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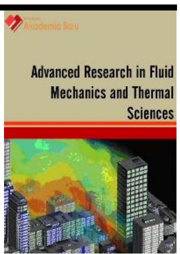

The Impact of Orbital Motion of Drill Pipe on Pressure Drop of Non-Newtonian Fluids in Eccentric Annulus

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ABSTRACT

For all drilling operation method used to explore a well, the hydraulics program design associated to the well must be carried out carefully. A wrong estimation of pressure drop of the drilling fluid in the annular space can induce several problems, like: stuck pipe, lost circulation and insufficient hole cleaning. ANSYS Fluent 18.2 code based on the finite volume method (FVM) is employed to evaluate the orbital motion impact of drill pipe on frictional pressure drop of non-Newtonian fluids (Ostwald-de Waele and Herschel-Bulkley models) flowing in laminar and turbulent regimes where the inner cylinder (drill pipe) makes an orbital motion around the centre of the outer cylinder (casing) and pure rotation around its own axis. Moreover, impact of the eccentricity on frictional pressure drop is discussed. Numerical results exhibit that as the Reynolds number increases, effect of the orbital motion speed of the inner cylinder becomes more severe on frictional pressure drop of the Ostwald-de Waele fluid for laminar regime. However, after a certain speed, frictional pressure drop begins to decrease. In addition, increase of the eccentricity induces a decrease of frictional pressure drop of the Ostwald-de Waele fluid in which this effect is more pronounced when the inner cylinder makes orbital motion for both laminar and turbulent regimes.

Keywords:
CFD approach; orbital motion; frictional pressure drop; non-Newtonian fluid; flow regime

1. Introduction

An efficient frictional pressure drop prediction in the annular space of a wellbore is the most important factor for a proper hydraulic well design to avoid the non-productive time (NPT). Among problems that can be caused by a poor hydraulic design are stuck pipe, insufficient hole cleaning and lost circulation especially for recent challenging drilling operations like: slim holes, deep water wells and extended reach wells. Pressure drop of the drilling fluid in annulus mainly depends on fluid

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properties (density and rheology), geometry characteristics (eccentricity and diameter ratio) and flow regime.

The main role of the drill pipe is to transfer torque from the kelly drive (top drive) or rotary table to the bit where the drill pipe is under axial and lateral loads which result in axial, lateral and torsional vibrations. Due to these vibrations, drill pipe may lose its stability and start to make very complicated motions such as orbital motion [1]. Since the middle of the 20th century, numerous authors studied different cases of the dynamic characteristics and mechanics of the drill pipe in vertical, horizontal and deviated wellbores [1-7]. However, there is limited information in the literature about the influence of such complicated motions of the drill pipe on hydrodynamics and pattern of the drilling fluids in annular space.

Different studies have been carried out using either numerical or experimental studies (flow loop) to evaluate effect of the inner cylinder rotation on frictional pressure drop of non-Newtonian fluid flow in annulus [8-20]. Most of these studies, the inner cylinder was supposed to make pure rotation around its central axis and did not take into account presence of complicated motions of the inner pipe such as orbital motion on the hydrodynamics of drilling fluids in both cases with and without cuttings.

Ahmed and Miska [8] carried out an extensive experimental study to evaluate the influence of the inner pipe rotation on frictional pressure drop of non-Newtonian fluids. They concluded that inertial effect dominates the shear-thinning effect for high eccentricities as the inner pipe rotates which increases pressure drop.

On the other hand, numerous studies reported that pressure drop of the drilling fluid either increases or decreases with the inner cylinder rotation [9, 13-14, 16]. Moreover, Haciislamoglu and Langlinais [21] found that pressure drop diminishes with increase of the eccentricity.

To evaluate the contribution of the drill pipe to hole cleaning, Sanchez *et al.,* [15] used an experimental setup to study impact of rotating drill pipe on the cuttings transport performance in deviated wells. They found that the drill pipe rotation has a major influence on the hole cleaning in which orbital motion is needed to enhance the cleaning process. Where Avila *et al.,* [10] pointed out that the orbital motion occurs when the drill pipe rotation is in the range of 80 to 110 rpm.

Erge *et al.,* [11] considered a flow loop to carry out an experimental study about effect of different buckling configurations of the drill string on pressure drop, they deduced that rotation as well as buckling of the drill string reduce significantly pressure drop of non-Newtonian fluid. Furthermore, Ozbayoglu *et al.,* [22] observed that orbital motion is required rather than pure rotation to enhance the cleaning process during drilling operation, moreover, empirical correlations for prediction of cuttings bed area and pressure drop were developed.

Bicalho *et al.,* [23] carried out a numerical investigation of pseudo plastic fluid flow through partially obstructed cross section of the annulus in which the inner pipe makes orbital motion, however, they did not take into consideration pure rotation of the inner pipe.

Drilling fluids almost have non-Newtonian behaviour and it can be modelled using both Herschel-Bulkley (yield power-law) and power-law models [11, 18, 24] which fit the rheological behavior of drilling fluids with accuracy. However, these models are not utilized for many industrial application and other models like: Casson and non-Newtonian second-order fluid can be used [25, 26].

Many researchers have been using the CFD approach to estimate pressure drop of different fluids in annulus such as Singhal *et al.,* [27] and Pereira *et al.,* [28] without involving significant costs for experimental setup. Moreover, CFD could be used to analyze flow characteristics, such as velocity distribution, which improve understanding of the physical problems associated with fluid flow [29-31]. Recently, CFD approach is extensively employed to handle problems in petroleum engineering due to the growth of computer processing speed and high available memory [32-34].

