Numerical simulation of bottomhole flow filed of PDC bit with side nozzles

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Abstract

To analyze the effects of a steerable nozzle on the flow field at the bottomhole, CAD software in conjunction with Gambit is used to design PDC drill bit models with steerable nozzles. Fluent flow modelling was then used to perform flow simulations at the bottom of the hole. The research results show that the assemblage of steerable nozzles has maximized the hydraulic energy of two jet streams to enhance drill cuttings cleaning and minimize the formation of mud in drill mud PDC to ultimately improve the mechanical drilling rate.

Introduction

For conventional nozzles (single-hole nozzle drill bit), there one stream from the nozzle outlet so it is not possible to maximize the effect of the hydraulic energy of the jet stream in the bottomhole and drill bit surface cleaning. In order to overcome this phenomenon experts have proposed a plan for designing new nozzles, called the steerable nozzles, installed on the drill bit.

This nozzle type appeared as early as in 1962 and was installed to a 3-cone rotary drill bit. In 1998, Winton and Dickey carried out installation of a steerable nozzle on a PDC drill and yielded good results [1]. In recent years steerable nozzles has been extensively used, proving their superiority in terms of cleaning surface and bottomhole drill during drilling [2].

To analyze the effects of steerable nozzle of PDC drill on bottomhole flow field, the author has used the combination of CAD software in conjunction with Gambit to design a steerable nozzle PDC drill simulation and then applied fluent flow modelling to examine simulated characteristics of the flow field of the steerable nozzle in the bottomhole.

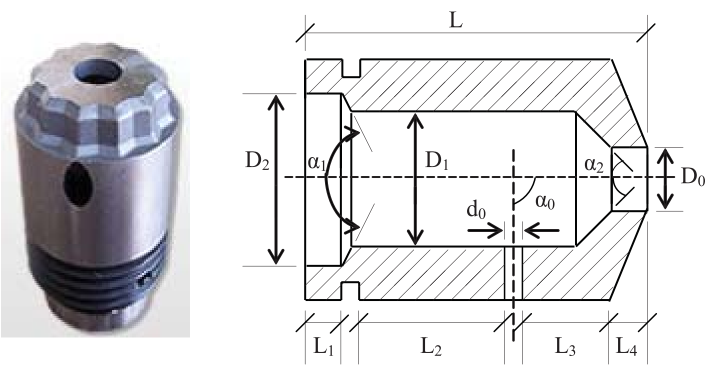

Fig. 1. The structure of directional nozzle
L: Length of the nozzle; D_2: Diameter inlet of the nozzle; D_1: Diameter in of the nozzle; D_0: Diameter outlet of the main nozzle; d_0: Diameter outlet of nozzle on the body; α_2: Spray angle outlet of the main nozzle; α_0: Spray angle outlet of nozzle on the body; α_1: Spray angle inlet of the nozzle.

1. Steerable nozzle assemblage

The structure of steerable nozzles when compared with conventional nozzle has one or more extra nozzles on the body of spray. called a tilt steerable jet stream (Fig. 1).

The assemblage parameters of nozzle geometry including size and shape of the nozzle flow path... Depending on the size and type of PDC drill, the parameters of the nozzle will be determined [3].

The direction of the jet axis and tilt axis of the spray nozzle forms an angle (α_0) that is controlled in the range from 45 to 90 degrees, the magnitude of α_0 being influenced by the assemblage of the drill. If using small angle smaller than 45 or greater than 90, the flow direction injection nozzle flows will impact directly on the body of the drill bit or the impact with drilling equipment on the borehole surface that ultimately reduces the efficiency of cleaning surface and bottomhole drill orientation of the nozzles [4].

The diameter outlet of the main nozzles (D_0), the diameter outlet of the nozzles on the body (d_0) and the distance between them (L_0) has a strong influence on the hydraulic characteristics of the jet stream. To ensure the outlet energy of the nozzles outlet is stable, the diameter (d_0) must be relatively smaller than the (D_0) and must meet the conditions $0.2 < d_0/D_0 < 0.4$. In addition, when choosing the nozzle diameter it is necessary to ensure no clogged jets by large particles of drilling mud flowing back into the injector pump when pumping is stopped [5].

2. Modern design and calculation conditions

The calculation parameters were selected as follows: drill diameter is 215.9mm diameter in of the nozzle D_1 = 15mm, flow rate of inlet nozzle Q = 32L/s, speed of the nozzle inlet 45.3m/s, the diameter of the nozzle outlet is designed as D_0 = 9mm and d_0 = 3mm, distance between nozzles L_0 = 10mm), relative angle of the jet flow direction inclined to the main injection was designed as α_0 = 45 and α_0 = 60, rotary drill bit speed is 120rph, working fluid is water.

