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Performances of two heat exchangers assisted by ultrasound

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ABSTRACT

In this experimental work, performances of a double-tube heat exchanger are investigated with and without the influence of ultrasonic vibrations. A comparison is made with results obtained previously for an analogous shell-and-tube heat exchanger. The system of interest is made of two concentric straight pipes. An external ultrasonic transducer is connected to the largest one in order to make it vibrate at 35 kHz. A smaller pipe is inserted into the vibrating one in order to build a double-tube heat exchanger, always using water as working fluid. The ratio between the overall heat transfer coefficients with and without ultrasound, named the enhancement factor, was used alongside energy balances as means of comparison between experiments and heat exchangers performances. This enhancement factor was found between 1.5 and 2.3, and slightly more for the shell-and-tube heat exchanger. Nevertheless, whatever the heat exchanger configuration, the use of ultrasonic vibrations appears to be an interesting way for the enhancement of thermal performances.

1. Introduction

The positive effect of ultrasonic vibrations on heat transfer enhancement was reported by several authors [1]. Free convection [2], boiling [3,4] and also melting [5] were deeply studied and the consequences of ultrasound upon these phenomena are well known. Cavitation and acoustic streaming are physical processes subsequent to ultrasound propagation into a liquid medium and their impact on heat transfer can be of major importance [6,7]. But concerning vibrating heat exchangers, where ultrasound can have influence on two or more fluids, analyses remain scarce, except about fouling reduction. Indeed, scale deposition and biofouling can be highly prevented or reduced by ultrasonically induced phenomena [8–10]. This non-negligible advantage was probably studied before the heat transfer enhancement possibility and must be kept in mind if any economical evaluation of such system is made in the future.

A pioneer work dealing with forced convection was carried out by Bergles and Newell [11]. They studied heat transfer to water flowing in annuli, with a heating cylinder at the center and under the direct influence of an ultrasonic field. The best improvement they reported was an increase by 40%. Concerning thermal radiation, Fairbanks [12] managed to enhance water heating by combining solar radiation and ultrasound. He found a synergy between these two means of energy transfer. However, the first work on the effects of ultrasound on heat exchangers performances was initiated by Kurbanov and Melkumov [13]. They claimed 20% intensification of the heat exchange process in a refrigeration system, but it was not the only benefit. According to these authors, ultrasonic vibrations help to decrease the flow friction and the pumping power. They also disrupt the velocity boundary layer, often constituted by a lubricant film which represents an important thermal resistance, hence the improved effectiveness. Also dealing with more than one fluid, Monnot *et al.* [14] studied the cooling rate of a sonochemical reactor where ultrasound enhanced the convection heat transfer coefficient between 135 and 204%.

The work proposed here is an extension of preliminary studies performed by Gondrexon *et al.* [15] using a vibrating shell-and-tube heat exchanger, in which the overall heat transfer coefficient was enhanced up to 2.5 times by the use of ultrasound. Nevertheless, the geometry of the system has been modified by removing the internal U-shaped tube and inserting a straight pipe instead in

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