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Computational Modeling of Blade's Impact on the Hole Cleaning Device's Decaying Swirl Flow

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Abstract: This work presents the Decaying swirl flow behaviors of turbulent flow in active mixer through a numerical examination and analysis. The numerical analysis was carried out by solving the 2D Navier-Stokes equations for new dynamic mesh tecnic, using the computational fluid dynamic (CFD) tool . The computation of the hydrodynamic and swirl flow efficiency yields an estimated index for various scenarios, the tangential velocity distribution, and the variation of pressure are analyzed. When it comes to hole cleaning, the swirl flow will be nearly parallel to the radial flow. Moreover, as the blades rises above the critical threshold, the swirl flow's rotational direction will alter.

Keywords: Swirl Flow, Tangential velocity, Computational fluid dynamic, Turbulent flow.

1. Introduction

Lately, complicated hydrocarbon resources with low permeability, deep water, unconventionality, etc., have seen extensive development. More and more horizontal well drilling technology is being used to increase the recovery efficiency of complex reservoirs. It could significantly increase the output of gas and oil and help to resolve the problem of energy scarcity [1]. However, when drilling directional or horizontal wells with drilling fluid circulation, the cuttings particles that the drill bit cuts are likely to deposit on the bottom side of the annulus and form a cuttings bed due to gravity. Inadequate hole cleaning can lead to clogged pipes, excessive torque, high drag, and premature drill bit wear. Poor hole cleaning can result in high torque, high drag, premature drill bit wear, clogged pipes, and other safety issues, particularly in the deviated and horizontal wellbores [2]. It offers great promise for a variety of industrial uses [5-8]. The fluid in the tube can be made to swirl more by using a number of techniques, such as the spiral wall [9], tangential intake [10], and blade induction [11,12].

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Due to the current demand for oil and gas, we expect to drill more wells, either vertical, deviated or horizontal (Bashir Busahmin et al.2017). These represent 70⁄ of the wells drilled. But the cost of a horizontal well is 1.5 times that of a vertical well. We know that the cost depends on the duration of the work, so we must increase the ROP penetration speed, which itself depends on the state of cleaning of the well. The less the well is cleaned, the more the drilling is exposed to accidents.

The literature has few works that use an active mixer to create turbulent flow. Consequently, the goal of the current study is to ascertain how well an active mixer performs when mixing fluids in an effort to achieve a high pressure drop and mixing quality. Using CFD code, numerical simulations were carried out turbulent regime in order to examine the flow structures and the hydrodynamic mixing performances within the concerned active mixer. Various fluid cases were proposed to investigate the chaotic flow formation and thermal mixing performances within the suggested micromixer. In order to get important homogenization of the fluids' indices and pressure losses will be appraised.

2. Geometry and Governing Equations :

Based on the finite volumes method, the ANSYS 16 CFD program solves steady conservation equations of an incompressible fluid numerically in a laminar domain. The SIMPLEC scheme is our choice for pressure and velocity coupling. A second-order upwind scheme was nominated to solve the concentration and momentum equations. The numeric's were ensured and simulated to be converged at 10^6 of root mean square residual values. A Newtonian solution of water is used as working f luid for the simulation

of fluid flows. The density of CMC solutions according to Fellouah et al. [11] and Pinho et al. [12], is 1000 kg/m^3. The coherence coefficient and the power law indexes of the CMC solutions are indicated in Table 1, where the diffusion coefficient equals 10^{-11} m^2/s.

The geometric model of the concentric annulus is composed of a drill pipe and a casing.

The required inlet section length of the turbulent flow Le is calculated by Munson [20] to ensure that the fluid reaches the complete development stage before entering the area of the blade.

$$Re_D = \frac{\rho U_{in} D_h}{\mu}$$

where Dh is the hydraulic diameter; ReD is the Reynold number; is the fluid density; Uin is the axial

velocity; and, is the dynamic viscosity.

