Experimental Investigation of Forced Convective Heat Transfer in Circular Pipe with Wire Mesh Porous Media

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Introduction

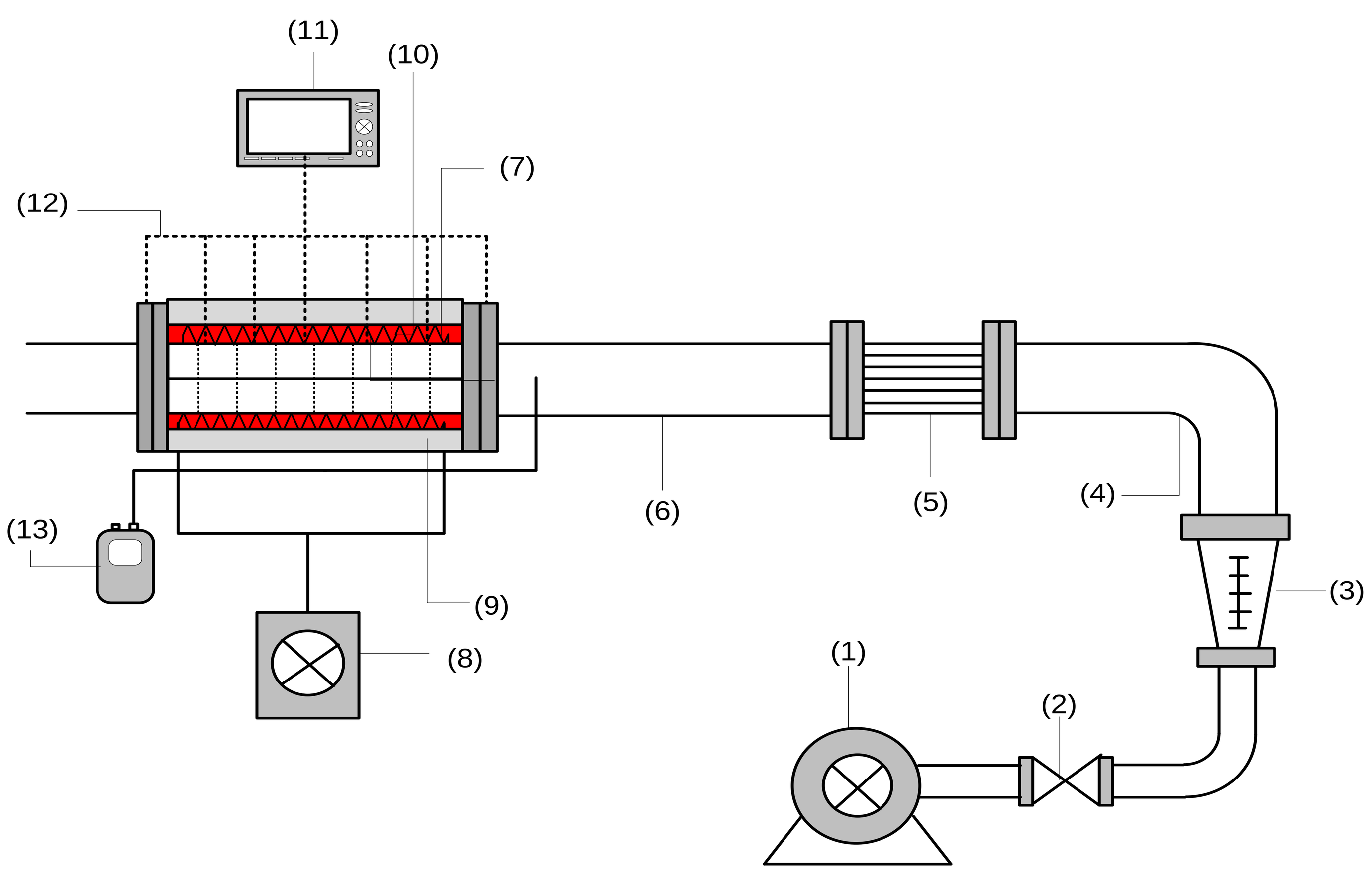
Heating system and cooling system often involve heat transfer within fluid flowing through a pipe. This kind of flow is regarded as internal flow, such as the flow of cold air through the air duct, the flow of cooling water through the pipe. Enhancement to the heat transfer can be made by inserting porous media into the pipe because the prominent feature of porous media is having a higher ratio of surface area to volume than general opaque materials. With such characteristic, the heat transfer both in a pattern of heat conduction and in a pattern of heat convection of any device using the porous media will be much enhanced [1]. Researchers have consistently endeavored to conduct both the experimental study and theoretical analysis in order to apply the porous media for enhancing the heat transfer, particularly in a form of the forced convection within fluid flowing through the pipe. The related research studies have been presented as follows [2]-[11].