In this work, influence of orbital motion of the inner cylinder on frictional pressure drop of the non-Newtonian fluids (Ostwald-de Waele and Herschel-Bulkley models) flowing through annulus in laminar and turbulent regimes. Furthermore, effect of eccentricity is considered since orbital motion increases with increase of eccentricity. This is carried out using ANASYS Fluent (18.2) based on finite volume method (FVM) ANSYS Fluent [35].

2. Materials and Methods

2.1 Mathematical Equations

Flow of the non-Newtonian fluids in the annular space are considered to be fully developed, isothermal, incompressible and steady in both laminar and turbulent regimes in which they obey the equations of continuity and momentum. Can be expressed respectively as [36]

$$\frac{1}{r}\frac{\partial(rv_r)}{\partial r}+\frac{1}{r}\frac{\partial(v_\theta)}{\partial\theta}+\frac{\partial(v_z)}{\partial z}=0 \tag{1}$$

$$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial\theta}+v_z\frac{\partial v_r}{\partial z}-\frac{v_\theta^2}{r}\right)=-\frac{\partial P}{\partial r}-\left(\frac{1}{r}\frac{\partial(r\tau_{rr})}{\partial r}+\frac{1}{r}\frac{\partial(\tau_{\theta r})}{\partial\theta}+\frac{\partial(\tau_{zr})}{\partial z}-\frac{\tau_{\theta\theta}}{r}\right)+\rho g_r \tag{2}$$

$$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial\theta}+v_z\frac{\partial v_\theta}{\partial z}+\frac{v_r v_\theta}{r}\right)=-\frac{1}{r}\frac{\partial P}{\partial\theta}-\left(\frac{1}{r^2}\frac{\partial(r^2\tau_{r\theta})}{\partial r}+\frac{1}{r}\frac{\partial(\tau_{\theta\theta})}{\partial\theta}+\frac{\partial(\tau_{z\theta})}{\partial z}+\frac{\tau_{\theta r}-\tau_{r\theta}}{r}\right)+\rho g_\theta \tag{3}$$

$$\rho\left(\frac{\partial v_z}{\partial t}+v_r\frac{\partial v_z}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_z}{\partial\theta}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial P}{\partial\theta}-\left(\frac{1}{r}\frac{\partial(r\tau_{rz})}{\partial r}+\frac{1}{r}\frac{\partial(\tau_{\theta z})}{\partial\theta}+\frac{\partial(\tau_{zz})}{\partial z}\right)+\rho g_z \tag{4}$$

where v_r, v_θ and v_z are the velocity components, P is pressure, ρ is density, g is gravity acceleration and μ is the fluid viscosity.

The Ostwald-de Waele and Herschel-Bulkley models are expressed as follows:

$$\tau=K(\dot{\gamma})^n \tag{5}$$

$$\tau=\tau_0+K(\dot{\gamma})^n \tag{6}$$

where τ_0 yield stress, K is the flow consistency index and n is the flow behavior index.

2.2 Physical Description

The physical situation modelled in this work is based on movement of adjacent layers of fluid (in terms of viscosity). Thus, two motions will affect the domain flow in the annulus as follows: layers near the inner pipe affected by pure rotation, layers in between affected by orbital motion and layers near the outer pipe are in static case and are not affected since the outer pipe is not moving.

The outer and the inner cylinders are positioned eccentrically where the non-Newtonian fluid flows in between. The outer cylinder is fixed and the inner one has orbital motion as well as pure rotation around its own axis at the same time.

Since the orbital motion starts to appear when the inner cylinder rotation reaches 80 to 110 rpm [10], the inner cylinder is considered to make both pure rotation and orbital motion simultaneously. Thus, in the present work, orbital motion speed is assumed increasing (from 0 to 400 rpm) with increase of the inner cylinder rotation (from 0 to 400 rpm) in the counter-clockwise direction as shown in Figure 1.

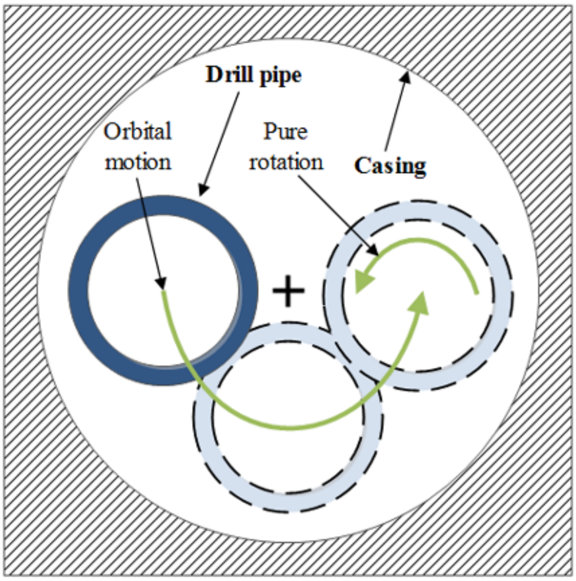


Fig. 1. Cross section of the annulus in which the inner pipe makes pure rotation and orbital motion

To evaluate effect of the orbital motion, eccentricity of the cylinders is considered (E = 0.5). The eccentricity is expressed as:

$$E = \frac{2e}{D_0 - D_i} \tag{7}$$

where e is the distance between the cylinders center, D_0 is the diameter of the outer cylinder and D_i is the diameter of the inner cylinder.

The correction factors (R) proposed by Haciislamoglu and Langlinais [21] and Haciislamoglu and Cartalos [37] for laminar and turbulent regimes, respectively, where these correction factors depend on eccentricity, flow consistency index, flow behaviour index and diameters ratio.