The azimuthal position of the nozzle is determined according to four directions A, B, C, D along OO relative azimuth and is distinguished by the clamp angle 62, 38, 60, 35, and must ensure that all the bottomhole is covered by the spray from the nozzle. The installation locations of the nozzles are arranged on the circumference of a circle with various radii from the center of the nozzle to the central axis. Moreover, in order to clean the mud at the bottomhole and the mud layer covered drill strings, the jet flow direction of the main spray nozzle (diameter D_0) is tilted at a suitable angle, and the jet flow direction of the tilt nozzle (diameter d_0) must be arranged parallel to the surface of the appropriate blades (Fig.2) [6].

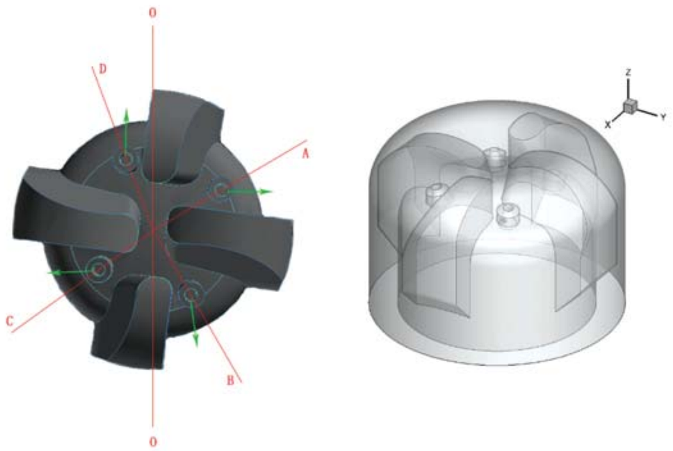

Fig. 2. *Nozzle arrangement diagram*

When designing the model parameters, the three-dimensional model of PDC drill steerable nozzle and the physical model of the flow field flow at the bottom of the well were designed in CAD software in combination with Gambit in order to optimize the designed models. Fluent flow modelling was then used to perform the simulations of efficiency of steerable nozzle to the flow field characteristics at the bottomhole.

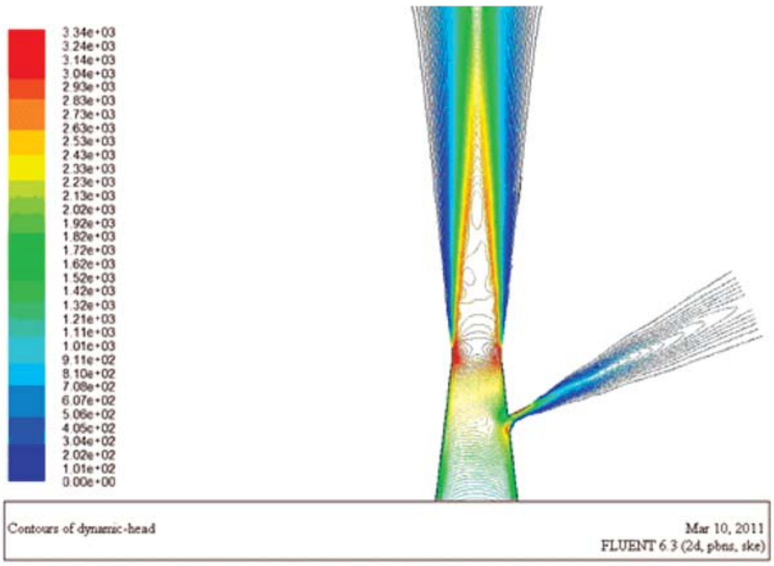

Fig. 3. *The dynamic head isoline of directional nozzle center section ($\alpha_0 = 60^o$)*

3. Analysis of the effects of steerable nozzle to the low current at bottomhole

3.1. The effect of tilt angle (α_0)

Distribution problems inside the nozzle flow is an important indicator in determining the function of a steerable nozzle. The working efficiency of the injector nozzle is always better than a conventional nozzle because of more support from the tilted jet stream in the process of cleaning the drilling mud covered drill bit. The scope of coverage and speed of the tilted jet stream will determine the efficiency of cleaning the mud. When the angle (α_0) is small, the distribution characteristics of the flow in the nozzle is relatively good,, creating high spray rate and extent of the coverage of tilted spray that consequently benefits the cleaning and limits the mud formation in the drill bit [7]. Based on the limited angle ($45 \le \alpha_0 \le 90$) and in order to create favourable conditions for the spray manufacturing processes, the values of α_0 = 60 and α_0 = 45 were chosen to conduct simulation.

