embrittlement in Ultra-high Strength Steels and Possible Countermeasures

Hardy Mohrbacher, NiobelCon BV, Belgium

Failure of ultra-high strength steel caused by hydrogen is related to more specific processes such as stress corrosion cracking (SCC), corrosion fatigue cracking (CFC), and hydrogen-induced cracking (HIC). The latter is also referred to as hydrogen embrittlement (HE). Embrittlement can occur by hydrogen located within the bulk of the steel during the application of a load. In addition, embrittlement might result from the exposure of a steel under load to a hydrogen-containing environment. Both situations can be experienced over the life of a vehicle. The embrittlement manifests itself by a non-ductile fracture mode, reduced ductility (elongation), and reduced tensile strength. In martensitic steels isolated areas are observed of either intergranular or transgranular brittle fracture, depending on the relative strength of the grain-boundaries and interfaces. The higher the strength level of the steel, the greater is its susceptibility to HE and the lower is the amount of allowable diffusible hydrogen content. At these lower hydrogen levels, the local hydrogen distribution appears to be more relevant than the average diffusible hydrogen content. Consequently, countermeasures to HE should focus on reinforcing boundary strength as well as obstructing local aggregation of hydrogen. Important mechanisms in this respect are microstructural refinement, hydrogen trapping by precipitates and reduced mobility of dislocations or vacancies. Molybdenum and niobium are shown to be alloying elements providing these beneficial effects in manifold ways. Alloying strategies that have led to significant reduction of HE sensitivity in press hardening steels (tensile strength range of 1500 to 2000 MPa) are demonstrated and the underlying interferences with hydrogen-induced damage mechanisms are discussed.

16:15-16:35

Influence of Aluminium on Grain Refinement in As-Rolled Vanadium-Microalloyed Steels

Dannis Rorisang Nkarapa Maubane, Kevin Mark Banks, Carel Coetzee, University of Pretoria, South Africa

The influence of aluminium additions on the as-rolled final microstructure of V-microalloyed and C-Mn plate steels has been investigated for steels containing 0 - 0.073 % aluminium and 47 – 130 ppm nitrogen. Laboratory reheating, hot rolling and air-cooling simulations for 6 and 20 mm thick plates were performed on a Bahr deformation dilatometer with the aid of a one-dimensional heat transfer model. Aluminium contents below 0.075 % had no influence on the as-rolled ferrite grain size in V-N steels which were subjected to conventional (high temperature) rolling. For a given thickness, the ferrite grain size in V steels was comparable after both industrial and simulated laboratory rolling. There was no significant influence of initial austenite grain size or Aluminium content on the final austenite grain size immediately after hot rolling in V steels. The as-rolled ferrite grain sizes were coarse but similar in C-Mn and V-steels. This was attributed to the relatively slow plate cooling rate which leads to coarser AlN and V(C,N) particles being less effective in pinning of grain boundaries to retard growth. Lowering the reheat temperature to 1100 °C decreased the initial austenite grain size but did not influence the final ferrite grain size. The final microstructure was insensitive to the N content. In 6 mm plate rolling schedules, the as-rolled ferrite grain sizes were fine and similar in high N steels after reheating to 1220 °C. A small sizing strain produced coarse pearlite regions in both C-Mn and V steels containing low nitrogen levels. Increasing the sizing strain refined the microstructure due to increased nucleation sites via strain accumulation. The finest microstructures were observed after reheating at 1100 °C and subjecting V-Al steels to 6 mm plate rolling schedules and pointed to a refining influence by Al under these conditions. Multi-pass flow curves revealed that the softening kinetics is similar in all V-Al steels at temperatures above 900 °C. Below this temperature, recrystallisation is markedly reduced.

16:35-16:55

In Situ Observation of Acicular Ferrite Formation in Ti-Zr Combined Deoxidized Low Carbon Steel

Yongkun Yang[1], Dongping Zhan[1], Yuli Li[1], Hong Lei[1], Zhouhua Jiang[1], Huishu Zhang[2]

1. Northeasten University, China;

2. Liaoning Institute of Science and Technology, Chian

Acicular ferrite (AF) was the most desirable microstructural feature in heat affected-zone. It was of great significance to study its nucleation and growth during cooling process after high temperature reheating. High temperature confocal laser scanning microscope (HT-CLSM) technique was considered as a powerful tool to observe phase transformation and microstructural evolution in real time. And Ti-Zr oxides, as the products of Ti-Zr complex deoxidation, were usually used as AF nucleation cores. Based on that, the Ti-Zr combined deoxidized low carbon steel with a chemical composition (wt %) of Fe-0.21C-0.28Si-0.80Mn-0.50Cr-0.57Ni-0.17Mo-0.005S-0.033Ti-0.002Zr-0.0019O-0.0025N was select as the research object to in situ observe and investigate AF first nucleation temperature and growth rate during cooling process after re-heating at 1673 K. The sample was first heated to 1673 K with heating rate of 10.0 K/s, and isothermal held for 180 s, then immediately continuous cooling to 573 K with cooling rate of 1.0 K/s. In order to observe the detailed information of ferrite nucleation and growth, the images were recorded at 2 frames per second. For obtaining the AF growth rate, some AF laths were randomly selected from the HT-CLSM images to observe growth and measured the AF length by the image process software, Image Pro Plus 6.0. After heating cycle, the sample was treated by standard grinding and polishing, and then etched by 4% Nital (volume fraction) to observe the microstructure by optical microscope. The resulted indicated that as the sample cooling from the re-heated temperature with cooling rate 1.0 K/s, AF first nucleation on the inclusion was at 895.1 K, which was 39.9 K lower than the temperature of ferrite nucleation on the grain boundary. The maximum growth rate of AF was 67.84 μm/s, and the average growth rate was 41.54 μm/s. The volume fractions of AF and bainitic ferrites in microstructure were equivalent, 41.67% and 47.40%, respectively.

16:55-17:15

Microstructure and Properties of High Titanium Low Carbon Steel

Zhimin Zhang[1], Quanli Wang[2], Haoyu Wang[3], Yun Han[1]

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2. Shougang Group Co., Ltd., China;

3. Shougang Jingtang United Iron & Steel Co., Ltd., China

Microstructure and precipitates of high titanium low carbon steel were observed by optical microscope, scanning electron microscope and transmission electron microscope. Precipitation of TiC was calculated by solid solubility formula in order to obtain amount of precipitated TiC in steel at different temperature. Results show that the main precipitates in high titanium low carbon steel are micron-scale TiN, Nano-scale Ti4C2S2 and TiC. Size of TiC is 5 ～ 16 nm. The number of precipitated TiC is 3.2×108 per square millimetre. TiC begins to precipitate at 1186 °C. Precipitation process of TiC ends at 700 °C. The maximum volume fraction of precipitated TiC is 0.347%. With increases of Ti content, size of precipitated TiC increases and yield strength of steel decreases. With increases of C content, size of precipitated TiC increases but yield strength of steel increases.

B3 Physical Metallurgy and Properties

Friday, 11 November 2022, GMT+8 (Beijing)
Room B, Zoom Link: TBD

8:30-8:55

Vanadium Effects on Recovery in Bainitic and Martensitic Microstructures

K.O Findley, J. Benz, J. Klemm-Toole, S.W. Thompson, J.G. Speer, A. Carley-Clopton, G.S. Ansell Department of Metallurgical and Materials Engineering, Advanced Steel Processing and Products Research Center, Colorado School of Mines, USA

Two examples of the influence of vanadium on recovery in low to medium carbon steels with bainitic and martensitic microstructures are presented. In one example, high strength low alloy steels with and without a vanadium addition were subjected to austenitization and subsequent isothermal austempering at temperatures of 400 and 550 °C to produce bainitic microstructures. Hardness data and dislocation density measurements were used to estimate strengthening and recovery effects during aging. The experimental data and a recovery model fit to the data indicate a prominent effect of vanadium microalloy precipitates inhibiting recovery. In a second example, vanadium microalloyed medium carbon steels (0.4 wt. pct. C) were heat treated to form martensite or bainite microstructures in two alloy variants containing 0.1 or 0.26 wt. pct. vanadium. These different conditions were then tempered at temperatures of 500 and 650 °C. The alloy containing a higher amount of vanadium had a higher dislocation density compared to the lower vanadium condition for both microstructures after tempering. This difference at a tempering temperature of 500 °C is due to a higher volume fraction of MX precipitates slowing recovery. At 650 °C, the higher V conditions again had a higher dislocation density but the difference with the lower V condition was less, suggesting that higher temperatures provide a greater driving force to overcome the influence of precipitation on recovery. These two examples demonstrate that vanadium containing microalloy precipitates inhibit recovery in microstructures with high dislocation densities over a range of processing paths in low to medium carbon steels.

8:55-9:15

Regulation Effect of Nb Content on Microstructure Evolution of 2000MPa Martensitic Ultra-high Strength Steel

Hongyan Liu1,2, Zigang Chen2, Xiangtao Deng1, Zhaodong Wang1

1. State Key Laboratory of Rolling and Automation, Northeastern University, China;

2. Handan Iron & Steel Company of Hebei Iron & Steel Group Co., Ltd., China

Through the research on the regulation effect of Nb content on the microstructure evolution of 2000MPa martensitic ultra-high strength steel, the development of 2000MPa ultra-high strength F-grade wear-resistant steel was realized for the first time, and the toughness control problem caused by high toughness of this kind of products was solved. The research shows that when the Nb content is 0.01%, 0.03%, 0.04%, with the increase of Nb content, the original austenite grain size is significantly refined from 19μm to 8μm, the lath packet size is 8.1μm, 2.36μm and 1.86μm respectively, the average width of martensite blocks are 2.03μm, 1.53μm, 0.57μm respectively; and the proportions of high-angle grain boundaries are 52.2%, 59.5%, and 63.5% respectively. With the increase of Nb content, the proportion of high-angle grain boundaries is significantly increased, which ensures good toughness in ultra-low temperature environment. After tempering at 200°C, the ultra-low temperature toughness test at -60°C shows that the impact energy of NM600-SYA with a Nb content of 0.040% is higher than that of NM600-SYB and NM600-SYC, which is between 35 and 58J, without ductile-brittle transition.

9:15-9:35

Physical Metallurgy of Steel—Titanium Microalloyed High Strength Steel

Liejun Li[1], Xiangdong Huo[2], Jixiang Gao[3], Zhengwu Peng[1], Songjun Chen[1]

1. South China University of Technology, China;

2. Jiangsu University, China;

3. Guangdong Polytechnic Normal University, China

In microalloyed high strength steel, strength is enhanced while maintaining good ductility and formability by nanoprecipitates. Therefore, it is widely used in the automotive industry, construction machinery, oil pipelines and other fields. Industrially, the refining limit of grain size in steel is about 3-5μm . Further refining the grain size to improve the strength and toughness has reached a bottleneck. In addition to fine grain strengthening, the brittleness vector of precipitation strengthening is the smallest, which is the most effective way to improve strength. Ti, a strong carbide forming element, play a significant role in precipitation strengthening and has a potential to be developed into high-strength steel. Compared with microalloyed elements such as Nb and V, Ti

resources in China are the most abundant and the price is the cheapest. Therefore, the research on precipitation control and strengthening in Ti microalloyed steel can give full play to the advantages of cost and resources. It helps to reduce the consumption of steel, so as to reduce energy consumption and carbon dioxide emissions, which is in line with the national strategy of "carbon peaking and carbon neutralization".

As the company with the first thin slab continuous casting and rolling production line in China, Zhujiang Iron and Steel company had started the research and development of Ti microalloyed high-strength steel as early as 2004. Today, nearly two decades later, the hot rolled high strength steel produced by titanium microalloying technology has been more and more widely accepted. In the process of product development, researchers mainly conducted research through the experience between technology and performance, without deeply realizing the important role of "organization" as a bridge between "technology" and "performance". The most prominent problem in titanium microalloyed steel is the performance fluctuation, that is, the precipitation is very sensitive to temperature and cooling process, which is difficult to be stably controlled, and finally limits the application of titanium microalloying technology. In recent years, our team has carried out a lot of research on physical metallurgical characteristics such as recrystallization, phase transformation and precipitation `in titanium microalloyed steels. The research results showed that the carbides play a remarkable role in precipitation strengthening in titanium microalloyed steel mainly come from the isothermal or coiling stage. Subsequently, the precipitation kinetics, precipitation process characteristics and mechanism, the relationship between isothermal precipitation behavior and phase transformation during the isothermal phase transformation were further studied. Finally, combined with the TMCP, the influence of precipitates on microstructure and properties, the strengthening mechanism were revealed. The basic data of physical metallurgy of "process-precipitation-microstructure-strength" were established, which provides an important theoretical basis for controlling the uniformity of microstructure and the stability of precipitates.

Finally, this paper attempts to summarize the possible development direction and application prospects of titanium microalloyed high-strength steels. For example, the production of the steel can be expanded to the fields of cold-rolled strip, medium and heavy plate and construction reinforcement, so as to meet the application requirements in more industries for steel mechanical properties, physical properties and process properties. Therefore, we hope to attract more people's attention and thinking, and jointly promote the development of titanium microalloying technology.

9:35-9:55

A New Cooling Strategy in Curved Continuous Casting Process of Vanadium Micro-alloyed YQ450NQR1 Steel Bloom Combining Experimental and Modelling Approach

Kun Dou[1], Qing Liu[2], Wanlin Wang[1]

1. School of Metallurgy and Environment, Central South University, China;

2. State Key Laboratory of Advanced Metallurgy, University of Science and Technology Beijing, China

Considering the proper cooling scheme for the continuous casting of steel bloom, a kind of vanadium-containing micro-alloyed steel is studied with both experimental investigation and mathematical modelling in this work. The authors firstly investigate the hot ductility of bloom surface microstructures at various cooling rates using a Gleeble thermal simulator. Then, the precipitation of V(C, N) particles and its influence on ferrite formation during continuous cooling are studied and characterized using High Temperature Laser Scanning Confocal Microscopy (HTLSCM). Based on these, the preferred cooling rate for surface microstructures at the straightening position in the caster is obtained. To further reduce the solute macro-segregation through enlargement of the equiaxed crystal zone, a cellular automaton-finite element (CA-FE) model is used to calculate heat transfer and solidification structure evolution during the continuous casting process. After calibration with industrial trials, the model is utilized to determine the critical position for columnar to equiaxed transition and to adjust the pouring temperature for the melt. Combining the above research, a new cooling strategy for the studied steel bloom is obtained, which can improve crack-resistance of bloom surface microstructures and reduce solute macro-segregation at the same time.

10:20-10:45

The Optimization of Slab Microstructure and Effect on Silicon steel Magnetic Property

Jian Gong, Maolin Sun, Xianhui Wang, Weiguang Pang, Beijing Shougang Co., Ltd., China

The silicon steel has high Si content which is ferrite stable element and some grades of silicon steel have no austenite and some grades have part of austenite which cause no phase or part phase transformation. So the slab microstructure has direct effect on the magnetic property and surface quality of final product. The solidification behaviors of silicon steel slabs have been investigated in industrial strand electromagnetic stirring (S-EMS) and the morphology of the microstructure of columnar crystal zone and the equiaxed crystal zone and the columnar-to-equiaxed transition zone were illustrated. The microstructure of different grades of silicon steel slab with electromagnetic stirring

by optimum parameters and without electromagnetic stirring were investigated. The evolution of slab microstructure during hot rolling, normalizing process, cold rolling, annealing process and final product have been reasearched. The effect of different microstructure of slab on final product magnetic property and surface quality was investigated and the optimization of the microstructure of different grade silicon steel slab was discussed.

10:45-11:10

Strength and Toughness Mechanisms of 700 MPa Grade High Strength Ti-Zr Composite Microalloyed Steel

Hanyu Luo[1], Jianchun Cao[1], Juncai Wang[1], Fanlin Zhang[1], Shubiao Yin[2], Chuangwei Wang[3], Xiaoyu Ye[3], Qinchun Liu[3]

1. School of Materials and Engineering, Kunming University of Science and Technology, China;

2. Faculty of Metallurgy and Energy Engineering Kunming University of Science and Technology, China;

3. Panzhihua Iron and Steel Research Institute Co., Ltd., China

The effects of different coiling temperatures on the microstructure and mechanical properties of Ti-Zr composite microalloyed steel sheets were investigated by means of TEM, EDS, tensile and impact tests and combined with theoretical calculations, and the toughening mechanism of Ti-Zr steel was explored. The results show that he microstructure of both test steels at room temperature is acicular ferrite and polygonal ferrite, and that the addition of Zr and the lowering of the coiling temperature results in a finer ferrite grains. The addition of Zr reduces the consumption of Ti at high temperatures and promotes the precipitation of fine TiC particles at low temperatures, which plays a role in precipitation strengthening and refining the ferrite grains, thus improving the strength and plastic toughness of the steel plate and giving it excellent overall mechanical properties.