These factors are used for comparison to evaluate effect of the eccentricity on frictional pressure drop in which the inner cylinder has 3 cases (pure rotation, orbital motion and static) and static case is compared with R correction factors of Haciislamoglu and Langlinais [21] and Haciislamoglu and Cartalos [37] since they did not take into consideration rotation of the inner pipe rotation. R is expressed as follows

$$R = \left(\frac{\Delta P}{\Delta L}\right)_{\substack{eccentric \\ annulus}} \Big/ \left(\frac{\Delta P}{\Delta L}\right)_{\substack{concentric \\ annulus}} \tag{8}$$

The Non-Newtonian fluids used in this paper and geometry characteristics are detailed in the Table 1.

Table 1
Fluid and geometry characteristics

Rheological behaviour	Fluids and geometry characteristics				
	τ_0 [Pa]	K [Pa.s^n]	n [-]	D$_o$ [mm]	D$_i$ [mm]
Power-law	-	0.25	0.61	38.1	19.05
Yield power-law	10.5	0.97	0.53	38.1	19.05

Madlener, Frey and Ciezki [38] presented relationships to calculate the Reynolds number for Ostwald-de Waele and Herschel-Bulkley models, respectively defined as

$$Re_{PL} = \frac{\rho D_h^n u^{2-n}}{K\left(\frac{3n+1}{4n}\right)^n 8^{n-1}} \tag{9}$$

$$Re_{YPL} = \frac{\rho D_h^n u^{2-n}}{\left(\frac{\tau_0}{8}\right)\left(\frac{D_h}{u}\right)^n + K\left(\frac{3m+1}{4m}\right)^n 8^{n-1}} \tag{10}$$

where u is the bulk velocity and D_h is the hydraulic diameter which is calculated as

$$D_h = D_o - D_i \tag{11}$$

m is calculated as follows

$$m = \frac{nK\left(\frac{8u}{D_h}\right)^n}{\tau_0 + K\left(\frac{8u}{D_h}\right)^n} \tag{12}$$

The fully developed fluid flow is ensured by the annulus length which is considered longer than the hydrodynamic entrance. The last is given as [39]

$$L_{h,laminar} = 0.05(D_o - D_i)R_e \tag{13}$$

$$L_{h,turbulent} = 1.359(D_o - D_i)R_e^{1/4} \tag{14}$$

2.3 Turbulence Model

It is worthy to note that the range of parameter is selected in such manner to ensure that the flowing fluid is either in laminar or turbulent regime. Thus, the reported Reynolds number in this work is axial Reynolds number because in the open literature there are no papers about influence of the orbital motion on flow regime especially for non-Newtonian fluids. For that, as an assumption, the Reynolds number is kept as low as possible in such manner even in the presence of orbital motion or rotation would be laminar

The turbulence model selection is based on the simulation runs of non-Newtonian fluids (power-law model) in both concentric and fully eccentric annulus. The experimental model of McCann *et al.,* [12] is employed to investigate the suitable turbulence model for the numerical study of power-law fluid flow through annulus.

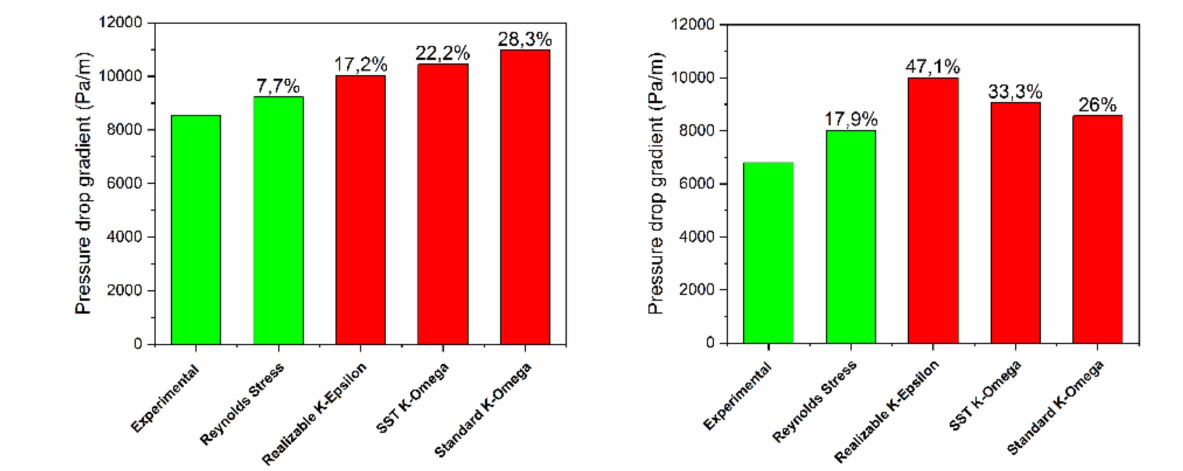
The average absolute percent relative error (AAPE) is utilized for evaluation of turbulence models.

$$AAPE = 100\frac{1}{N}\sum_{i=1}^{N}\left|\frac{(y_i - \hat{y}_i)}{y_i}\right| \tag{15}$$

where N the number of simulations per bulk velocity, y_i is the experimental value and $\hat{y}_i$ is the predicted value.

Figure 2 indicates that the Reynolds stress model provides accurate results compared with other models (Realizable K-Epsilon, Standard K-Omega and SST K-Omega) in which it presents an AAPE of 7.7 % and 17.9 % for concentric and fully eccentric annulus, respectively. This proves ability of the Reynolds stress model to predict the behavior of non-Newtonian fluids in turbulent regime with accuracy due to its ability to model fluid flows with complex strain fields caused by rotation of the inner pipe and eccentricity of pipes. On the other hand, the Reynolds stress model is basically developed to overcome a number of major drawbacks experienced by the K-Epsilon model and SST model [40].

Furthermore, Sultan *et al.,* [41] investigated performance of different turbulence models and they found that the Reynolds stress model predicts the behavior of either single phase or two phases in turbulent regime with high accuracy. Based on this, the Reynolds stress model is employed to investigate effect of the orbital motion of the inner cylinder on pressure drop gradient of non-Newtonian fluids in turbulent regime.



