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Analytical and experimental research on erosion wear law of drill pipe in gas drilling

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ABSTRACT

Erosion of drill pipe caused by the rock particles in annular space is very serious in gas drilling. The aim of this paper is to study the erosion wear law of drill pipe by theoretical derivation and laboratory experiment. Based on the micro-cutting model of single rock particle, the erosion model of drill pipe is established to calculate the erosion wear loss. This model establishes the relationship between the erosion wear loss of drill pipe and drilling parameters, such as gas injection volume and rate of penetration (ROP). The laboratory experiment is carried out to verify and revise the erosion model, and the results show that when ROP is less than 20 m/h, the erosion wear loss of drill pipe is approximatively proportional to the square of gas injection volume and has positive correlation with ROP. However, it has negative correlation with ROP when ROP is faster than 20 m/h. In addition, it is also obtained that gas injection volume has more impact on drill pipe erosion compared to ROP based on the analysis of an engineering example, and high ROP will suppress the erosion wear of drill pipe. Therefore, under the premise of satisfying the drilling requirements, employing lower gas injection volume and higher ROP can reduce drill pipe erosion in gas drilling, which will save the drilling cost greatly.

1. Introduction

Gas drilling is a kind of under-balanced drilling technology using high-speed gas to carry cuttings to surface, which can improve the production capacity of oil gas well significantly [1]. However, high-speed cuttings-carrying flow erodes drill pipe persistently, especially for drill pipe joint [2]. It is clearly observed from Fig. 1 that cracks and erosion pits present on the drill pipe surface in gas drilling, easily causing drill pipe fracture and washout, or even personal casualty. The statistics show that the drill pipe would lose 1–10 kg/m due to flow erosion in gas drilling. Just in 2014, erosion wear accidents account for 65% of the total failure accidents of dill pipe in one gas field in China. Therefore, it has great practical value to study the erosion wear law, in order to reduce drill pipe erosion in gas drilling.

Several scholars have studied the erosion phenomena and erosion profile prediction [3–7]. Their findings suggest that the velocity of erosion particles, material properties and impact angle are the most important factors of erosion [8]. In addition, some erosion wear theories were proposed [9–12]. With the development of oil and gas industry, erosion wear of drill pipe has become the research hotspot [13,14]. Wei [15] proposed a cuttings-carried theory and modified the critical cuttings-carried model for the gas-solid flow in gas drilling. Due to the complexity of the practical drilling conditions, the field and laboratory experiment studies of drill pipe erosion

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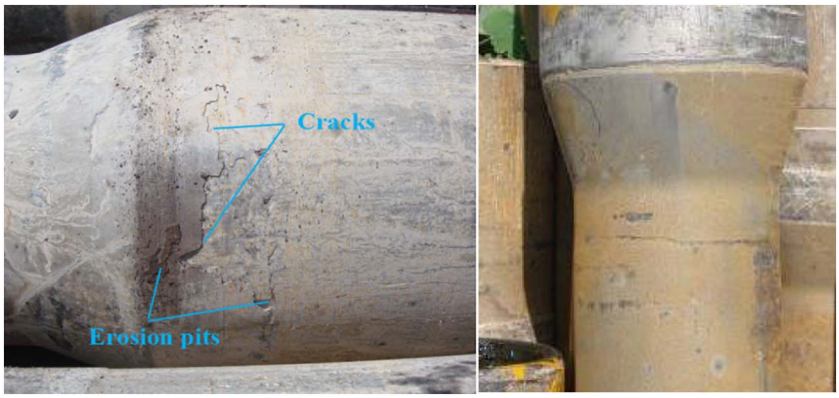

Fig. 1. Cracks and erosion pits on the drill pipe surface.

are very difficult. Therefore, computational fluid dynamics (CFD) is more and more wildly employed. Zhu [16] investigated the factors affecting the erosion rate of drill pipe in gas drilling using the CFD methodology. The impacts of gas velocity and drill pipe eccentricity on erosion rate were reasonably captured. Zhu and Liu [2,17,18] investigated drill pipe erosion in gas drilling using CFD simulation technique, obtaining the erosion rate of drill pipe along with different factors of gas drilling. Ming [19] established the CFD model of drill pipe erosion in gas drilling, and researched the effects of different gas drilling conditions on the trajectory and distribution of cuttings and gas velocity. In conclusion, there are few references available to the theoretical derivation of drill pipe erosion model. The mathematic relation between the erosion wear loss of drill pipe and the key drilling parameters in gas drilling has not yet been reported.

In this paper, the erosion model of drill pipe is established based on the micro-cutting model of single rock particle. In order to verify and revise the erosion model, the erosion experiment of drill pipe is implemented in laboratory. The revised erosion model establishes the relationship between the erosion wear loss of drill pipe and drilling parameters. The analysis of an engineering example is carried out, and the conclusions will assist engineers to optimize drilling parameters to reduce drill pipe erosion in gas drilling. This is an important way to decrease the drilling cost.

2. Theoretical derivation of drill pipe erosion model

In order to study the effects of drilling parameters on drill pipe erosion in gas drilling, the erosion model of drill pipe is established by theoretical derivation. Given the complexity of the erosion process, the micro-cutting model of single rock particle is analyzed firstly.

2.1. Micro-cutting model of single rock particle

When single rock particle carried by gas flow hits the drill pipe surface at impact velocity $U$and impact angle α, its motion can be divided into three sections: the intrusion movement perpendicular to the drill pipe surface, the cutting motion parallel to the drill pipe surface and the arc movement of the touch point, as shown in Fig. 2. The barycenter of rock particle is O, and its coordinated system consists of X, Y and θ. The location of the touch point between rock particle and drill pipe is determined by X_T and Y_T.

In order to establish the mathematical model, five assumptions are introduced: (1) The turbulence of injected gas is not

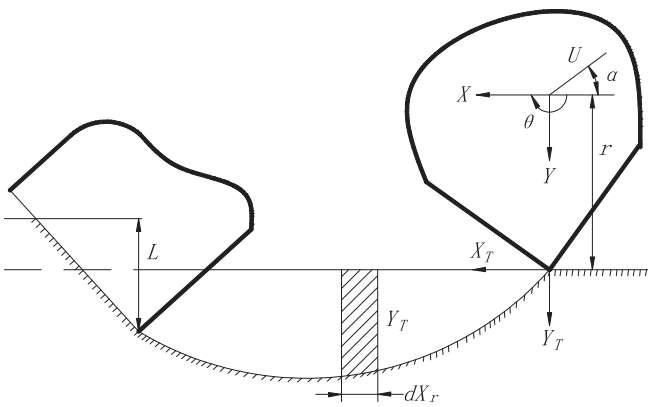

Fig. 2. Micro-cutting model of single rock particle.