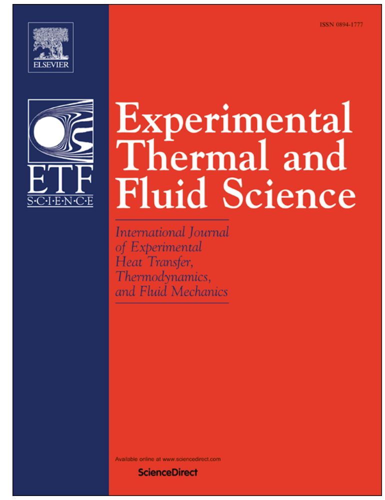
Accepted Manuscript



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PII: S0894-1777(18)30779-9
DOI: https://doi.org/10.1016/j.expthermflusci.2018.04.022
Reference: ETF 9457

To appear in: *Experimental Thermal and Fluid Science*

Received Date: 18 September 2017
Accepted Date: 25 April 2018

Please cite this article as: K. Sodjavi, F. Ravelet, F. Bakir, Effects of axial rectangular groove on turbulent Taylor-Couette flow from analysis of experimental data, *Experimental Thermal and Fluid Science* (2018), doi: https://doi.org/10.1016/j.expthermflusci.2018.04.022

Effects of axial rectangular groove on turbulent Taylor-Couette flow from analysis of experimental data

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Abstract

The effects of the number of surface grooves on the hydraulic resistance are experimentally investigated in the case of fully turbulent Taylor-Couette flow at a fixed radius ratio $\eta = 0.9375$ and for Reynolds numbers Re_i from 2×10^4 to 13×10^4. Three configurations of inner cylinder having 6, 12 and 24 grooves of the same rectangular shape and regularly distributed are compared to a reference smooth cylinder case. Such configurations are common in electric motors of high power density and of very high rotation rate, for which better understanding and knowledge of the flow patterns and aerodynamic losses are essential to enhance their design and to develop appropriate cooling systems. Torque and pointwise velocity measurements are performed. The effects of the flow modulations induced by the grooves on the friction coefficient and the flow features are examined. The results show significant difference in the average flow pattern, the presence of the grooves suppressing the Taylor Vortices. An increase of the friction coefficient with the groove number is reported. However, the individual drag-increasing contribution of each groove is reduced when increasing the groove number. It is also found that the local scaling exponent of the friction coefficient as a function of the Reynolds number is insensitive to the present surface roughness, suggesting that the bulk flow contribution is similar for all the four configurations.

Keywords: Rough boundary, Rectangular groove, Friction coefficient, Taylor-Couette flow, LDV measurement,

1. Introduction

Fluid flow around solid body of rough or structured surface topology has attracted considerable interest since it is encountered in many natural phenomena and engineering applications. The design of more compact electric motor with high power density is one of the related application. Generally, this configuration is analogous to a canonical topology known as Taylor-Couette flow, consisting of the flow between two coaxial cylinders with a stationary outer cylinder and a rotating inner cylinder. In some cases an axial flow is also considered and the flow is then refered to as Taylor–Couette–Poiseuille flow. As noticed by Fénot *et al.* [1] in their review, there are a lot of studies and results for the aerodynamics and heat transfer capacity on smooth cylinders, but the few studies dedicated to slotted cylinders mainly focused on the heat transfer. For the specific issue of high power compact electric motors rotating at very high rotation rates, with rotors presenting slotted shapes for electromagnetical reasons, the aerodynamic losses in the annulus between the two cylinders become a major issue to optimize their performances. Better understanding of the flow field and to a lesser extent of the heat transfer characteristics in this confined environment still requires dedicated studies for axially grooved inner cylinders. This is needed in order to enhance their design and to develop appropriate cooling system. As far as heat and aerodynamic behavior are concerned only a few investigations contain references to an axially grooved cylinder. Likewise, most of the reported results concern global physical quantities.

For instance, Hayase *et al.* [2] used numerical simulation to compare three different flow configurations in terms of momentum and heat transfer coefficient in a laminar flow. The authors specifically studied the influence of twelve cavities embedded in either the inner rotating or the outer fixed cylinder in laminar flow. They observed larger effects, both on the momentum and heat transfer when the cavities were located on the inner cylinder rather than on the outer cylinder. Lee & Minkowycz [3] and Gardiner & Sabersky [4] investigated experimentally the heat transfer and pressure drop characteristics of smooth or axially grooved cylinders, with a superimposed Poiseuille flow, for Reynolds numbers based on the rotation rate and on the gap width up to $Re_i \simeq 4000$. The authors observed that the presence of grooves on the rotating inner cylinder significantly increased the heat coefficient. They also noted that the grooved rotor were associated to friction factors which were generally higher than those for a smooth rotor.

Several experimental studies, such as, for instance that of Cadot *et al.* [5], van den Berg *et al.* [6], or Motozawa *et al.* [7] were devoted to the dissipation in Taylor-Couette

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