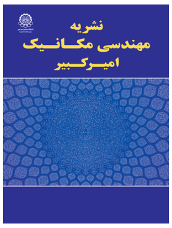

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Numerical investigation of the effect of the porous coating layer on the heat transfer plate in the flow of impinging jet array

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ABSTRACT: The main objective of the current numerical research is to study the effects of covering the impingement surface by a porous layer in order to increase the heat uniformity throughout the surface without losing the advantage of high heat transfer rates in a multiple impinging jet flow. The porosity, permeability and thickness of the porous layer are considered. The results show that among the scenarios studied, the highest overall heat transfer performance coefficient is equal to 23.45 and corresponds to the case where the porous layer covers half of the depth of the channel and the porosity and permeability of the porous medium are at their highest (ε=0.8) and lowest (k=1.76*10-12) values, respectively. This study shows that using different arrangement for porous media can lead to a more uniform heat generation rate while maintaining high heat transfer in the flow of multiple impinging jets.

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1- Introduction

Due to the ease of implementation and reliability, as well as low cost and simple design, the impinging jets have been used in a wide range of applications in industry [1]. Due to providing a high heat transfer rate, multiple impingement jets have attracted the attention of many researchers and engineers in the past decades. However, achieving a uniform distribution of heat transfer over the entire contact surface, along with the required heating rate in many applications, is still considered a challenge. By using some appropriate methods, an opportunity can be created to better manage the distribution of heat transfer on the surface. Using a porous layer on the heat transfer surface is one of the effective methods to increase the heat transfer rate in some industrial applications [2]. However, few researches have been done on the application of a porous medium attached to a solid surface under the impact of arrays of jets [3-5]. Available studies have been experimental and there are no numerical analysis that can reveal the flow details. Therefore, it seems necessary to perform this numerical study in order to analyze the characteristics of the flow field and heat transfer in a channel including an array of impinging jets connected to a porous medium. The aim of the current research is to reduce the difference between intermittent changes in local heat transfer on a surface, while achieving the lowest drop in overall heat transfer. To achieve this goal, a comprehensive parametric study on the effect of porous media on heat transfer performance in the range of low Reynolds number has been carried out. Identifying the effect of porosity, permeability and thickness of the porous layer in such a flow has not been studied before.

2- Methodology

In the current study, Ansys Fluent commercial code is used to simulate the fluid flow and heat transfer characteristics. The SIMPLE algorithm is chosen to couple the velocity and pressure terms. The second-order upwind scheme is used to consider the convergence stability of the solution. The boundary conditions and parameters used, governing equations, turbulence models, numerical solution method, checking the computing network and independence from the number of grids, as well as validating the numerical results are fully explained. Figure 1 shows the three-dimensional view of a physical model of the flow in which the channel bed is covered with a porous medium, under the condition of impinging jet array.

3- Results and Discussions

The average Nusselt number over the target surface is displayed in Fig. 2 for of different cases with various permeability, porosity and thicknesses of the porous layer. It is obvious from Fig. 2 that the characteristics of the porous medium have a great influence on the performance of the heat transfer intensity of the impinging jet flow field. Therefore,

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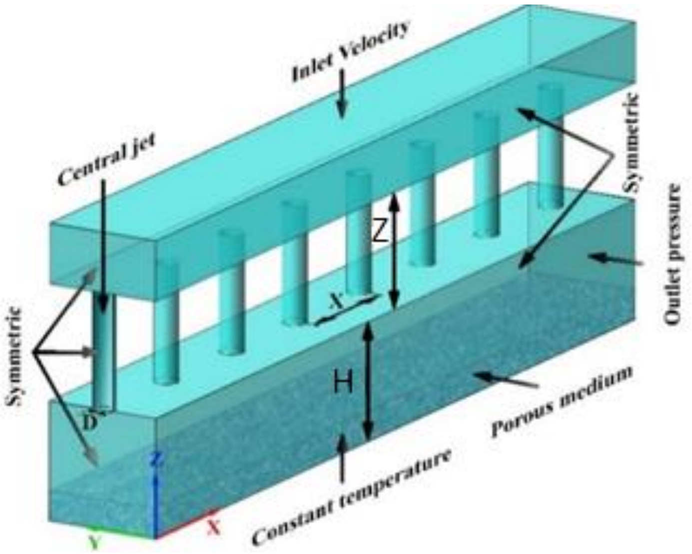

Fig. 1. 3D schematic view of the computational domain consisting of a channel covered with a porous layer substrate.