11:10-11:35

Evolution of Prior-austenite Grain Structure during Reheating of As-cast Microalloyed Steels

Debalay Chakrabarti[1], Kumar Aniket Anand[2], Vinod Kumar[2]

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2. Research & Development Centre for Iron & Steel, Steel Authority of India Limited, India

To study the effect of microalloying strategy on the evolution of austenite grain size distributions in microalloyed high-strength low alloy (HSLA) steels containing Nb, Ti and V in different combinations, seven as-cast steel blocks are reheated 1000-1250C, soaked for 1 h, and water quenched. The precipitates before and after the reheating treatment are characterized. The prior-austenite grain structures and the corresponding austenite grain distributions are presented and the effect of microalloying elements on the formation of bimodal austenite grain size distributions is discussed.

C1 Niobium Microalloyed Steels Helping the Dematerialization in Civil Construction

Thursday, 10 November 2022, GMT+8 (Beijing)
Room C, Zoom Link: TBD

Session 1 Reinforced Concrete

8:30-8:35 Opening Address

8:35-8:55

The Benefits of Using 500MPa as the Yield Strength of Reinforcement Bars for Civil Construction

Marcos A. Stuart Nogueira[1], Carlos J. Massucato[2], Alexandre Magnus Jordão[3]

1. ST3 Consulting. Consultant for Niobium Technology at CBMM;

2. Massucato Consulting. Consultant for Niobium Technology at CBMM;

3. Market Development of CBMM

Reinforced concrete structures have a significant environmental impact, representing about 6% of the global CO2 emissions. To reduce the carbon footprint and meet the Paris agreement goal of limiting global warming to below 2.0°C, new low carbon material solutions are needed. Meanwhile, carbon taxes are becoming popular in some countries such as China and will progressively erode the competitiveness of carbon-intensive solutions and favor new low-carbon solutions. An increase in rebar yield strength without increasing the CO2 footprint is a potential solution to reduce the carbon of reinforced concrete structures since less steel is consumed in the building structure. Additionally, the use of high-performance concrete collaborates with this reduction. Microalloying steel is a well proved route to produce higher yield strength steel without reducing ductility. Based on a literature review on real buildings that used higher strength reinforcing bars, this paper will quantify the environmental benefits of using these steels, discussing the influence of different design parameters. The preliminary results suggest that the minimum yield strength of 500MPa will be adopted widely in China as it is nowadays in several countries

such as South Korea, Germany, France, and Brazil. In China, the equivalent grade HRB500, ruled by GB/T 1499.2-2018, has started to be used more intensively. Moreover, higher benefits can be achieved using 600MPa despite being less used in the market. The results also show that the benefits were higher for buildings that use rigid-frame and flat-plate structures, where the beams reached up to 21% of steel savings when using 500MPa and 31% when using 600MPa. However, additional research is required to fully explore the benefits of using steel with yield strength above 500MPa, including the influence of design parameters, building typology and seismic loads.

8:55-9:15

Case Study on Optimal Structural Design and Economic Analysis of 500MPa Rebar in Building Structures

Dewen Chu[1], Mingzhe Cui[1], Hongrui Ma[1], Jirui Shi[1], Yuxin Jiang[1], Alexandre Jordão[2]

1. China Academy of Building Research Co., Ltd., China;

2. CBMM Niobium, São Paulo, Brazil

At present, global warming is an extremely important issue for our time, and greenhouse gases emission lies at the root of this issue. However, steel industry has the largest carbon emissions among the 31 manufacturing sectors in China. To achieve carbon emission peaks in advance during the "14th Five-Year Plan" period and to reduce the carbon dioxide emission, one effective way is to promote the application of high-strength steel and reduce the overall consumption of material. This research summaries specification for HRB500 in Chinese codes and focuses on the application of HRB500 high-strength rebar in the above-ground structure of an actual reinforced concrete frame-core wall project of 223m height. The beneficial effects of replacing HRB400 rebar with HRB500 rebar in this project were analyzed using the finite element analysis software PKPM. It is demonstrated that, based on the current reinforced concrete design code, replacing all HRB400 rebar with HRB500 high-strength rebar can save 9.3% of total rebar consumption. Factoring in rebar amount and rebar price, a more economically optimized model is proposed and HRB500 high-strength rebar are used only in certain type of reinforcement. The results show that the total amount of rebar of the optimized model can be saved by about 8.8%, and the total rebar cost can be saved by about 6.5%, compared with the original design with HRB400 rebar. Finally, the suitable applicability of HRB500 rebar in different positions are obtained. This paper provides reference for the application of HRB500 rebar in relevant structure design.

9:15-9:35

Development, Promotion and Application of HRB500E in China

Yongqing Zhang[1], Aimin Guo[1], Marcos A. Stuart Nogueira[2], Rafael A. Mesquita[2]

1. CITIC Metal Co., Ltd., China;

2. CBMM, Brazil

Reinforcing bars (abbreviated as rebars) have been widely used for reinforcement of concrete, and total yearly production output has topped steel products, accounting for about 25.0 percent in recent years in China. In order to relieve the constraints of natural resources and environment protection, promotion of high strength hot rolled rebars, namely 400MPa grades and above grades, has been proposed by metallurgical ministry since last century, only by adding 400MPa into GB50010-2002: Code for design of Concrete Structures. The application of 400MPa replacing 335MPa was fast growing from 2.85 percent in 2001 to 35.0 percent in 2010. During the Twelfth Five-Year plan (2011-2015), China's two ministries, Ministry of Industry and Information Technology, Ministry of Housing and Urban-Rural Development, set up working group with related departments, and released some guidelines to accelerate application of high-strength rebars, that is, to eliminate 335MPa grade, to prioritize use of 400MPa, and to promote 500MPa grade positively. With concentrated efforts, application percentage of 400MPa had increased from 45 percent in 2011 to more than 90.0 percent in 2015. However, promotion and application of 500MPa had not met the anticipated expectation, while large amounts of development and application research on 500MPa had been initiated and conducted. Although 500MPa grade had been incorporated in GB1499.2 since 1998, and then was incorporated and recommended by revised "Code for Design of Concrete Structures" (GB50010-2010) in 2011, it need more time to recognize and promote 500MPa grade by all sides along the whole industry chain, including production, design, and application. Secondly, not all rebar makers mastered the know-how to produce 500MPa with earthquake resist requirement at that time, in particular small sizes HRB500E. Thirdly, economic benefits by using 500MPa grade to replace 400MPa grade are not clear for all sides, in particular complicated by the minimum reinforcement ratio in shear wall structures.

For these possible reasons, large amounts of works had been conducted by CITIC-CBMM and partners, including development, promotion and application research since 2012. By applying Nb plus V microalloying, it was validated tensile-to-yield ratio would increase especially for small sizes of HRB500E, while some metallurgical mechanisms need further study. According to the market investigation in 2011, total production of HRB500E is more than 3.0 million tons, of which majority of rebar makers have started to adopt Nb plus V production process. In order to expand application, CITIC-CBMM once cooperated with Kunming to organize promotion meeting based on application cases of

Kunming Changshui International Airport, that was initiated in 2008 and completed in 2010. In 2021, CITIC-CBMM, together with CABR cooperated to optimize design with 500MPa for eight typical building cases to confirm specific advantages of 500MPa grade, in terms of economic benefits to all sides and social benefits like carbon emission reduction. Based on these works, the promotion and application of 500MPa grade can be accelerated at moment and in a near future.

Fortunately, President Xi Jinping proposed China's new climate target at the 75th session of the UN General Assembly, that is, to achieve peaking of CO2 emissions before 2030 and carbon neutrality before 2060, which is a strategic decision coordinating the overall domestic and international situations. Considering the carbon emission amounts by construction and steel industry, promotion of 500MPa rebars will obtain policy support and opportunity in the future. This paper reviews some important milestones in promotion of high strength rebars, and then figure out the bottleneck and solution for promotion of high strength rebars. In addition, some highlight is placed on the development of 500MPa and even 600MPa grade. If all 400MPa rebars are replaced by 500MPa rebars, China would decrease steel production by roughly 22 million tons, which in turn reduces 50 million tons of direct CO2 emissions, with further gains in indirect emissions through the supply chain.

9:35-9:55 Q&A

Session 2 Structural Steels

10:20-10:40

Stronger Steels in the Built Environment: Structural Response and Application of S460 to S700 Hot Rolled and Fabricated Sections

Nancy Baddoo[1], Jitendra Patel[2,3]

1. Associate Director – Steel Construction Institute, Ascot, UK;

2. Director – International Metallurgy Ltd., Oxford, UK;

3. Consultant – CBMM Technology Suisse S.A., Geneva, Switzerland

Steel structures maintain a dominant presence in the construction industry because of continuous advances in material properties, production methods and innovative design and construction techniques. Modern production techniques, such as thermomechanical rolling, and quenching and tempering, now enable the economic production of steels with yield strengths between 460 and 700 MPa and the weldability, fracture toughness and ductility required for structural applications.

The use of high strength steels (HSS) can lead to significant reduction in the quantity of steel used, leading to a lighter structure, thus requiring smaller foundations and shorter transportation and construction times. It also results in lower CO2 emissions and energy use (both directly and indirectly). Despite the advantages of HSS, the use of steels S460 and above in structures remains rather low (around 5%) and there is great potential for wider use in building structures across the world. A better understanding of how to maximize the benefit of a higher strength will help designers make informed decisions on material selection and related benefits at the conceptual stage of a project, hence overcoming reluctance to use a material they are not familiar with, and which is less widely available.

This paper presents the outcome of a recently completed European RFCS (Research Fund for Coal and Steel) collaborative research project, Stronger Steels in the Built Environment (STROBE), that studied the structural response of HSS from S460 to S700, considering both hot rolled and fabricated I shaped sections (homogeneous and hybrid). Focus is on basic issues allowing for usage of HSS with lower ductility values, exploiting plastic capacity, leading to more slender and highly utilized profiles. The benefits are quantified by design comparisons and importantly, life cycle assessments (LCA) and cost comparisons. Attention is given to both single and multi-storey building structures. However, the results have generic applicability to a far wider range of structures where HSS can be applied.

10:40-11:00

Application and Research of High Strength Steel Structure in Super High-rise Buildings in China

Honglei Wu[1,2], Shiyu Wang[1], Jiemin Ding[1,2]

1. Tongji Architectural Design (Group) Co., Ltd., China;

2. College of Civil Engineering, Tongji University, China

With the booming development of China's economy in the past 20 years, super high-rise buildings above 250m in China have a high tide of construction. Compared to reinforced concrete structure, steel structure have the advantages of high strength, good ductility, light weight and highly industrialization, making it widely used in super high-rise buildings. First, this paper makes a big data analysis for the super high-rise buildings above 250m in China, to introduce the development status of China's super high-rise buildings. Then, combined with typical super high-rise buildings, the application of steel structure in China's super high-rise buildings is comprehensively introduced and deeply analyzed through four aspects, including steel product, steel frame column, steel beam and floor system, steel brace. The analysis results show that China has constructed a total of 304 super high-rise buildings above 250m, mainly adopting steel-concrete hybrid structure, and also there are a certain number of steel structures. The steel grade adopted in China's super high-rise buildings is mainly Q345 and Q390. For the obvious strength advantages of high-strength steel product, some super high-rise buildings have begun to adopt high-strength steel product such as Q420, Q460, Q550 and Q690. Steel frame columns include steel column and concrete filled steel tubular column. The pure steel column is mainly used in 300-meter super high-rise buildings. For the concrete filled steel tubular column has a high bearing capacity, it is widely used in 500-meter super-high-rise buildings. The floor system mainly adopts formed steel plate composite floor and H-shaped steel beam. Steel braces can improve the structural lateral stiffness of super high-rise buildings, and mainly include ordinary steel brace, mega-steel brace and buckling restrained brace, which are usually arranged in strengthened layer, steel core tube and mega-frame structure, etc.

11:00-11:20

Case Study on High Strength Steel Grades Used in High Rising Structure CITIC Tower

Weibiao Yang, Beijing Institute of Architectural Design, China

With the improvement of smelting technique, high strength steel with better mechanical properties, has gradually drew public's attention in the field of construction engineering. Its high strength characteristics benefits large-scale steel and concrete structures. CITIC Tower is located in Beijing, China ' s capital. It is the highest super high-rise building in China ' s high-intensity earthquake area, attracting worldwide attention. Using high-strength steel to redesign the China Tower can optimize the seismic performance of the structure, save steel consumption, and reduce carbon emissions, while matching the code requirements and architectural function requirements. The equal strength method is used to replace the high-strength steel of the raft foundation, pile, concrete filled steel tube huge column, diagonal brace, steel plate shear wall and other key components of CITIC Tower, for the calculation, analysis and statistics. When high strength steel is used for design, the limits of width-thickness ratio of components in Chinese, American and European codes are compared. When high strength steel is applied in the design, the direct analysis method is used to analyze the cross section of the huge column.

11:20-11:40

Recent Developments of the Use of Advanced Niobium HSLA Flat Steels for Stadiums and High-rise Buildings

Houxin Wang, Aimin Guo, CITIC Metal Co., Ltd., China

The Chinese steel industry has been developing at an amazing rate for over ten years, providing great quantities of steel materials to downstream industries and also stimulating the development of these industries. In recent years, with the further development of urbanization and modernization, many high-rise buildings and large span structures have been built in China, and a large amount of steel has been used in those buildings. Before giving some examples of the buildings in which niobium microalloyed steels have been used, Chinese steel standards are reviewed. The new version of the code for the design of steel structures allows more steel grades to be considered for building structures. There is no doubt that niobium microalloyed steels, with outstanding mechanical properties, will play a very important role in the booming era of high-rise buildings in China.

11:40-12:05 Q&A

12:05-12:10 Closing Speech

C2 Construction Steel

Thursday, 10 November 2022, GMT+8 (Beijing)
Room C, Zoom Link: TBD

14:00-14:25

Metallurgical Aspects of Nb Application in Rebar Production

F. Bastos[1], Y. Zhang[2], B. Pereda[3], B. Lopez[3], J.M. Rodriguez-Ibabe[3]

1. CBMM, Brazil;

2. CITIC Metal Co., Ltd., China;

3. CEIT and University of Navarra-Tecnun, Spain

This manuscript analyzes how Nb, alone or combined with other microalloying elements, exerts different metallurgical functions depending on the rolling strategy and final rebar diameter. In the case of low temperature rolling strategies, Nb fine precipitates exert a control of austenite grain size during all the processing steps, from reheating of the billet to the final rebar cooling at the exit of the mill before transformation. In addition, Nb in solution delays the recrystallization kinetics of austenite during hot rolling and will provide an additional hardening during transformation. Finally, some contribution of precipitation strengthening in ferrite can occur. In the case of higher temperature rolling strategies, more Nb will remain in solid solution, increasing the delay in recrystallization during rolling. The austenite grain size before transformation will also be coarser. In these conditions, to obtain full ferrite-pearlite microstructure it will be necessary a balance between other alloying elements affecting hardenability and the corresponding cooling strategy. The model developed, PhasTranSim, allows defining these aspects in economically and technically efficient conditions.

14:25-14:50

Strengthening of High-strength Rebars

Jingliang Wang, University of Science & Technology Beijing, China

14:50-15:10

Development of HRB400E Rebars with Nb Microalloyed for High Speed Bar Production Lines

Yi Luo[1,2], Yongqing Zhang[1,2], Bastos Felipe[3,4], Siqian Bao[5], Xuehai Qian[6]

1. CITIC Metal Co., Ltd., China;

2. CITIC-CBMM Microalloying Technology Center, China;

3. Universidad de Navarra, Spain;

4. CBMM, Brazil;

5. Wuhan University of Science and Technology, China;

6. Guangxi Liuzhou Iron and Steel Group Co., Ltd., China

In the view of important role of Nb in the development of thermomechanical processing (TMP) flat products, Nb has been regarded as the most effective TMP microalloy element. Rebars with Nb microalloyed have been also researched and developed more and more nowadays, and the physical metallurgical mechanism of which is gradually clear. At present, the development and mass production of Nb-bearing hot rolled rebars, along with V-bearing ones, can save iron and steel consumption and reduce carbon emission, and jointly promote the healthy development of construction industry in China. CITIC Microalloying Technology Center together with scientific research institutions and domestic leading rebars makers, after years of exploring the physical metallurgy mechanism of Nb microalloyed steel, and R&D of Nb-bearing aseismic rebars, has clarified the role of Nb in rebars. The recent launched high speed bar rolling lines make controlled rolling of rebars available. Combined with above researches and production on the Nb-bearing HRB400E rebars, and the character of the upgraded rolling lines, development and production of HRB400E rebars with Nb microalloyed are introduced for the high speed bar rolling lines.