Based on a review of previous studies, there are some noticeable issues concerning the heat transfer using wire mesh that have not been adequately examined. The present research, thus, uses the stainless steel wire mesh 304 with the number of pores per inch of 8 (PPI = 8) as porous media to enhance the forced convective heat transfer within fluid flow in a pipe. The effects of the distance between wire mesh plates (P) on the heat transfer rate are researched. The knowledge acquired from this study will be advantageous for improving the performance of tube heat exchanger.

Objectives

This experimentation aims to study Nusselt number (Nu) and Friction factor (f) deriving from the forced flow of fluid inside a circular pipe under a uniform heat flux condition.

Experimental Materials and Methods



(1) Blower (2) Valve (3) Rotameter (4) PVC pipe
(5) Flow straightener (6) Developing flow pipe (7) Heater (8) Controller
(9) Insulation (10) Test section (11) Data logger (12) Themocouples
(13) Micro manometer

Fig. 1. Schematic diagram.

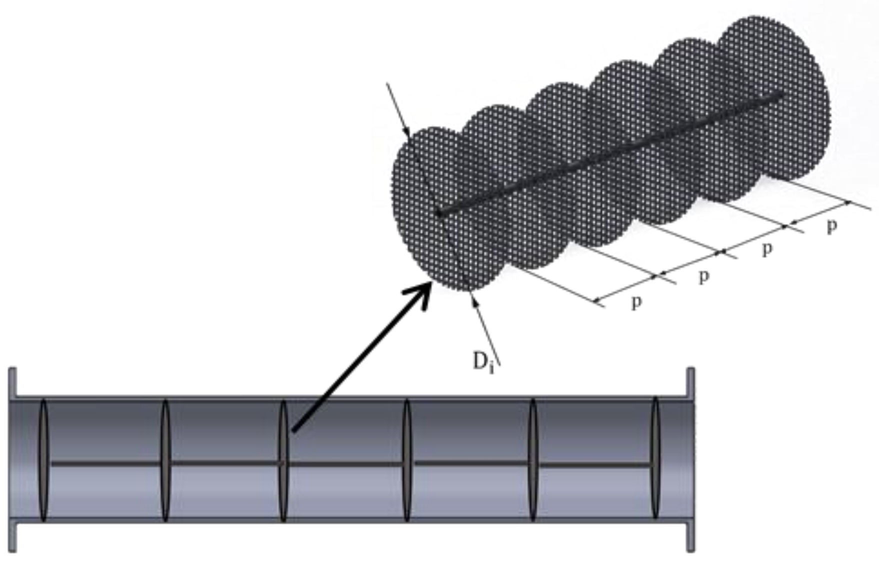


Fig. 2. Details of the test section.

With reference to the Fig. 1. and Fig. 2., the experimental methods are started off by (1) inserting the porous media in the test section, (2) adjusting and releasing the air into the test section with the Reynolds number (Re) ranging from 3000 – 15000, (3) enabling the electric coils to heat up the pipe wall and waiting until the inlet and exit temperatures of the air stay constant or are in a steady state, and (4) then recording the experimental results, including the surface temperature, the inlet/exit temperatures, and the pressure drop inside the test section.

