Data Article

Data on the flow of shear thinning fluids in a rotating cylinder device

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ABSTRACT

The data assembled regarding the flows generated in a device with rotating cylinders is disclosed in the present paper. The device studied consists of two cylinders; the internal cylinder is driven at a constant rotational speed, while the external remains stationary. The study is carried out by numerical simulation using the CFX calculation code, which is based on the finite volume method for solving the equations describing the motion. The simulated fluid is a complex non-Newtonian (shear thinning) fluid modeled by Oswald De Waele's law. For a process which is supposed isothermal and stationary and for a laminar regime, the effects of the cylinder rotational speed and its eccentricity are highlighted. The data presented in this paper support and augment information in the research papers [1−6].

1. Data

The data obtained concerning the flows of complex fluids in a rotating cylinder device is discussed in this paper. One Table and six Figures are included and which contain some information on the flow fields of such devices.

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Specifications table

Subject area	Mechanical Engineering
More specific subject area	Fluid dynamics
Type of data	Figures, tables, text file.
How data was acquired	Based on three-dimensional calculations of velocities and pressure in the rotating device.
Data format	Raw, descriptive and inferential
Experimental factors	The working fluid is non Newtonian.
Experimental features	Geometry of the rotating device is created by the computer tool Ansys ICEM CFD. Then, calculations are achieved with the help of the computational code Ansys CFX. The finite volume method is used to solve the equations of momentum. A computer machine having an Intel Core i7 CPU, 12.0 GB of RAM and a clock speed of 2.20 GHz has been used.
Data source location	University Center of Naama, Algeria
Data accessibility	Data is given in this paper.

Value of the data
- The data presented in this paper gives information on the flow structures of non-Newtonian shear thinning fluids in rotating cylinders.
- A comparison is made between the concentric and eccentric annuli.
- The data presented herein may be useful for those who want to outline the hydrodynamics characteristics for this kind of devices and fluids, therefore, avoiding a great effort for achieving a high number of experiments.
- This geometrical configuration is often used to transport liquids in many industrial fields, such as in heat transfer equipment, suspensions or slurries, extrusion of plastics, drilling of oil wells, industrial waste and food-stuffs.
- Data presented in this paper provide further insight into the hydrodynamics of complex fluids, and especially for this class of fluid (shear thinning) which is highly encountered in many industrial devices.
- This research data enhances our knowledge on how the location of internal cylinder is acting on the shear of fluid, which may be useful for laboratory and industrial applications.
- Data on the spatial distribution of flow patterns presented here give further visibility of the movement of fluid particles in such devices.
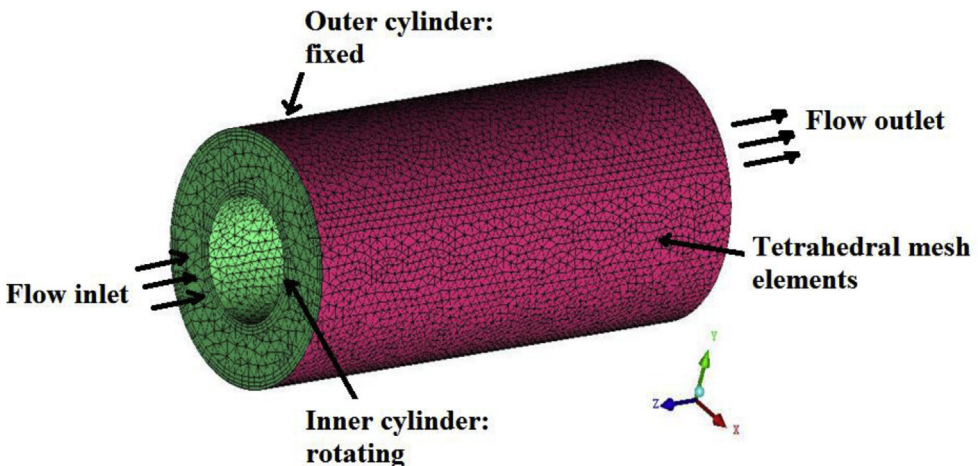- The data can serve as a benchmark for future research on centric eccentric annuli.

Fig. 1. Tetrahedral mesh generated.

Table 1
Mesh test.

