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THE STUDY OF POLYMERIC HOLLOW FIBER HEAT EXCHANGERS

I. Astrouski, M. Raudensky *

Abstract: *The polymeric hollow fibre heat exchanger (PHFHE) is a modern apparatus, using polymeric fibres, with a small diameter of 1 mm, separating heat transfer mediums. The main goal of this work is to study different factors affecting heat transfer in polymeric hollow fibres (diameter, length, material of fibres, liquid temperature, and velocity) and to obtain conclusions concerning hollow fibre application. The values of heat transfer coefficient, heat transfer rate, number of transfer units (NTUs), efficiency and pressure drops were obtained for the applications, water-water and water-air. Delphi-based software was designed by the laboratory especially for the computation process.*

Keywords: ***Polymeric hollow fibres, heat exchanger, heat transfer.***

1. Introduction and Theory

Polymer materials have a lot of advantages that are attractive for the design of heat exchange equipment. On the other side thermal conductivity of polymer materials is low, usual between 0.1 and 0.4 $W \cdot m^{-1} \cdot K^{-1}$ which is 100-300 times lower than the thermal conductivity of metals. This considerably limits using of polymers for heat exchange equipment because of a big magnitude of wall thermal resistance. There are two existing approaches to overcome such disadvantage. The first one is to increase the thermal conductivity of material by adding different fillers such as metal dusts, graphite or carbon nanotubes. The second approach is to use thin walls between the heat transfer mediums. Polymeric hollow-fibre based heat exchanger (PHFHE) is a type of a thin-wall polymer heat exchanger, firstly designed by Zarkadas & Sirkar (2004) as a useful alternative for lower temperature applications.

Standard polymeric hollow fibres have internal diameters of 0.05 – 2 mm. They can be classified as the so-called microdevices (Herwig, 2001) and require considering additional factors during the modelling process. However, in accordance with Zarkadas & Sirkar (2005), the axial heat conduction, flow work and viscous dissipation are negligible for laminar flow in the polymeric hollow fibres. Two methods of fibres heat transfer modelling were proposed: the simplified correlation suggested by Hickman and the rigorous solution of the extended Graetz problem by Hsu (Zarkadas & Sirkar, 2004). A simple relationship how to calculate an internal mean Nusselt number of thermal developing region was designed also by Zarkadas & Sirkar (2005) based on the Hickman's study and incremental heat transfer number calculated by the Hsu's approach.

2. Results and discussion

The input parameters were varied in order to study the influence of different factors on heat transfer and pressure drops in polymeric hollow fibres. Moreover, several comparisons of different fibres were applied.

In the study of liquid velocity around the fibres it was determined that the velocity of cross-flow water around the fibres has no strict influence on heat transfer performance. Even values of heat transfer coefficient are not so small at very low water velocities (for example 0.005 m/s). However, this conclusion is not true for water-air application because of external wall-air thermal resistance influencing the total heat transfer rate.

* Ing. Ilya Astrouski, prof. Ing. Miroslav Raudenský, CSc.: Heat Transfer and Fluid Flow Laboratory, Faculty of Mechanical Engineering, Brno University of Technology, Technicka 2896/2; 616 69, Brno; CZ, e-mail: astrouski@lptap.fme.vutbr.cz

In the study of the fibres with different diameters (see Figure 1) it was found that linear heat transfer coefficient is not so much depending on the fibre diameter. Fibres of the same length and different diameter have similar heat transfer capacity. Big difference in overall heat transfer coefficient is influenced by a big difference of outside surface of the different fibre diameter. A unit of heat transfer surface created from small fibres has a bigger heat transfer capacity than the unit of surface created from bigger fibres. However, the pressure drop is much bigger for the small fibres and this is an important factor limiting the application of relatively small fibres.

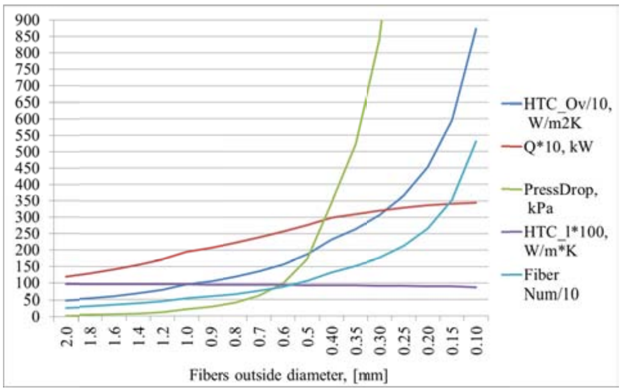

Fig. 1: Comparison of different polypropylene fibers which have the constant total external surface for water-water cross-flow

To determine the influence of wall material thermal conductivity two types of fibres were studied. The first one was an isotactic polypropylene with a thermal conductivity k of 0.18 $W \cdot m^{-1} \cdot K^{-1}$ and the second was an arbitrary material with a conductivity of 2 $W \cdot m^{-1} \cdot K^{-1}$ (11 times higher). It was found that the wall thermal resistance plays the main role in the overall thermal resistance (about 55 %) in the case of a polypropylene application. The opposite situation exists in the case of a material thermal conductivity of 2 $W \cdot m^{-1} \cdot K^{-1}$ where the wall resistance has a minimal influence on total resistance. Moreover, it was found that an increase of material conductivity 11 times higher (from 0.18 to 2 $W \cdot m^{-1} \cdot K^{-1}$) gives approximately two times bigger linear heat transfer coefficient.

In addition, three types of fibres were compared for two heat exchanger designs, water-to-air and water-to-water. These fibres have the same efficiency in the exchanger. The comparison of linear heat transfer coefficients, heat transfer rate, number and mass of fibres for water-air application is presented in Figure 2. This shows that the linear heat transfer coefficient (and thus thermal performance) is slightly better for bigger fibres (an outside diameter of 0.8 mm). The heat transfer rate is several times higher for these fibres based on its larger length and so less fibre needed to obtain required heat transfer capacity. On the other side the small fibres (outside diameter of 0.4 mm) have bigger values of overall heat transfer coefficients and smaller values of the required surface.

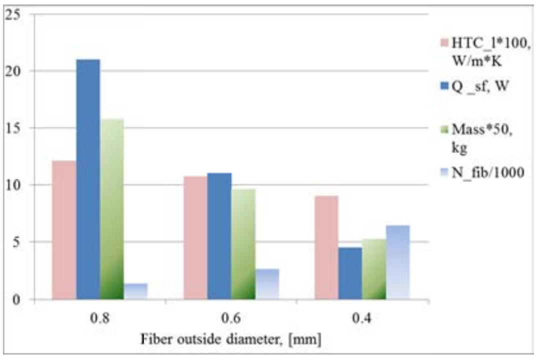

Fig. 2: Three diameters of fibers comparison for constant efficiency ($E \approx 53\%$)(0.8 mm length 1.4 m, 0.6 mm length 0.8 m and 0.4 mm length 0.4 m)

3. Conclusions

The factors influencing heat transfer of the polymeric hollow fibres with respect to cross-flow water-water and water-air application were theoretically studied. The conclusions and comparisons done show the tendencies of the heat transfer existing in the polymer fibres and can help to choose adequate fibres and flow conditions.

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