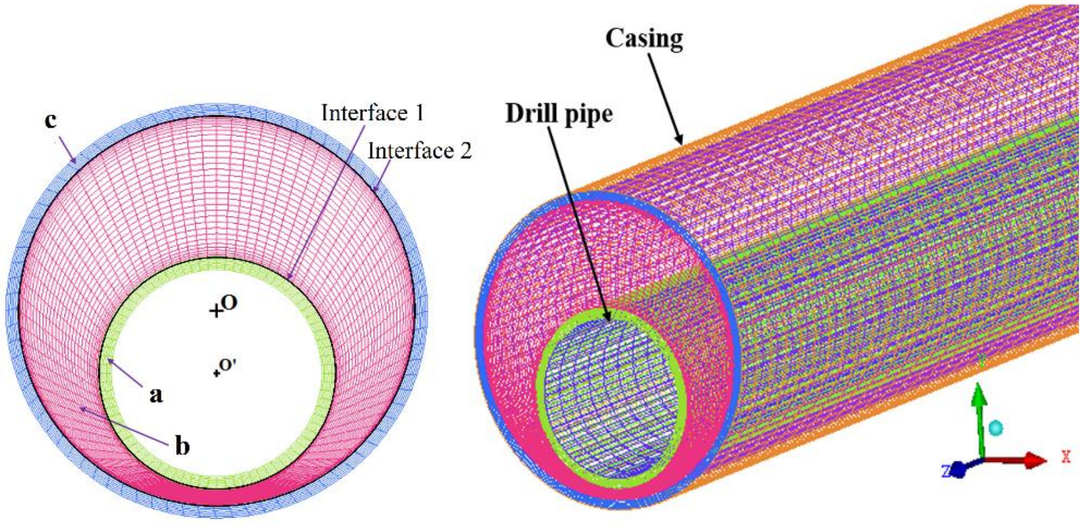
a) Concentric anulus

b) Fully eccentric annulus

Fig. 2. Comparison of different turbulence models with the experimental work of McCann *et al.,* [12]

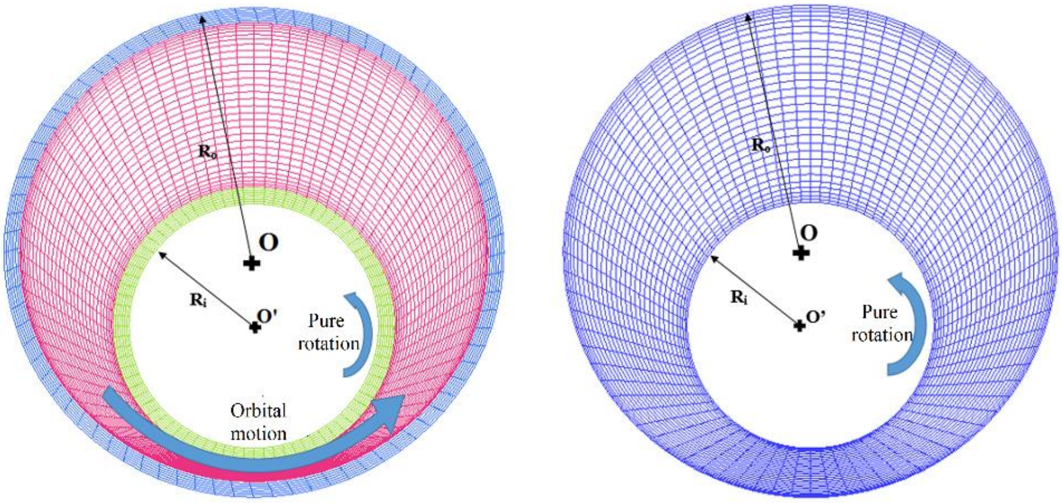
2.4 Numerical Method

The annular space is discretized into three parts (part influenced by pure rotation, part influenced by orbital motion and static part) in which these parts are connected with two interfaces to transfer variables (pressure, velocity) as shown in Figure 3, Figure 4 and Table 2. Moreover, mesh motion technique is employed to simulate effect of pure rotation and orbital motion of the inner cylinder on the fluids flow in the annulus. Where the cell zone of the part influenced by the orbital motion makes rotation around the center of the outer cylinder, which allows to create the orbital motion. Pure rotation of the inner cylinder is obtained by rotation of cell zone of the part influenced by rotation of the inner cylinder.



a. Part influenced by pure rotation
b. Part influenced by orbital motion
c. Part not influenced

Fig. 3. Mesh of annulus in which the inner pipe makes pure rotation and orbital motion



a) Mesh cross section of annulus in which the inner cylinder makes rotation and orbital motion.

b) Mesh cross section of annulus in which the inner cylinder makes pure rotation around its own axis.

Fig. 4. Mesh cross section of the domain flow

Table 2
Mesh characteristics

	Mesh of the domain flow in the presence of orbital motion			Mesh of the domain flow without orbital motion
	Region affected by rotation	Region affected by orbital motion	Region not affected	
Number of elements	$7(r)\times80(\theta)\times500(z)$ $= 2.8 \times 10^5$	$30(r)\times80(\theta)\times500(z)$ $= 1.2 \times 10^6$	$7(r)\times80(\theta)\times500(z)$ $= 2.8 \times 10^5$	$30(r)\times80(\theta)\times500(z)$ $= 1.2 \times 10^6$
Sum	1.76×10^6 elements			1.2×10^6 elements

Since the inner and outer pipes of the present simulation correspond to the drill pipe and casing in the real bottom hole, respectively, the inner pipe is considered rotating and the outer pipe is fixed, moreover, no slip condition is adopted at the outer and inner pipes. Different inlet velocities for both laminar and turbulent regimes are considered and the atmospheric pressure is attributed the outlet.

