Experimental investigation of forced convective heat transfer in cylindrical pipe flow

Yoshinori Hattori
Shibaura Institute of Technology, Mechanical Engineering
Tokyo, Japan
Graz Institute of Technology, Institute of Fluid Mechanics and Heat Transfer
Graz, Austria
md18060@shibaura-it.ac.jp

***Index Terms*—Forced convection, Nusselt number, Wall friction, Laminar, Turbulent, Cylindrical pipe flow**

I. Introduction

In recent years, forced convective heat transfer in cylindrical pipe flow plays an important role in many technical cooling systems. Nusselt number (Nu) is a dimensionless number which represents the ratio of convective (h) and conductive heat transfer (k).

$$Nu = \frac{h \cdot L}{k} \tag{1}$$

From general dimensional analysis, Nusselt number represents function of Reynolds number (Re) times Prandtl number (Pr) as following equation.

$$Nu = \alpha \cdot Re^{\pi_\beta} \cdot Pr^{\pi_\gamma} \tag{2}$$

Here, factors α, β and γ are constant value depend on flow regime and calculated from experimental result. Nusselt number is one of the most important numbers for forced convective heat transfer moreover calculated from above (1)(2).

Many studies have pointed out that heat transfer coefficient vary depending on the type of flow: laminar, transition and turbulent. Gnienlinski [1] showed calculation method for laminar heat transfer coefficient of two kinds of boundary conditions. (I) Constant wall temperature (UWT) and (Ⅱ) Constant heat flux (UHF). Petukhvov and Kirillov [2] showed calculation method for turbulent flow. There are very scarce experimental data of laminar-to-turbulent transitional region. Bertsche et al, [3] focused on reliable prediction of heat transfer coefficient for transitional flows. In their study, Bertsche et al, showed experimental heat transfer coefficients for Reynolds number $500 < Re < 23000$ and Prandtl number $7 < Pr < 41$.

Much remains to be studied for providing experimental data except water and glycole as operation fluids. In this paper, we focus on forced convective heat transfer in cylindrical pipe flow with water and glycole. A 50/50vol% mixture of water and glycole which is a typical liquid coolant in automotive applications were used as a operating fluid. The experiment carried out considering a board range of Reynolds number, spanning from laminar to fully turbulent flow. In this paper we apply the techniques of Laser-induced fluorescence (LIF) to find out temperature distribution in cylindrical pipe flow. Moreover, the investigation shall also include the measurement of wall friction coefficient. The experimental data compared with other sources as well as computational results obtained from already existing numerical simulations (CFD) by Steiner [4].

Acknowledgment

I would like to thank my thesis advisors Prof. Helfried Steiner and Prof. Guenter Brenn of the Institute of Fluid Mechanics and Heat Transfer at Graz University of Technology. I am also grateful to Prof. Shirai of Mechanical Engineering department at Shibaura Institute of Technology. I am extremely thankful and indebted to him for sharing his experiments. I would also like to thank Prof. Tange allowed my studying in Graz, Austria.

References

[1] V. Gnienlinski, "Heat Transfer in Laminar Flow," VDI Heat Atlas, second ed., Springer Verlag, 2010 (Chapter Ga 1-7), Section 3.
[2] B.S. Petukhov, V.V. kirillov, Teploenergetika 4 (1958) 91-98.
[3] Dirk Bertsche, Paul Knipper, Thomas Wetzel, "Experimental investigation on heat transfer in laminar, transitional and turbulent circular pipe flow," International Journal of Heat Transfer, 95 (2016) 1008-1018.
[4] Steiner, "Title of paper if known," unpublished, 2018.