	Number of elements	Dimensionless maximal velocity	Computational time (second)
Mesh 1	55 681	0.9745	4260×10^2
Mesh 2	115 698	0.9912	5342×10^3
Mesh 3	268 231	0.9982	9189×10^3
Mesh 4	422 365	0.9987	4341×10^4

2. Experimental design, materials and methods

2.1. Materials

In the present work, we study the flow of complex fluids through two concentric and/or eccentric cylinders. The internal cylinder is driven by a rotation speed, while the external remains fixed. The ratio of the radii between the two cylinders $S = R_1/R_2 = 0.5$.

The beam gap is filled with the solution of CMC (Carboxy Methyl Cellulose) which has the following rheological properties: concentration $c = 0.04$ [g CMC/g], consistency index $m = 0.79$ [Pa s^n], behavior index $n = 0.83$. This fluid has a shear thinning behavior modeled by Ostwald's law.

For an incompressible fluid and an isothermal and stationary process, the Reynolds number (Re_g) is set at 500 (i.e. laminar regime). The influence of the rotational speed of the inner cylinder (ω) was examined ($\omega = 5$, 10 and 30 rpm). Also, the effects of eccentricity were tested ($e/d_2 = 0$, 0.3 and 0.6).

Table 2
Boundary conditions.

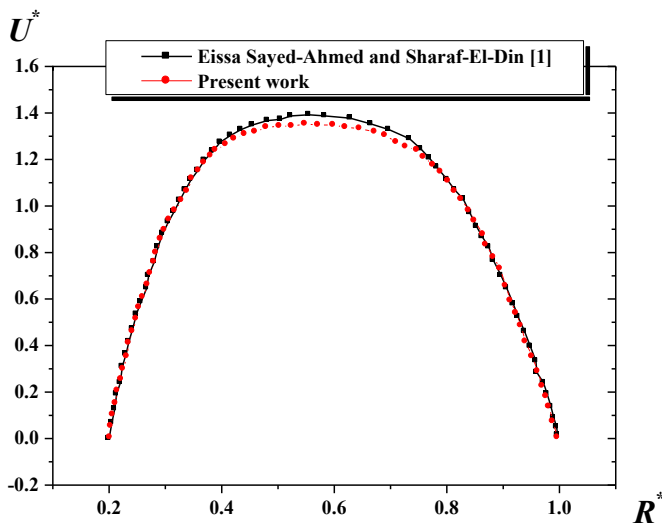| Boundary	Condition
Inlet	A uniform inlet velocity is set.
Outlet	A pressure outlet boundary condition (set to zero) was used.
Inner cylinder	The inner cylinder is considered as a rotating wall. The value of angular velocity w is given.
Outer cylinder	The outer cylinder is considered as a fixed wall.

Fig. 2. Axial velocity for $n = 1$, $S = 0.5$.

