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Experimental evaluation of pressure drop in round tubes provided with physically separated, multiple, short-length twisted tapes

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ABSTRACT

Isothermal pressure drop tests were performed on horizontal round tubes each containing identical, physically separated, equally spaced, short-length twisted tapes (TTs). The tests investigated the dependence of the Darcy friction factor, f, on the empty tube Reynolds number Re, TT twist ratio y, and TT spacing s. The variation of f across TTs belonging to the same test section was also examined. Ranges of the experimental variables examined were: $10{,}000 \leqslant Re \leqslant 90{,}000$, $1.5 \leqslant y \leqslant 6$, and $s = 30$, 40 and 50. The number of 360° revolutions was held constant for all the tapes and equal to 1.5. Tap water at room temperature and nearly atmospheric pressure was used as the working fluid. A correlation for the Darcy friction factor, in the form $f = f(Re, y, s)$, was developed from the collected experimental data, with excellent accuracy.

1. Introduction

Twisted tapes (TTs) are often employed in heat exchangers as turbulence promoters. By generating a centrifugal field (which enhances wall-to-bulk mixing) and increasing the fluid velocity axial component, they increase heat transfer coefficient (HTC) and critical heat flux (CHF), at the expense of an increased pressure drop. Depending upon the conditions, the fin effect can also contribute to the increase in HTC and CHF.

The most well known TT design, the full-length TT (FLTT), consists of a TT whose length is equal to that of the channel in which it is inserted. This TT design has been studied extensively in the past, and correlations are available for both HTC and pressure drop in the presence of such a device. Correlations for CHF are also available, although less numerous. A complete overview of FLTT performance is presented by Manglik and Bergles [1].

For a FLTT the increase in pressure drop, with respect to an empty tube, depends on the tape geometry and is always larger than about 1.85 times for any FLTT geometry [2]. The need to reduce this extra pressure drop induced some researchers (see Table 1) to examine a different TT design, consisting of either a single short-length twisted tape (SLTT) located at the inlet of a short channel, or multiple short-length twisted tapes (MSLTTs) inserted into a long channel and spaced by an empty length. These TT designs, which are conceptually equivalent, rely on the persistence of swirl flow downstream of the TTs, where HTC and CHF can be enhanced without having the hydraulic diameter reduced, and therefore without the pressure drop increase associated with such a reduction. It is important to mention that the pressure drop benefit of MSLTTs relative to FLTTs may not be sufficient to make the former design preferable over the latter when pressure drop and HTC are considered simultaneously. In fact, although in most cases MSLTTs yield a lower pressure drop than a FLTT having the same twist ratio [3], inconsistent results have been found in the literature regarding whether MSLTTs are able to transfer more heat than FLTTs for the same pumping power. Saha et al. [3,4] state that MSLTTs perform better than FLTTs only in the laminar regime, while in the turbulent regime they perform worse. However, they did not test physically separated MSLTTs, but MSLTTs connected with a solid rod, which has a detrimental impact on pressure drop. If that rod had not been present, their results would have shown better performance for the MSLTT design. Whether or not such performance would have outperformed that of FLTTs cannot be known with certainty. Results by Klepper [5] may however help in this regard. Klepper, who used nitrogen as the working fluid, tested a single SLTT followed by a 50 diameter long swirl decay region, and compared the heat transfer coefficient of this design with that

Abbreviations: CHF, critical heat flux; FLTT, full-length twisted tape; HTC, heat transfer coefficient; MSLTTs, multiple short-length twisted tapes; PWR, pressurized water reactor; SLTT, short-length twisted tape; TT, twisted tape.

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