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Simulation analysis of flow field and shear stress distribution in internal upset transition zone of drill pipe

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ABSTRACT

Perforation in internal upset transition zone is one of the main failure styles for drill pipes. Due to the flow channel specificity of upset transition zone, in this paper, drill pipe failure analysis from the point of flow erosion was put forward. Flow field of drilling fluid in the internal upset transition zone of Φ127 mm API IEU S135 drill pipe under various conditions were obtained using finite volume CFD solver FLUENT 13.0. Pressure, velocity and wall shear stress distribution in upset transition zone indicated the erosion of flowing fluid on drill pipe. The type and displacement of drilling fluid and the structure of internal upset transition zone exert great effects on the flow field. Under the same displacement of drilling fluid, mud shows the most severe erosion effect. And the larger the displacement, the more obvious is the washout. An increase in length or radius of the transition can weaken the flow erosion.

1. Introduction

Drill pipe failure is an outstanding problem in drilling engineering, which gives rise to great financial losses. Perforation in internal upset transition zone is one of the main failure styles for drill pipes (Fig. 1). From Li's surveys [1], 65.7% failure occurred in upset transition zone in 108 failure accidents of 16 oil fields in China. Taking Tarim oil field for example [2], the failure frequency caused by perforation in upset transition zone has been increasing each year. Many Φ127 mm API IEU S135 drill pipe failures of perforation occurred after 2000 h of pure drilling time with 80–120 rpm rotary speed in wells, whose depths are more than 2000 m. Just in 2004, such drill pipe failure accidents were more than 170.

Previous drill pipe failure studies have mainly focused on finite element stress analysis or failure statistics [3–5]. The impact of drilling fluid on drill pipe is generally ignored. However, sudden change of flow field presents in the internal upset transition zone due to the change of flow channel. The fluctuation of pressure and the existence of local low-pressure aggravate the flow impact on drill pipe. Therefore, it is very urgent to do drill pipe failure analysis from the perspective of flow erosion.

Several studies have been performed in attempts to explain flow erosion. Ranjbar [6] reported that the changes of fluid velocity inside tubes may cause severe erosion. Arefi et al. [7] proposed that erosion can be reduced by decreasing the fluid velocity. Ferng [8] pointed out that the geometry of flow channel presents obvious effect on flow erosion. Thus, flow field of drilling fluid in drill pipe may be one of the important factors governing erosion. In this paper, simulation analysis of flow erosion in internal upset transition zone of Φ127 mm API IEU S135 drill pipe has been performed. Based on computational

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Nomenclature

ρ	density of drilling fluid
ρ_l	density of liquid
ρ_g	density of gas
v	velocity of drilling fluid
v_l	velocity of liquid
v_g	velocity of gas
v_x	*X* direction velocity
v_y	*Y* direction velocity
α	volume fraction of gas
τ	viscous stress
p	pressure
F	other volume force
g	gravitational acceleration
k	turbulent kinetic energy per unit mass
ε	turbulent kinetic energy dissipation rate per unit mass
μ	dynamic viscosity
υ	molecule kinetic viscosity
G_k	production term of turbulent kinetic energy due to the average velocity gradient
G_b	production term of turbulent kinetic energy due to lift
Y_M	impact of compressible turbulence inflation on the total dissipation rate
E	time-averaged strain rate
$C_{1\varepsilon}$	empirical constants taken as 1.44
$C_{3\varepsilon}$	empirical constants taken as 0.09
C_2	empirical constants taken as 1.9
σ_k	Prandtl numbers corresponding to turbulent kinetic energy
σ_ε	Prandtl numbers corresponding to turbulent kinetic energy dissipation rate

fluid dynamics (CFD), finite volume method was employed to obtain pressure, velocity and wall shear stress distributions under different drilling methods, different drilling fluid displacements or different structures of upset transition zone. Then the impact of each factor was analyzed concretely.

2. Numerical procedure

2.1. Governing equations

Flowing fluid is different in different drilling method. For conventional mud drilling, non-Newtonian liquid is flowing in drill pipe. For air drilling, compressible gas acts on the drill pipe. And gas–liquid two-phase flow presents in foam drilling. The universal averaged Navier–Stokes equations were solved to obtain the flow field of drilling fluid in internal upset transition zone [9,10], which express the conservation of mass and momentum:

$$\frac{\partial \rho}{\partial t} + \nabla(\rho v) = 0 \qquad (1)$$

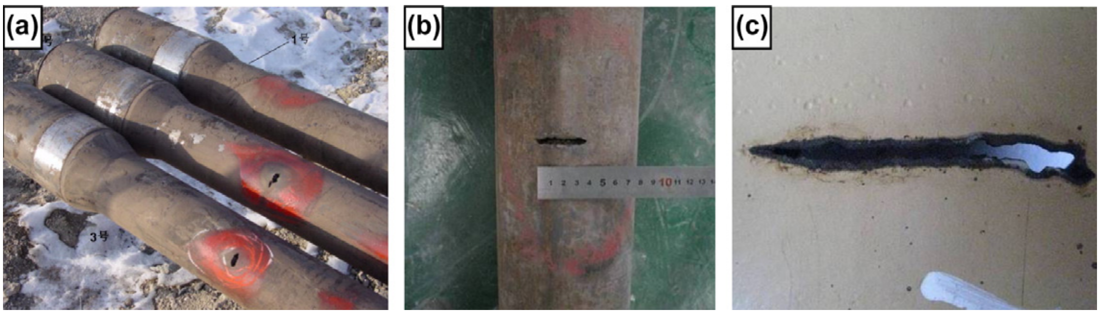

Fig. 1. Macro photographs of failed drill pipes due to piercement in internal upset transition zone: (a) failure site; (b) a perforation seemed from outside and its size; (c) a perforation seemed from inside.