Experimental results

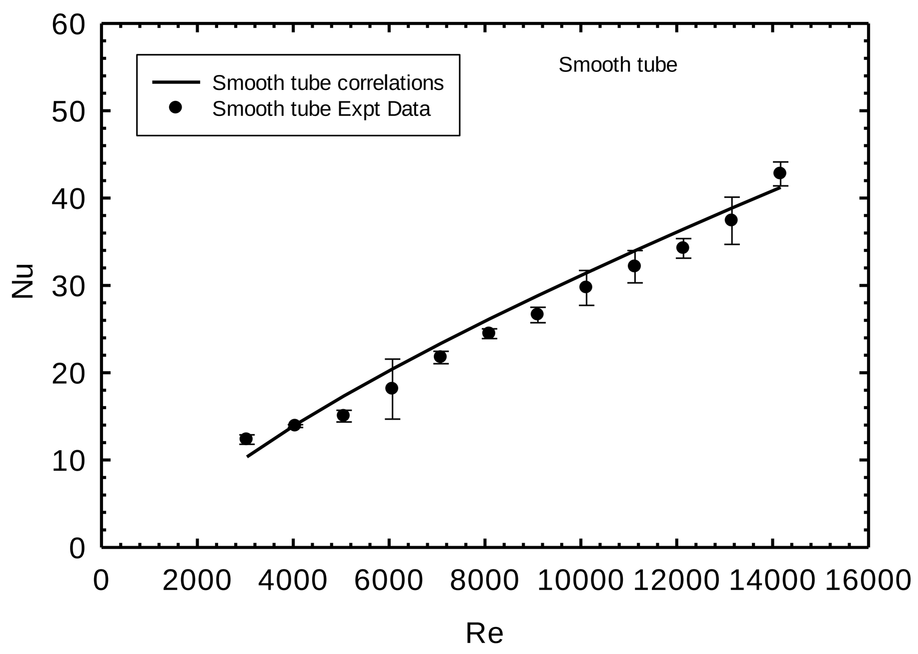


Fig. 3. Relationship between the Nu obtained from the experiment and the Nu according to the Gnielinski correlation for the smooth pipe.

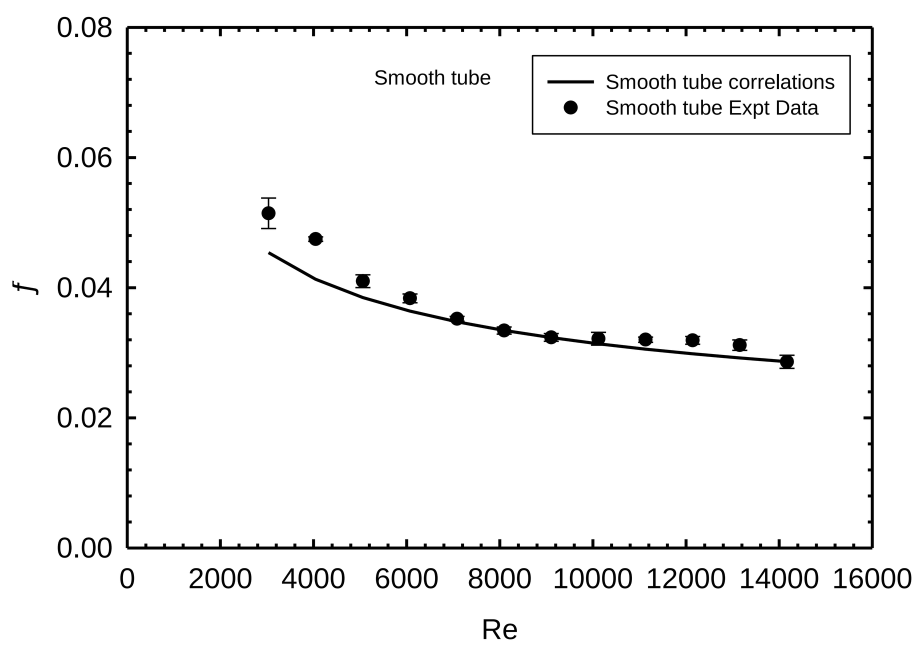


Fig. 4. Relationship between the f obtained from the experiment and the f calculated with Petukhov formula for the smooth pipe.