The result of the simulation process is shown in Fig. 3 and Fig. 4, confirming that with a smaller angle the spray coverage and the speed of the spray would be better. So, when designing steerable nozzles installation on PDC drill, the selected angle α_0 = 45 is the most appropriate one to create good and effective cleaning and limit the formation of mud in the drill bit. It also makes for conveniences in manufacturing steerable nozzles.

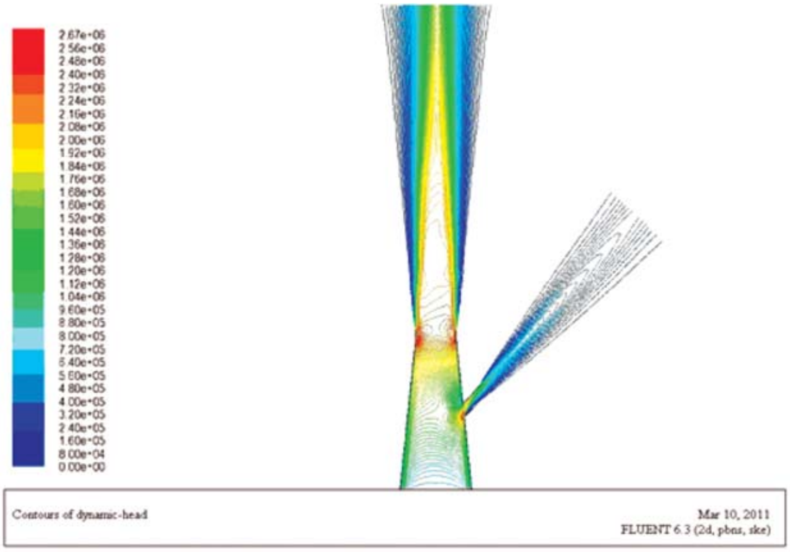

Fig. 4. *The dynamic head isoline of directional nozzle center section ($\alpha_0 = 45^0$)*

3.2. Effect of steerable nozzle on the flow field at the bottomhole

The influence of a conventional nozzle on the flow field at the bottomhole is categorized into four main areas: the impact area, the flow out area, the counter flow area and the turbulent flow area [8]. The impact area supports the more effective process of destroying rock, the flow out area helps cleaning drill cuttings from the bottomhole, the counter flow area carries drill cuttings to the surface, while the turbulent flow region, due to the flow rate, speed and pressure is relatively low, and prevents the upward push of drill cuttings. Therefore, to limit the influenced region of the turbulent flow area and to support mud cleaning processes, the steerable nozzle is proved to work very well when compared to a conventional nozzles. The result of simulation is displayed in Fig. 5 and 6.

From Figs.5 and 6, it was shown that when compared with a conventional nozzle, the spray assemblage of the steerable nozzle raises some issues with the participation of the tilted jet stream. In the flow out area of the main jet stream, the further support of a tilted stream is recognized, which is very beneficial to the process of cleaning drilling cuttings at the bottomhole. Simultaneously, in the area of turbulent flow of the main jet stream with strong support from the tilted jet stream, there would form a new impact flow area which, though weaker than that of the main jet stream, works very well to reduce the coverage area of the turbulent