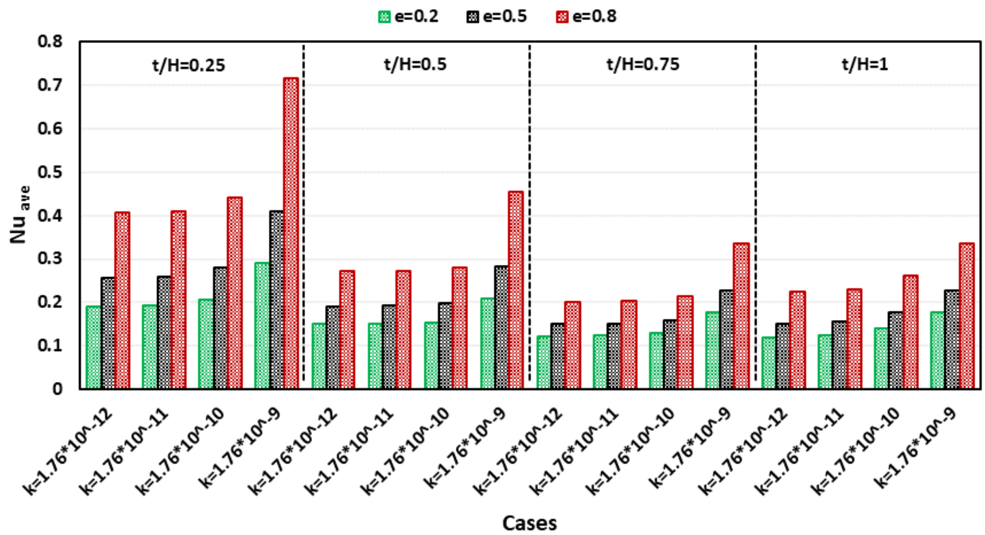

Fig. 2. The average Nusselt number on the target surface with different characteristics of the porous medium.

changing the type of arrangement of the parameters of the porous medium can be a useful tool to control the intensity and manage the heat transfer rate on the target surface.

The distribution of heat transfer over the channel bed can be determined from the standard deviation of the local Nusselt numbers as well as largest difference between the maximum and minimum values. This is shown for different cases in Fig. 3.

There is an almost similar qualitative trend for both uniformity evaluation indices under the influence of porous media parameters. However, these effects on both indicators are very complex in some cases, and quantitatively, sometimes there is a big difference between various cases.

In order to simultaneously evaluate the overall heat transfer performance, the HTP heat transfer performance index is defined, which considers the quantitative and qualitative measures of heat transfer on the plate at the same time. Fig. 4 shows the variations of the overall heat transfer performance under the influence of different porous layer specifications.

4- Conclusions

In a multiple impinging jet flowing in a channel covered by a layer of porous medium, the heat transfer performance depends highly on the porous medium specifications including its thickness, permeability and porosity. Utilizing the porous layer with different properties can be considered