15:10-15:35

Overview of Application of Nb Microalloyed- and Micro Nb Treated Hot Rolled Value-added Sections in China

Houxin Wang, CITIC Metal Co., Ltd., China

Hot rolled H beams, as very economical products for their shapes, have been used in a variety of steel structures around the world. In comparison to flat products, it is much more difficult to produce such type of sections due to the limitations in mills' weak capacity, layout of production line, rolling method, lack of post cooling and many other factors. For long time, V among the three main microalloying elements is mostly recognized for sections production, mainly due to its precipitating tendency for making strength. However, steel structures built in cold areas, high-rise building, heavy load transmission towers and many other developments demand for improved sections with high strength, high toughness at low temperatures and/or improvement in weldability, seismic resistance and so on. Under circumstances, using only V become challenging and other microalloying elements like Nb and Ti have to be considered.

15:50-16:15

Industrial Trials and Role of Nb Microalloying for Hyper-eutectoid Wire Rod Products

Yongqing Zhang[1,2], Maoqiu Wang[2], Qilong Yong[2]

1. CITIC Metal Co., Ltd., China;

2. China Iron & Steel Research Institute Group, China

Since Microalloying'75 conference, microalloying steels and matched thermo-mechanical processing have obtained quick development, and microalloyed steels with Nb, V, Ti and their combination have been successfully and widely used for different application segments, such as oil & gas, automotive, machinery, shipbuilding, construction field, etc. Among three microalloying elements of Nb, V and Ti, Nb-bearing steels have been viewed the most active for modern microalloyed steels, but most Nb-bearing steels are limited to low-carbon flat products due to limited solubility, and research and application for high-carbon long products have been almost blank. In this paper, industrial trials and strengthening effects of Nb microalloying on hyper-eutectoid wire rod products have been carried out and explored.

Considering limited solubility for high-carbon steels, aim Nb additions are controlled less than 0.025% for 82B, 87B and 92Si products. According to analysis results, small amount Nb additions can markedly refine pearlite colony, which was resulted from retarding effects by undissolved Nb(C,N) particles during reheating and hot-rolling process, as well as precipitates of niobium during hot rolling process. Regarding the effect of Nb microalloying on pearlite interlamellar spacing, it is depended on the degree of Nb in steel: precipitation or solution. In addition, niobium adding can change aspect ratio of pearlite or sorbite, which is assumed by precipitation and gathering of Nb(C,N) particles. By testing, it was found that area reduction ratio improves markedly through Nb microalloying, but strengthening effect on tensile level is not so conspicuous. Regarding the refinement of pearlite interlamellar spacing, it is dependent on the status of niobium in steels before transformation. Niobium additions remaining in the austenite before transformation will increase the hardenability, which will in turn refine pearlite interlamellar spacing for higher combination of tensile strength and ductility.

What is more, interaction between NbC precipitates and high dislocation density resulted from cold drawing can offset the strength loss caused by galvanizing, which provide possibility to develop higher grade products like 2060MPa and 2100MPa bridge cable products. Finally, Nb(C,N) particles can serve as trap to capture Hydrogen for long service life.

By this work, it is confirmed that Nb microalloying demonstrates positive effect on reduction of area , which is effective to improve drawability during down-stream processing. Up to now, some steel mills and end users have started to adopt Nb microalloying for hyper-eutectoid wire rod products.

16:15-16:35

Effects of Reheating Temperature and Time on Grain Boundary Cementite Dissolution in Wire Rods for Super High Strength Steel Cord

Dayong Guo[1], Bo Zhang[1], Junfeng Zhang[2], Hang Gao[1], Liguo Ma[1], Yang Pan[1], Bingxi Wang[1], Wenzu Li[1]

1. Ansteel Iron and Steel Research Institute, China;

2. Wire rod Plant of Ansteel, China

This paper presents the effects of reheating temperature and time on GBC dissolution in high carbon steel billet. The study was carried out on the specimens of hypereutectoid steel. It is found that the GBC of the specimen with 0.96% C almost totally dissolved into austenite after the specimen was maintained at 1050 °C for 1 minute. When the reheating temperature was decreased to 900 °C, GBC of the sample totally dissolved after the it was held for 10 minutes. There were several coarsen GBC in the microstructure even after the sample with 1.12% C was maintained at 900 °C and 975 °C for 30minutes, which means that grain boundary cementite (GBC) in billet of the hypereutectoid steel can't be fully dissolved during industrial reheating process. It is clear from present study that the heavier the center segregation of the billet of hypereutectoid steel, the higher the soaking temperature for the billet in order to fully dissolve GBC to improve the drawability of the wire rods for the production of super high strength steel cord.

16:35-17:00

Ultra-low Niobium (ULNb): Reducing Cost and GWPe in S275 & S355 Commodity Grade Structural Steels

Jitendra Patel, International Metallurgy Ltd., Oxford, UK

Conventionally the addition of micro-alloying elements such as niobium (Nb), typically ≥0.020wt.%, has been associated with high strength low alloy (HSLA) steels with lower carbon content and processed by means of Thermo-Mechanical rolling. Here it is well established, that Nb has the strongest effect in retarding static recrystallisation of austenite during inter-pass times by precipitate pinning mechanism. Due to the lower solubility of Nb in austenite at typical carbon levels associated with commodity grade structural steels (i.e., ≥0.15wt.%C), the use of Nb has been somewhat limited and widely regarded to be applied only when higher strengths, ≥355MPa and/or low temperature impact toughness properties are specified.

However, recent laboratory studies coupled with industrial trials have demonstrated an alternative solution to make commodity grade structural steels, without making any changes to existing processing routes employed. By using Ultra-Low Niobium (ULNb) additions (i.e.,≤100ppmNb) it is possible to enable cost savings in ferro-alloying expenditure coupled with a reduction in grade specific GWPe/tonne of steel produced. This paper summarises and presents these recent finding towards extracting greater value from existing commodity grade structural steels through Ultra-Low additions of Nb.

17:00-17:20

Effects of Finishing Temperature on Mechanical Properties of the Economical Fire-resistant Steel Q390FRE

Lingming Meng[1], Qiang Cui[1], Zhaodong Li[2], Xin Wang[2]

1. Nanjing Iron and Steel Group Co., Ltd., China;

2. Department of Structural Steels, Central Iron and Steel Research Institute, China

The economical fire resistant steel Q390FRE is designed by the way of composite microalloying composition which contains low C, low Mn, low Mo (≤0.25wt.%), Nb and V. Bainite + a small amount of massive ferrite and proeutectoid ferrite + a small amount of bainite/pearlitic structure steels are obtained by three controlled rolling processes respectively. The steel plates obtained by the three processes all have good tensile properties at room temperature, but the impact properties of the experiment steel obtained at -40 °C at high finishing temperature fluctuate and do not meet the requirements specified in the standard. The tensile properties of the experiment steel obtained at 600 °C at low finishing temperature are poor, and the steel obtained at suitable finishing temperature has excellent comprehensive mechanical properties. OM, SEM, TEM and other analysis methods are used to characterize the hot-rolled state, as well as the matrix structure and nano second phase which are tensiled at 600 °C. The results show that the the experimental steel obtained at high final rolling temperature has poor low-temperature impact performance at -40 °C due to uneven grain size and large grain size; The microstructure dominated by proeutectoid ferrite has a smaller ferrite grain size and sufficient second phase precipitation, while the microstructure dominated by bainite has a higher dislocation density, a small amount of the second phase M(CN) precipitation, and insufficient precipitation of microalloying elements, but the yield strength of the three steel plates at room temperature is similar; After 600 °C tensile or short-time thermal treatment, the dislocation density of bainite is still maintained, and the second

phase M(CN) particles are further precipitated which largely compensates for the loss of high temperature yield strength caused by the decrease of shear modulus at high temperature and the failure of fine grain strengthening. The fire resistance of the matrix mainly containing bainite is higher than that mainly containing fine grain preeutectoid ferrite. The fire resistant steel Q390FR has excellent comprehensive mechanical properties when the final rolling temperature is 850 °C.

C3 Low Temperature Steel

Friday, 11 November 2022, GMT+8 (Beijing)
Room C, Zoom Link: TBD

8:30-8:55

Development of High-Mn Austenitic Steels for Cryogenic Applications and their Deformation Performances in Liquid Helium

Zhenyu Liu, Jiakuan Ren, Pengjie Wang, Jun Chen, Weina Zhang, Northeastern University, China

There exists strong motivation to develop structural material used at cryogenic temperatures due to the construction of large-scale cryogenic engineering. High manganese steels (HMS) are promising cryogenic materials, but their deformation behaviors and mechanical properties at 4.2 K (liquid helium) have not been investigated yet. Moreover, the aging-induced embrittlement of HMS also severely restricts their application at extremely low temperatures. Here, Fe-Mn-Al-C steels with different Al contents (0, 4, 10 or 15 at.%) and grain sizes (small and large) were fabricated, and their deformation behaviors and mechanical properties at 4.2 K were systematically investigated. It is found that with increasing Al content, (Fe, Mn)23C6 carbides are effectively inhibited, and the premature fracture is hence avoided in the 10%Al HMS, and the excellent combination of high strength (~1.5 GPa) and high fracture toughness (255 MPa·m1/2) can be attained in 10%Al HMS at 4.2 K even after aging at 923 K for 10 days. The major deformation mechanisms shift from the extensive twinning and deformation bands in the 0Al HMS to the lesser, Taylor lattices and deformation bands in the 10%Al HMS, which contribute to the high strength and ductility of the 10%Al HMS. Furthermore, the 10%Al MEA with larger grains displays a much higher KIC (255 MPa·m1/2) at 4.2 K as compared to 84 MPa·m1/2 of its counterpart with smaller grains. These finding are believed to facilitate the development of HMSs with superior mechanical properties and promote their applications at extremely low temperatures.

8:55-9:15

Cryogenic Fracture Behavior of High-manganese Austenitic Steel with TWIP/TRIP Effect

Yangwen Wang, Honghong Wang, Wuhan University of Science and Technology, China

Cryogenic toughness is one of the most important mechanical properties of structural materials for cryogenic application. The primary objective of this research is to elucidate the cryogenic fracture behavior of a high-manganese austenitic steel with both twinning-induced plasticity (TWIP) and transformation-induced plasticity (TRIP) effects. Thermodynamic calculation from chemical composition includes Gibbs free energy difference between g- and e-phases and stacking fault energy in g-phase. They are the key factors to control the microstructure at room temperature and cryogenic deformation mechanism. The fracture behavior of the steel was studied by Charpy V-notch impact test with dynamic load-deflection (DDC) curve and post-mortem analysis of fractured sample using electron back-scattered diffraction (EBSD). The impact tests were conducted at the temperature of 273 K and 77 K, and their impact absorb energies were 255.4 J and 143.6 J, respectively. Based on the criterion of the maximum load, the fracture initiation and propagation energy were determined to be 107.5 J and 147.9 J at 273 K, 93.6 J and 50.0 J at 77 K. When the temperature lower to 77 K, the fracture initiation energy was decreased by only 13.9 J because two deformation mechanisms (TWIP and TRIP) ensure the cryogenic deformation ability of the steel. The drop in the fracture propagation energy with decreasing temperature is the main factor causing the decrease of total impact energy. However, the fundamental plastic fracture mode, microcrack nucleation-growth-convergence, was not changed with decreasing temperature. As the main deformation mechanism, TWIP effect contributes to plastic deformation before fracture, but the intersections of primary and secondary twins become the source of crack initiation due to stress concentration. For TRIP effect, on the one hand, both the phase transformations of g → e and g → e → ɑ' contribute to local stress relaxation and preventing crack initiation. On the other hand, e- and ɑ' -phases effectively prevents the propagation of cracks, which is the important factor for good crack propagation energy of 50 J at 77 K.

9:15-9:35

Mechanical Properties of Welded Joints of Novel High Manganese Austenitic Steel for Cryogenic Application

Shuchang Zhang, Honghong Wang, Wuhan University of Science and Technology, China

Cryogenic high-manganese austenitic steel has become a highly competitive preferred material for liquefied natural gas (LNG) storage tanks to replace the expensive 9% Ni steel with its excellent mechanical properties and economy. The good mechanical properties of the welded joints play a vital role in the structural integrity and service safety. In this paper, The joints of a novel cryogenic high-manganese austenitic steel were welded with solid wire by The following welding methods: Shielded

Metal Arc Welding (SMAW 1G), Submerged Arc Welding (SAW 1G) and Gas Tungsten Arc Welding (GTAW 1G) in the horizontal flat position and Shielded Metal Arc Welding in the vertical flat position (SMAW 3G). The welding heat input of the four welding methods were 10.2-17.3, 13.2-22.3, 12.7-20.2 and 10.4-19.7 kJ/cm, respectively. Then, the microstructures and mechanical properties of the welded joints are investigated. It is confirmed that the microstructures of both heat affect zone (HAZ) and weld metal (WM) were austenite tissue. No defect was found on the surfaces of welded joints by Nondestructive Testing-Penetrant Testing (NDT-PT) or Nondestructive Testing-Radiographic Testing (NDT-RT). Furthermore, no crack was detected on the joints in transverse side bending tests. The tensile strength of the joints welded by SMAW 1G, SMAW 3G, SAW 1G and GTAW 1G were 763.7, 699.4, 708.4 and 771.9 MPa at 18 °C, respectively. And the elongation of weld metal in the four joints were 43.9%, 39.3%, 51.4%, and 50.3%, respectively. The impact absorbed energy of weld metal in the four joints were 42.5, 51.8, 74.8 and 69.3 J at -196 °C, respectively, and the average impact absorbed energy of heat affect zone were 29.5, 38.6, 53.5 and 50.2 J at -196 °C, respectively. These mechanical properties satisfy the technical requirements of the International Maritime Organization (IMO). It is confirmed that the joints welded with solid wire by SMAW 1G, SMAW 3G, SAW 1G and GTAW 1G performed excellent mechanical properties and stability.

9:35-10:00

Development of 7Ni Steel Plate for Cryogenic Storage Tanks and Transportation Vessels

Zhanglong Xie, Nanjing Iron & Steel United Co., Ltd., China

Based on more than 10 years of development and production experience on 9Ni steel, NISCO has developed 7Ni steel plate to further cater for the evolving demand, aiming towards safe and economical construction in cryogenic tank and vessel region. 7% Ni steel plates provide an excellent level of strength, toughness properties and a very good ability to arrest brittle cracks at very low temperatures, equivalent to those of 9Ni steel, which was introduced in ASME standard SA553/SA553M as Type III. Relative to 9Ni steel, 7Ni steel offer about 4000 yuan per ton cost reduction attribute to 2% nickel reduction for construction of cryogenic tanks or vessels for LNG, ethylene, ethane and other liquefied hydrocarbons, and also significantly contributes to save natural resources. More ever, 7Ni steel can be weld by the means of the same welding technologies as for 9Ni steel, which is convenient for rapid promotion and application. After comprehensive evaluation, 7Ni steel had been applied on a new ethylene tank.

10:20-10:45

Study on Hydrogen Embrittlement Susceptibility of WHAZ in 9Ni Steel

Zhaoxia Liu, Yun Bai, Buqiang Han, Xin Zhang, Jun Liu, Jiangyin Xingcheng Special Steel Works Co., Ltd., China

Because welding heat affected zone (WHAZ) is the poorest toughness zone in the welded joint of 9Ni steel, hydrogen embrittlement susceptibility of WHAZ in 9Ni steel were investigated. The thermomechanical simulator was employed to simulate the welding thermal cycle processes of different sub-zones in WHAZ of 9Ni steel. The microstructure was characterized by an optical microscope (OM), the toughness and hardness were tested by a drop weight impact tester and a microhardness tester, respectively. The eltrochemical hydrogen charging test is performed on the DH1720A-1 charger. The results show that a series microstructure types as coarse martensite, fine martensite, martensite and sorbite mixture microstructure with a small amount of retained austenite are found in the sub-zones in WHAZ. The hardness tests show that the hardness increases as peak temperature (PT) increases. The toughness loss vs PT curve after hydrogen charging has same trend as the curve of mean primary austenite grain size vs PT. There is no direct relationship between strength and hydrogen concentration.

10:45-11:05

Comparative Study of the Weldability for 5Ni and 9Ni Steels

Huibin Liu[1], Liqian Xia[1], Jinhua Huang[2], Zhaoxia Qu[1], Hanqian Zhang[1]

1. Central Research Institute of Baosteel, China;

2. Manufacturing Management Department of Baosteel, China

Use of liquefied gas becomes more necessary in the needs of achieving carbon peaking and carbon neutrality. Nickel alloy steels are of great importance in the low temperature application worldwide. Among them, 5Ni and 9Ni steels are used for storage and transportation of liquefied ethylene gas (LEG) and liquefied natural gas (LNG) respectively. In present study, both 5Ni and 9Ni steel plates as thick as 50 mm were welded with heat input of 15 kJ/cm and 30 kJ/cm respectively for evaluation of their weldability. Different types of mechanical tests including tensile, impact, bend, and Vickers hardness tests were conducted in the evaluation of the welded joints. Results show that both steels exhibit excellent weldability in the as-welded condition, though they have different strength levels and adaptability for different temperatures. Analysis reveals that nickel content plays a major role in their difference in properties of welded joint.