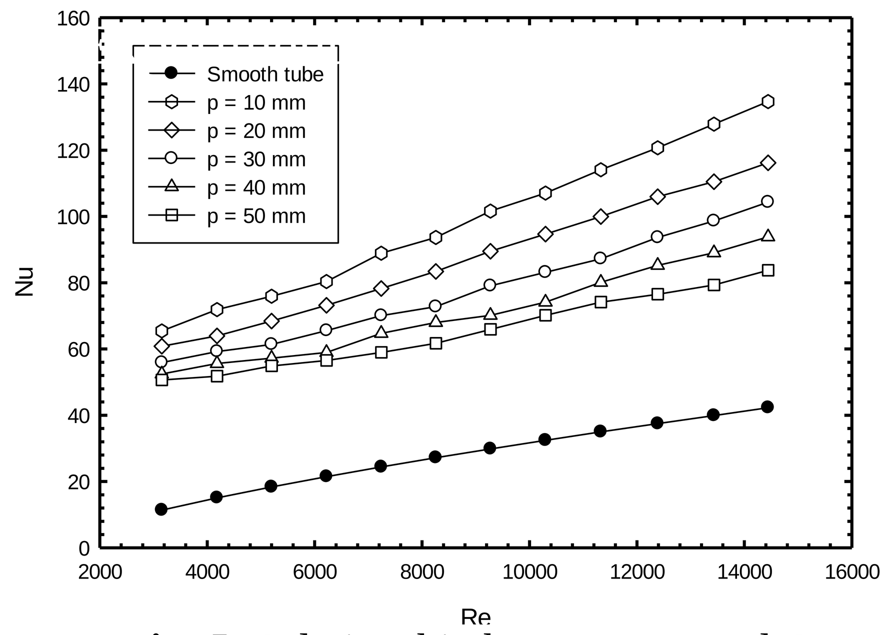


Fig. 5. Relationship between Nu and Re.

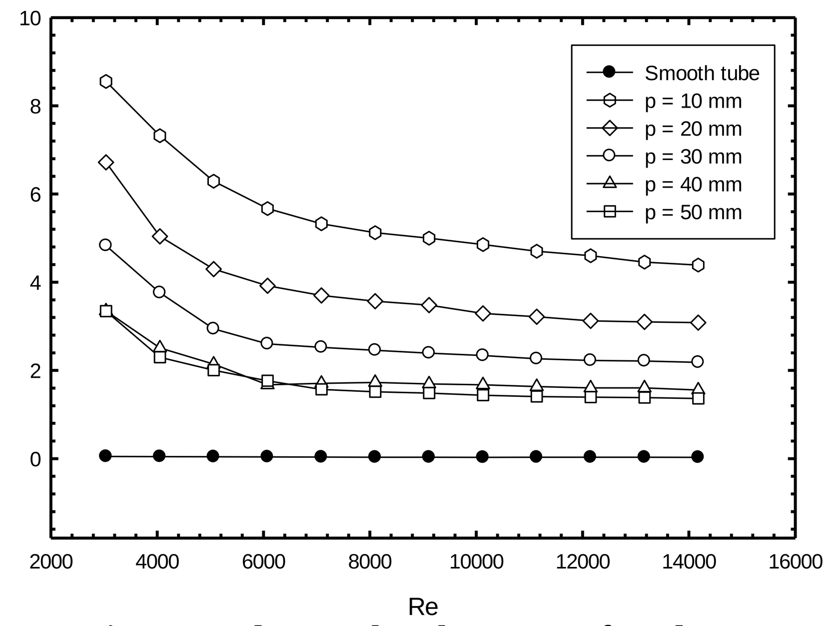


Fig. 6. Relationship between f and Re.

