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Analysis of the failure probability of copper tubes in heat pump

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As **flammable refrigerants** are more and more widely used, their leakage is becoming an important issue concerning safety. Failure of copper tube is one of the main reasons that causes **refrigerant leakage** of air conditioners. Based on the **ISO-9223** equation about copper corrosion in the atmosphere, a failure model of copper tube in a heat pump is established. The effect of high discharge temperature on corrosion rate is described by Arrhenius relationship. The **probability of leakage failure** in service life of **heat pump** is forecasted. The effects of geographic location, copper tube size, refrigerant type, welding condition and coating on the corrosion rate and leakage probability are analyzed. It is found that the tube of R32 system is more susceptible to corrosion as compared the tube of R290 system, and the corrosion rate of the former is about twice of the corrosion rate of the latter. The probability of tube failure is largely influenced by environmental conditions during heating season. For heat pump installed in Harbin, the failure probability at the tenth year will reach 8.8% with no coating.

ABSTRACT

Refrigerant leakage may not only cause degradation of air conditioning performance, but also do damage to air conditioning compressor. For alternative refrigerants, there is an additional risk of ignition and explosion events. Zhang et al, Tang Weier, and Yuan Xiaoyong have studied the concentration distribution in the room after refrigerant leakage, all revealing the existence of room areas where the lower limits of refrigerant ignition and explosion are reached. Most heat exchangers of air conditioning systems are composed of copper tubes, and corrosion of copper metal is inevitable in the environment. Sulfides, chlorides, and ammonia in the air can corrode copper tubes, and may form the undetectable ant-nest erosion. Therefore, it is important to know the safe and effective life time of copper tubes in air conditioning systems under specific conditions. Predicting the service life of copper tubes is especially critical in the current context of alternative refrigerant promotion. In this paper, a mathematical model is established to predict the safe service life of copper tubes for household air conditioners. The model consists of two parts, the Arrhenius correction model for corrosion rate of air conditioning copper tubes based on ISO-9223(referred to as the atmospheric corrosion rate model for copper tubes) and the safe crack depth model for copper tubes based on stress intensity factor method[16] (referred to as the minimum crack depth model for copper tubes).

Introduction

Impact Analysis of Multiple Factors

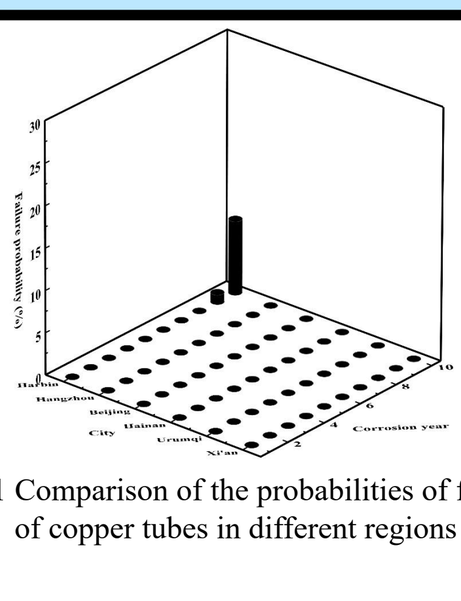


Fig. 1 Comparison of the probabilities of failure of copper tubes in different regions