11:05-11:30

Development and Application of High-Performance Plate for Polar Icebreaker

Shan Gao, Caiyi Zhang, Xiao-hui Lu, Central Research Institute of Baoshan Iron & Steel Co., Ltd., China

Polar icebreakers and polar research ships play an important role in polar transportation and the development and utilization of polar environmental resources. In order to ensure the safety of polar icebreaker in extreme service environment, the steel for hull construction is required to have high strength, well weldability, excellent low-temperature impact toughness and crack arrest performance. China owns the "XUE LONG" and "XUE LONG 2" polar research icebreakers. On the basis of laboratory research, the plate with the maximum thickness of 60mm and the maximum steel grade of FH40 for high-performance polar icebreaker is designed with low-carbon, Nb\Ti microalloy and appropriate addition of Cu\Ni alloy. The microstructure steel with acicular ferrite and polygonal ferrite is obtained by TMCP process, and the low-temperature toughness, crack arrest performance and weldability are systematically evaluated. All mechanical properties meet the design and construction requirements. With low temperature impact energy CVN ≥ 100J at -80 ℃ and Kca greater than 14000N/mm3/2 at -10ºC, it shows excellent fracture resistance and crack arrest performance. The high-performance steel plate for polar icebreaker developed by Baosteel has been successfully applied to the reconstruction of China's polar icebreaker "XUE LONG" and the construction of "XUE LONG 2", which provides a strong guarantee for China's polar scientific expedition.

11:30-11:50

Study on the Effect of Surface Oxides on the Friction Mechanism of Polar Marine Steel

Chaoyi Wang[1,2], Xueting Chang[3], Tao An[2], Ling Yan[1]

1. State Key Laboratory of Metal Materials for Marine Equipment and Application, China;

2. Ansteel Beijing Research Institute Co., Ltd., China;

3. Shanghai Maritime University, China

Ships sailing in the polar sea ice environment will cause the surface paint to fall off due to the ice load.The exposed steel is corroded by seawater first, and then undergoes friction and wear under ice load after forming oxides.Different oxide states have great influence on the friction and wear performance and mechanism of steel. In this paper, the reciprocating friction behavior of the polar marine low-temperature steel plate after different oxides are formed on the surface had been tested by the multifunctional friction machine.White light interferometer and scanning electron microscope were used to characterize the micro-structure morphology and wear scar morphology of the different steel samples.The steel withγ-FeOOH layer,the steel with Fe3O4 oxide layer and the untreated steel had been obtained. Among them, the steel sample with the dense and complete Fe3O4 oxide layer has the lowest amount of wear, the wear scar profile is the shallowest and narrowest, and the surface is dominated by adhesion and abrasion, and the corrosion resistance is also the best; The coefficient of is the steel sample with theγ-FeOOH oxide layer the smallest, but the amount of wear is the largest under the coupling of friction and corrosion,the amount of wear of untreated steel was between theγ-FeOOH oxide layer and the Fe3O4 oxide layer.The wear mechanism of both oxide layer sample were mainly abrasive wear, while and the surface of the untreated steel sample had more furrows and pits.Then,the erosion performance of test steel under simulated sea ice environment had been tested by self-made equipment,The results show that the erosion mechanism of the test steel is mainly point pits under the simulated sea ice environment

C4 中文分会场

Friday, 11 November 2022, GMT+8 (Beijing)
Room D, Zoom Link: TBD

D1 Shipbuilding, Offshore Engineering and Vessel Steels

Thursday, 10 November 2022, GMT+8 (Beijing)
Room D, Zoom Link: TBD

8:30-8:55

Multi-phase Microstructure Design of High-performance Crack Arresting Heavy Plate Steel and its Industry Practices

Hua Wang[1,3], Chengjia Shang[2,3], Ling Yan[1,3], Peng Zhang[1], Xiucheng Li[2], Longhao Zhu[1,3]

1. Iron & Steel Research Institutes of ANSTEEL Group Corporation;

2. Collaborative Innovation Center of Steel Technology of USTB;

3. State Key Laboratory of Metal Materials for Marine Equipment and Application

According to the requirements of the International Association of Classification Society, crack arrest plate steel must be used in the construction of super large container ships. The crack arrest of ultra-high strength heavy plate steel plate is derived from the microstructure design of the material. Based on the plastic deformation behavior of multi-phase structure, this paper introduces the basic researches on the dislocation accumulation in soft and hard phases, micropore nucleation and evolution characteristics of different phases during deformation in multi-phase low alloy steel composed of ferrite and bainite, and discusses the principle of improving crack arrest toughness by multi-phase microstructure design. The technical route of using multi-phase design to greatly improve the crack arrest performance of heavy plate steel is also verified by industrial practice results.

8:55-9:20

Research on the Application of High-strength Steel Plates on the Towers of Wind Turbines

Xudong Cao, Ziping Zhang, Gela Ji, Beijing Goldwind Science & Creation Windpower Equipment Co., Ltd., China

Study the impact of the use of high strength steel on tower weight and cost. Using Q390, Q420, and Q460 to design the tower respectively, and combining with the tower design principle, the recommended steel grade for improving the strength of the tower material is obtained. Combined with the actual project, a more economical way to upgrade and replace materials is obtained through analysis. The results show that, under certain conditions, for the tower driven by the ultimate load, when Q390 is used for part of the tube section material, it has more technical and cost advantages than the use of Q345 steel plate for all materials, and the use of Q390 steel plate for all materials, which can improve the competitiveness of products. And for Q420, it will have less competitive when stell prices ara higher. And for Q460, the current design theory needs to be updated or the FEA should be used to apply.

9:20-9:40

Comparative Study on Interface Microstructure and Properties of Al-Al-steel and Al-Ti-steel Clad Plates

Xiyang Chai, Xiaobiao Mu, Tao Pan, Xiaobing Luo, Feng Chai, Central Iron and Steel Research Institute, China

In order to evaluate the reliability of Al-Al-steel and Al-Ti-steel clad plates, the stability and microstructure evolution of Al-steel and Al-Ti interface were compared under different heat treatment temperatures. The Al-Al-steel and Al-Ti-steel clad plates were heat treated at 250-550 °C for 1h in a box resistance furnace. After heat treatment, the shear properties and tensile properties of clad plates were tested. The evolution of the interfacial reaction phases was characterized by SEM and HRTEM. The results show that Al-Ti-steel has more excellent heat stability. The damage to the interface performance is smaller and the damage speed is slower for Al-Ti-steel. Al-Al-steel appears in layer intermetallic compounds above 450°C, and the phase types are Fe2Al5 and Fe4Al13. Al-Ti-steel begins to appear discontinuous Ti-Al intermetallic compounds at 500 °C, and forms a continuous layer product at 550 °C, and the type is TiAl3. The thickness of the Al-steel interface product is much greater than the thickness of the Al-Ti interface reaction product. Meanwhile, the thermodynamics and kinetics of reaction phase formation in Fe-Al and Ti-Al systems were analyzed. It was found that the interface reaction driving force of Ti-Al system was smaller than that of Fe-Al system, and the diffusion reaction rate was slower, which may be the main reason for the better microstructure and performance stability of Al-Ti interface.

9:40-10:00

Effect of Ni Content on Copper Aging Weldable Steel Corrosion Behavior in Simulated Tropical Marine Atmosphere

Haifeng Yang[1], Zhizhong Yuan[1], Jian Li[2], Naipeng Zhou[2], Feng Gao[2]

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2. Central Iron & Steel Research Institute, China

Through the use of an indoor dry-wet alternate accelerated test, the corrosion behavior of three different types of Nicontaining copper-aging easy-to-weld steels was investigated. The experimental steel's corrosion resistance was determined using the weight loss method, and the protective qualities of the rust layer were examined using electrochemical test methods, scanning electron microscopy, X-ray diffraction, and other techniques. The tested steel corrodes at a slower rate the higher the Ni concentration. The form and chemistry of corrosion products are impacted by changes in Ni concentration. The largest density and greatest protection are found in the rust layer of 2.5 Ni, which also contains the highest amount of the stable phases Fe3O4 and α-FeOOH. The propensity for self-corrosion and the resistance of the rust layer increase with an increase in Ni concentration. Effectively preventing anodic disintegration and the transmission of charged particles is the rust layer.

10:20-10:45

Study on QLT Heat Treatment of 1000MPa Ship Hull Steel

Xiaobing Luo[1], Tianyang Guo[2], Feng Cha[1], Tao Pan[1]

1. Institute for Structural Steel, Central Iron and Steel Research Institute, China;

2. School of Iron and Steel, Soochow University, China

The effect of intercritical quenching temperature on the microstructure and properties of 10CrNi8MoV steel was studied. The results show that when quenching between 640 °C to 780 °C, the properties of the material show two phenomena. when the quenching temperature between 640 °C to 700 °C, the strength of steel increases with the increase of intercritical temperature, and the toughness decreases. In this quenching temperature range, the mechanical properties of the material are determined by the composition of F&M microstructure and the formation of reversed austenite. With the increase of the intercritical quenching temperature, the proportion of F in the dual phase structure decreases from 40% to 10% and the content of reversed austenite reduced from 11% to 1%.When the quenching temperature changed from 700 °C to 780 °C, the change of strength and toughness of test material is not obvious. The main reason is that the intercritical quenching temperature exceeds the Ar3 temperature , the steel transforms into a single martensite structure after cooling, and the change of austenite grain size is not significant,which is between 7.3-8.5 μm. The results show that the best match of strength and toughness can be obtained by intercritical quenching at 680 °C.

10:45-11:05

Research on Microstructure and Mechanical properties of Hot-Rolling TRIP Wear-Resistant Steel NM400 Under Different Cooling Process

Haotian Chen[1], Renbo Song[1], Kunpeng Che[1], Yan Huang[1], Guannan Li[2]

1. School of Materials Science and Engineering, University of Science and Technology Beijing, China;

2. Technology Center of HBIS Group Hansteel Company, China

The low-alloy multiphase transformation-induced plasticity (TRIP) wear-resistant NM400 hot-rolling steel plate with high ductility was developed by Ti-Nb-B micro alloying. According to the CCT curve obtained by thermodynamic simulation software JmatPro, four cooling processes were designed, i.e., air cooling temperture 700 °C and air cooling time 3s, air cooling temperture 700 °C and air cooling time 5s, air cooling temperture 650 °C and cooling time 3s, air cooling temperture 650 °C and cooling time 5s, then quenching to 100 °C. The hardness of the four samples was measured by Brinell hardness tester. The tensile strength and elongation of the four samples were measured by tensile test. The microstructure of four samples were obtained by scanning electron microscope (SEM). The results show that the hardness, tensile strength and elongation are 393.9 HBW, 1523.5 MPa and 8.04% for the sample with air cooling temperature (T1) of 700 °C and air cooling time (t) of 3s. The hardness, tensile strength and elongation are 336.7 HBW, 1443.3 MPa and 9.44% for the sample with air cooling temperature of 700 °C and air cooling time of 5s. The hardness, tensile strength and elongation are 418.8 HBW, 1515.3 MPa and 10.34% for the sample with air cooling temperature of 650 °C and air cooling time of 3s. The hardness, tensile strength and elongation are 366.3 HBW, 1325.701MPa and 11.2% for the sample with air cooling temperature of 650 °C and air cooling time of 5s. The sample with air cooling temperature of 650 °C and air cooling time of 3s has the best comprehensive mechanical properties. Its SEM image show that the microstructure of specimen is mainly composed of ferrite (F), lath martenstie (M), bainite (B) and retained austenite (RA), which provide a high combination of strength and plasticity for the sample and the retained austenite can induce TRIP effect under external force.

11:05-11:25

Effect of H2S Partial Pressure on Sulfide Stress Corrosion Behavior of SA387M Gr.11CL2 Anti-hydrogen Steel

Fangfang Ai[1,2], Yiqing Chen[1,2], Chu Wang[1,2], Peng Gao[1,2], Lin Li[1,2], Bin Zhong[1,2], Xiandong Su[1,2], Hongyu Shan[1,2]

1. State Key Laboratory of Material for Marine Equipment and Application, China;

2. Ansteel Iron & Research Institute, China

The work aims to study the effect of H2S partial pressure on the sulfide stress corrosion behavior of SA387M Gr.11CL2 anti-hydrogen steel in high pressure wet H2S environment. Corrosion morphology and corrosion products of SA387M Gr.11CL2 in different H2S partial pressures are investigated by high-pressure reactor tests, SEM, EDS, EPMA and XRD. The results indicated that corrosion rates of SA387M Gr.11CL2 increased with H2S partial pressure increasing in the simulated solutions. General corrosion occurred when H2S partial pressures were less than 0.5MPa. Localized corrosion was obviously observed with H2S partial pressure up to 1.0MPa. Sulfide stress corrosion cracking (SSCC) resistant of SA387M Gr.11CL2 with different H2S partial pressures was excellent. The main composition of corrosion products was tetragonal system FeS1-x. Small amount of hexagonal system Fe1-xS and cubic system FeS formed with H2S partial pressure increasing. The Cr compound and iron sulfides had a synergistic effect to inhibit Cl- invading, improve pitting corrosion resistant and reduce SSCC sensitivity.

11:25-11:45

The Development of Large Thickness Marine Structure Steel Plate with Strength of 490MPa

Xiaoshu Wang[1], Peng Zhang[2], Weijun Zhang[2], Baojun Zhao[1], Jie Long[2]

1. Jiangxi University of Science and Technology, China;

2. Wuyang Iron and Steel Co., Ltd., HBIS, China

In this paper, large thickness of 490MPa grade marine structure steel used for offshore platforms was developed. The content of C was reduced to improve the low-temperature toughness and weldability. Microalloying elements Nb, V and Al was added and rolling technology was designed. The mechanical properties of the steel plate with thickness of 250mm are tested and evaluated. The experiment of crack tip opening displacement (CTOD) was carried out at -10°C and the characteristic values of CTOD were calculated. The results show that the steel plate has the mixed microstructure of fine ferrite, pearlite and small quantity of

bainite, with grain size up to 8.0 grade, which is beneficial to high strength and toughness. The tensile strength of the steel plate is more than 490MPa and the low temperature impact toughness is more than 150J at -40℃. The characteristic values of CTOD are more than 0.30, which shows high cracking resistance due to appropriate alloy design and production technology. The NDTT of the developed steel is below -50℃. This improves the safety factor of offshore engineering use due to the excellent crack arrest properties.

D2 Shipbuilding, Offshore Engineering and Vessel Steels

Thursday, 10 November 2022, GMT+8 (Beijing)
Room D, Zoom Link: TBD

14:00-14:25

Influence of Band Microstructure on Carbides Precipitation and Toughness of a 1 GPa Grade Ultra-heavy Gauge Low Alloy Steel

Zhenjia Xie[1], Zhipeng Liu[1], Peng Han[1,2], Yaohui Jin[2], Xuelin Wang[1,3], Chengjia Shang[1,3]

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2. State Key Laboratory of Metal Material for Marine Equipment and Application, China;

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The present study describes the influence of band microstructure induced by centerline segregation on carbides precipitation behavior and toughness in an 80 mm thick 1 GPa low carbon low alloy steel plate. The microstructure evolution, carbides precipitation and their effects on mechanical properties of 1/4 thickness (1/4t) and center (1/2t) positions during quenching and tempering were studied comparatively. Similar ductility and toughness were obtained after quenching for 1/4t and 1/2t positions of the heavy gauge steel plate. After tempering, both elongation and low temperature toughness at -40˚C were enhanced by ~50% and ~25%, respectively, without decrease in yield strength for 1/4t position, whereas, the toughness of 1/2t position was simultaneously decreased by ~46% with decrease in yield strength and elongation. It is found that lower bainite and lath martensite were obtained for both 1/4t and 1/2t positions after quenching, but microstructure bands were only observed at 1/2t positions. After tempering, uniformly dispersed short rod-like M23C6 carbides and sphere MC precipitates were obtained at 1/4t position with diameter of ~20-100 nm and smaller than 20 nm, respectively. The uniformly dispersed nano-sized M23C6 carbides and (Mo,V)C precipitates contributed to the balance of high strength and high toughness. For 1/2t position, high dense large M3C carbides in needle-like shape were obtained in band microstructure after tempering. The length and width of large M3C carbides were ~200-500 nm and ~20-50 nm. Fractography study shows that the high dense large carbides led to delamination cleavage fracture, which reduces toughness significantly.

