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Predicting the Relation Between the Eddy Length Versus Reynolds Number for Cylinders

John H Jennings
Jennings Research & Editing, 2530 Hilegass Ave. #307, Berkeley, CA 94704, USA

Corresponding Author: **John H Jennings**

Abstract
In numerical modeling, for the problem of predicting the eddy for a viscous fluid flowing perpendicular to a cylinder of radius d and eddy L units long: the data of eddy length L/d versus Reynolds number for a cylinder $N_{re} = (dv)/\upsilon$ is solved. There are various data that line up from (4.773, 0) in a line up to $N_{Re} = 50$ according to different theories. In this paper the author will show the agreement of the data of Taneda (1956) [1] and the numerical model of Hamielec and Raal (1969) [2]. In Pruppacher, *et al* (1970) [3] there is a graph with a straight line between L/d and N_{re} that includes Taneda and Hamielec/Raal.

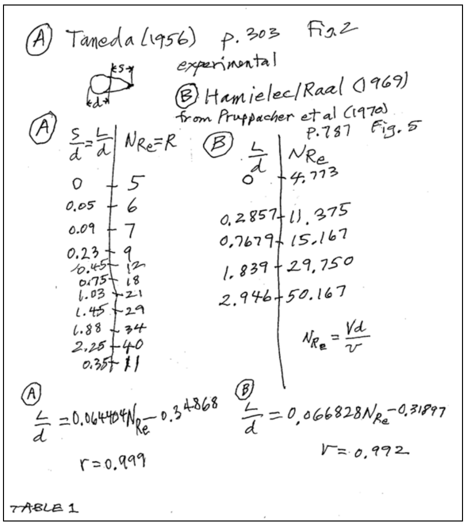
Keywords: Numerical Model, Reynolds Number, Eddy Length, Cylinder

Introduction

In Pruppacher/Klett (1997) [4] there is a graph showing the agreeement of theory versus experiment for fluid flow perpendicular to a cylinder (L/d eddy length vs N_{Re} Reynolds number). There are three experimental treatments and six theories. All of the points fall on the same line. Here we will focus particularly on the agreement beween Taneda's data and Hamielec/Raal's numerical model.

Results

The author read from the graphs and did Y = AX + B and both Taneda and Hamielec/Raal have very straight lines. Hamielec/Raal did computation on a finite difference equation and Taneda did a photographic study to observe the eddy as the viscous fluid goes perpendicular to the cylinder. The author read S/d (L/d) directly from Taneda's Fig. 2, page 303 against R (N_{Re}), and got L/d and N_{Re} from Pruppacher *et al*'s Fig. 5, page 787. The numbers are in Table 1 with the workup.



A Taneda (1956) p. 303 Fig. 2
experimental

B Hamielec/Raal (1969)
from Pruppacher et al (1970)
p. 787 Fig. 5

A

$\frac{S}{d} = \frac{L}{d}$	$N_{Re} = R$
0	5
0.05	6
0.09	7
0.23	9
0.45	12
0.75	18
1.03	21
1.45	29
1.88	34
2.25	40
0.35	11

B

$\frac{L}{d}$	N_{Re}
0	4.773
0.2857	11.375
0.7679	15.167
1.839	29.750
2.946	50.167

$N_{Re} = \frac{Vd}{\nu}$

A
$$\frac{L}{d} = 0.064404 N_{Re} - 0.34868$$
r = 0.999

B
$$\frac{L}{d} = 0.066828 N_{Re} - 0.31897$$
r = 0.992

TABLE 1

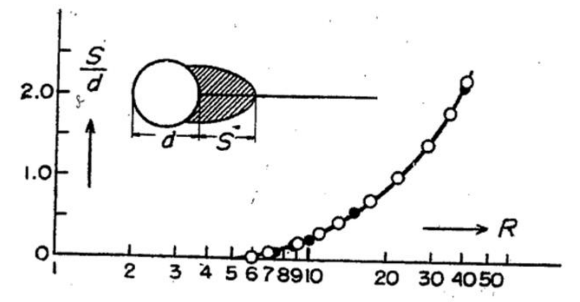


Fig. 2. Plot of s/d against R.

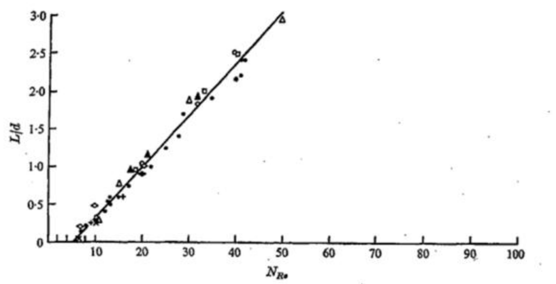


FIGURE 5. Variation of the eddy length with Reynolds number for the case of a cylinder. Theory: ○, Kawaguti–Jain; ×, Underwood; □, Son–Hanratty; △, Hamielec–Raal; •, Apelt; +, Keller–Takami; ◆, Thom; ◇, Dennis–Shimshoni. Experiment: ■, Homann; ▲, Fage; ●, Taneda.

Discussion

In science it is nice when there is exact agreement between theory and experiment. For Taneda the experimental workup gives L/d = 0.064404 N_{Re} – 0.34868 [r = 0.999] and the Hamielec/Raal theory gives L/d = 0.066828 N_{Re} - 0.31897 [r = 0.992], so they are linear. Notice the slope and L/d intercepts are close and the N_{Re} inercepts are Taneda 5.414 and Hamielec/Raal 4.773. They both round to 5. 5 is when there starts to be an eddy length from the perpendicular flow past the cylinder. In Hamielec/Raal, they solve the Navier-Stokes equation (1) for an incompressible Newtonian fluid normal to the long axis of a circular cylinder of diameter d and eddy L units long. Nomenclature is excluded.

$$(N_{Re}/2r)\ ((\partial\ \psi, \omega)/(\partial r, \theta)) = +\ \nabla 2\ \omega \qquad (1)$$

They come to a finite difference equation which involved computation time. Hamielec/Raal's numbers are included in Fig. 5, which is from Pruppacher *et al*, page 787.

Conclusion

There is agreement between Taneda and Hamielec/Raal for eddy length versus Reynolds number for cylinders. In science the best thing is to have a simple equation and Y = AX + B works for theory and experiment here.

Acknowledgement

At NEWMAN HALL, I remember the deceased Priest, Father Al Moser, who came to my apartment to bless it. Father Al said, "Do the best you can, Angels can do no better." Father Al enjoyed being a Priest and was very much loved at NEWMAN.

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