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PDC Bits : All Comes From the Cutter Rock Interaction

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Abstract

PDC drill bit performances in hard rock has been greatly improved during the last decades by innovations in PDC wear, impact resistance and better vibrations understanding. The bit design is generally done by balancing the bit, distributing uniform wear along the profile and achieving high drillability and steerability. To obtain required drilling performances, drill bit designer adjust features such as profile shape, gage and mainly cutter characteristics (shape, type and orientation). Cutter rock interaction model became a critical feature in the design process. But previously used models considered only three forces on a cutter based on the cutter-rock contact area : drag force, normal force and side force. Such models are no longer valid with the introduction of PDC cutters with chamfer and special shape.

This paper presents a new cutter rock interaction model including some several improvements. It is based on the presence of a build-up edge of crushed materials on the cutting face often described in the literature. In addition, the chamfer, which significantly affects bit Rate Of Penetration (ROP), is taken into account (shape and size). Forces applied on the back of the cutter and due to the rock deformation and back flow of crushed materials are considered in the model. Finally, results of numerous single cutter tests (under atmospheric and confining pressure) are presented and compared to the new cutter rock interaction model predictions. An analysis of the influence of the PDC characteristics (shape, size, chamfer, back and side rake angles, ….) is presented. The model has been applied to optimize the cutting efficiency and bit steerability and some design rules are given to minimize the specific energy and maximize the rate of penetration. Finally, full scale laboratory drilling tests and field results indicate that the use of accurate cutter rock interaction model can help the drill bit designer to find the best drill bit for a specific application. Standard laboratory full scale drilling procedures have been developed. The tests have shown that drillability, stability, steerability and wear can be improved and controlled by acting on the cutter characteristics, cutter setup, trimmer characteristics and gage type.

Introduction

Since their introduction in the 1970's, PDC drill bit performances increase continuously by improving PDC technology[1], cutting structure[2,3], dynamic stability[4,5], hydraulic[6] and steerability[7] to drill more and more smoothly and rapidly. Now, with the development of surface and downhole drilling parameters measurements, real time performance analysis[8] become the key of the future drilling performance improvement. Real time performance analysis allows to optimize the drilling parameters[9] to reach the optimum ROP while post analysis helps the driller to choose the best bit adapted to a specific application.

What is common with the major part of all the previous topics ? The cutter rock interaction process. Indeed, to estimate the bit drillability versus the nature of formations to be drilled, to calculate the imbalance force for stabilization, to determine the bit steerability, we need to know what are the elementary cutter forces and how you can handle them. Furthermore, to optimize the drilling parameters in order to increase the ROP, you need to know the real drill bit response which is a direct function of the cutter rock interaction.

While abondent literature deals with PDC bit design, there is no progress in the cutter rock interaction understanding and modeling since many years. It is generally assumed both in analytical[10,11] and empirical[12] models, that the magnitude of the cutting force acting on a cutter, while cutting a groove in a rock sample, is proportional to the cut surface area. This modeling gives good results with sharp cutter (15° back rake angle) but when you change back rake angle or use chamfered cutters, theoretical results do not fit with experimental results[13] and give higher cutter forces when increase back rake angle compared to experimental results. Although the importance of chamfer and back face cutter have been outlined in some recent papers[1,2], no modelling of these effects on the cutting forces have been done. To improve PDC bit performance and design, it is now very important to take into account this phenomena.

The new cutter rock interaction model presented in this paper consider the effect of side and back rake angle by introducing a build-up edge of crushed materials on the cutting face. The use of crushed materials provided a better force estimation . Chamfer size and shape effects are also modeled as well as rock deformation on the back cutter.

New cutter-rock interaction model has been applied to