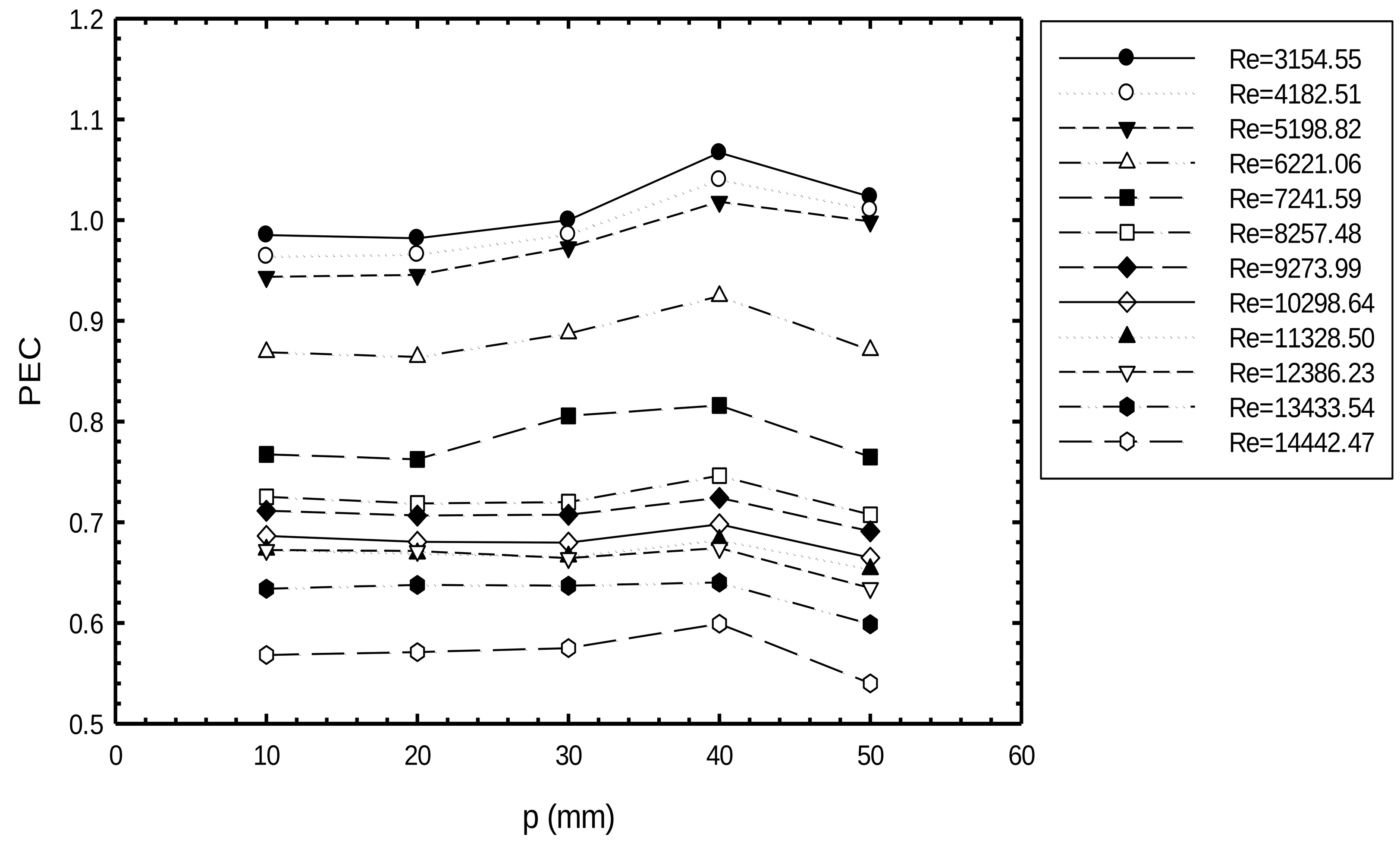


Fig. 7. Relationship between PEC and p.

Conclusions

1. The Nusselt numbers (Nu) obtained from the smooth pipe in this research tend to be in line with the Nusselt numbers calculated according to the Gnielinski correlation. The Nu values deriving from the two methods approximate each other
2. The friction factor (f) obtained from the smooth pipe tends to be in line with the friction factor calculated according to the Petukhov correlation. The f values deriving from the two methods approximate each other.
3. The Nusselt numbers (Nu) and the friction factor (f) increase with the increasing Re and the decreasing p because the increase in volume of material will enable it to store a large quantity of energy from the hot air, causing the heat to be transferred to the pipe wall in a higher rate. The increasing friction factor (f) results from the hindrance to the flow which causes the pressure drop (DP) to go up, which conforms to the general principles of nature.
4. The PEC reaches the maximum value where p is 40 mm since the ratio of Nu to f is the most appropriate figure.

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Acknowledgement

The author would like to express his sincere gratitude to the Development in Technology of Porous Material Research Laboratory (DiTo-Lab), Department of Mechanical Engineering, Faculty of Engineering and Architecture, Rajamangala University of Technology Isan (RMUTI) for the financial support and place to conduct this research.