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The swirl number S_n is defined as the ratio of the tangential momentum flux to the axial momentum flux,as given by:

$$S_n = \frac{\int_{R_0}^{R_1} uwr^2 dr}{R_1 \int_{R_0}^{R_1} u^2 r dr}$$

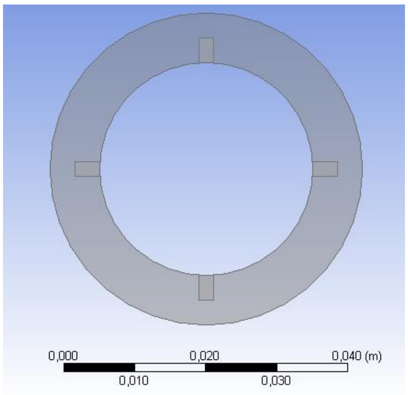
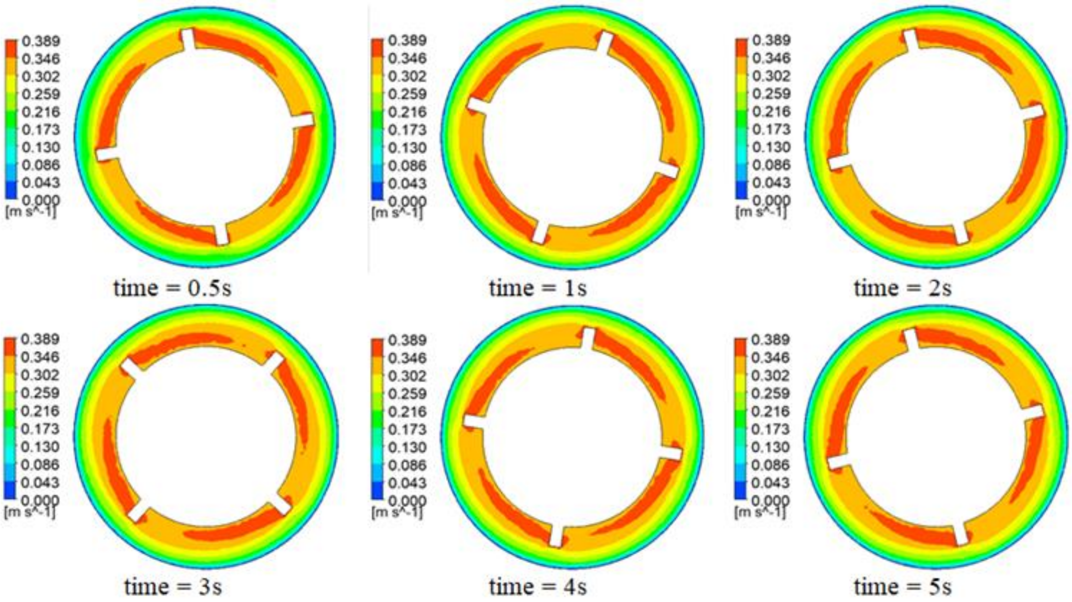


Figure 1: Active mixer with blades.

Where R_1 and R_0 are the radius of the drilling pipe and casing , respectively; u is the axial velocity ;w is the tangential velocity; and,ri the radial coordinate.

3. Results and Discussion

This work present an effects of varying cases of rotational speeds on the hydrodynamic properties of transient swirl flow at different times.



time = 0.5s time = 1s time = 2s

time = 3s time = 4s time = 5s

Figure 2: Tangential velocity contours with different times at 200 rpm. Source author.