2.2. Method of investigation

The problem is studied by numerical simulations using the ANSYS CFX 18.0 calculation code, which is based on the finite volume method for the discretization of the conservation equations. The tetrahedral mesh (Fig. 1) is generated by Ansys ICEM CFD 18.0. The size of the mesh has a considerable influence on the results obtained. Table 1 summarizes the different mesh tests carried out for a ratio $S = 0.5$. The analysis of the results entered in the table results in choosing the mesh 3 (268 231 elements) as optimal, given a combination between the accuracy and the reduced computational time. At every wall of the computational domain, the non-slip flow condition, also, the other required details on boundary conditions are provided in Table 2. The Navier-Stockes governing equations were solved by a segregated implicit iterative scheme. The SIMPLE (Semi-Implicit Pressure Linked Equation) algorithm was used to deal with the pressure−velocity coupling. Results are considered to be converged when the
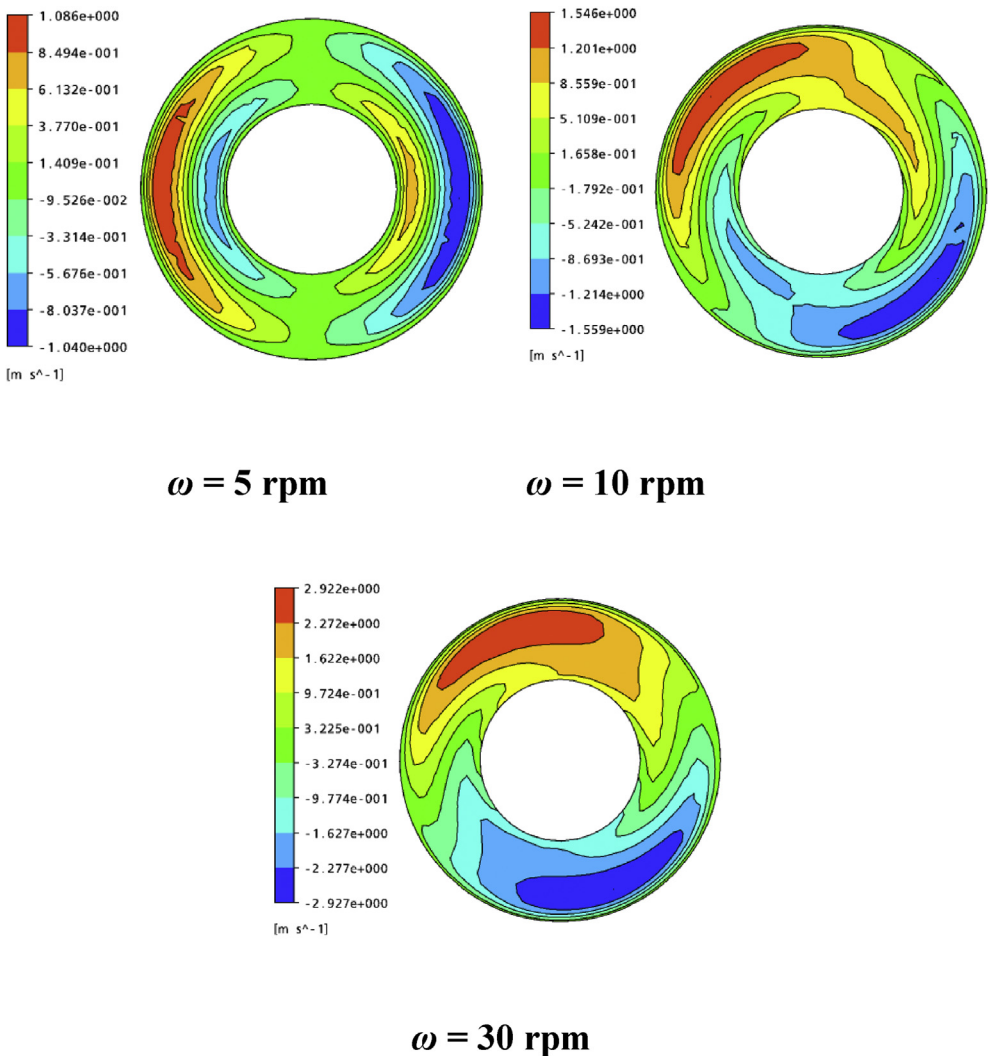

$\omega = 5$ rpm $\omega = 10$ rpm

$\omega = 30$ rpm

Fig. 3. Tangential velocity for $X^* = 0.5$, $Re = 500$, $S = 0.5$.
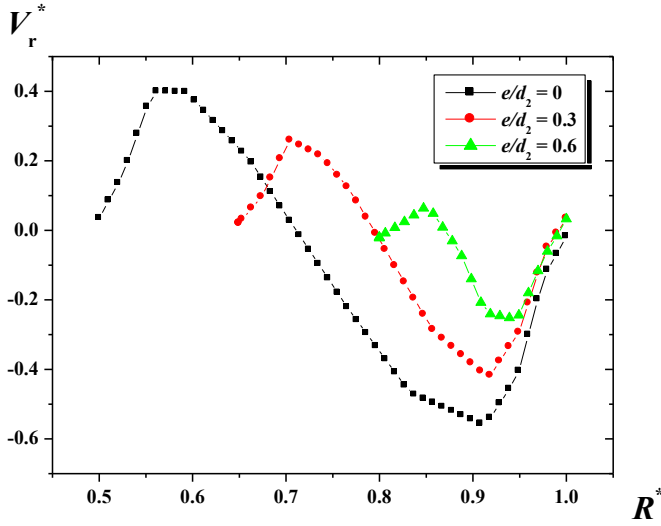
Fig. 4. Radial velocity for $X^* = 0.25$, $\omega = 10$ rpm, $Re = 500$.