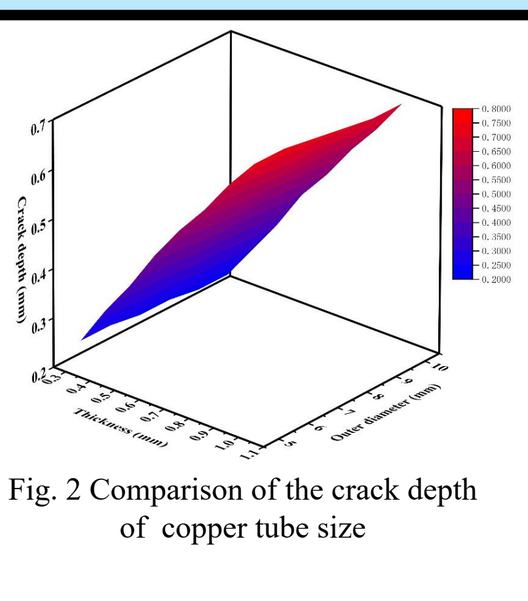


Fig. 2 Comparison of the crack depth of copper tube size

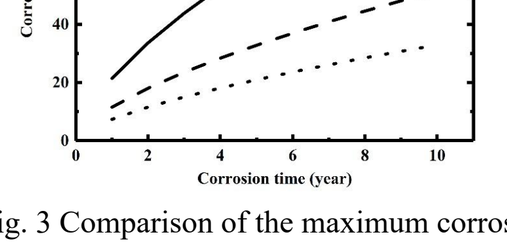


Fig. 3 Comparison of the maximum corrosion depth of alternative refrigerants

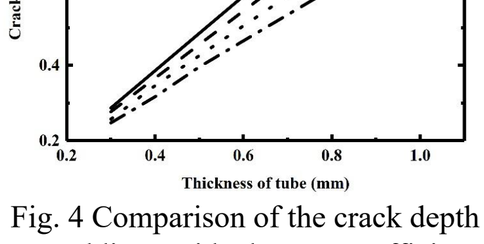
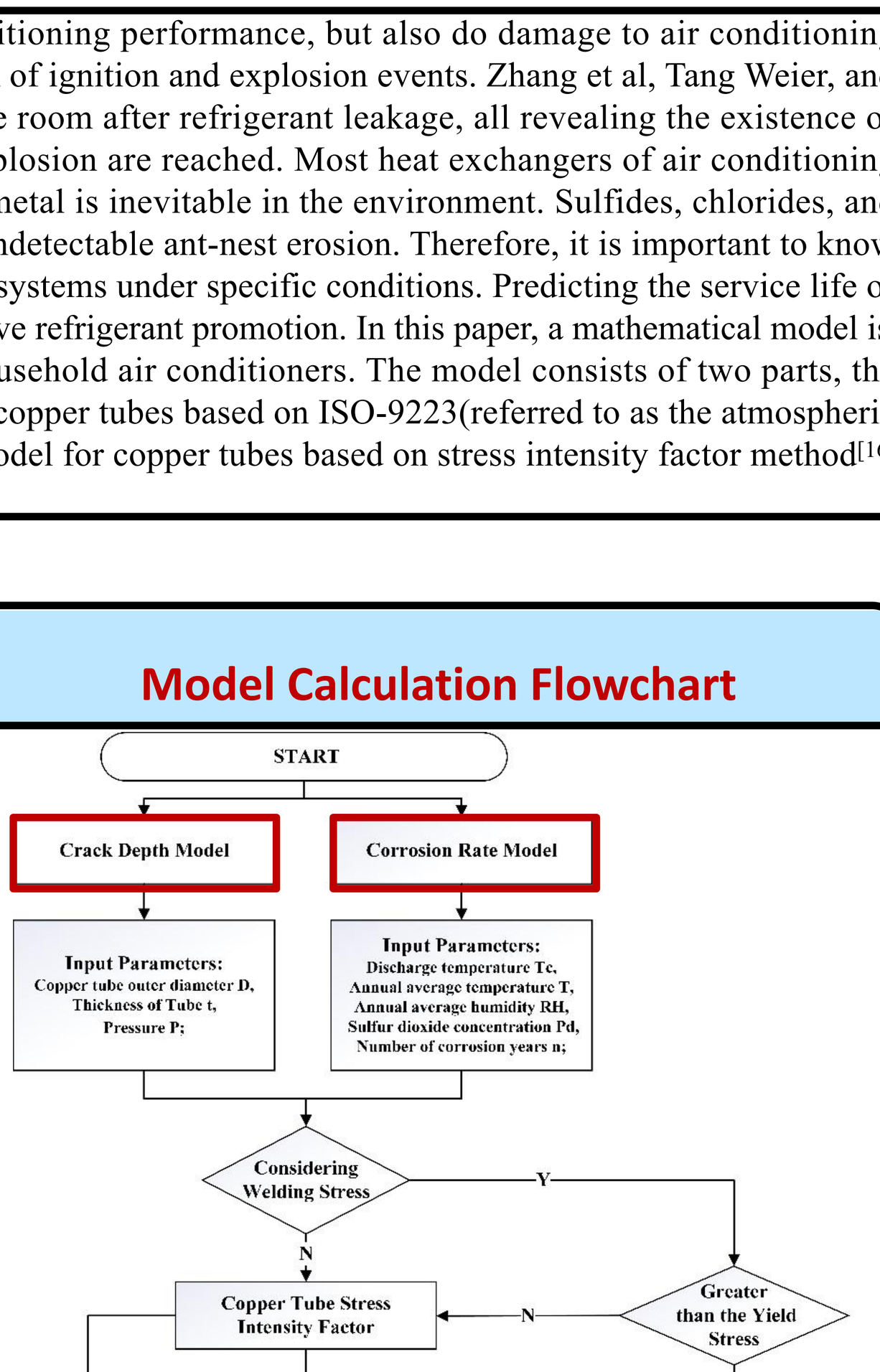


Fig. 4 Comparison of the crack depth of welding residual stress coefficient

Fig. 5 Comparison of crack depth of coatings

The above are figures of the effect of geographic location, copper tube size, refrigerant type, welding condition and coating on the corrosion rate.

Model Calculation Flowchart



Based on the total corrosion rate and the minimum crack depth model, the probability of leakage failure is programmed and calculated by combining the probability of chloride concentration after normal distribution.