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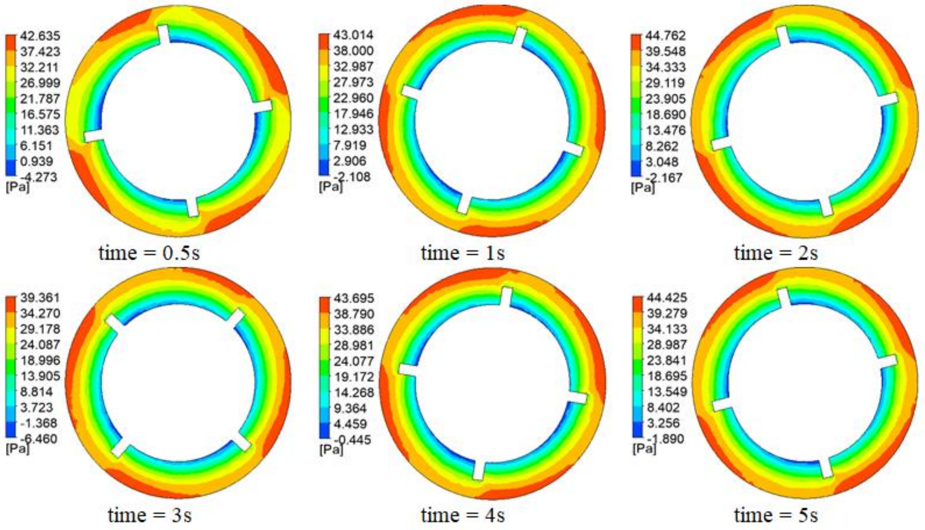


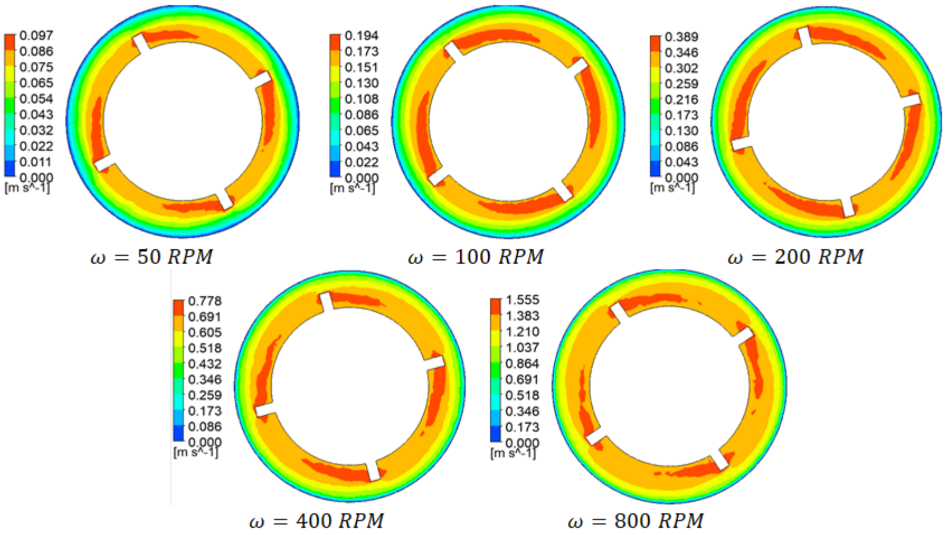
time = 0.5s time = 1s time = 2s

time = 3s time = 4s time = 5s

Figure 3: Static preesure with different times at 200 rpm. Source author.

The findings provide guidance for designing the hole cleaning tool used in drilling engineering.

The fluid's tangential velocity and static pressure distribution are displayed in Figures 2 and 3 at various times (t=3s to 12s) and rotational speeds. The fluid beneath the blade's suction surface gains more tangential velocity as a result of rotation. The greatest tangential velocity can surpass 0.188 m/s at time = 12s, but both the intensity and distribution range of the fluid with a high tangential momentum grow as the number of times increases.



$\omega = 50\ RPM$ $\omega = 100\ RPM$ $\omega = 200\ RPM$

$\omega = 400\ RPM$ $\omega = 800\ RPM$

Figure 4: Tangential velocity contours with different rotating speed at time = 5s. Source author.