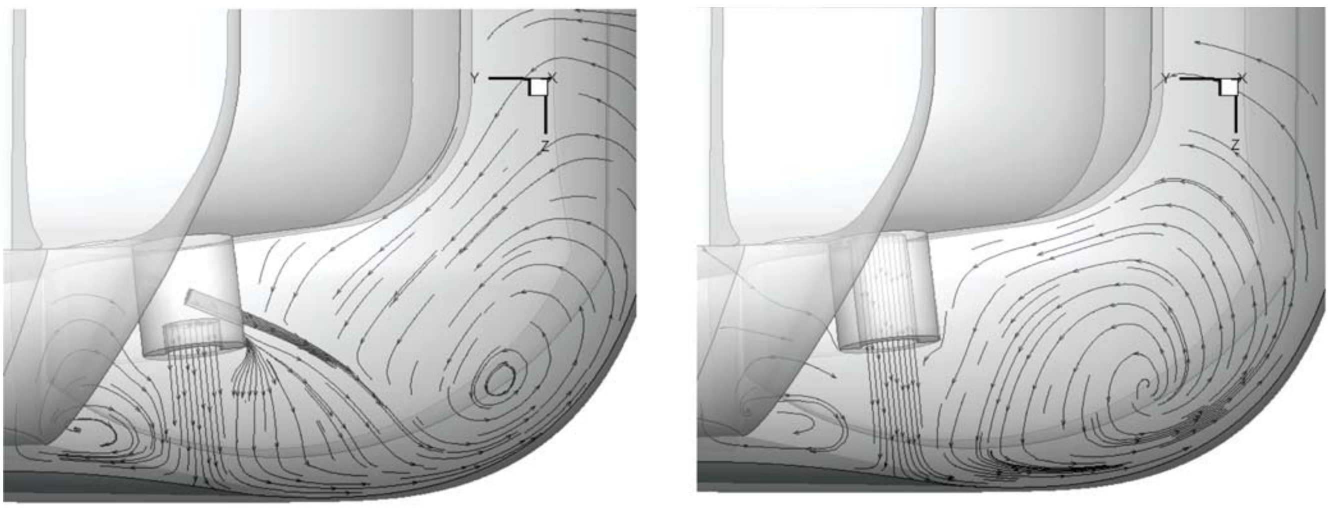

Fig. 5. *The flow graph of bottom - hole section (a - directional nozzle; b - conventional nozzle)*
1 - The impact area; 2 - The flow out area; 3 - The counter flow area; 4 - The turbulent flow area.

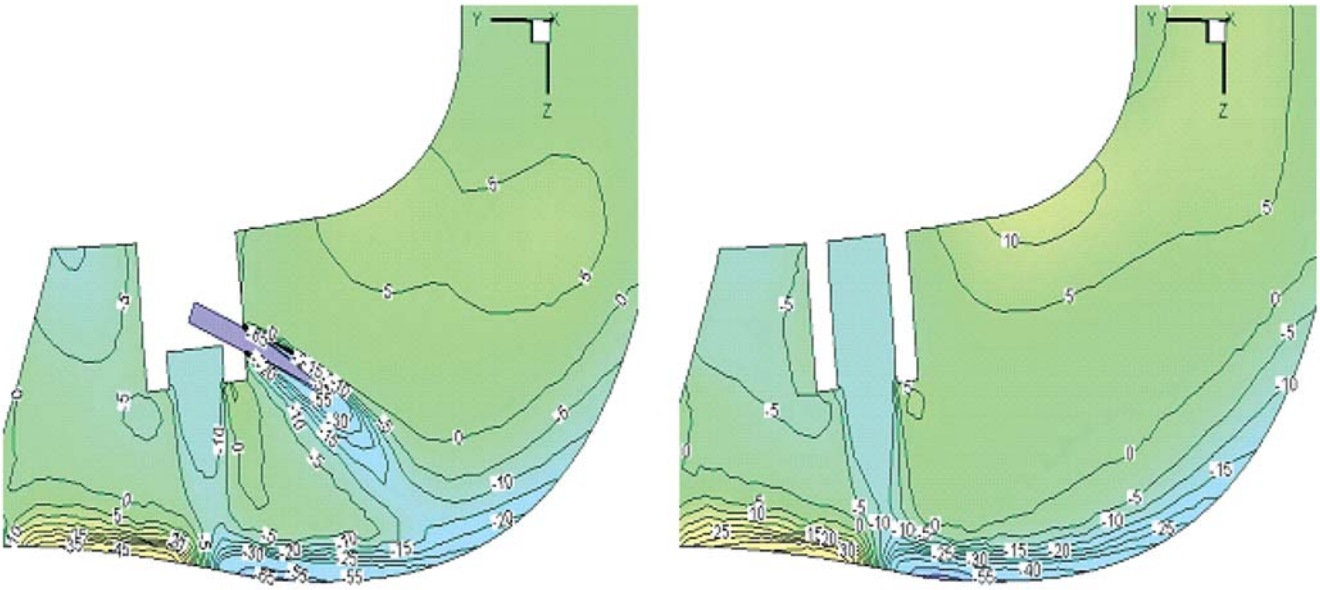

Fig 6. *The isoline of bottom lateral velocity (a - directional nozzle; b - conventional nozzle)*

flow, which is extremely beneficial for pushing the drill cuttings up, to improve the efficiency of the drilling.

4. Conclusion

The following conclusions could be inferred from the results of flow field simulation at the bottomhole to analyze the effects of steerable nozzles:

1) the relative deviation angle of the tilted and the main jet spray α_0 = 45 is the most appropriate angle to support the efficient cleaning of drill cuttings and preventing the formation of mud on PDC drill bit, as well as making favourable conditions for the manufacturing of the steerable nozzles.

2) With the same simulation conditions, when compared with conventional nozzles, the steerable nozzles with support from a tilted jet stream, enhances drill cuttings cleaning at the bottomhole, and reduce the coverage area of the turbulent flow area to accelerate the process of transporting drill cuttings to the surface and ultimately to improve the efficiency of drilling.

References

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