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A numerical study on heat transfer and friction factor characteristics of laminar flow in a circular tube fitted with center-cleared twisted tape

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ABSTRACT

Twisted tape is a widely used technique for heat transfer enhancement. In the present paper, we proposed a center-cleared twisted tape aiming at acxhieving good thermohydraulic performance. A comparative study between this type and the short-width twisted tape was performed numerically in laminar tubular flows. The computation results demonstrated that the flow resistance can be reduced by both methods; however, the thermal behaviors are very different from each other. For tubes with short-width twisted tapes, the heat transfer and thermohydraulic performance are weakened by cutting off the tape edge. Contrarily, for tubes with center-cleared twisted tapes, the heat transfer can be even enhanced in the cases with a suitable central clearance ratio. The thermal performance factor of the tube with center-cleared twisted tape can be enhanced by 7–20% as compared with the tube with conventional twisted tape. All these demonstrated that the center-cleared twisted tape is a promising technique for laminar convective heat transfer enhancement.

1. Introduction

Twisted tapes, as one of the passive heat transfer enhancement technology, have been extensively studied due to their advantages of steady performance, simple configuration and ease of installation. By generating swirls which enhance the fluid mixing of the near-wall and central regions, the heat transfer in tubes with twisted tapes could be enhanced [1–3]. Moreover, the twisted tape can partition and block the flow, reduce the hydraulic diameter, elongate the twisted flow path and generate a fin effect [1,2]. All these lead to additional heat transfer improvements. However, the thermal improvements are accompanied by increased pressure drop.

How to optimize the thermohydraulic performance of tubes fitted with twisted tapes has gained increasing attention [4–21]. For instance, Saha et al. [4] experimentally studied the heat transfer and pressure drop characteristics of laminar flow in a circular tube fitted with regularly spaced twisted tape elements connected with rod. The results showed that the pressure drop of the tube fitted with the segmented twisted tape elements is 40% smaller than that of the tube fitted with a continuous twisted tape, and the former has a better thermohydraulic performance. Eiamsa-ard et al. [5] experimentally investigated the convective heat transfer behaviors in a circular tube fitted with regularly spaced twisted tape elements in laminar and turbulent flows, and they found that the heat transfer coefficient and friction factor were both significantly reduced as compared with those of the tube fitted with a continuous twisted tape. Later, Saha et al. [6] further investigated the effects of the width of tape elements and the diameter of connecting rod on heat transfer and pressure drop characteristics. This work indicated that a narrower width of tape elements led to a worse thermohydraulic performance, while a thinner connecting rod resulted in a better one. Therefore, he proposed to abolish the connecting rod and 'pinch' the tube to fix the segmented twisted tape elements. Jaisankar et al. [7] studied the heat transfer and friction factor characteristics of thermosyphon solar water heater system using full-length twisted tape, and short-length twisted tapes with and without connecting rod. In their experiment the segmented twisted tape elements with several twist cycles were used, while in Saha and Eiamsa-ard's investigations the segmented twisted tape elements only have half twist cycle. Jaisankar et al. found that whether it is fitted with rod or not, the heat transfer coefficient and friction factor for the segmented twisted tape elements were both much smaller than those for the full-length twisted tape. Moreover, the overall performance for the segmented twisted tape elements connected with rod was better than that for the elements without rod.

Other researchers investigated the convective heat transfer behaviors in tubes fitted with short-width twisted tapes. In these cases, there is a gap between the twisted tape edge and tube wall,

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