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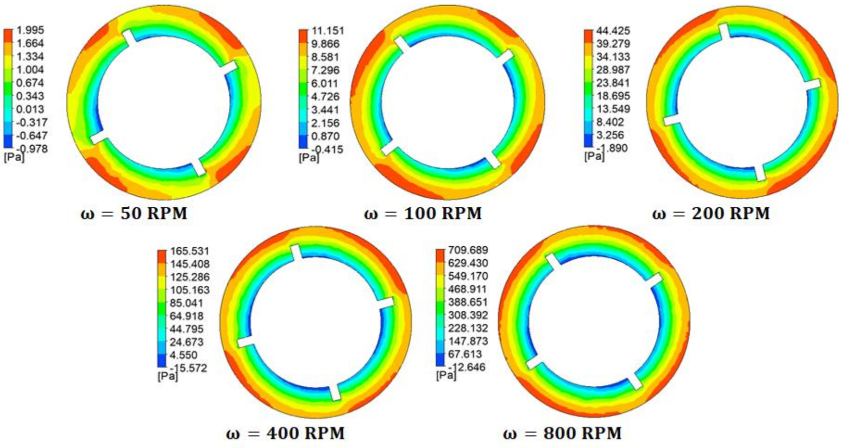
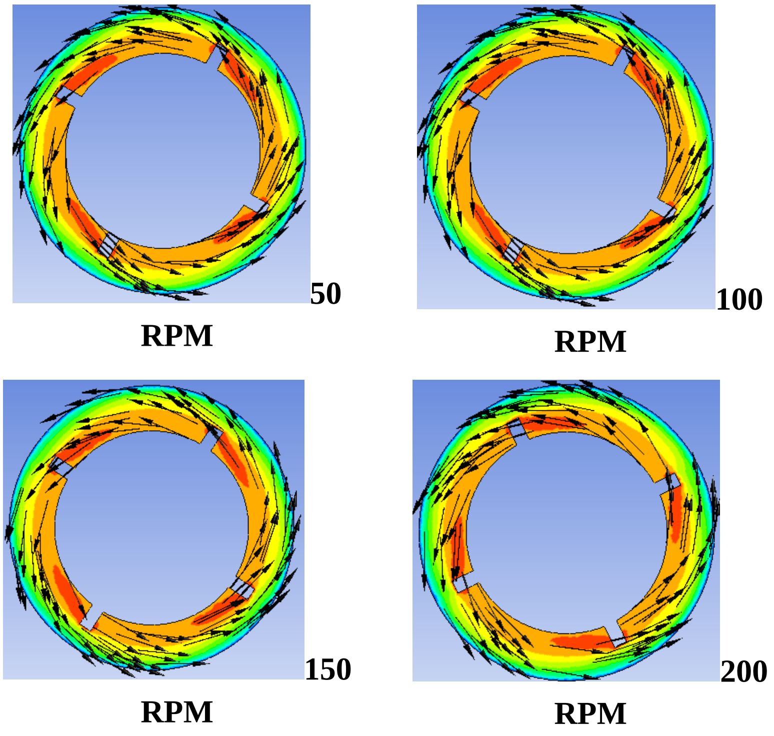


Figure 5: Static preesure with different rotating speed at time = 5s. Source author.

Figures 4 and 5 show the fluid's tangential velocity and vorticity distribution contours at time = 10s with different rorating speeds. The fluid's tangential velocity in this section is almost zero near the output tube because the positive blade's flow direction is close to the axial flow. When the rotational speed is increased to = 200, the swirl intensity increases and the direction of the swirl flow's rotation changes; the highest tangential velocities in this section can approach 0.05 m/s and 0.15 m/s.



50 RPM

100 RPM

150 RPM

200 RPM

Figure 6: Stram line of magnetic velocity vectors with different rotating speed. Source author.

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The swirl flow's rotational direction is altered as the blade deflects into the liquid. As a result of this phenomena, swirl flow flows in the opposite direction from tip leakage vortices, which originate in the direction of rotation (see figure 6 and table 1).

Table 1 : Effect of rotational speed on Preesure, tangentiel velocity , vorticity rate and Stretched Swirling. Source author.