14:25-14:50

A Production Process of V-N Microalloyed HSLA Steel without vacuum degassing and the Mechanism of Controlling Hydrogen Induced Defects of Steel Plates

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In the manufacturing process of high strength low alloy(HSLA) steel, when the dissolved hydrogen content in cast steel exceeds a certain threshold(usually 1.5-2ppm), hydrogen will cause a series of problems in hot rolling or forging of steel with heavy sections, such as hydrogen embrittlement, delayed fracture, rejection in ultrasonic monitoring, internal hairline cracks, hydrogen"flakes"or "fisheyes" and so on. This articles introduces a green, short and economic production process of V-N microalloyed HSLA steel without vacuum degassing process during steelmaking, which allowed the threshold hydrogen content increase to 4-4.5ppm in molten steel when the central segregation degree of continuous casting slab is controlled below Manneysman level 3.0. The V-N microalloyed steel has low rejection rates in ultrasonic monitoring and good central metallurgical quality. The mechanism of controlling hydrogen induced defects of V-N microalloyed HSLA steel was explained. By designing and optimizing the chemical composition and TMCP process of V-N microalloyed HSLA steel, large numbers of VN second phase particles can form in the prior austenite grain, which promote the intragranular nucleation of ferrite and improve the austenite decomposition temperature above 550 ℃. The acicular ferrite microstructure can be obtained in the whole thickness direction of steel plates, which is conducive to the diffusion out of internal hydrogen. A kinetic model of internal hydrogen diffusion out from steel plates has been established to calculate and estimate the effects of various factors on the dehydrogenation process after rolling. At present, the technology has achieved industrial production and application, and has produced remarkable social and economic benefits.

14:50-15:10

Effect of Al Content on Seawater Corrosion Resistance of B Steel Plate for Shipbuilding

Jian Li, Feng Chai, Xiaobing Luo, Naipeng Zhou, Feng Zhang,
Central Iron and Steel Research Institute, China

The effect of different Al content on the seawater corrosion resistance of grade B steel was comparatively studied by weight-loss measurement, scanning electron microscopy (SEM), X-ray diffraction (XRD), polarization curves and impedance curves analysis. The results show that the addition of Al to the B-grade steel helps to improve its seawater corrosion resistance, the corrosion rates of the test steels with 0.5% Al and 1% Al additions are 13.8% and 27.6% lower than the comparative steel after corrosion for 720 h. Compared with the comparative steel, the rust layer of Al-containing steel is more closely combined with the matrix after corrosion, and the thickness of the inner rust layer is larger. The addition of Al can reduce the self-corrosion current density. And $FeAl_2O_4$ with cation selectivity is formed in the corrosion product, which inhibits the intrusion of Cl^- into the metal matrix and improves the protection of the rust layer, thereby improving the seawater corrosion resistance of steel.

15:10-15:30

Effect of Ni on the Micro-substructure, Strength and Toughness of HSLA Steel

Zhengyan Zhang[1], Feng Chai[1], Xiaobing Luo[1], Sencai Wang[1,2], Caifu Yang[1]

1. Central Iron and Steel Research Institute, China;

2. China University of Petroleum, China

High strength low alloy (HSLA) steels are widely used in the construction of ship structures, oil pipelines, offshore platforms and so on because of their good strength, toughness and weldability. HSLA steel is generally designed with low carbon and Cu, Ni alloying. Tempered lath bainite or martensite and nano-precipitate phase of Cu can be obtained by quenching and ageing process after rolling to ensure the excellent matching of strength, low temperature toughness and weldability of HSLA steel. The addition of Ni will affect the microstructure and mechanical properties. However, there are relatively few studies on the mechanism of Ni improving the strength and toughness of steel. In this work, the microstructure and nano-sized Cu precipitates of 1.3-3.5%Ni HSLA steel bearing Cu were characterized by means of OM, SEM, EBSD, TEM, etc. At the same time, the strength and toughness of the overaged heat treated tested steel were tested, and the mechanism of Ni improving the strength and toughness of the test steel was systematically analyzed. The results show that with the increase of Ni content in the steel from 1.3% to 3.5%, the hardenability of the test steel is improved, and the microstructure changes from granular bainite to lath bainite, to lath bainite/martensite, and finally to lath martensite. In addition, with the increase of Ni content, the prior austenite grain size of the tested steel decreases, and the cooling transformation temperatures such as AC1 and Bs decrease significantly, which leads to the increase of transformation driving force. Therefore, the sub-structures such as lath packet, block and lath sizes are gradually refined, and the fine grain strengthening and toughening effects are enhanced. However, after the aging heat treatment at 620 °C, Ni has no significant effect on the nano-precipitate phase of Cu, and the average size of nano-sized Cu precipitate is about 12 nm. Meanwhile, no reversed austenite is found in the steel. According to the analysis, Ni mainly improves the strength and low-temperature toughness by refining grains and improving the hardenability. In addition, according to the Hall-Petch relationship and the theory of large angle interface hindering dislocation slip, the block in bainite/martensite is the smallest large angle grain unit, which is the "effective grain size" controlling the strength and toughness.

15:50-16:15

Effect of Nb Microalloying on Microstructure and Low Temperature Toughness of 630MPa Mobile Pressure Vessel Steel

Wenbin Liu[1,3], Liqin Zhang[2], Zhongzhu Liu[4], Fangzhong Li[5], Baozhu Liang[6]

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6 Echeng Iron & Steel Co., Ltd., of China Baowu Steel Group, China

The effect of Nb microalloying on the microstructure and mechanical properties of mobile vessel steel was studied by employing scanning electron microscope (SEM) and transmission electron microscope (TEM), and the effect mechanism of Nb on the low temperature toughness of the VN microalloyed test steel was revealed. The results show that the grain size of 0.015%Nb test steel was the smallest when N content was 90ppm and 146ppm. The mechanical properties of the test steel meet the technical requirements by reducing the content of V and N in the test steel and adding 0.015wt%Nb and 0.025wt%Nb at the same time, and the 0.025wt%Nb test steel has higher toughness at low temperature. The structure of the test steel after normalizing

was typical pearlite + ferrite, the volume fraction of ferrite in 0.015wt%Nb steel and 0.025wt%Nb steel was 66.2vol% and 69.7vol% respectively. In addition, the volume fraction of ferrite structure was increased by 3.5%, and the increase of ferrite improved the toughness of the test steel. The average size of pearlite cluster in the 0.015wt%Nb steel was 4.24μm, the lamellar spacing was 165nm. The average size of pearlite cluster in the 0.025wt%Nb steel was 3.96μm, and the lamellar spacing was 108nm. Compared with the 0.015wt%Nb steel, the frequency of 40°-60° large angle grain boundary was higher in the 0.025wt%Nb steel, while the proportion of small angle grain boundary was obviously reduced, with more small grains and lower local average misorientation. The local stress concentration of 0.025wt%Nb test steel was relatively low, with better toughness. The increase of the Nb content in the test steel will refine the pearlite cluster and reduce the lamellar spacing, resulting in smaller grain size. The dimples are denser after fracture, and the proportion of large angle grain boundaries increase with the increase of Nb content. In conclusion, 0.025wt%Nb design is preferred for the 630MPa grade mobile pressure vessel steel.

16:15-16:35

Study on Core Impact Performance for API 2W Offshore Structural Steel

Xing Jin, Plate Business Unit of Nanjing Iron & Steel Co., Ltd., China

API 2W offshore structural steel has a higher toughness requirement for 1/2 position of plate. In order to improve the mechanical properties for steel with thickness from 12mm to 75mm, some measures have been used such as composition design optimization, central segregation control, rolling process parameters and pass reduction optimization. The testing results show that the effective rolling compression ratio plays a key role on toughness improvement for heavy plate. It can be greatly improved by increasing the effective rolling compression ratio and optimizing pass reduction to refine grain size for heavy plate. The developed steel has good transverse impact performance at 1/2 position of plate for -40 °C, excellent aging impact properties and welding performance. The plates have better toughness performance, and impact performance ductile brittle transition temperature is below -50 °C. The developed offshore structural steel has excellent impact performance and welding performance, which can satisfy the customer of shipbuilding and marine engineering and market requirements.

16:35-16:55

Quantitative Analysis for the Cross-Section Effect of Quenched and Tempered Ni-Cr-Mo Ultra-heavy Steel

Kaihao Guo, Tao Pan, Ning Zhang, Li Meng, Feng Chai, Xiaobing Luo, Central Iron and Steel Research Institute, China

In this work, quantitative analysis of microstructural evolution and its effect on mechanical properties for the 120 mm Ni-Cr-Mo industrial ultra-heavy steel were investigated by means of optical microscope (OM), scanning electron microscope (SEM), transmission electron microscope (TEM) and electron back-scatter diffraction (EBSD). The results show that the martensite fraction is 65% at 10mm and disappear at 40mm. Due to the influence of martensite fraction, the strength decreases with the gradual coarsening of the laths from the surface to the center. Meanwhile ,the toughness is mainly affected by the size of block and the morphology and quantity of M-A, which increases first and then decreases. The study established a multivariate function between the microstructure and FATT50 with comprehensive consideration about the influence of effective grain size (EGS) and M-A size distribution.

D3 Pipeline Steel and Welding

Friday, 11 November 2022, GMT+8 (Beijing)
Room D, Zoom Link: TBD

8:30-8:55

Improved API X80 Heavy Gauge Pipe Body and Weld Mechanical Property Stability by Optimized Niobium Metallurgical Processing

Stalheim Douglas[1], Jinxing Jiang[2], Chunyong Hou[3], Han David[4], Yongqing Zhang[5], Bacalhau Jose[6], Litschewski Aaron[7]

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2. Nanjing Iron and Steel Company, Ltd., China;
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4. International Welding Technology Institute, China;
5. CITIC Metal, China;
6. CBMM, Brazil;
7. CBMM NA, USA

Today's market for API pipeline steels requires higher strength and fracture toughness performance in heavier gauges and larger pipe diameters. Meeting basic average mechanical properties of strength, TCVN and DWTT performance has been achieved by many with newer powerful plate mills and cooling systems. However, stability/standard deviations of plate/pipe strength and toughness along with pipe seam/girth weld toughness continues to be challenging for many. Current focus has been on pipe seam and girth weld HAZ toughness stability which has proven to be difficult to achieve. Optimization of the alloy and processing design are critical components of creating the desired final through thickness microstructure, grain size/homogeneity and a volume fraction of proper size Nb precipitates in the hot rolled condition and corresponding final base and weld metal ductility properties. Optimized processing of two Nb levels, 0.055% and 0.075%, Nanjing Iron and Steel Company successfully improved base metal plate strength and toughness stability that translated into improved pipe strength and toughness stability including pipe seam/girth welds HAZ toughness. The optimized 0.075% Nb girth weld HAZ fusion line average was 339 J @ - 80 °C with a 9.3 J standard deviation while the optimized 0.055% Nb girth weld HAZ fusion line was 307 J @ -80 °C with a 55.2 J standard deviation.

8:55-9:20

Effect of Nitrogen Content on the Microstructures and Mechanical Properties in Simulated Properties in Simulated CGHAZ of Normalized Vanadium Microalloyed Steel

Feng Chai, Zhongran Shi, Xuehui Chen, Research Institute of Structural Steels, Central Iron and Steel Research Institute, China

Thermal simulation method was used to examine how nitrogen content affected the microstructure and toughness for the simulated coarse-grain heat-affected zone (CGHAZ) of normalized vanadium micro-alloyed steel. The findings demonstrate a substantial relationship between nitrogen content and low-temperature toughness, precipitates, impact fracture morphology, and final microstructure. The CGHAZ toughness of steel with 0.0031% or 0.021% N is low. 0.012% N steel offers the best CGHAZ toughness. Large-sized ferrite side-plate in the major microstructure can act as a channel of cracking due to the slight Ti-enriched carbonitride and grain boundary ferrite present in the steel of 0.0031% N, which leads to poor CGHAZ toughness. Poor toughness results from the crack being able to extend along the coarse grain boundary ferrite in CGHAZ of 0.021% N, which contains coarse (Ti, V)CN. Thin (Ti, V)CN, fine grain boundary ferrite, and abundant acicular ferrite are present in CGHAZ of 0.012% N, which can operate as a barrier to the crack extension and increase CGHAZ toughness.

9:20-9:40

Influence of Heat Input on Microstructure and Toughness Properties in Simulated CGHAZ of High Niobium X80 Steel Manufactured Using High Temperature Processing

Jian Han[1], Frank Barbaro[1,2], Jose Britti Bacalhau[2], Lihua Qi[3], Xiaodong He[3], Meijuan Hu[3]

1. School of Mechanical, Materials, Mechatronic and Biomedical Engineering, University of Wollongong, Australia;

2. CBMM, Brazil;

3. Tubular Goods Research Institute of CNPC, China

Utilization of high-grade pipe steels with excellent combined mechanical properties is beneficial to the economy and environment because the total tonnage of steel structures and thus the carbon dioxide (CO2) emissions associated with steel manufacture and transport can be significantly reduces. On the other hand, welding, as an essential part of the integrity of pipelines, hitherto is still an important fabrication process for line pipe manufacture and construction. And the heat-affected zone (HAZ) is usually regarded as the weakest part in the welded joint and controls the overall performance of pipelines. To determine and demonstrate the weldability of high Nb high temperature processed (HTP) steels and provide extremely valuable information for future line pipe steel design and general steel manufacture, in the current study the toughness in simulated coarse grained heat affected zone (CGHAZ) of an X80 grade steel manufactured using HTP was evaluated. The simulated CGHAZs subjected to thermal cycles with various heat inputs (HIs) (0.8 - 5.0 kJ/mm) were produced using a Gleeble 3500 simulator. The microstructures and corresponding mechanical properties were investigated by means of optical microscopy (OM), scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD), hardness testing and Charpy V-notch (CVN) testing. The microstructural examination shows that the simulated CGHAZs consisted of a bainite-dominant microstructure and relatively low amount (< 2%) of martensite-austenite (M-A) constituent. The prior austenite grain size was controlled to be 45 - 55 μm at HIs of 0.8 - 3.5 kJ/mm due to both Ti-Nb precipitates and solute Nb, and remarkably increased to 85 μm at HI of 5 kJ/mm. The results of CVN testing suggest that superior toughness can be achieved in the studied range of HIs (0.8 - 5 kJ/mm). The desirable CGHAZ toughness performance was primarily related to the fine austenite grain size, fine sub-structures and low fraction of fine dispersed M-A constituents.

9:40-10:00

The Effect of Heating Speed on Phase Transformation and Properties Of Pipeline Steel

Meijuan Hu, Tubular Goods Research Institute of CNPC, China

The matching use of microalloy elements was an almost irreplaceable composition design for pipeline steel. The addition of a small amount of microalloying elements was conducive to controll the grain size of austenite recrystallization during the rolling process, and the carbon and nitrogen precipitates formed during the rolling process had the effect of precipitation strengthening. Its strength and toughness of low-carbon microalloy pipeline steel could be improved at the same time under the reasonable thermomechanical rolling process (TMCP) or high temperature rolling process (HTP) The original microstructure of pipeline steel was changed by the welding

heating cycle, which in turn affected the strength and toughness of the heat affected zone. Phase transformation was the important factor to control the microstructure. The dissolution of carbon and nitrogen compounds and grain growth also had great influence to the properties of heat affected zone during the welding heat stage. Most of the research focused on the phase and microstructure transformation during the welding cooling process, and there was few studies on the heating stage.

In this paper, different chemical composition of X80 pipeline steel was chosen. Round bar and square samples were prepared along the transverse direction of the steel pipe. Thermal simulation tests were done on a Gleeble 3500 thermal simulation machine. the phase transformation temperature of X80 pipeline steel was tested. The prior austenite grain size of heat affected zone were measured after thermal simulation tests. The microstructure, microhardness and toughness of heat affected zone were tested. The rules of microstructure after welding thermal cycle were analyzed. The results showed that the chemical composition had a great influence on the phase transformation temperature. The effect of the original microstructure was increased with the high heating speed. Due to the short residence time at high temperature in the welding process, the structural transformation and the grain growth during heating hada greater impact on heat affected zone performance.

10:20-10:45

Cheyenne Plains X80 with Low Carbon and 0.10% Nb: The Best Example of High Quality and Cost Competitive Steel for Pipelines

Marcos A. Stuart Nogueira, ST3 Consulting Consultant for Niobium Technology of CBMM, Brazil

CBMM has been studying the steels for pipelines that use carbon content below 0.05% with up to 0.10%Nb. The steel used at El Paso Cheyenne Plains Project in 2004 has been considered one of the best references for using this concept since it presents excellent mechanical properties and a lean and competitive alloy design. CBMM sent samples of Cheyenne Plains pipes to different R&D Centers around the world to characterize this material. This paper presents the summary of the results of tests made with longitudinal pipes with thickness of 14.3mm and diameter 762mm, pointing out the main reasons for getting excellent properties when adding 0.10%Nb to X80 steels. The steel has a fine and homogeneous microstructure that guarantees Charpy values higher than 290J for all tests made at -200C and -420C and a low temperature of 50% FATT between -700C and -780C. The Girth Welds present very good toughness when using GMAW or SMAW but, with the automatic process of GMAW, the reliability of the results is much better than using the SMAW. The automatic GMAW girth welding ensures Charpy results higher than 200J when tested down to -400C to the HAZ and less softening when compared with SMAW in the HAZ. The CTOD values between 0.45mm and 0.79mm tested from 00C to -700C where much above the 0.25mm recommended by API1104 for the FL of girth welds in strain-based design. The premium mechanical properties improve safety of the pipelines especially when using automatic GMAW. Another important advantage of using Cheyenne Plains is its lean alloy design that brings economic advantages. The alloy costs are reduced relative to regular grades since the use of 0.10%Nb with carbon content below 0.05% eliminates the need of adding more expensive alloys, especially when considering thicknesses below 20mm. The development of high strength, high toughness and cost competitive 0.10%Nb X80 pipeline steels was the basis for the success of high gas capacity transmission pipeline projects around the world as El Paso Cheyenne Plains Project can demonstrate.