To ensure that the results of the present study are independent of the mesh adopted for both situations (pure rotation and orbital motion), a mesh sensitivity analysis is carried out with critical conditions (turbulent regime and fully eccentric annulus) to investigate the threshold value of the elements number in which the numerical results are no longer influenced. Moreover, data for the sensitivity analysis are extracted from the experimental study of Ahmed and Miska [8]. Figure 5 shows that pressure drop gradient becomes roughly constant when a certain value of the elements number is reached (360000 elements) for both pure rotation and orbital motion cases. Thus, the domain flow is subdivided into 1.76×106 and 1.2×106 hexahedral elements for orbital motion and pure rotation cases, respectively. Based on the finite element approach, a CFD code (ANSYS Fluent 18.2) is employed to solve the transport equations (continuity and momentum) for the current study.

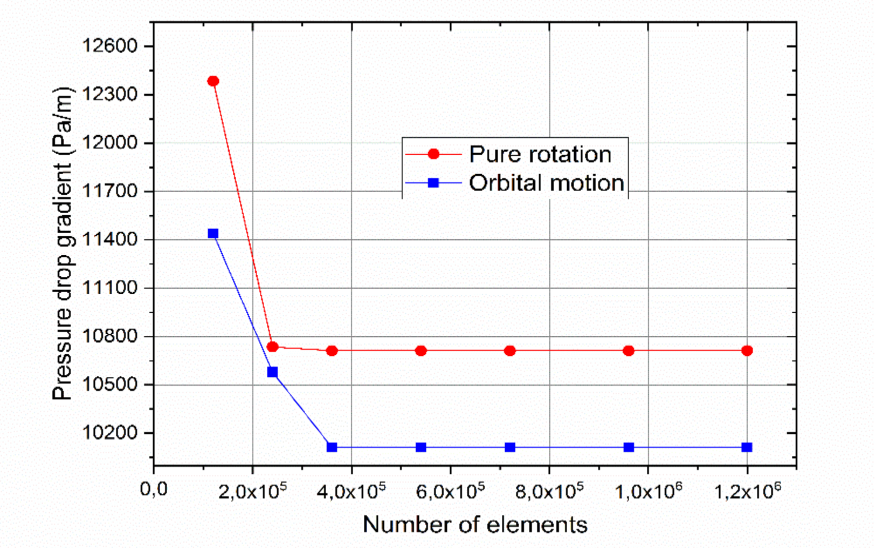


Fig. 5. Mesh sensitivity analysis for both pure rotation and orbital motion cases for fully eccentric annulus (3 m/s fluid velocity)

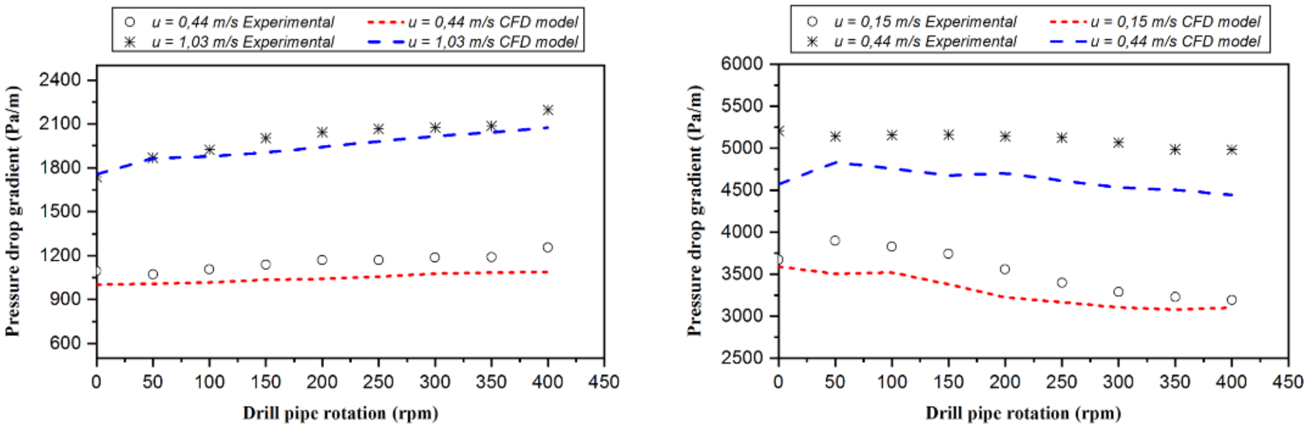
All simulation runs are performed with SIMPLE algorithm where discretization of pressure and momentum equations, PRESTO and second order upwind are adopted, respectively. A fixed time step of 10-4 allowed to get a convergence from 10^{-4} to 10^{-5} for all simulations.

2.5 Validation Model

Since, there are few experimental studies carried out taking into account orbital motion of the inner cylinder, limited experimental data are available in the literature about influence of the orbital motion on frictional pressure drop of the non-Newtonian fluids through annulus. For that, the cell zone of the part influenced by pure rotation of the inner cylinder of the adopted mesh (Figure 2) is used to simulate pure rotation of the inner cylinder. Results of the numerical study are compared with experimental data of Ahmed and Miska [8] in which the inner cylinder has only rotation around its own central axis. Then, the numerical study is extended to take into consideration influence of the orbital motion.

As shown in Figure 6, a good concordance between the experimental and numerical studies is observed in which the average absolute percent relative error (AAPE) is utilized for evaluation of CFD prediction.