	Pressure (Pa)	Tangentiel velocity (m/s)	Vorticity rate (1/s)	Stretched Swirling
50 Rpm	0.969555	0.06067843	15.29728	0.804454
100 Rpm	7.160282	0.185288	21.38542	1.59273
200 Rpm	28.8625	0.2766578	58.60715	3.12878
400 Rpm	100.0928	0.5673266	127.5806	7.38385
800 Rpm	444.9791	1.171175	245.4139	15.1572

As can be observed, the tangential velocity steadily decreases along the radial direction towards the wall after peaking in the central area. The tangential velocity rapidly drops close to the wall before reaching zero at the wall's surface. A Rankine vortex's profile resembles the tangential velocity distribution profile, see figure 7.

The tangential velocity distribution curve of the with varying rotational speeds is displayed in Figures 8 and 9. It is established that the swirl flow's rotation direction at w = 800 and the blade's rotation direction coincide. In addition, the swirl flow's tangential velocity caused by the geometry is higher than it is for the others.

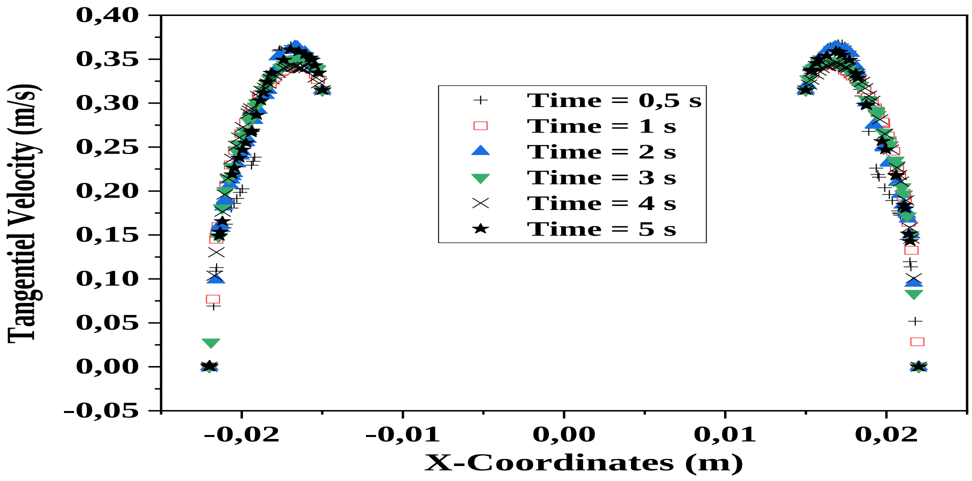

Figure 7 : Tangential velocity VS Time Source author.

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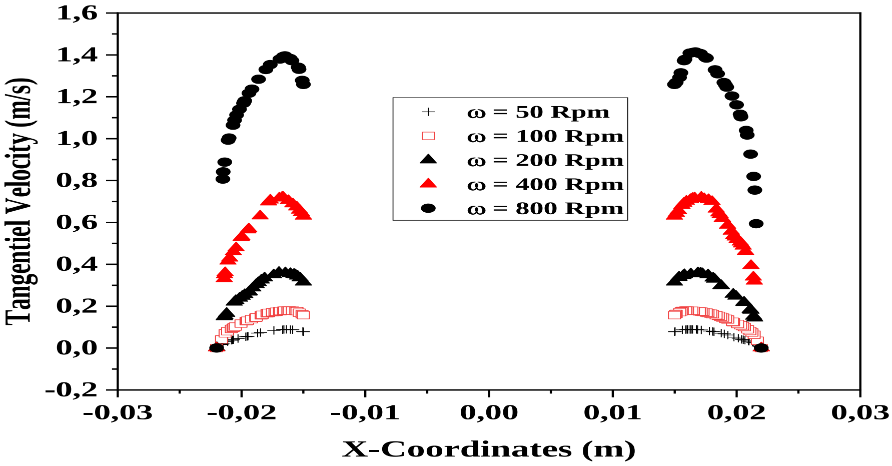

Figure 8 : Effect of rotational speed on tangential velocity Source author.

