A Novel Method for Simulate the Drilling Fluid Filtration Under Dynamic Conditions

H. Movahedi, S. Jamshidi*
Sharif University of Technology, Azadi Av, Tehran, jamshidi@sharif.edu

Abstract
Efficient fluid filtration could lead to formation damage reduction and the stuck pipe minimization in over-balanced operations. Filtration volume depends not only on the rheological properties of the drilling fluid but also on the static or dynamic conditions of mud in the hole. In static conditions, the mud cake formed on wellbore increases and filtrate volume decreases continuously with time. However, at the real condition in well, due to mudflow circulation, the mud cake deposited on wellbore will be eroded and the volume of filtrate loss in near-wellbore could be increased. In this study, a novel method for measuring and modeling the filtration phenomenon under dynamic conditions has been conducted. A filtration cell using an agitating system that can be measuring the rheological changes of drilling fluid due to the loss of the base fluid of drilling mud has been developed. Afterward, in order to model the wall shear stress on the mud cake face, a CFD simulation was performed. The results show that this method is useful and operational for modeling of mud filtration under dynamic conditions.

Keywords: Mud Filtration, Dynamic mud Filtration, Filtration Cell, CFD Simulation.

Introduction
In petroleum drilling industry, researchers have concentrated on optimizing the operational parameters in order to reduce the drilling costs and minimize drilling time. Hydraulic system as one of the most crucial systems in drilling operation plays the substantial role in properly reducing drilling costs and time. The hydraulic system performance essentially depends on drilling fluid properties. Specifically, the hydraulic system and rheological properties of drilling fluid are utterly interdependent and influenced by each other [1]. The basic functions of drilling fluid such as hole cleaning, filtration loss control, bit cooling and lubricating are mainly affected by the drilling fluid properties. Therefore, optimized hydraulic system performance could be achieved through appropriate drilling fluid design.

Formation damage reduction and the stuck pipe minimization in over-balanced operations could be achieved through efficient fluid filtration control. Filtration volume depends not only on the rheological properties of the drilling fluid, but also on the types of additives used for mechanical filtration control. Blend of fibers, cellulose, mica, modified hydrocarbons, ground walnut shells, and starch are the most prevalent lost circulation materials (LCM) which are applied for mechanically filtration control. Gunawan et al. [2] modeled formation damage caused by drilling fluid filtration in the radial system. Farahani et al. [3] proposed a
mathematical model in the radial system of coordinates to estimate the rate of filtrate invasion into a homogenous formation and the mud cake thickness as a function of time in a dynamic filtration process. They indicated that the mud cake thickness formed on the wall reaches a certain value in dynamic filtration. Low injectivity and permeability of damaged formation due to filtrate invasion was studied by Bennion [4]. Thickness and quality of mud cake formed on the wall are the other significant properties of drilling fluid. Barry et al. [5] investigated rheological and filtration properties of drilling fluids containing bentonite enhanced by nano particles. It was observed that nano particles cause reduction in filtration through distributing clayey plates.

Formation damage reduction and the stuck pipe minimization in over-balanced operations could be achieved through efficient fluid filtration control. Filtration volume depends not only on the rheological properties of the drilling fluid, but also on the types of additives used for mechanical filtration control [6, 7].

As seen in literature, the researcher have concentrate on static filtration condition while at the real condition in well, due to mudflow circulation, the mud cake deposited on wellbore will be eroded and the volume of filtrate loss in near-wellbore could be increased. In this study, a novel method for measuring and modeling the filtration phenomenon under dynamic conditions has been conducted. A filtration cell using an agitating system that can be measuring the rheological changes of drilling fluid due to the loss of the base fluid of drilling mud has been developed. Afterward, in order to model the wall shear stress on the mud cake face, a CFD simulation was performed. The results show that this method is useful and operational for modeling of mud filtration under dynamic conditions.

**Apparatus Design**

Filtration characteristics of the drilling fluid are evaluated by the filter press apparatus which is a pressurized cell and fitted with a filter medium. This experiment is at both LP/LT and HP/HT conditions. The schematic of API LP/LT filter press is shown in Fig. 1. This apparatus consists of a cylindrical mud cell with the standard inner diameter and height. Moreover, a filter paper with the standard mesh size is placed at the bottom of the cylinder to remove the solid particles presented in the drilling fluid. The working procedure for this apparatus is available in API RP 13B-1 [8, 9].

![Fig. 1 The schematic of API LP/LT filter press](image-url)
The filtration process under the dynamic conditions in which the slurry is being circulated over the filter cake so that the cake is simultaneously eroded and deposited. The following equations describe the deposited rate of particles in the mud cake under dynamic conditions. The erosion rate depends on the shear rate of the fluid at the face of the cake. In order to achieve this goal, an apparatus with a special spindle has been constructed. Fig. 2 shows the schematic of dynamic filtration cell. Fig. 3 shows the dynamic filtration apparatus. Fig. 4 shows the spindle with different sizes of connectable rotation disk in order to imply various shear rates on the mud cake surface. The electrical motor connected to the spindle can rotate the discs with different rotational speeds from 10 to 1000 rpm. The volume of filtrate loss can be measured by an accurate and real-time sensor. The pressure on the confined cell also can be measured in real-time with a special pressure transducer sensor.

![Fig. 2 Schematic design of dynamic filter press](image)

![Fig. 3 Dynamic filter press apparatus](image)
Results and discussion
A CFD simulation was conducted in order to determination of wall shear stress distribution on the mud cake surface. The geometry and mesh of the cell body as a continuum media are depicted in Fig. 4. To simulate the flow field in the cell body due to rotation of the different spindles, the Fluent (6.3.26) software is used. The Eulerian two-phase model has been applied to a three-dimensional system for accurate modeling of slurry agitating flow in the cell body. The computational grid was created for geometry which indicates in Fig.4. The structured grid is used in the simulations and the computational domain consists of 10000 nodes. The grid was generated using GAMBIT 2.4.6, which is compatible with FLUENT 6.3.26.

Fig. 4 shows the velocity and wall shear stress distribution around the rotating disc and on the membrane surface. The mud cake deposited on the membrane would be reduced due to the wall shear stress. Fig.7 shows the total filtration loss of a mud sample with rheological
properties of 33 cp and a density of 8.9 ppg for 30 min. As shown the filtration rate in the dynamic condition is higher than the static condition.

![Flow velocity distribution and Wall Shear Stress](image)

**Fig. 5 Flow velocity and wall shear stress distribution**

![Filtration loss in the static and dynamic conditions](image)

**Fig. 6 Filtration loss in the static and dynamic conditions**

**Conclusions**

In this study, a novel method for measuring and modeling the filtration phenomenon under dynamic conditions has been conducted. A filtration cell using an agitating system that can be measuring the rheological changes of drilling fluid due to the loss of the base fluid of drilling mud has been developed. Afterward, in order to model the wall shear stress on the mud cake face, a CFD simulation was performed. The results show that this method is useful and operational for modeling of mud filtration under dynamic conditions. The experimental procedure has been performed on a simple bentonite mud. The results indicate that under the
dynamic conditions and 100 Psi differential pressure, the filtration loss of mud sample is higher than static conditions due to mud cake erosion.

References