The AAPE of the Ostwald-de Waele fluid is 9.3 % and 3.7 % for 0.44 m/s and 1.03 m/s, respectively. While the AAPE of the Herschel-Bulkley is 6.5 % and 9.4 % for 0.15 m/s and 0.44 m/s, respectively. Based on the comparison of the experimental and numerical results of Ostwald-de Waele and Herschel-Bulkley models, we can conclude that CFD method can predict the behaviour of non-Newtonian fluids in complex geometries with high accuracy.



a) Ostwald-de Waele model

b) Herschel-Bulkley model

Fig. 6. Comparison of simulation results and experimental data of Ahmed and Miska [8]

3. Results and Discussions

Figure 7 shows behaviour of frictional pressure drop of the Ostwald-de Waele with increase of the orbital motion speed for various Reynolds numbers in laminar regime. As shown, increase of the orbital motion speed from 0 to 400 rpm has a slight effect on frictional pressure drop for Reynolds number 35 and starts to decrease when the orbital motion speed reaches 200 rpm due to domination of the shear thinning effect induced by orbital motion speed. However, for the Reynolds numbers 94, 246 and 433, frictional pressure drops increase with increase of the orbital motion speed until 300 rpm where this increase is intensified by increment of the Reynolds number, after that, frictional pressure drop begins to decrease. It is worthy to note that increase of the Reynolds number results in increase of the value where frictional pressure drop begins to diminish, thus, domination of shear thinning effect is delayed.

Figure 8 shows impact of the orbital motion speed on frictional pressure drop of the Ostwald-de Waele fluid in turbulent regime. As can be seen, frictional pressure drops increase with increment of the orbital motion speed where this increase is estimated at about 10 % for all Reynolds numbers. This behaviour could be attributed to the turbulence production due to the increase of the Reynolds number even though non-Newtonian fluids with high shear thinning character tend to decrease turbulence production [42].

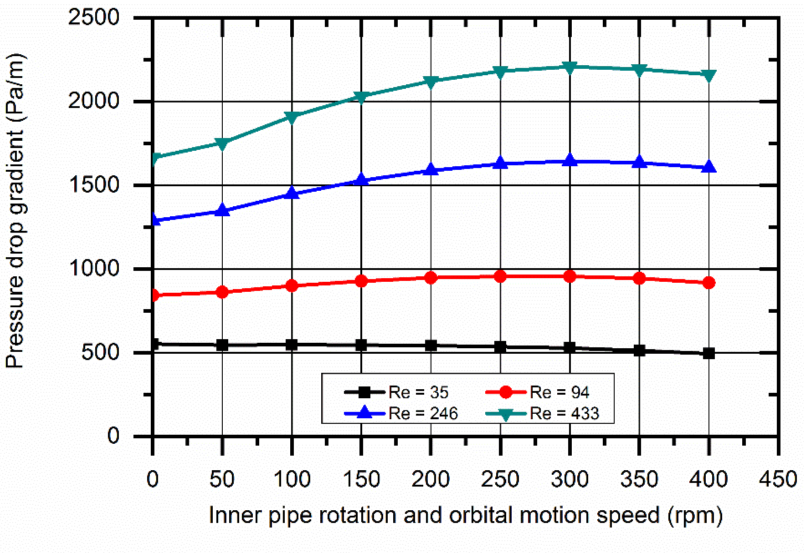


Fig. 7. Effect of the orbital motion and rotation of the inner pipe on the pressure drop gradient of Ostwald-de Waele fluid for laminar regime

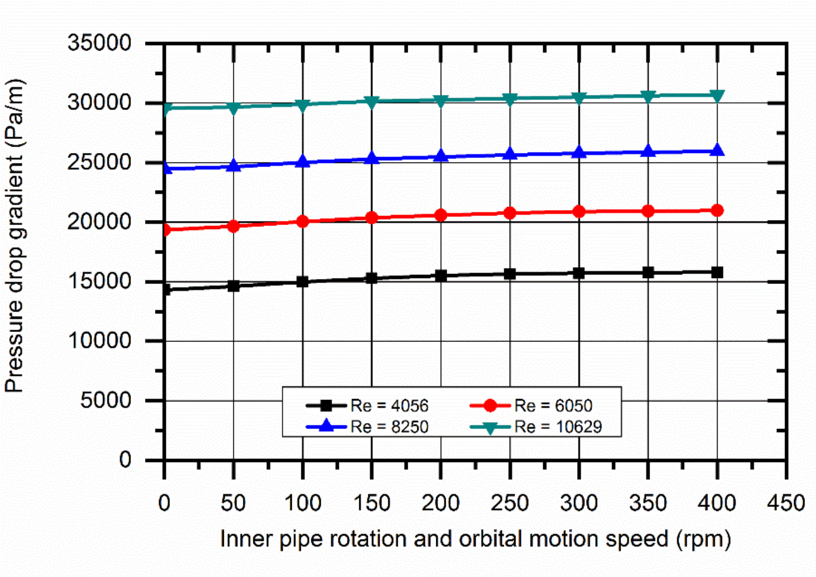


Fig. 8. Effect of the orbital motion and rotation of the inner pipe on the pressure drop gradient of Ostwald-de Waele fluid for turbulent regime

Figure 9 depicts that increment of the orbital motion speed from 0 to 400 rpm causes a decrease of 38.57 % and 17.22 % of frictional pressure drop of the Herschel-Bulkley fluid for the Reynolds numbers 4 and 16, respectively. This indicates that the Herschel-Bulkley fluid is dominated by shear thinning phenomena where this effect decreases with increment of the Reynolds number. While for the Reynolds numbers 52 interaction between inertial and shear thinning effects results in a slight effect of the orbital motion speed. With increase of the Reynolds number up to 104, the inertial effects dominate flow of the Herschel-Bulkley fluid through annulus which make frictional pressure drop increases with 8 % when orbital motion speed increase from 0 to 400 rpm.