4. Conclusion

Hole cleaning devices have been used to address the problem of cutting accumulation during horizontal well drilling. However, under different settings, especially with different active mixers, little is known about the intensity of swirl flow generated by the hole cleaning device's blade and its decay behavior along the flow direction. The hydrodynamic effects of the hole cleaning device are investigated in this work. Using hole cleaning devices has solved the problem of cutting accumulation during active mixing when rotation speed is influencing the process. This work investigates the hydrodynamic effects of different blade forms and rotational speeds on swirl flow quantitatively using the CFD approach.

References

1. 1.Guan, Z.C.; Liu, Y.M.; Liu, Y.W.; Xu, Y.Q. Hole cleaning optimization of horizontal wells with the multi-dimensional ant colony algorithm. J. Nat. Gas Sci. Eng. 2016, 28, 347–355.
2. 2.Ogunrinde, J.O.; Dosunmu, A. Hydraulics Optimization for Efficient Hole Cleaning in Deviated and Horizontal Wells. Niger. Annu. Int. Conf. Exhib. 2012, 16.
3. 3.Massie, G.W.; Castlesmith, J.; Lee, J.W.; Ramsey, M.S. Amoco's training initiative reduces wellsite drilling problems. Pet. Eng. Int. 1995, 67, 3029–3035.
4. 4.Hopkins, C.J.; Leicksenring, R.A. Reducing the risk of stuck pipe in the Netherlands. In Proceedings of the IADC/SPE Drilling Conference, Amsterdam, The Netherlands, 28 February–2 March 1995; pp. 757–766.
5. 5.Oh, J.; Choi, S.; Kim, J. Numerical simulation of an internal flow field in a uniflow cyclone separator. Powder Technol. 2015, 274, 135–145.

Received: 09-02-2025 *Revised: 18-03-2025* *Accepted: 18-04-2025*

6. 6.Duangthongsuk, W.; Wongwises, S. An experimental investigation of the heat transfer and pressure drop characteristics of a circular tube fitted with rotating turbine-type swirl generators. Exp. Therm. Fluid Sci. 2013, 45, 8–15.
7. 7.Varava, A.N.; Dedov, A.V.; Zakharov, E.M.; Malakhovskii, S.A.; Komov, A.T.; Yagov, V.V. Study of pressure drop and heat transfer in a swirl flow with one-sided heating in a range of heat flowrates below boiling crisis. Therm. Eng. 2009, 56, 953–962.
8. 8.Lee, C.; Na, Y.; Lee, J.W.; Byun, Y.H. Effect of induced swirl flow on regression rate of hybrid rocket fuel by helical grain configuration. Aerosp. Sci. Technol. 2007, 11, 68–76.
9. 9.Fokeer, S.; Lowndes, I.; Kingman, S. An experimental investigation of pneumatic swirl flow induced by a three lobed helical pipe. Int. J. Heat Fluid Flow 2009, 30, 369–379.
10. 10.Derksen, J.J. Simulations of confined turbulent vortex flow. Comput. Fluids 2005, 34, 301–318.
11. 11.Li, H.; Tomita, Y. Particle velocity and concentration characteristics in a horizontal dilute swirling flow pneumatic conveying. Powder Technol. 2000, 107, 144–152.
12. 12.Bali, T.; Sarac, B.A. Experimental investigation of decaying swirl flow through a circular pipe for binary combination of vortex generators. Int. Commun. Heat Mass Transf. 2014, 53, 174–179.
13. 13 Fellouah, H.; Castelain, C.; Ould-El-Moctar, A.; Peerhossaini, H. The Dean instability in power-law and Bingham fluids in a curved rectangular duct. J. Non-Newton. Fluid Mech. 2010, 165, 163–173.
14. 14.Pinho, F.T.; Whitelaw, J.H. Flow of non-Newtonian fluids in pipe. J. Non-Newton. Fluid Mech. 1990, 34, 129–144.