Finite element modelling of downhole rock breaking using a PDC bit

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Abstract. The demand of improving drilling productively and reducing the cost of drilling process significantly depends on the efficiency of drilling tools and the understanding of drilling behaviours. The drillstring, which is one of these main tools during the drilling operation, used to drill a hole by transmitting the required torque and drilling fluid to the drill-bit. Due to the tough destructive nature of the drilling process, the drillstring always exposed to various unwanted vibrations that turns the drill-bit to a severe wear and failure along with the other accessories. These vibrations diminish the drillstring life due to its nonlinear occurrence as an excessive axial, lateral and torsional mode. This work provides adequate understanding to the nonlinear drillstring dynamics to predict the premature vibrations and study drilling parameters using a finite element (FE) model that was validated experimentally using a laboratory drilling rig. Riedel Hiermaier Thoma material (RHT) model was adopted in which a series of experiments tests were conducted to identify its parameters. Our numerical results present a strong correlation with the experimental results for analysing the nonlinear dynamics to characterise the effect of drillstring impact and friction with the surrounding states and performing a parametric study to predict the effects of weight on bit and rotary speed on the rate of penetration.

Introduction

The nonlinear dynamics caused by the drillstring, which is a long sequence of connected drill-pipes with other additional equipment are very complicated issue in oilwell drilling. These dynamics are subjected to various nonlinear axial, lateral and torsional vibrations due to the shocks between the drill-bit and rock formation and impacts between the drillstring with the borehole [1]. Therefore, this work aims to investigate the nonlinear drillstring dynamics caused during drilling prospecting to enhance the rate of penetration and non-productive time as well as to avoid the unexpected economic consequences. This study will provide a significant foundation to analyse the nonlinear dynamics and optimise drilling parameters using both experimental and numerical methods (see Fig. 1). The effectiveness of the numerical model is essentially achieved by the employed material model as shown in Fig. 1(c). RHT model was taken into account to formulate the drilling model along with the damage model in both initially vertical wells and then developed to involve horizontal wells [2], see Fig. 1(d). Limited studies were conducted to study the effect of drillstring dynamics during rock breaking with the RHT model in rotary drilling [3]. It is significant to study the drillstring to estimate drilling nonlinearities and optimise drilling parameters for a better production performance.

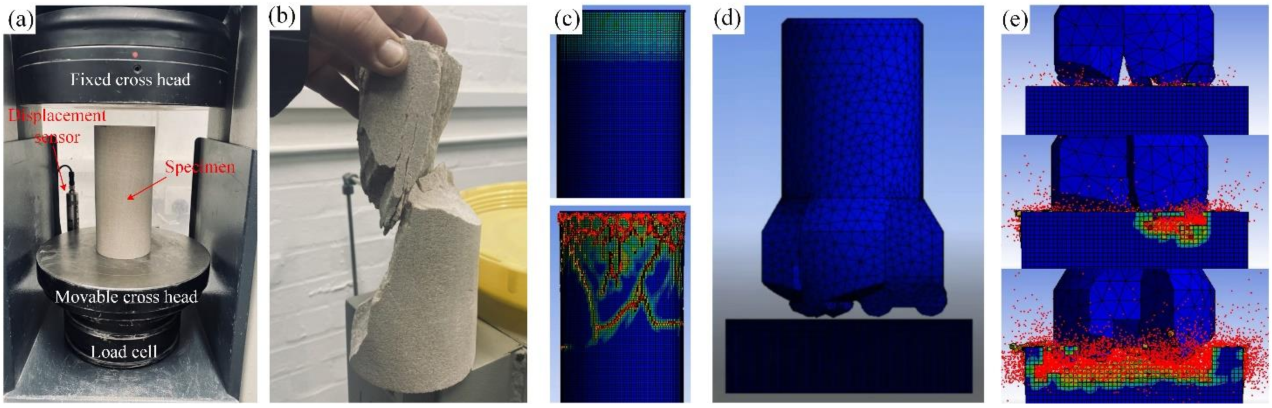

Figure 1: (a) Compressive test and (b) failure; (c) Compressive failure, (d) drilling model and (e) rock breaking via FE modelling.

Results and Discussion

The RHT model was initially verified from various compressive and tensile tests to obtain its parameters for the elastic limit, failure and damage surface that eventually validated with the FE model. The model was convenient to analyse the rock breaking behaviour and consequently relate the drilling performance with the experimental drilling rig results. For instance, at speed 15 rpm, force and torque on bit shows a good agreement for both FE and experimental results as presented in Fig. 1(e). The identified drilling parameters can help to predict drillstring dynamics, so providing timely mitigation methods for undesired instabilities.

References

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