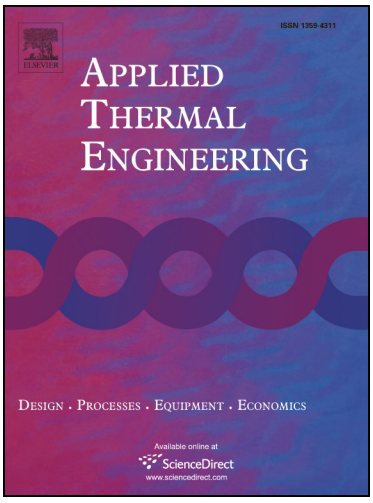

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Tengfei Hou, Yongchang Chen, Zepeng Wang, Chongfang Ma

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Experimental study of fouling process and antifouling effect in convective heat transfer under ultrasonic treatment

Tengfei Hou, Yongchang Chen*, Zepeng Wang, Chongfang Ma

Key Laboratory of Enhanced Heat Transfer and Energy Conservation, Ministry of Education and Key Laboratory of Heat Transfer and Energy Conversion, Beijing Education Commission, Beijing University of Technology, Beijing 100124, China

Abstract: An experimental study was carried out by a dynamic fouling monitor system to investigate the fouling process in convective heat transfer by ultrasonic treatment. During the experiment, the cooling water in heat exchanger was used as working fluid with the inlet temperature of 22.5 ℃ and 44 ℃ and the initial hardness of 300 mg/L and 500 mg/L, respectively. For all cases the inlet temperature of hot water was kept at 70 ℃, and the flowrates of cooling water and hot water were set at 0.77 m^3/h and 0.81 m^3/h, respectively. In this experimental setup, a double-tube heat exchanger was served as a test section of heat transfer, in which hot water flows inside the inner copper tube and cooling water flows in the annular gap between the two tubes, thus forming a counter-flow situation. Further, an ultrasonic device was installed for water treatment with a frequency of 20.7 kHz and power ranging from 0 to 75 W. The results showed that the fouling resistance for hard water increased evidently with increasing of water temperature and hardness. With the ultrasonic treatment, the fouling resistance decreased remarkably compared with the untreated case, and the asymptotic fouling resistance decreased monotonously with increasing of the ultrasonic power. Subsequently, the crystal morphology of calcium carbonate was observed in microscopic view and the transform of crystal from the vaterite to aragonite and calcite was analyzed based on the theory of the formation energy. It was confirmed that the ultrasonic treatment may have significant effect on the crystal shape, and more aragonites appeared with increasing powers of ultrasound.

Keywords: fouling resistance, ultrasonic treatment, crystal morphology, convective heat transfer

1.Introduction

Fouling usually exists in heat exchangers of industrial process, which not only reduces heat transfer performance and increases flow resistance, but also erodes heat transfer equipment. Chemical agents are proven to be effective in fouling inhibition, but limited by high costs and environmental pollution. Consequently, physical treatments such as electrical, magnetic, ultrasound tech etc. are developed to restrain fouling in heat exchangers. The techs are effective in fouling inhibition, energy saving and environmental protection. One of them is the ultrasonic tech for water treatment, which has attracted attentions of many researchers around world.

Early from 1950s, ultrasonic cleaning tech has been widely used in industry for cleaning mechanical parts by effect of ultrasonic vibration. In recent years, with the requirement of fouling inhibition the ultrasound techs are recognized and applied to water treatment for antifouling process, which utilize integrated effects of cavitation, vibration, heating etc. to restrain fouling on heat transfer surface [1-2]. A number of studies on ultrasonic antifouling have been reported in literatures [3-12]. Fu et al. [3] carried out a descaling experiment by ultrasonic frequencies of 20