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Experimental and Numerical Investigation on the Torque in a Small Gap Taylor-Couette Flow with Smooth and Grooved Surface

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Abstract : Fundamental studies were performed on bifurcation, instabilities and turbulence in Taylor-Couette flow and applied to many engineering applications like astrophysics models in the accretion disks, shrouded fans, and electric motors. Such rotating machinery performances need to have a better understanding of the fluid flow distribution to quantify the power losses and the heat transfer distribution. The present investigation is focused on high gap ratio of Taylor-Couette flow with high rotational speeds, for smooth and grooved surfaces. So far, few works has been done in a very narrow gap and with very high rotation rates and, to the best of our knowledge, not with this combination with grooved surface. We study numerically the turbulent flow between two coaxial cylinders where R1 and R2 are the inner and outer radii respectively, where only the inner is rotating. The gap between the rotor and the stator varies between 0.5 and 2 mm, which corresponds to a radius ratio η = R1/R2 between 0.96 and 0.99 and an aspect ratio Γ= L/d between 50 and 200, where L is the length of the rotor and d being the gap between the two cylinders. The scaling of the torque with the Reynolds number is determined at different gaps for different smooth and grooved surfaces (and also with different number of grooves). The fluid in the gap is air. Re varies between 8000 and 30000. Another dimensionless parameter that plays an important role in the distinction of the regime of the flow is the Taylor number that corresponds to the ratio between the centrifugal forces and the viscous forces (from 6.7 X 105 to 4.2 X 107). The torque will be first evaluated with RANS and U-RANS models, and compared to empirical models and experimental results. A mesh convergence study has been done for each rotor-stator combination. The results of the torque are compared to different meshes in 2D dimensions. For the smooth surfaces, the models used overestimate the torque compared to the empirical equations that exist in the bibliography. The closest models to the empirical models are those solving the equations near to the wall. The greatest torque achieved with grooved surface. The tangential velocity in the gap was always higher in between the rotor and the stator and not on the wall of rotor. Also the greater one was in the groove in the recirculation zones. In order to avoid endwall effects, long cylinders are used in our setup (100 mm), torque is measured by a co-rotating torquemeter. The rotor is driven by an air turbine of an automotive turbo-compressor for high angular velocities. The results of the experimental measurements are at rotational speed of up to 50 000 rpm. The first experimental results are in agreement with numerical ones. Currently, quantitative study is performed on grooved surface, to determine the effect of number of grooves on the torque, experimentally and numerically.

Keywords : Taylor-Couette flow, high gap ratio, grooved surface, high speed
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