Experimental investigation of forced convective heat transfer in cylindical pipe flow

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***Index Terms*—Forced convective heat transfer, Nusselt number, Wall friction, Laminar, Turblent, Cylindical pipe flow**

I. Introduction

In recent years, forced convective heat transfer in cylindical pipe flow plays an important role in many technical cooling systems. Considering heat transfer issues, heat transfer coefficient is one of the most important numbers.

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

From general dimensional analysis, Nusselt number represents function of Reynolds number (Re) times Prandlt 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. By using above (1), we can easily find out heat transfer coefficient from (2).

Many studies have pointed out that heat transfer coefficient vary depending on the type of flow: laminar, transition and turblent. For laminar flow...

$$Nu_{lam} = \sqrt[3]{Nu_1^3 + b^3 + (Nu_2 - b)^3 + Nu_3^3} \tag{3}$$

For turblent flow...

$$Nu_{turb} = \frac{\frac{\xi}{8} \cdot Re \cdot Pr}{1 + 12.7 \cdot \frac{\xi}{8})^{0.5} \cdot (Pr^{\frac{2}{3}} - 1)} \cdot (1 + (\frac{d_h}{l})^{\frac{2}{3}}) \tag{4}$$

$$\xi = (1.8 \log 10Re - 1.5)^{-2} \tag{5}$$

Bertsche et al,[Bertsche2015] focused on reliable prediction of heat trasnsfer coefficient for transitional flows. In their study, Bertsche et al, showed experimental heat transfer coefficients for Reynolds number $500 < Re < 23000$ and Prandtl number $7 < Pr < 41$.

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- Use a zero before decimal points: "0.25", not ".25". Use "cm^3", not "cc".)

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Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \tag{6}$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use "(6)", not "Eq. (6)" or "equation (6)", except at the beginning of a sentence: "Equation (6) is . . ."

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An excellent style manual for science writers is [7].

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TABLE I
TABLE TYPE STYLES

Table Head	**Table Column Head**		
	Table column subhead	***Subhead***	***Subhead***
copy	More table copy[a]		

[a]Sample of a Table footnote.

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ACKNOWLEDGMENT

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REFERENCES

[1] G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955.
[2] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
[3] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
[4] K. Elissa, "Title of paper if known," unpublished.
[5] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.
[6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
[7] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

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