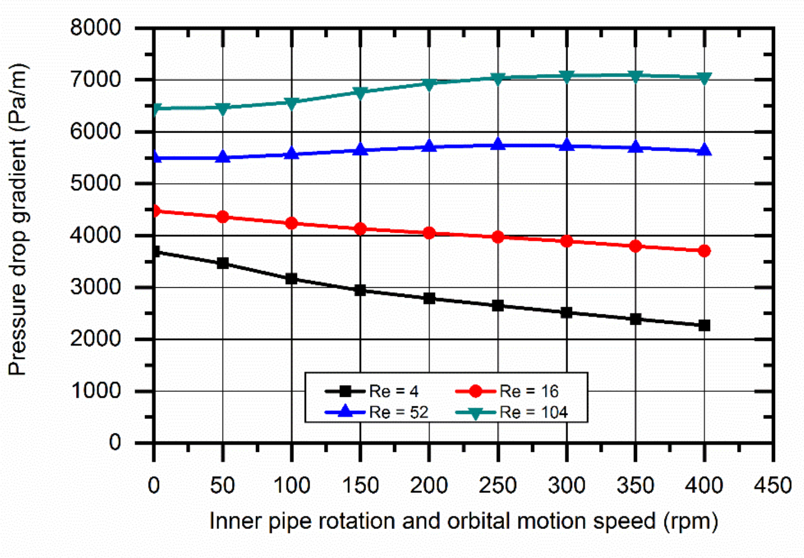


Fig. 9. Effect of the orbital motion and rotation of the inner pipe on the pressure drop gradient of Herschel-Bulkley fluid for laminar regime

Presence of the orbital motion of the inner cylinder could apply additional shear stress on the Herschel-Bulkley fluid which enhance shear thinning phenomenon, especially for low eccentricities. Thus, if the flow of non-Newtonian fluid through annulus is dominated by the shear-thinning phenomenon, frictional pressure drop will diminish with increment of the orbital motion speed.

Figure 10 shows that increment of the orbital motion speed is found to increase frictional pressure drop of the Herschel-Bulkley fluid in turbulent regime for all Reynolds numbers. Similar influence was observed for the Ostwald-de Waele fluid in turbulent regime. Therefore, turbulent regime prevents shear-thinning phenomenon to dominate the flow of Ostwald-de Waele and Hershel-Bulkley fluids in annulus which leads to the increase of frictional pressure drop with orbital motion speed.

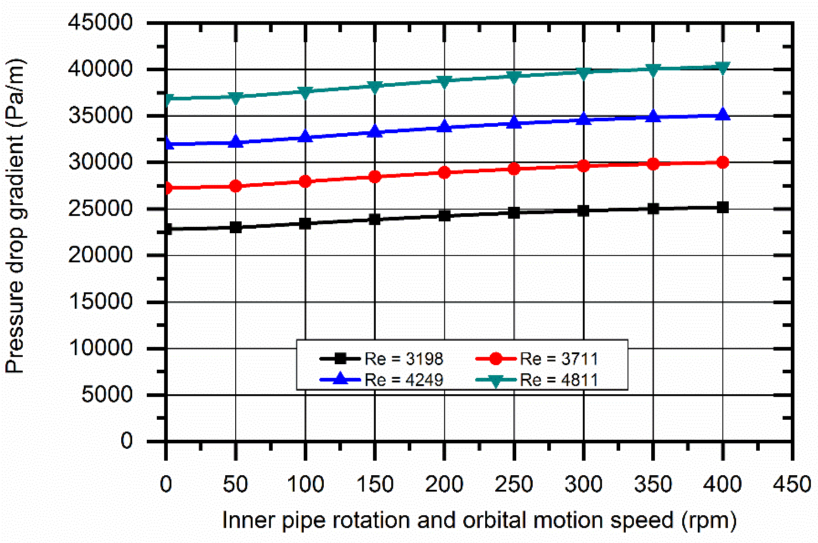


Fig. 10. Effect of the orbital motion and rotation of the inner pipe on the pressure drop gradient of Herschel-Bulkley fluid for turbulent regime

Figure 11 shows influence of eccentricity on frictional pressure drop of the Ostwald-de Waele fluid through eccentric annulus compared with concentric annulus in laminar regime. As can be seen, the eccentricity is found to decrease frictional pressure drop up to 44 % when it increases from E = 0.1 to E = 0.9 in the case where the inner cylinder did not make rotation. This trend is also stated by Haciislamoglu and Langlinais [21]. However, for flow of the Ostwald-de Waele fluid in which the inner cylinder makes pure rotation around its own axis, frictional pressure drop decreases more gradually for low values of eccentricity. This effect is due to the inertial effect induced by introduction of the inner cylinder rotation. Appearance of the orbital motion makes frictional pressure drop diminish more than previous cases (flow without rotation of the inner cylinder and flow with rotation of the inner cylinder around its own central axis). This may indicate that presence of the orbital motion during rotation of the inner cylinder improves shear-thinning phenomenon which reduces even more frictional pressure drop of the power-law fluid through annulus.

