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Discussion

Roughness Influence on Turbulent Flow Through Annular Seals Including Inertia Effects[1]

D. W. Childs.[2] The authors are to be congratulated for an excellent and well-written article. The decision to use an equivalent sand roughness to characterize wall roughness in the seal follows the pattern of other authors who have translated friction-factor results from pipe flow to annular seals. Yamada's (d1962) initial tests for flow in a smooth annulus compared well to pipe-friction data. Von Pragenau (d1982) adopted the Moody friction-factor law to seals, and Nelson and Nguyen (d1987) made comparison between Blasius and Moody models. The Moody model normally uses the "relative-roughness" parameter $\epsilon_r = e/2H$ where e is the "absolute roughness" and H is the local radial clearance. The sensitivity of the Moody friction factor to ϵ_r causes a significant deviation between the Moody and Blasius models for prediction of rotordynamic coefficients, particularly for the direct stiffness coefficients.

The central question of interest in modeling roughness in seals using extrapolated pipe data is: Are the pressure-drop phenomena the same in both flow situations? Roughness in pipes is caused by protrusions into the flow. By contrast, deliberately roughened seals use holes in the stator to enhance roughness. Round-hole-pattern roughness and knurled indentations are the most commonly used roughness patterns, Childs et al. (1985). Fortunately, test data are now available to directly demonstrate fundamental differences between friction-factor performance for pipe flow and annular-seal flow. Figure D.1 is taken from DeOtte et al. (d1994). The results show friction factors measured from a flat-plate tester for a round-hole pattern. The change in friction factor due to a change in clearance at the same Reynolds number is illustrated. Note that increasing the clearance, which presumably reduces the relative roughness, *increases* the friction-factor, versus a pipe-friction-model prediction of a decrease in friction factors.

Pipe-friction models may be applicable to nominally-smooth annular seals with machining imperfections. However, DeOtte et al.'s test results demonstrate (to the discusser) that they are not appropriate for deliberately-roughened annular seals. The discusser does not have an alternative (rational) replacement, but suggests that further refinements of pipe-friction models are not productive, and research efforts should be devoted to a clearer understanding of the fluid mechanics involved in annular-seal flow.

[1]By V. Lucas, O. Bonneau, and Jean Frêne, published in the January 1996 issue of the JOURNAL OF TRIBOLOGY, Vol. 118, pp. 175–182.

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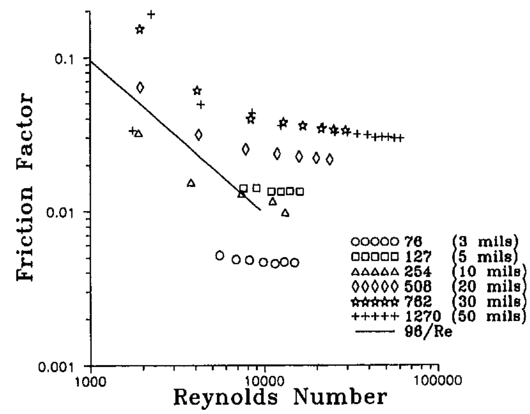

Fig. D.1 Flow between two plates, one with a smooth surface and the other with small cylindrical recesses, for six clearances

References

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Nelson, C., and Nguyen, D., 1987, "Comparison of Hirs' Equation with Moody's Equation for Determining Rotordynamic Coefficients of Annular Pressure Seals," ASME JOURNAL OF TRIBOLOGY, Vol. 109, pp. 144–148.

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Authors' Closure

Dara W. Childs is to be congratulated for his pertinent comments on our paper. The authors agree with the remarks concerning the use of the Blasius or Moody models for the modelization of wall roughness in annular seals. In our opinion, these models can be applicable to annular seals with machining imperfections. In other words, it is applicable to a standard type of roughness seeing that this kind of roughness is small compared with the dimensions of a seal. But friction models cannot quantify the influence of round-hole-pattern or knurled indentations on annular seals' behavior accurately. In this regard, we concluded our paper saying that this sort of obstacles in the flow are more than roughness, therefore friction models are not adapted any longer and can only give an approximate solution to annular seals' behavior.

In fact, the dimensions of this type of roughness imply a significant modification in the structure of annular seals' flow and a different one from this produced by pipe roughness and machining imperfections. A three-dimensional study would be necessary to take into account deliberate roughness as round-hole-pattern or knurled indentations and big asperities according to the film height. This roughness is approximately of the same