10:45-11:05

Research on Manufacturing Technology of Steel for Low Alloy Drill Pipe Joint with High Strength and Resistance to Hydrogen Sulfide Stress Corrosion

Yaze Tan, Hui Wen, Nanjing Iron and Steel Co., Ltd., China

Steel for petroleum drilling tools is a consumable and irreplaceable industrial product, which is mainly used in the field of formation drilling and exploitation such as oil and natural gas. There is serious H2S corrosion in the production process of oil and gas fields, which is one of the main reasons for the rapid corrosion failure of drilling tool steel, and the corrosion intensifies with the increase of H2S content. Hydrogen sulfide stress cracking mostly occurs at the joint of drill pipe and drill pipe joint, so the hydrogen sulfide resistance of drill pipe joint is much higher than that of drill pipe. Drill pipe joint is an important part and loss part of drilling string in oil and gas field. Generally, high-quality alloy steel is used to obtain excellent comprehensive mechanical properties through forging, hot extrusion and quenching and tempering. According to the statistics of the demand of Sinopec, PetroChina and CNOOC, the annual demand of domestic drill pipe joints is about 40000 tons.

With the development of high acid oil and gas fields and the progress of drilling technology in China, there is an increasing demand for high-grade H2S resistant drilling tool steel. The higher the level of H2S resistance, the higher the requirements for material strength and toughness. Therefore, solving the matching problem between high strength and high toughness of H2S corrosion resistant drilling tool steel is an urgent problem to be solved in the development of higher-grade H2S stress corrosion resistant new steel.

In this paper, through the study of H2S stress corrosion mechanism, the influencing factors of H2S stress corrosion of drilling tool steel are analyzed. Combined with the characteristics of production line equipment of NISCO, the hot-rolled round steel with high strength, high toughness and H2S resistance for drilling tools is successfully developed. After proper heat treatment process, the finished products of round steel can achieve yield strength greater than 827Mpa, and impact toughness greater than 100J at - 20 °C, reaching the H2S stress corrosion resistance standard of 120Ksi. It is the highest steel grade H2S stress corrosion resistant drilling tool steel that can be stably produced in batch at present.

11:05-11:25

Effect of Different Strength Matching on Properties of High Nb X80 Pipeline Girth Weld Joint

Xiaodong He[1,3], Xiongxiong Gao[1], Jian Han[2,3], Qiang Chi[1,3], Chunyong Huo[1,3], Lihua Qi[1,3]

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2. University of Wollongong, Australia;
3. International Welding Technology Center, China

Long distance pipeline transportation needs high strength, large diameter and thick wall pipeline steel pipe. Thermomechanical controlled rolling (TMCP) process designed with C-Mn-Si-Mo-Nb or C-Mn-Si-Cr-Nb alloy is often used to meet the requirements of microstructure and properties of X70, X80 and even higher grade pipeline steel pipes. Therefore, Nb is an important microalloying element in high performance pipeline steel and its pipe. The girth welds of oil and gas pipelines are often welded by a combination of shielded metal arc welding (SMAW) and self-shielded flux cored arc welding (FCAW-S).In recent years, there have been many failure accidents of X80 pipeline FCAW-S girth welding joints at home and abroad. The investigation shows that the strength matching is one of the key factors for the fracture failure of girth welds. In this paper, the high Nb X80 pipe girth weld was carried out by SMAW and FCAW-S combined welding process, and the effect of different strength matching on the properties of X80 girth weld joint was studied. The results show that the average values of impact toughness of E7016+E81T8-Ni2J and E9016-G+E91T8-G are equal, but the single value of impact toughness of the former fluctuates greatly. The distribution of hardness map shows that the strength of the weld with E7016+E81T8-Ni2J is obviously lower than that of the base metal, and the fracture failure of X80 girth weld is very easy to occur under tensile load; However, the strength of X80 girth welded joint with E9016-G+E91T8-G is higher than that of the base metal, and the fracture position is in the base metal. The fracture behavior of two kinds of joints with different strength matching was tested by DIC tensile test. It was further confirmed that the girth weld joint of X80 pipeline with E7016+E81T8-Ni2J had large strain concentration under load, which led to the failure of girth weld joint. On the other hand, because the use of FCAW-S tends to lead to higher heat input, which contributes to the softening of the heat affected zone (HAZ), it can also lead to fracture failure of girth welded joints along the HAZ.

D4 Pipeline Steel and Welding

Friday, 11 November 2022, GMT+8 (Beijing)
Room D, Zoom Link: TBD

14:00-14:25

The International Welding Technology Center in China: Advancing Technology for Pipeline Welding

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3. CBMM, Brazil;
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The demand for clean efficient energy has been the basis for the rapid growth of long-distance gas pipelines in China, using higher strength API X80 for pipes with diameters up to 1,422mm. High strength steels with superior weldability provide the economic benefits and the necessary safety requirements of such significant infrastructure projects. The International Welding Technology Center (IWTC), is a joint initiative of the Chinese National Petroleum Company (CNPC), its R&D Center, Tubular Goods Research Institute (TGRI), together with CITIC Metals and CBMM. The vision of the IWTC is to advance welding expertise in China when the demands for more environmentally friendly energy needs are growing at unprecedented rates. Natural gas will be the interim energy source that will provide immediate reductions in carbon footprint while other renewables are maturing. At present, natural gas represents less than 5% of the total energy sources employed in the generation of China's hunger for electrical energy. The current strategic plan is to grow this energy source to more than 20% in the next decade. In meeting these demands for improved economics and safety in pipeline operations, the IWTC conducts advanced research on high quality steels using the latest technological equipment. It has now been demonstrated that optimized steel alloy designs provide benefits in terms of steel production, pipe manufacture and pipeline construction but this is all subject to comprehensive weld procedure specifications which must be controlled during the production and construction processes. This paper shows the IWTC facilities and deliverables presenting the strategic direction

and some results which will support the Chinese pipeline industry.

14:25-14:50

Development of Steel Plates with Excellent HAZ Toughness after HHIW With Mg Deoxidation

Jian Yang, Xiaoqian Pan, Longyun Xu, Yinhui Zhang, Dekun Liu, School of Materials Science and Engineering, Shanghai University, China

The heat affected zone (HAZ) toughness will be deteriorated after the high heat input welding (HHIW) for conventional steel plates. The Mg deoxidation technology has been used to improve the low-temperature HAZ toughness of steel plates after HHIW. The effect of Mg deoxidation on inclusions, microstructures and toughness of HAZ of steel plates after HHIW was experimentally investigated. The typical inclusions found in the steels are the complex inclusions comprising central oxide and peripheral MnS. With the increase of Mg content in the steel from 0 to 27, 38 and 99 ppm, the phase of central oxide inclusions changes sequentially from Al2O3 to (Mg-Ti-O), and MgO. The number density of nano-scale precipitates is greatly increased after Mg deoxidation. The former austenite grain sizes are obviously decreased and the main microstructure constituents in HAZ are changed from the brittle constituents of Widmanstätten ferrite, ferrite side plate and upper bainite to the ductile constituents of intragranular acicular ferrite(IAF) and polygonal ferrite. It reveals that the IAFs are only observed in steel with Mg addition and the volume fraction of IAF is as high as 55.4% in the steel containing 27 ppm Mg. It shows the MgO-Al2O3-Ti2O3-MnS inclusions with size around 2 μm are effective nucleation sites for IAF. After the industrial experiments with 300 ton scale, the V-groove, one pass and double wire vibration gas electric vertical welding is carried out for the steel plate with a thickness of 70 mm. The developed steel plate has excellent HAZ toughness after HHIW of 400 kJ / cm.

14:50-15:15

Research and Development of Strain Based Design L485 offshore Linepipe

Chuanguo Zhang, Long Li, Leilei Sun, Bo Wang, Shiqiang Xie, Baoshan Iron & Steel Co., Ltd., China

The strain-based design L485 pipeline steel and O.D.559×W.T.31.8mm UOE offshore pipe were trial-manufactured. The results show that for the strain based design pipeline steel with soft phase and hard phase dual-phase microstructure, the longitudinal yield ratio of steel decreases and the uniform elongation increases with the increase of the hardness ratio of hard phase to soft phase.When the proportion of soft phase in steel is too high, it is not conducive to deformability due to the plastic deformation of pipe forming is mainly concentrated in the soft phase. There is obvious softening phenomenon in the heat-affected zone of weld joint of strain based design pipeline steel with ferrite and martensite dominated dual phase microstructure. The strain based design linepipe with ferrite and lath bainite dominated dual phase microstructure exhibit better comprehensive performance.

15:15-15:40

Metallurgical Characteristics for Ductile Fracture Resistance in High Strength Pipeline Steels

Alexey Gervasyev[1], Frank Barbaro[1], Chunyong Huo[2], Igor Pyshmintsev[3], Roumen Petrov[4,5]

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This paper addresses the perennial pipeline community concern about prediction and control of running ductile fracture in pipelines constructed of high strength steels. The generally accepted approach is built upon a predictive model which, although fundamentally sound, is based on laboratory-scale tests that bear no correlation with the mode or mechanism of failure in modern high strength and ductile steels. The lack of research success over this period has led to confusion in both pipeline and metallurgical industries and has hindered the economic application of higher-strength line pipe grades in new pipeline projects. The setback is related in part to the fact that the line pipe manufacturers are forced to achieve the specified level of a standard mechanical property, while very little knowledge is available about the link between the metallurgical design and the actual full-scale performance. The current work has addressed the ductile fracture complex from a metallurgical perspective using accurate data and samples from full-scale burst tests (FSBT) in conjunction with advanced 3D measurements to quantitatively define the strain distribution associated with crack propagation and to link it with the fracture velocity. Methodology improvements for the assessment of FSBT results are proposed. Most importantly, it has been demonstrated that the fracture resistance is related to specific microstructural features which were determined in the base metal of a variety of line pipes with comprehensive FSBT results available. Multi-scale microstructural characterization has been performed at several positions through the pipe wall thickness. The parameters considered included crystallographic texture, banding of texture components, content of microstructure constituents, grain boundary misorientation angle, estimation of dislocation density, size and morphology

of microstructure constituents. Main microstructure designs implemented by thermo-mechanical controlled processing and corresponding alloying compositions are outlined and related to the performance in FSBT. The outcomes of this present work now require validation using FSBT and the development of an alternative small-scale test that more uniquely confirm fracture resistance for modern high strength steels.

15:40-16:00

Microstructural Features of X100 Plate and Pipe Production with Increased Impact Toughness and Cold Resistance

Dmitrii Ringinen, Andrei Chastukhin, Leonid Efron, Sergey Golovin, OMK Vyksa Steel Works, Russia

The increasing volumes of energy consumption and the desire of many countries for independence from energy imports are forcing exploration and production of primary energy sources in the North, in earthquake zones, in the Arctic. Moreover, transportation is carried out for several thousand kilometers. In turn, increased requirements for the mechanical properties of pipelines and their safety. The world experience in developing the production of plate products with unique requirements, for example, K65 (X80) for pipes of the Bovanenkovo-Ukhta project, shows that the achieved metal properties and the ratios between them are not always optimal, several important characteristics, including toughness and cold resistance, are unstable in mass production conditions. The toughness and toughness stability depends on the dispersity and uniformity of the final structure of the rolled metal. Formation of such structure is possible only by controlled rolling (TMCP) which includes slab reheating, roughing and finishing rolling, and accelerated cooling. Each stage plays a specific role in metal structure formation, and thus affects final product structure-sensitive properties. In this work, all stages of TMCP are sequentially considered from a point of view of uniform structure formation of austenite and then bainite, which allows reaching the level of impact toughness in a plate of 320 J. The role of the MA-constituent in reducing the effect of properties degradation during pipe processing is also described. The objectives of this work are a determination of patterns of structure formation at TMCP stages; the establishment of mechanisms to control the uniformity of the microstructure; development on this basis of the production technology of plates and pipes X100 with a high level and stability of tough properties. An example of industrial testing of the production of pipes with a diameter of 1220 with a wall thickness of 20 mm is given. These pipes meet the modern requirements of Gazprom for the base metal of X100 (K80) pipes are characterized by extremely high toughness requirements: KV-20 ≥ 256 J; KV-40 ≥200 J; CTOD-20 ≥ 0.2 mm.

E1 Automotive and Special Steels

Thursday, 10 November 2022, GMT+8 (Beijing)
Room E, Zoom Link: TBD

8:30-8:55

The Influence of Vanadium Additions on Hot Rolled Carbide-Free Bainite Microstructure

Irina Pushkareva[1], Juan Macchi[2], Babak Shalchi-Amirkhiz[1], Fateh Fazeli[1], Guillaume Geandier[2], Frederic Danoix[3], Julien Da Costa Teixeira[2], Sébastien Yves Pierre Allain[2], Colin Scott[1]

1. Canmet Materials, Natural Resources Canada, Canada;

2. Institut Jean Lamour, France;

3. Normandie Université, UNIROUEN, INSA Rouen, CNRS, Groupe de Physique des Matériaux, France

The influence of vanadium additions on isothermally formed bainite in hot rolled medium carbon carbide free bainite was investigated at different length scales using in-situ HEXRD, ex-situ TEM EELS and APT. No significant impact of V in solid solution on the bainite transformation rate, final phase fractions or on the width of bainite laths occurred for transformations in the range 375°C-430°C and no strong influence on the dislocation density could be detected. A reduction in the carbon content of retained austenite Cg that is not believed to be due to competition with VC or cementite precipitation was observed. Surprisingly, the addition of a strong carbide forming element (vanadium) in solid solution did not influence the carbon distribution in bainitic ferrite. A beneficial refinement of blocky MA and a corresponding size effect induced enhancement in austenite stability was found at the lowest transformation temperature.

8:55-9:20

High-throughput Design of Vanadium Microalloyed Lightweight Steels

Weisen Zheng, Shanghai University, China

9:20-9:45

The Hydrogen Embrittlement Mechanism and Effect of Nb for Minimizing Hydrogen Embrittlement in Press Hardening Steel

Hongzhou Lu[1,2], F. D'Aiuto[3], Yi Feng[4], Yan Zhao[5], Jiangtao Liang[6], Yisheng Chen[7], Wei Li[8], Wenjun Wang[1,2], Aimin Guo[1,2], Zhengzhi Zhao[9], Mingtu Ma[4]

1. CITIC Metal Co., Ltd., China;

2. CITIC-CBMM Microalloying Technical Center, China;

3. CBMM Europe, Netherlands;

4. China Automotive Engineering Research Institute Co., Ltd.,

China;

5. New Materials Technology Laboratory, Beijing Institute of Technology Chongqing Innovation Center, China;

6. Shougang Group Co., Ltd., China;

7. The University of Sydney, Australia;

8. School of Materials Science and Engineering, Shanghai Jiao Tong University, China;

9. University of Science and Technology Beijing, China

The press hardening steel (PHS) and hot-stamping components were utilized widely on the reinforcement and lightweight structure of car body due to its ultra-high strength. There existed an obstacle of hydrogen embrittlement (HE) for coated 1.5-2.0GPa PHS, and uncoated 1.8-2.0GPa PHS. The typical hot-stamping components were industry-tried by Nb-bearing and Nb-free Al-Si coated 1500MPa PHS, various dew points (without dew point control and -20 ℃) and austenitizing process parameters(e.g. 220s and 300s austenitizing time) were applied for components, and the U-shaped constant bending load test of samples from components were performed based on automotive industry standard T/CSAE155-2020, to compare the hydrogen embrittlement resistance, and the results show that the break time of hot-stamping components samples with Nb are significant higher than that without Nb, and the break time of hot-stamping components samples(without dew point control) with Nb are higher than that(at -20 ℃ dew point) without Nb. A hydrogen embrittlement mechanism deduction is that the original diffusible hydrogen in steel and the diffusible hydrogen produced by reduction reaction in austenitizing process, leads to initial micro cracking under higher bending stress according to HELP effect, after that microcrack passivates, and restart of microcrack by the effect of dislocation, grain boundary and applied stress, then hydrogen embrittlement fracture occurs by repeated microcrack passivation and restart. The new mechanism is named as HEPD, based on this new mechanism, 4 main triggers were presented which causing of hydrogen embrittlement. The effect of Niobium for minimizing hydrogen embrittlement in PHS are presented. Niobium microalloying was proved for minimizing hydrogen embrittlement in PHS, by various physical methodologies and testing. However, the challenge of measuring the precise location of hydrogen atoms limits our understanding for mechanism. Cryo-transfer atom probe tomography (APT) are used for identifying hydrogen retention and observe hydrogen at niobium carbides, respectively. Hydrogen observed at an interface between NbC and the surrounding steel provides direct evidence that these NbC boundaries can act as trapping sites. This paper proves that Niobium could form more high energy trapping sites- NbC precipitates as well as more grain boundaries (low energy trapping sites), lower diffusible hydrogen in unite grain boundary and inhibit the dislocation slip, which can enhance initial crack energy and restrain crack propagation, the triple features are effective to minimize hydrogen embrittlement. So, Niobium as a "prevention vaccine" is vital for designing embrittlement resistant PHS and guaranteeing safety of vehicles.

