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A discrete Element Simulation for the Effects of In-situ Stresses on the Mechanical Specific Energy of PDC Drill Bits

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INTRODUCTION

Among the influential factors of Rate of penetration (ROP) in oil well drilling bits, i.e. the mechanical properties of rock, the drill type, the weight on drill (WOB), the revolution per minute (RPM), the hydraulic drill head, the drilling mud and the bottom hole pressure; the effect of in situ stresses is of paramount importance [1]. The value of Δp demonstrates the well situation in terms of under balance, balance and over balance. In each of these wells, along with temperature and speed of the rotating bits, the deformation mechanism of rock and its failure process makes the drilling operation harder [2,3] The researchers succeeded in simulating the effects of the weight on drill (WOB), the revolution per minute (RPM) of the drill bit, bottom hole pressure by using the numerical method such as finite element method (FEM) and also using the numerical software of particle flow code to investigate the impact of these factors on the rate of penetration and mechanical specific energy [4,5]. In this study, the numerical method (distinct element method) is used to understand the relationship between rock fracture and confining pressure and its effect on the mechanical specific energy. The unconfined compressive strength (UCS) test is used to validate the micromechanical parameters of limestone which are need to simulate the geo-mechanical problem. Then by simulating the weight on drill, drilling mud pressure and bottom-hole pressure, the mechanism of rock cutting process by PDC drill bits was analyzed.

NUMERICAL SIMULATIONS

Numerical simulations of the model samples have been accomplished based on the unified

compressive strength (UCS) values gained from the laboratory testing results.

SAMPLE PREPARATION

In this research, the micromechanical properties of the modeled samples are adjusted based on the macro-mechanical values gained from the unified compressive strength tests carried out in the laboratory. The micromechanical properties of a typical lime stone is used for validating and performing the simulation models for the rock cutting process due to rock drilling PDC bits.

SIMULATING THE PDC CUTTING TEST

To simulate the rock cutting process due to drilling bits under confined pressure conditions, a sample test with a dimension of 150x40 mm is designed and a single PDC cutter with a diameter of 13 mm at the bake rake angle, 20 degrees (Figure 1) is assumed. In this process, a constant horizontal speed of 1.5 m⁄s and 10000 N weight on bit at the five different depths (i.e. 0-500-1000-1500-2000) with a 35 mm motion is also considered.

RESULTS AND DISCUSSION

To verify the results of the numerical model, the effect of confining pressure on the mechanical specific energy and its transfer to rock deformation has been investigated. Under confined pressure conditions, a different mechanism is taking place, and the difference in pressure created in the rock structure keeps crushed material on each other and increases the specific energy of the drill bit (Figure 2).

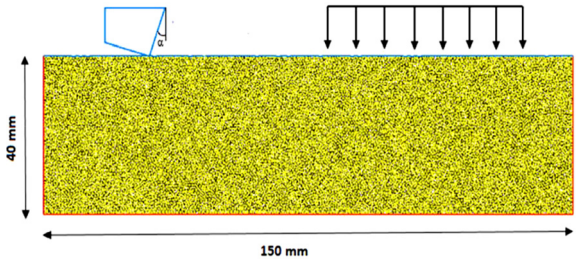

Figure 1: Schematic of numerical simulation.

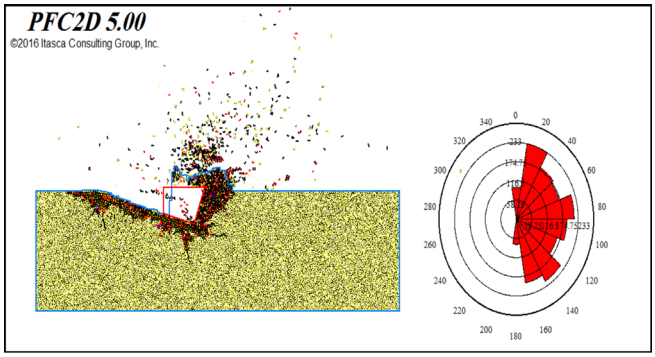

Figure 2: Mechanism of rock fracture in a confining pressure condition for a typical limestone under the cutting action of a PDC drill bit.

CONCLUSIONS

The discrete element method (DEM) can be used to analyze the stress and deformation in underground structures with discontinuities within different environments. In this study, the rock cutting mechanism of PDC drill bits under different circumstances have been modeled using the sophisticated two dimensional particle flow code (PFC2D). It has been concluded that this computer software is able to simulate the

mechanical behavior of rocks due to the rock cutting actions of PDC drill bits used in oil well drilling technology. The main important conclusions gained from this study may be explained as follows:

The force applied to the cutter blade causes the rock failure at the inter-granular connections in a single failure plane under the conditions of no confining pressure.

-On the other hand, under confined pressure conditions, a different mechanism is taking place, and the pressure difference created in the rock structure may crush the rock material and increase the mechanical specific energy of the cutting process.

- Also, up to a confining pressure of about 26 MPa, with increasing tension, the specific energy has a relatively linear increase in its value.

- If the confining pressure goes higher to that of 26 MPa, the incremental increase in the specific energy of the PDC drill bit decreases by increasing the depth of drilling.

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