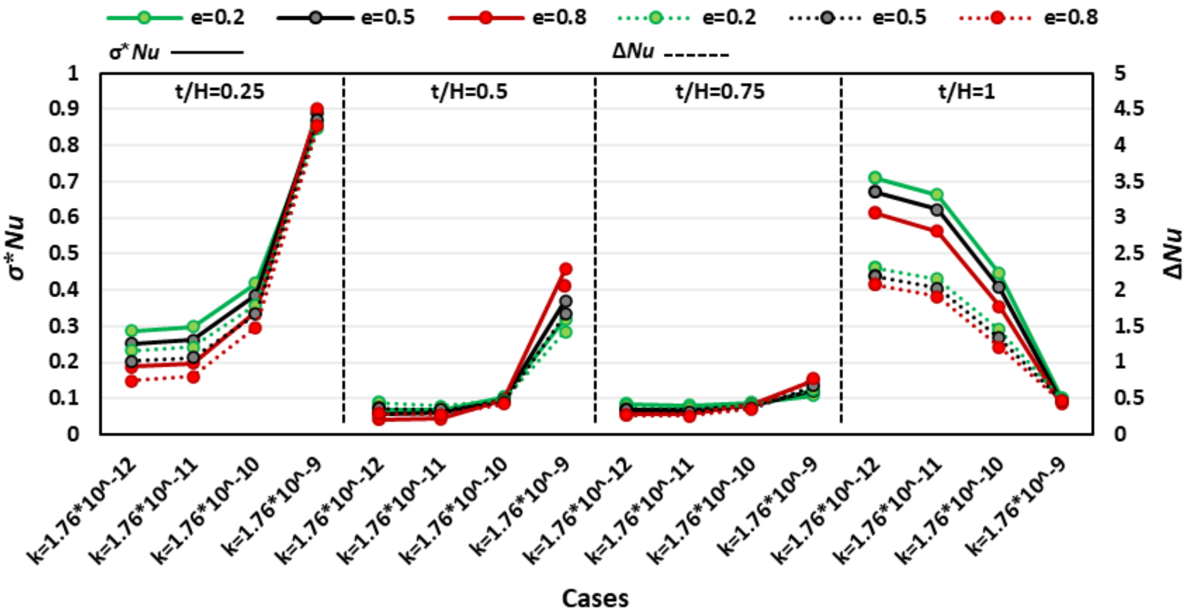

Fig. 3. Standard deviation and maximum normalized difference of the local Nusselt number for various scenarios

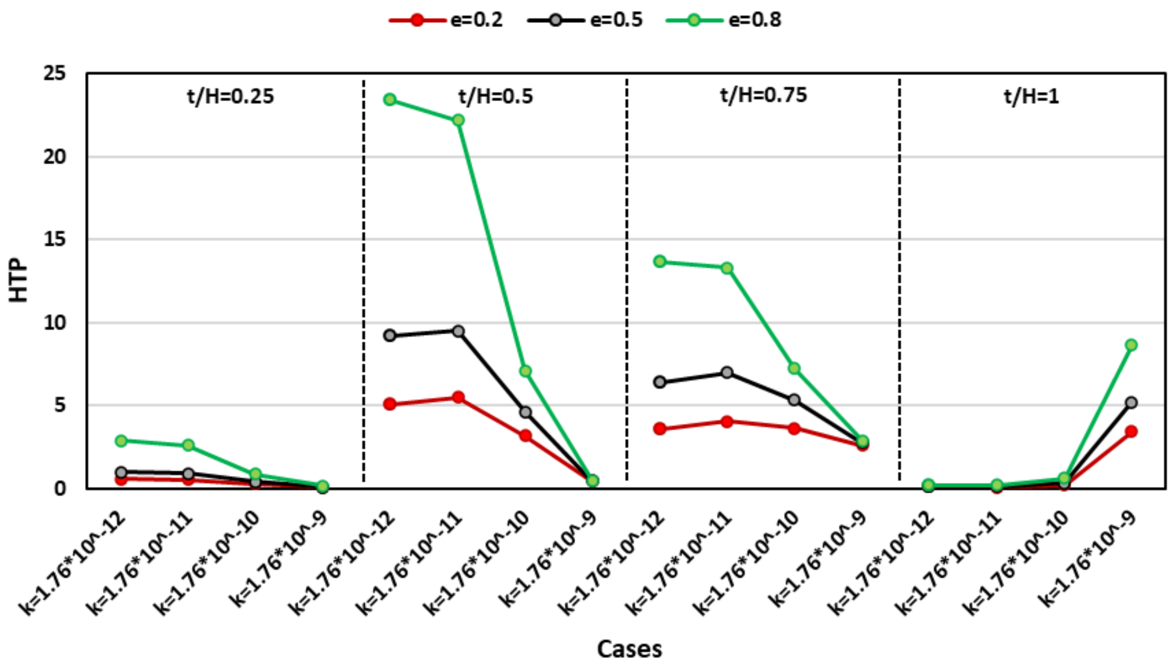

Fig. 4. The total heat performance coefficient on the heat transfer surface for different arrangements of the porous layer

as an effective method to improve the uniformity of heat transfer while benefiting from the advantage of the high rate of heat transfer in multiple jet streams. Among the types of scenarios studied for the porous layer in this research, the case where the channel is half filled with the porous layer and the coefficients of permeability and porosity are at their lowest and highest values, respectively. Such configuration leads to the best overall thermal performance of HTP = 23.45.

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