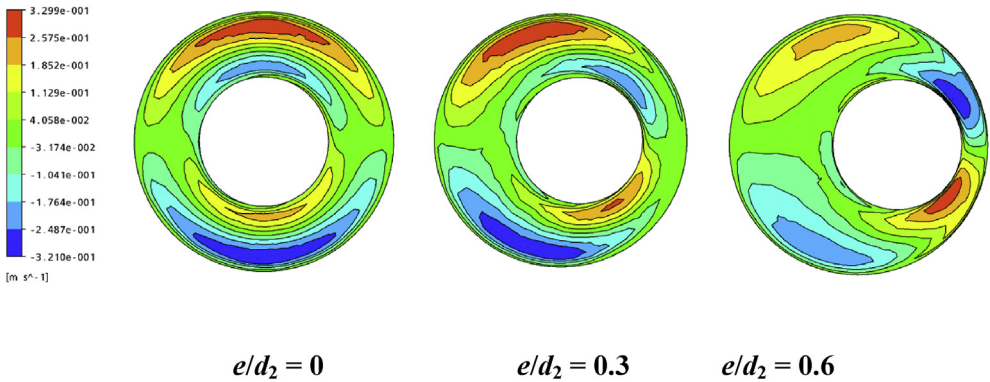$e/d_2 = 0$ $\qquad\qquad$ $e/d_2 = 0.3$ $\qquad$ $e/d_2 = 0.6$

Fig. 5. Tangential velocity for $X^* = 0.5$, $\omega = 10$ rpm, $Re = 500$.

residual target drops below 10^{-7} for the mass and momentum equations. Most simulations required about 500–600 iterations and about 2–3 h on a computer machine with Intel Core i7 CPU, 8.0 GB of RAM and a clock speed of 2.20 GHz.

3. Data obtained

In the first step, a validation of some simulation results was performed. For this purpose, a reference was made to the work of Eissa et al. [1]. With the same operating conditions as those taken by these authors (i.e. two coaxial cylinders with a ratio $S = R_1/R_2 = 0.5$), the variation of the axial velocity U^* is presented in Fig. 2 along the radial coordinate R^* ($R^* = R/d_2$). The comparison of our results with those of Eissa and his co-workers shows a good agreement.
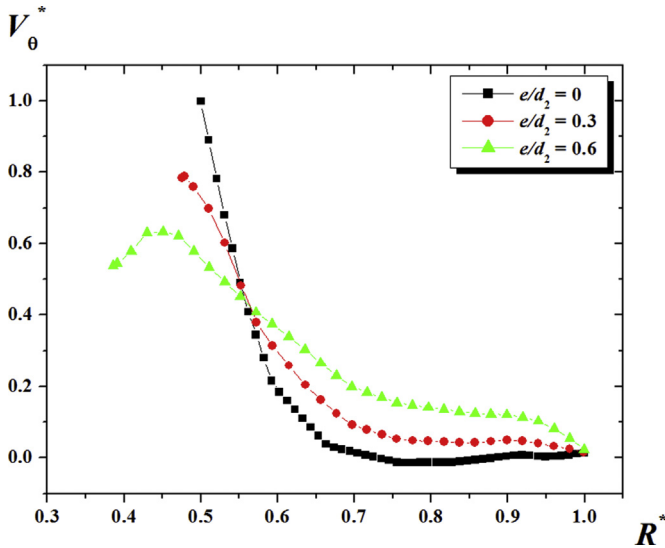
Fig. 6. Eccentricity effect on the tangential velocity, at $Re = 500$.

3.1. Effect of the rotational speed of cylinder

The rotational movement of the inner cylinder imposes centrifugal forces, acting strongly on the structure of the flows generated [2–6]. Three values for the rotation speed ω are chosen to explore these effects. The test results are shown in Fig. 3, where $X^* = X/d_2$ is the axial coordinate. The first slice in the figure (corresponding to $\omega = 5$ rpm) reveals the presence of a symmetry of small blocks separated from each other. Under the effect of increasing shear stresses, this symmetry disappears progressively with the increase of ω.

3.2. Eccentricity effect

Effects of the eccentricity of the inner cylinder are highlighted in this section. The close clearance of the inner tube to the wall causes a strong pressure gradient, where in the zone near the outer tube, the movements of the fluid particles weaken under the wall effects (Fig. 4).

The structure of the flows generated by the three geometries studied is illustrated in Fig. 5. The short distance between the cylinders walls causes intense shear stresses, which reflects the maximum value of the velocity reached in this region. On the other hand, in the other part where the space is rather small, the peak of the curve is less important (Fig. 6). In the zone close to the wall of the outer cylinder, a strong shear of the fluid layers is observed. But, the excessive increase in eccentricity intensifies the frictional forces with the wall of the outer tube, which can cause a subsequent heating of the fluid.

4. Data analysis

The data assembled is analyzed in Figs. 2–6.

References

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