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A mathematical model of the motion of cutting particles in reverse circulation air drilling

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ABSTRACT

In reverse circulation air drilling, the cutting particles are carried by compressed air to the central channel at the bottom of the borehole and then up to the surface. Keeping the bottom of the borehole clean is a difficult; thus, a mathematical model was proposed for studying the motion of cutting particles. The model describes the motion of cutting particles in the radial and axial directions. In the radial direction, the aerodynamic drag force and frictional force of the rock were considered. The relationships among the radial velocity of the particle, the particle size, and the friction coefficient of the rock were obtained by calculating the model. The particle size was significantly affected, and the results were employed to design the structure of the bit. In the axial direction, the model was built by considering the aerodynamic drag force, the frictional force of the drill pipe, and the weight of particles. The cutting particles with the same size exhibited the same axial velocity, although they entered the central channel with different initial velocities. The results would be helpful in estimating the demand of air volume. To verify the effects of particle size on axial velocity, the axial velocity of cuttings from the Lunchuang field with different particle sizes was measured. The results showed that the application condition of the axial model is that the air velocity and the particle size produced by the advancement of the bit were in harmony, or the approximate circular particles were produced by normal drilling.

1. Introduction

Air and gas drilling technology utilizes compressed air or other gases as rotary drilling circulating fluid to carry the rock cuttings generated at the bottom of the borehole by the advancement of the drill bit to the surface. This technology has been used since the 1950s [2]. This technology enhances the rate of penetration in hard formations [4] and addresses the problem of circulation loss in depleted and naturally fractured reservoirs [7,11,13,23]. Two general types of air and gas drilling methods are used in petroleum engineering: direct circulation and reverse circulation.

Reverse circulation air drilling is primarily used for straight boreholes. Using air as the drilling fluid (Fig. 1), this drilling method involves the injection of compressed air into the top of the annulus between the dual wall drill pipe, the flow of air down the annulus to the bottom of the borehole, the entraining of the rock cuttings into compressed air at the bottom of the borehole as the air sweeps past the bit cutting face, and the flow of compressed air with the entrained cutting particles inside the central channel, and then up to the surface [26]. One of its advantages is that the full hole reverse circulation of the fluid

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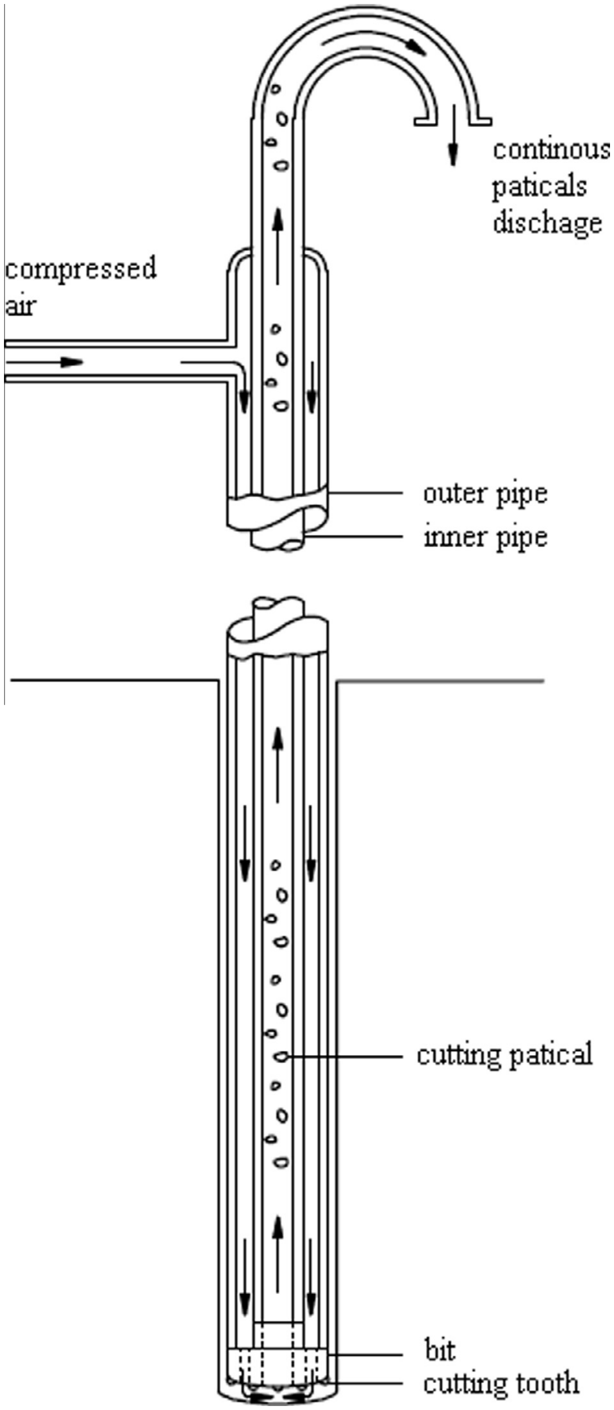

Fig. 1. Dual wall drill pipe closed reverse circulation operation.

medium and the continuous return of rock cuttings are achieved. That is, the reverse circulation system is a closed system. Hence, the air injection volume is proportional to the air velocity [9]. The effectiveness of this technology depends on whether or not the cuttings can be carried to the central channel at the bottom of the borehole and then up to the surface. The air velocity should satisfy the demand of continuous return of rock cuttings to keep the bottom of the borehole clean. Thus, to study the motion of the cutting particles in the compressed airflow is useful.

Researchers have already studied the motion of cuttings in direct circulation air and gas drilling [16,10,18,20,22,30]. In this drilling method, cuttings are carried to the surface through an annulus between the wall of the wellbore and the