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Determination of Temperature Distribution and Convective Heat Transfer Coefficient in a Scraped Surface Heat Exchanger for Non-Newtonian Fluids

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Extended Abstract

The thermal treatment of viscous fluids is generally processed using scraped surface heat exchangers, and chemical, pharmaceutical, cosmetic, and food engineering are commonly applied [1]. The study of scraped surface heat exchangers (SSHE) in the food industry is relevant because this equipment is used for pasteurization, gelation, emulsification, sterilization, heating, whipping, and crystallization processes, among others [2]. It was necessary to determine the temperature distribution in the SSHE, to understand the behavior of food inside the exchanger. It has been challenging to determine the distribution of temperatures in the scraped surface heat exchanger because various factors intervene in its operation, such as the number of scrapers, type of fluid being processed, rotation speed, and feed flow. The heat transfer coefficient is determined for the SSHE by different proposed mathematical correlations between the Nusselt number, the Reynolds number, the Prandtl number, and the Taylor number. The correlations have variables that refer to the rheological behavior of the fluid. Skelland *et al*. [3], proposed a mathematical model to predict the heat transfer coefficient considering the type of fluid, the number of blades, the diameter of the rotating shaft, and the axial velocity of the liquid flow.

This study focuses on determining the temperature distribution and the heat transfer coefficient (h) in a scraped surface heat exchanger, using a model food to compare the theoretical approximations to the Skelland equation and the results to the experimental heat transfer coefficient using Newton's law of cooling.

The heat transfer study was carried out in a SSHE, in which the temperature distribution and the heat transfer coefficient (h) were determined using a model food with pseudoplastic behaviour (aqueous solution of 0.5% w/w carboxymethylcellulose). It was obtained the replica of the rotor. It placed three thermocouples that allowed determining the temperature variation in different positions of the SSHE. Plackett-Burman experimental design was used to determine three factors to be analysed: volumetric flow, rotor rotation speed, and heating temperatures. The statistical analysis was performed to determine the type of distribution followed by the temperatures recorded by each of the thermocouples for each run of the experimental design. The average temperatures for each run and each thermocouple were used for the statistical analysis of the experimental design. Pareto charts were obtained to determine which of the three factors (volumetric flow, heating temperature, or rotor rotation speed) affects the temperature distribution of each thermocouple.

The heat transfer coefficient was evaluated using the Skelland equation, with the average internal temperatures, the external temperatures of the equipment, and the equivalent diameter. The results obtained demonstrated that the calculation with internal temperatures has a closer approximation of the theoretical heat transfer coefficient to the experimental coefficient. The characterization of the food model confirmed the pseudoplastic behaviour of the carboxymethylcellulose solution at the chosen concentration. It was determined that the variation of the temperature fluid concerning the SSHE position is inversely proportional to the volumetric flow, while for heating temperature and the rotor rotation speed, it is directly proportional.

References

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