9:45-10:05

Coating Free Press Hardening Steel and the Effect of Microalloying Elements

Xiao Zhang[1], Jun Hu[1], Lingyu Wang[1], Yanxin Song[1], David san Martin[2], Wei Xu[1]

1. The State Key Laboratory of Rolling and Automation, Northeastern University, China;

2. Materalia Research Group, Centro Nacional de Investigaciones Metalurgicas (CENIM-CSIC), Spain

The effect of Nb element addition on the structure-properties relationship of hot-rolled quenching and partitioning steels was investigated. Three different experimental steels containing 0, 0.033 and 0.048 wt.% Nb were compared. The results show that the addition of 0.033 wt.% Nb refined the tempered martensite laths and retained austenite, and the morphology of retained austenite changed from block to film, indicating the increase in the stability. Therefore, the refinement of microstructure resulted in the improvement of both tensile strength and elongation in the steel with 0.033 wt.% Nb, 1244 MPa to 1305 MPa and 13.9% to 16.3%, respectively. The stable retained austenite provides gradual and durable strain hardening at strains by taking the advantage of transformation induced plasticity effect, thus contributing to the enhanced mechanical properties. However, when the Nb content continued to increase to 0.048 wt.%, the effect of high amount of Nb on grain refinement and mechanical properties were limited.

10:20-10:40

Effect of Finishing Rolling Temperature and Cooling Rate after Rolling on Microstructure and Properties of Non-quenched and Tempered Steel

Liu Lei, Lei Zhou, Xueyi Peng, Qinglong Wang, Qunfeng Hou, Nanjing Iron & Steel Co., Ltd., China

The microstructure and mechanical properties of non-quenched and tempered steel at different finishing rolling temperature and cooling rate were studied by optical microscope, scanning electron microscope and tensile testing machine. The effect of different finishing rolling temperature and cooling rate after cooling on microstructure and properties of non-quenched and tempered steel were discussed under the same heating and deforming conditions . The results show that when the finishing temperature decreased from 1000 ℃ to 860 ℃, rolling in non recrystallized zone, the non-quenched and tempered steel

average grain size gradually decreased, the ferrite size is refined from 4.25μm to 2.21μm and the grain size (the pearlite cluster surrounded by ferrite is one grain) increased from grade 6 to grade 8. The cooling method is changed from air cooling(cooling rate is about 0.5 °C/s) to water cooling(cooling rate is about 25 °C/s), the surface layer of non-quenched and tempered steel is tempered sorbite, the sub surface layer is bainite and a few ferrite structure, and the sub surface layer to the core is perlite and ferrite. Compared with air cooling, the undercooling degree increases and the austenite transformation temperature decreases of water cooling, the ferrite content is reduced and obviously refined. The pearlite lamellar is refined from 0.33μm to 0.15μm. The non-quenched and tempered steel properties are obviously improved. After water cooling, the yield strength, tensile strength and impact energy is increased by 25%, 15% and 25%, respectively. The material has good strength and toughness matching with the combined process of finishing rolling temperature 860 °C and forced water cooling, and the comprehensive properties is the best. The yield strength, tensile strength, elongation reduction of area and impact energy are 822MPa, 1030MPa, 21%, 56%, 65J, respectively. The rotational bending fatigue limit is 453MPa,which is 20% higher than that of 42CrMo quenched and tempered material.

10:40-11:00

Enhanced Mechanical Properties by Retained Austenite in Medium–C Si-rich V-Nb Microalloyed Spring Steel Treated by Different Heat Treatment Processes

Kui Chen[1], Zhouhua Jiang[1,2], Fubin Liu[1], Congpeng Kang[1], Junzhe Gao[1], Xiaodong Ma[3], Baojun Zhao[3], Yang Li[1]

1. School of Metallurgy, Northeastern University, China;

2. State Key Laboratory of Rolling and Automation, Northeastern University, China;

3. School of Chemical Engineering, University of Queensland, Australia

The microstructure evolution and mechanical properties of a designed 0.56C-1.48Si-0.70Mn-0.71Cr-0.148V-0.011Nb (wt.%) steel subjected to three heat treatments including quenching–tempering, austempering and austempering–tempering have been investigated. In the quenching–tempering sample, the microstructure of the steel consists of tempered martensite and a small amount of retained austenite (~8 vol.%) with an average C concentration of 1.3 wt.%. In the austempering sample, the microstructure containing martensite/bainite composite laths and an adequate amount of retained austenite (~15 vol.%) with an average C concentration of 1.33 wt.%. Subsequent tempering promotes the formation of MC carbides and the decomposition of retained austenite, respectively, resulting in decreases in the retained austenite amount (~10 vol.%) and C concentration (~1.24 wt. %). The carbon distribution detections indicating that the stability of the C-rich area along prior austenite grain boundary is higher than that between the martensite/bainite laths. As a result, ultra-high ultimate tensile strengths (>2200 MPa) are obtained in quenching–tempering and austempering samples whereas the ultimate tensile strength dropped down to ~2100 MPa in austempering–tempering sample. The present steel also shows an excellent total elongation (~15%) after austempering treatment, which is mainly due to ultrafine multiphase of martensite/bainite and the presence of transformation-induced plasticity (TRIP) caused by the adequate retained austenite. Also, the impact toughness increases from ~12.5 J (quenching–tempering) to ~16 J (austempering) and ~17.5 J (austempering–tempering). As a result of TRIP effect, austempering sample has the highest values of strain hardening rate and strain hardening exponent in the uniform strain stage and necking stage among the three samples, thus it obtains a maximum uniform true strain of ~0.087. In addition, the crack source analysis of the three samples all shown an occurrence of ductile dimpled fracture while crack propagation presented as quasi-cleavage fracture. The orientation relationships between the matrix and RA are identified as the K-S relationship and the N-W relationship.

11:00-11:20

Galvanizing Process Optimization of High Strength Low Alloy Steel over 3.0mm Thickness

Yan Li[1,2], Tiejun Li[3], Guangrui Jiang[1,2], Huaxiang Teng[1,2], Haiquan Wang[1,2], Chengliang Xu[1,2]

1. Shougang Research Institute of Technology, China;

2. Beijing Key Laboratory of Green Recyclable Process for Iron & steel Production Technology, China;

3. Shougang Institute of Technology, China

The high strength low alloy steel with the thickness over 3.0mm has been used in some part of auto mobile body. During the production of the high strength low alloy steel with the thickness over 3.0mm, bad formation of the inhibition layer occasionally occurred which severly deteriorate the adhesion of the zinc layer. Reducing the oxidation of the strip inside the furnace and high temperature of strip entering zinc pot is good for the inhibition layer. But excessive temperature of strip entering zinc pot should be avoided and proper cooling method after the air knife should be used to remove the zinc wave defect.

11:20-11:40

Study on the Feasibility of the Q&P Steel Produced by TSCR Process

Cheng Wang[1], Jinping He[1], Chao Zhang[1], Jinping Wang[1], Yongkun Zhang[1], Chunfeng Wang[1], Bo Li1, Yang Liu[2]

1. CSP Branch of Long Product Plant of Wuhan Iron & Steel Co., Ltd., China;

2. Wuhan Branch of Baosteel Central Research Institute, China

In order to meet the requirement of the light weight development of automobile industry, as the representative of 3rd generation automobile steels, Q&P steel based on the concept of quenching and partitioning developed rapidly, the tensile strength of cold-rolled Q&P was as high as 1480MPa. With the substitution of cold-rolled by hot-rolled developed gradually and gained a lot in energy saving and emission reduction, the production of Q&P steel by hot-rolling process arose in more and more interests and numerous studies on the production of Q&P by hot-rolling process has been conducted recently. In this paper, the feasibility of the Q&P steel by TSCR was analyzed. Conclusion as below： (1) Direct quenched and dynamic partition after rolling of thin slab continuous casting can obtain a sufficient amount of metastable residual austenite, and produce TRIP effect in the deformation process to meet the microstructure performance requirements of Q&P steel. (2) Thin slab casting and rolling lines are capable of smelting and casting Q&P steel even some thin gauge Q&P steels. But it is difficult to product <1.5 mm thick Q&P steels. For some of the strong technical equipment and foil production technology has accumulated a wealth of production lines, there is the possibility of successful development. (3) The production of Q&P steel in thin slab continuous casting and rolling production line has a stringent requirement for laminar cooling. The laminar cooling arrangement in different production lines is somewhat different. For Wuhan Iron and Steel CSP, based on the existing conditions, it is possible to manufacture some thin gauge Q&P steel. However, the performance of the product may fluctuate to control the quenching temperature and the difference in cooling rate between the inside and outside of the coil. (4) Combined with the laminar cooling arrangement of the CSP production line in WISCO, the precise control of the quenching temperature can be realized through the replacement of traditional cooling header pipes in the preceding paragraph by the encrypted cooling header pipes. By utilizing the characteristics of longer laminar cooling roller conveyors, short time air cooling, across the martensite tempering temperature range before entering the coiler to avoid the coil after cooling capacity differences caused by fluctuations in performance, so the performance of hot-rolled Q&P steel can be stabled.

E2 Automotive and Special Steels

Thursday, 10 November 2022, GMT+8 (Beijing)
Room E, Zoom Link: TBD

14:00-14:25

Computational Design and Processing Simulation of V containing ultra-high Strength Automotive Steels

David Martin[1], Erik Claesson[1], Arron Middleton[2], Rolf Schmidt[2]

1. Swerim A B, Sweden;

2. East Metals A G, Switzerland

Hydrogen induced delayed fracture is a significant barrier to the widespread application of martensitic steels over 1500MPa ultimate tensile strength in structural applications in the automotive industry. Charging of Hydrogen during processing, such as can occur in press hardening and electro-galvanising, can result in subsequent cracking and splitting caused by hydrogen diffusion at high residual stress part features such as trimmed edges and pierced holes. As a result, manufacturers are required to use restrictive countermeasures to avoid the risk hydrogen induced delayed fracture in these types of steels, which reduce their robustness and breath of application. Several studies in the last two decades [Asahi 2003, Szost 2013, Turk 2018, Cho 2018] have demonstrated that Vanadium additions to steels with highly dislocated microstructure can yield carbides which act as functional trapping sites for diffusible Hydrogen, with apparent benefits in resistance to hydrogen induced delayed fracture. In this paper, we explore the practicalities of alloy design and processing to form these Vanadium carbides using computational thermodynamic methods for both the base alloy and the precipitation sequence design. Using these technqiues, we propose a composition and processing concept for an 1800MPa ultimate tensile strength press hardening steel with enhanced delayed fracture resistance via an optimal carbide structure formed during hot rolling, coiling, and annealing of steel strip.

14:25-14:50

A Shrinkage-based Criterion for Evaluating Resistance Spot Weldability of Alloyed Steels

Shuoshuo Li[1,2], Yanjun Wang[3], Bin Hua[2], Wu Tao[3], Shanglu Yang[3,4], Haiwen Luo[1,2]

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2. Department of Ferrous Metallurgy, University of Science and Technology Beijing, China;

3. Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, China;

4. Center of Materials Science and Optoelectronics Engineering, University of Chinese Academy of Sciences, China

For many decades, several classical formulas on carbon equivalent (CE) have been widely used for evaluating the weldability of

steels. Unfortunately, a single CE is impossible for various types of steels. In this study, the resistance spot weldability of medium-Mn steels (MMS) was investigated. In particular, the influences of paint baking processes at different temperatures on the mechanical properties, fracture mode and microstructure of weldment were studied. It was found that the paint baking above 170 °C can change the tensile-shear failure of weldment from the undesired interfacial failure to the desired pull-out one, because the shrinkage of weldment during welding was compensated by the thermal expansion during the baking, leading to the 'cold welding' realized for solid joining. Furthermore, a shrinkage-based criterion (Δl) was established for evaluating the weldability of greater range of alloyed steels more accurately and robustly than CE. The proposed criterion on measuring the weldability of high alloyed steels opens a promising path forward for designing new generation of AHSS requiring good weldability.

14:50-15:15

Development and Application of Microalloyed Steel for Commercial Vehicles

Wenjun Wang, CITIC Metal Co., Ltd., China

In the context of the implementation of the national emission peak and carbon neutrality policy, lightweight of commercial vehicles is becoming more and more important. On the one hand, in the field of oil consumption, the automobile industry accounts for about 55%, in while the fuel consumption of commercial vehicles accounts for about 60%. Each liter of fossil fuel burning produces 2 kg of carbon dioxide. According to relevant studies, when the vehicle weight drops by 100kg, fuel consumption decreases by 0.12l / 100km on average. Calculated based on the annual driving of 100,000km, CO2 emission can be reduced by 1.35 million tons/year in the process of commercial vehicle transportation. On the other hand, in the rapid development of electric commercial vehicles, due to the relatively large weight of the battery, it puts forward higher requirements for commercial vehicle lightweight, in order to achieve a longer range.

Using high strength steel to replace low strength steel is an economical and effective means of lightweight commercial vehicle, but with the continuous improvement of steel strength, commercial vehicle manufacturers put forward higher requirements on the formability, performance stability and fatigue performance of materials to meet the requirements of material in processing and service. Applications of niobium can effectively solve the above problems, in the process of high strength steel production of commercial vehicles use, niobium can effectively refine grain size, which can increase the steel strength and make the material has good toughness and formability. At the same time, the precipitated nano-sized niobium carbide can effectively improve the strength of the material and achieve the effect of precipitation strengthening. In addition, as niobium is an inactive element, its recovery in steel is stable, so the material has good performance consistency.

Based on the above characteristics of niobium and the performance requirements of the main components of commercial vehicles, a series of niobium containing high strength steels have been developed, which are used in lightweight towing tractor frames, bus body frames, freight cars, wheels, axle housings and leaf springs. The production practice shows that the weight of key parts of commercial vehicles can be reduced by 15-25% by using Nb-bearing high strength steels, which has good lightweight effect. Moreover, the use of Nb-bearing high strength steels can also effectively reduce carbon dioxide emissions in the steel production process due to the reduced steel consumption, which can reduce carbon dioxide emissions by more than 1 million tons per year.

15:15-15:35

The Fracture Behavior Analysis of Nb-bearing and Nb-free Press Hardened Steel under Different Stress States

Jifu Fan[1], Zihan Jiang[1], Hongzhou Lu[2], Yazhou Jiang[3], Xiaoyong Geng[4], Yan Zhao[1]

1. Chongqing Innovation Center, Beijing Institute of Technology, China;

2. CITIC Metal Co., Ltd., China;

3. Chongqing Changan Automobile Co., Ltd., China;

4. Central Research Institute, Lingyun Industrial Co., Ltd., China

Seven different stress state tests of Nb-bearing 22MnB5NbV and Nb-free 22MnB5 were carried out. The Modified Mohr-Coulomb fracture model was established and verified by carrying out the drop weight test of bumper beam. The results show that fracture strains of the two press hardened steel are quite different under different stress states, and the fracture strain of 22MnB5NbV is larger than that of 22MnB5 when the stress triaxiality is used as the independent variable. The fracture performance of 22MnB5NbV is better than that of 22MnB5 in the drop weight test. The deformation and crack initiation area of the parts simulated by the MMC fracture model are consistent with the test results, and the maximum load error and deformation intrusion error predicted by the simulation are both less than 10%.