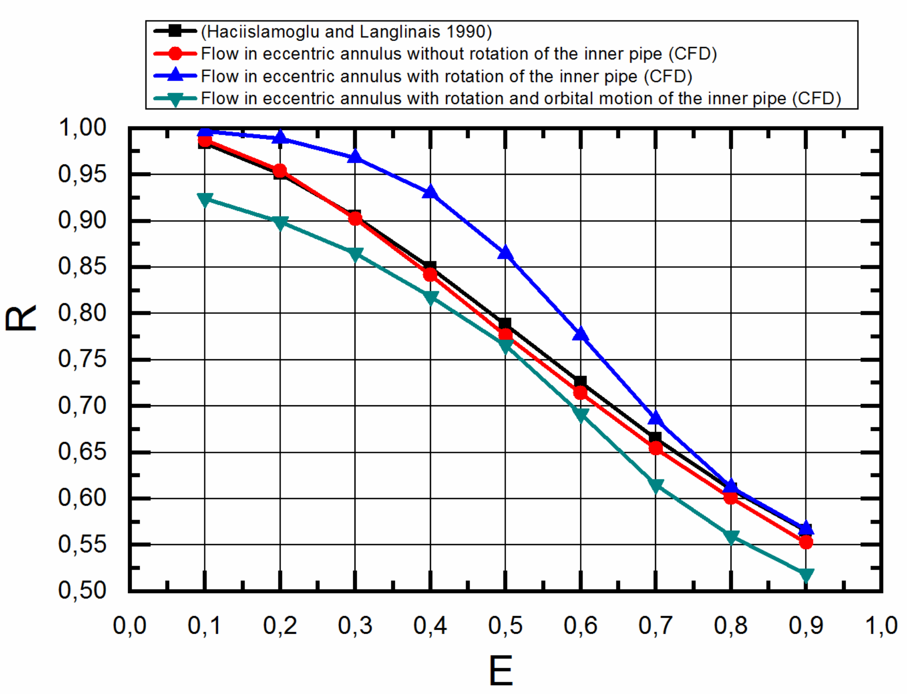


Fig. 11. Effect of eccentricity on pressure drop gradient of non-Newtonian fluid (Ostwald-de Waele) for different models in laminar regime

Figure 12 outlines that when the eccentricity increases from E = 0.1 to E = 0.9, frictional pressure drop of the Ostwald-de Waele fluid in turbulent regime is decreased by 23 % and 29 % for annulus with pure rotation of the inner cylinder and annulus with orbital motion of the inner cylinder, respectively. This indicates that influence of eccentricity on frictional pressure drop is less pronounced in turbulent regime as compared with laminar one because turbulence production tends to prevent frictional pressure drop of Otswald-de Waele fluid to decrease due to the eccentricity for all cases. Moreover, a minimal influence is induced by pure rotation of the inner cylinder on frictional pressure drop compared with annulus where the inner cylinder did not make rotation around its own axis.

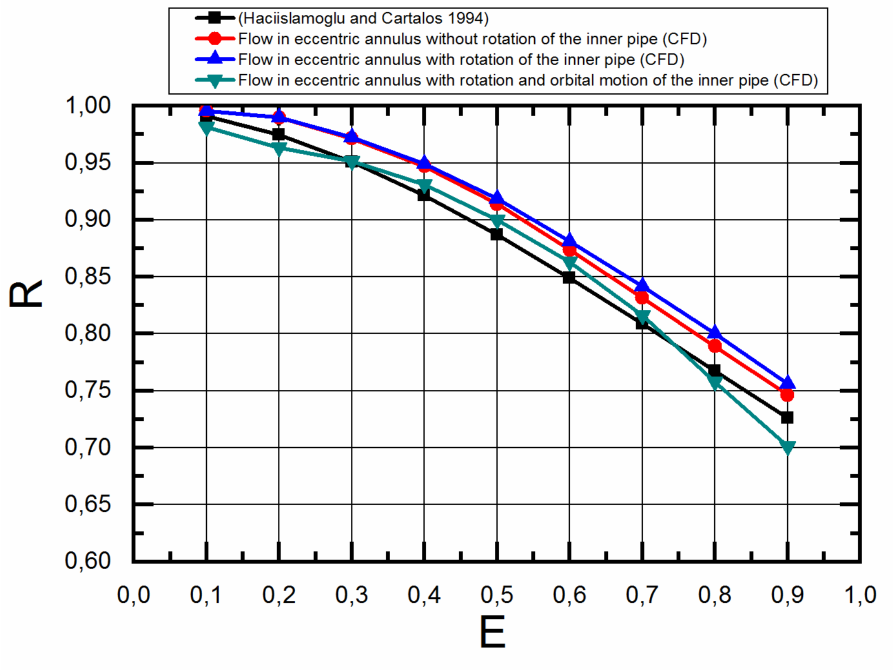


Fig. 12. Effect of eccentricity on pressure drop gradient of non-Newtonian fluid (Ostwald-de Waele) for different models in turbulent regime

Numerical results are in good concordance with correction factors R of Haciislamoglu and Langlinais [21] and Haciislamoglu [33].

4. Conclusions

In this work, the influence of the orbital motion on frictional pressure drop of non-Newtonian fluids (Ostwald-de Waele and Herschel-Bulkley models) through eccentric annulus is studied. As well as, the effect of eccentricity is evaluated using commercial CFD code ANSYS Fluent 18.2. As the Reynolds number increases, influence of the orbital motion of the inner cylinder becomes more severe on frictional pressure drop of the Ostwald-de Waele fluid for laminar regime. However, after a certain speed, frictional pressure drop begins to decrease due to the domination of shear-thinning phenomenon. Orbital motion of the inner cylinder enhances shear-thinning phenomenon of the Herschel-Bulkley fluid which causes a decrease of 38.57 % and 17.22 % of frictional pressure drop for the Reynolds numbers 4.69 and 16, respectively. Eccentricity of the inner cylinder is found to decrease pressure drop gradient of the Ostwald-de Waele fluid up to 44 % when it increases from 0.1 to 0.9 for laminar regime where Orbital motion of the inner cylinder causes additional decrease of frictional pressure drop the Ostwald-de Waele fluid compared with case where the inner cylinder makes only pure rotation. Turbulent regime prevents shear-thinning phenomenon to dominate the flow of Ostwald-de Waele and Hershel-Bulkley fluids in annulus which leads to the increase of frictional pressure drop with orbital motion speed.

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