15:50-16:10

Research on the Microstructure, Tensile Properties and Formability of 1180MPa Grade Cold Rolled Complex Phase Steel

Musheng Qiu[1], Yun Han[1], Huasai Liu[2], Longshuai Han[2], Huaxiang Teng[1]

1. Sheet Metal Research Institute, Shougang Group Co.,Ltd., Research Institute of Technology, China;

2. Jingtang Technology Center, Shougang Group Co., Ltd., Research Institute of Technology, China

This paper dealt with continuous annealing process and mechanical property of a 1180MPa grade cold rolled complex phase(CP) steel. The effects of simulation process parameters on mechanical property of the steel were investigated. Base on these simulation process above, the key process for industrial production of CP1180 has been established. It was found that the annealing temperature has the important effect on mechanical property of the steel. With the increase of annealing temperature, the tensile strength (TS) and yield strength(YS) increased, the elongation decreased. The microstructures and formability of industrial trial products were investigated by means of forming experimental device, Scanning electron microscope (SEM), the complex phase structure as well as dislocation distribution are also researched by transmission electron microscope(TEM).The results shown that industrial trial materials has the comprehensive performance with the tensile strength of 1272MPa, yield strength of 972MPa, elongation of 7.5%. The microstructure shows a ferrite matrix with martensite or bainite islands, TEM micrographs shows martensite and bainite with embedded ferrite phase, and the dislocation distribution near the ferrite-martensite interface, moreover, a large amount of dislocations are also accumulated inside the ferrite grains since it nanoscale size. The effect of punching clearance and hole expansion delayed period on the hole expansion ratio was studied, the hole expansion ratio is normal while the punching clearance is less than 15% of the plate thickness. However, the hole expansion ratio decreases by about 40% while the punching clearance is greater than 15%. On the other hand, the hole expansion delayed period has little effect on the hole expansion rate which is fluctuates in the range of about 10%. Moreover, springback angle increases linearly with the fillet radius, and the transverse springback angle is greater than the longitudinal bending angle. Which is due to the anisotropy of microstructure cause to the yield strength of the transverse sample is generally higher than that of the longitudinal direction. FLC0 can reach about 0.12.

16:10-16:30

Effect of Segregation on the Microstructure and Mechanical Properties of Multiphase Automotive Steels

Jingliang Wang, University of Science and Technology Beijing, China

Effect of alloying element segregation on the microstructure and mechanical properties of an intercritically annealed quenching and partitioning (Q&P) steel and a complex phase (CP) steel was experimentally studied. Phase constitution of the segregation band and matrix was compared to elucidate the effect of Mn enrichment on the relevant phase transformation processes. Tensile specimens including and excluding the segregation band were carefully prepared to reveal the effect of segregation on the mechanical properties of the Q&P steel. A quasi in-situ tensile test was performed on the CP steel to track the microstructure evolution during the deformation. The present study provides direct evidence of the influence of segregation on the microstructure and demonstrates the harmful effect of Mn segregation on the mechanical properties.

16:30-16:50

Revealing Tensile Fracture Mechanisms of Al Added Multiple Phase Steel with Membrane Like δ-ferrite

Hao Wu, Xiangtao Deng, Tianliang Fu, Northeast University, China

In order to cope with energy shortage and environmental pollution, the lightweight of construction equipment has become the development direction in the field of construction equipment manufacturing. Al added can effectilly reduce the density of steel,which is the reasonable way to reduce the weight of equipment and ensure the stiffness of structural parts. The alloy phase diagram was calculated by Thermo-calc software with TCFE 7 database. The result shows that the low density steel with 3wt% Al elementwas in the ferrite and austenite dual-phase region at the temperature range of 1200~A1 point. The stability of ferrite is improved by Al added, which makes the steel in the ferrite/austenite dual-phase zone at the hot rolling temperature. Based on the Al added composition, the low density steel with membrane like δ-ferrite was prepared by hot rolling and directly quenching in dual-phase zone. The Al added hot rolling steel containing multiple phase constituents like α'-martensite, α-ferrite, membrane like δ-ferrite represent excellent mechanical properties, such as ultra-high strength (1698MPa) and ultra-high low temperature impact toughness (391.0J). The multiple phase with membrane like δ ferrite leads to complex fracture mechanisms and evident anisotropy. Here the fracture mechanisms of two groups Al added steels with membrabe like δ-ferrite and different volume fraction of α-ferrite are investigated. The fracture surface shows cleavage fracture in δ-ferrite and ductile fracture in martensite. That the fracture cracks size in the transverse is much larger than that in longitudinal leads to tensile properties anisotropy. The microvoids initiate at the interface of α'-α and α'-δ, the microcrack growing and connecting under stress lead to fracture. The analysis coincidences well to the experimental results. By increasing the quenching temperature, the volume fraction of α-ferrite decreases and the totally elongation decreases from 8.7% to 6.9%. The ferrite/martensite interface decohesion caused by the local strain incompatibility is the main factor of microcrack initiation.

16:50-17:10

Study on the Composite Toughening Mechanism of 1800-2000MPa Strength Hot Stamped Steel Based on Alloy Optimization Design

Yi Feng, Materials Department, China Automotive Engineering Research Institute Co., Ltd., China

Under the trend of energy conservation and environmental protection becoming the two major themes of the development of automobile industry, vehicle lightweight has become the most effective technical means to ensure vehicle safety, power and fuel economy. Through the application of ultra-high strength steel, the material consumption and the number of parts can be reduced, and the vehicle lightweight can be effectively realized. The hot forming technology can realize the two processes of high temperature forming and quenching strengthening at the same time, and achieve the strength target of more than 1500MPa, which solves the contradiction between strength and forming well. The emergence of hot forming technology has greatly promoted the lightweight process of automobile industry at home and abroad. As a new type of material, there are still two common technical problems in the application of hot formed parts in automobile, i.e. low strength and toughness, and high hydrogen embrittlement sensitivity. In this paper, based on the composition system of 34MnB5 hot stamped steel and facing the two common problems of low toughness and high hydrogen induced delayed fracture sensitivity faced by 1800-2000MPa hot stamped steel at home and abroad, this paper optimized the design of Si \ Mn \ Nb \ V \ Ti and other alloy elements, combined with the innovative high temperature deformation non isothermal dynamic distribution tempering process (D & QPT), to meet the requirements of industrial mass production of steel plate its tensile strength ≥ 1800mpa, elongation ≥ 7%, impact toughness ≥ 40J, and hydrogen induced delayed fracture sensitivity decreased significantly. On this basis, the ultimate tip cold bending, lamination impact, high-speed stretching, slow strain rate stretching, hydrogen permeation, TDS and other means are comprehensively used to characterize the toughness and hydrogen induced delayed fracture sensitivity of the newly developed steel. In combination with SEM\TEM\EBSD\XRD\nano hardness\APT means, the qualitative and quantitative analysis is carried out from the perspective of "zero dimensional" nano second phase to "three-dimensional" composite non-uniform metastable phase Synergistic toughening mechanism of steel.

17:10-17:35

A Route for Production of Elevated-Strength Cold-Rolled HSLA Steel

C. Matthew Enloe[1], Fabio D'Aiuto[2], Hardy Mohrbacher[3]

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Well-established practices exist for production of cold-rolled and continuously-annealed high strength low alloy (HSLA) steels as both coated and uncoated variants. Through utilization of standard processing techniques, the yield strength of cold-rolled HSLA steel is practically limited by numerous process and alloy design factors to 550 MPa and less. A production methodology is proposed to achieve greater strengths in cold-rolled and continuously annealed HSLA steels. This methodology utilizes both increased precipitation of microalloy carbides prior to continuous annealing and a subsequent annealing process in which recrystallization of ferrite is successfully suppressed prior to partial or full austenitizing. The resultant microstructure, as a consequence of enhanced precipitate and grain refinement strengthening, achieves greater strengths than those traditionally produced for automotive application of cold rolled HSLA steels. The implications of mass adoption of such enhanced cold-rolled HSLA steels are discussed - including the potential for partial replacement of intermediate strength AHSS in automotive body structures.

E3 Automotive and Special Steels

Friday, 11 November 2022, GMT+8 (Beijing)
Room E, Zoom Link: TBD

8:30-8:55

Development and Prospect of High Strength Steel for Automobile in China

Li Wang, Baoshan Iron & Steel Co., Ltd., China

8:55-9:20

Influence of Annealing Temperatures on Initial Austenite Grain Size of 2GPa Hot Stamping Steel

Rui Wang, Bo Yang, Pengfei Liu, Yu Chen, Chongtao Su, R&D Institute of Benxi Steel Plates Co., Ltd., China

In this paper, the initial austenite grain size of 2GPa hot stamping steel at different annealing temperatures was studied by optical microscope and transmission electron microscopy. The results showed that in the microstructures at 850-900 °C, the austenite grain size was 4.2-5.0 μm, due to the pinning of V(C,N) precipitates. When the annealed temperature was 925 °C, the grain size was 7.07 μm. This is because of the decomposition of V(C,N) and the redissolution of V into austenite with the increase of heating temperature, however, Ti played a certain drag effect on the decomposition of V(C,N) and the redissolution of V, and the growth of austenite grain was still inhibited by the incomplete decomposition of V(C,N). When the annealed temperature was

950 ℃, the decomposition rate of V(C,N) increased sharply, the pinning effect decreased significantly, and the austenite grain size was 20 μm.

9:20-9:40

Development and Application of Nb-microalloyed Isotropic High Strength Uni-FISH Steel

Jiandong Guan[1], Jiaji Ma[1], quanli Wang[3], Dong Wei[2], Lei Jin[2], Tao Niu[2], Nai Wu[1]

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Lightweight and green are current trends to implement the carbon peak and neutrality targets in automobile industry, the development and application of high-strength body steel has been proved as a significant way to achieved them. Highstrength body steel has narrowly focused on structural and safety parts with little breakthrough in body panels, which is attributed various criteria like surface quality, formability and dimensional accuracy of body panels. Shougang has developed Uni-FISH series high-strength automobile panels steel by utilizing Nb microalloying to realize ultra-fine grain structure and PFZ (precision free zone) precipitates on IF steel matrix.

By controlling Nb/C ratio to 15-25 and utilizing Nb to inhibit deformed recrystallized austenite grain boundary migration to refine the austenite. The grain is futher refined to around 13um with ultra fast cooling and low coiling temperature (common IF steel has average grain size of 25um). Oversaturated NbC which unable to precipitate and retained in the hot rolling structure. And Large deformation energy is stored and cold fiber structure is introduced during cold rolling, resulting NbC precipitates at the grain boundary, dislocation and intragranular.

In addition, Ostwald ripening effect in NbC precipitates during hot rolling resulting a PFZ zone and fine dispersion distribution of intragranular precipitates below 10nm through parameter control. The precipitation of NbC and some solid solution Nb increase the recrystallization temperature, so the grain size after annealing can be controlled below 10um. For texture control, hot rolled microstructure with fine precipitates provide sufficient nucleation points for recrystallization during annealing to promote the development of {111} texture resulting higher R(>2.0) for this steel.

With mentioned above, Shougang has developed isotropic high-strength panels steels with strength levels of 340, 390 and 440MPa which has been used in production. Compared with the current product, the concave resistance of this steel is increased by 10-30% and has higher aging resistance than BH steel for no interstitial atoms. With fine and uniform microstructure and special morphology of precipitates, this steel possessed excellent properties like highly isotropic (r ≤ 0.10), high formability (r ≥ 2.0) ,low waviness (Wsa ≤ 0.25μm, which can be stably used in the production of medium free coating) and extremely low DBTT(≤-65 ℃). Such advantages are the perfect fit for the lightweight and green trends.

9:40-10:00

Effect of Continous Annealing Process on Microstructure and Properties of 2000MPa Grade Hot Stamping Steel

Xinghan Chen[1], Renbo Song[1], Weifeng Huo[1], Shuai Zhao[1], Xinwei Wang[1], Yu Zhang[2], Zhiyu Geng[2], Mingguang Yu[3]

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Hot stamping steel with high strength and high plasticity is mainly used in the production of automobile anti-collision parts, such as A-pillar, B-pillar and anti-collision beam, which can improve the safety performance of automobile and meet the development demand of automobile lightweight.The advantages of hot stamping include good shape stability, low stamping load, miniaturization of stamping equipment, integral stamping of large parts, reduction of splicing workload, excellent formability, etc. Based on the commercial 1500MPa hot stamping steel, the composition of 2000MPa hot stamping steel was designed, increased carbon content appropriately to improve steel strength and Nb microalloying was used to improve the product mechanical property. The phase transformation of the test steel was studied, the CCT curve was drawn and observed the microstructure of the samples under different cooling rates. Besides, the continuous annealing process of 2000MPa hot stamping steel after cold rolled was deeply studied, and the optimal continuous annealing temperature was explored by observing the microstructure and testing the mechanical properties. The results show that the temperature of Ac1 and Ac3 of 2000MPa hot stamping steel is 738 ℃ and 800 ℃. When the cooling rate is low, the transformation products of 2000MPa hot stamping steel are ferrite and pearlite. With the increase of cooling rate, the microstructure gradually changes into bainite and martensite, the temperature of Ms is about 200 ℃ and the yield strength and tensile strength of the sample are significantly improved. Set five annealing temperatures in the continuous annealing experiment which were 740 ℃, 760 ℃, 780 ℃, 800 ℃ and 820 ℃, When the annealing temperature is 740 ℃ and 760 ℃, a large number of carbides precipitate in the ferrite grains, which are spherical and tiny. The amount of carbide precipitation is the most when annealing temperature is 760 ℃. When the annealing temperature is higher than 760 ℃, the amount of carbide precipitation decreases obviously. With the increase of annealing temperature, the content of ferrite decreases, the grain size of ferrite decreases and the content of martensite increases.

10:20-10:40

Research on Strengthening Mechanism of 1800MPa Ultra-high Strength Hot Stamping Steel

Xinwei Wang[1], Renbo Song[1], Weifeng Huo[1], Shuai Zhao[1], Xinghan Chen[1], Yu Zhang[2], Zhiyu Geng[2], Mingguang Yu[3]

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Hot forming technology has developed rapidly in recent years. Hot forming technology is a material forming method that combines high temperature forming and quenching strengthening through simple alloy composition design to obtain the desired shape and simultaneously realize the phase transformation of metal materials. Hot stamping steel is widely used in key parts of the automobile body frame, such as A, B, C pillars, door anti-collision beams and other critical parts of collision safety. Hot stamping steel requires a certain degree of plasticity while having sufficient strength to improve the safety of the automobile body. At present, the research on hot stamping steel mainly focuses on the strength level of 1500MPa. The most widely used hot stamping steel is 22MnB5, which cannot meet the increasing development of the automobile industry. The demand for light weight and high collision safety and energy absorption. In this context, based on the composition of 1500MPa grade hot forming steel 22MnB5, this paper appropriately increases the carbon content, while adding 0.04% of microalloying element Nb, and studies the effect of Nb on the grain refinement of hot forming steel. effect. With the aid of scanning electron microscope (SEM), optical microscope (OM), X-ray diffractometer (XRD) and other analytical testing methods, through microstructure analysis and mechanical performance research, the hot stamping steel comprehensively analyzes the influence of the strengthening and toughening mechanisms such as precipitation strengthening, fine-grain strengthening and martensite morphology control on the improvement of the strong plasticity of ultra-high-strength hot stamping steel. The microstructure evolution and performance characteristics of the test steel under different hot forming process parameters were systematically explored, and the results were obtained by adapting the hot forming process parameters, and developed a kind of ultra-high-strength hot forming steel with tensile strength not less than 1800MPa and total elongation not less than 6%.

10:40-11:00

Step-cooling Process for Strength and Toughness Matching Coordination of Vanadium Containing Railway Wheel: Effect of Intragranular Ferrite

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Effects of low undercooling in austenite on microstructure and mechanical properties of a commercial vanadium containing wheel steel were studied by optical microscope (OM), scanning electron microscope (SEM), transmission electron microscope (TEM) and mechanical properties test. The result shows that slightly cooled to an appropriate temperature above Ac3 point for a short time after the wheel steel austenitized at an elevated temperature, the dissolved V is pre-precipitated in form of V(C,N) second phase semi coherent with the matrix in original austenite grain, which hardly participates in the matrix strengthening. Due to the small mismatch between V(C,N) and ferrite, in subsequent cooling phase transformation stage, the pre-precipitated second phase becomes the ferrite nucleation point, and induces granular and ellipsoidal intragranular ferrite (IGF, average size 4 - 6 μm) to nucleate in original austenite. The higher the undercooling degree is, the more IGF it produces, but the greater the strength sacrifice is also. Based on this, Masteel Co. has developed a new heat treatment step-cooling process that can promote the formation of IGF, which significantly improves the level and uniformity of fracture toughness on the premise that the strength and hardness of wheel are almost unchanged.

11:00-11:20

Research and Application of Key Technology of High Wear Resistance Rail

Gangtie Hou, Chaojun Guo, Dongning Chen, Bo Lian, HBIS HanSteel, China

In this paper, we have drawn on the experience of destructive examination of RCF samples, site monitoring, laboratory testing and specialist metallographic examination. We also have conducted a research programme to understand the fundamental metallurgical factors that affect the life of rails. Based on the above two points, this paper carried out component design optimization in rail steel-making process, at the same time physical and chemical performance and online service evaluation were investigated. In other hand, this paper analyzes the mechanism of micro-alloying chromium and vanadium, the inclusions in steel and its effect on the property and structure of finished rail. Accordingly, the composition and process optimization of steel making to improve the performance of rail .

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