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Rock Strength and Deformability Characterisation and Assessment for Drilling Performance Estimation

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SUMMARY

Rock Strength and Deformability Characterisation and Assessment for Drilling Performance Estimation

Rock drilling and cutting is essential in the mining industry. Rock characterisation and classification methods have been proposed to assess drilling or cutting performance. However, a unique method to relate rock characteristics to rock cutting performance has not yet been developed. This is due to the complexity of interactions among the variables involved in the drilling process encompassing not only rock properties, but also the nature of drilling. Cost-effective drilling is achievable by allocating the available gross energy towards the drilling action and, at the same time, reducing systematically that energy consumed in frictional processes inherent to tool-rock interactions.

Several attempts have been made to assess drilling performance by correlating different rock properties with the drilling rate. For instance, rock texture, grain size, Unconfined Compressive Strength (UCS), Mohs hardness and rock mass structural parameters, and others have been used to build a number of drillability indices. However, not only rock properties, but also different sets of drilling parameters and drilling techniques have an impact on the drilling performance and efficiency of the process.

On one hand, to predict rock drilling performance and optimisation of drilling operation, tool-rock interaction laws, i.e. the relations between forces acting on the tool in contact with rock, are essential. For instance, through tool-rock interaction laws, it was found that during rotary drilling, the energy consumed in pure cutting action of rock is measured by the intrinsic specific energy. In the case of percussive drilling, tool-rock interactions are focused

mostly in the prediction of the penetration rate and the optimum thrust. On the other hand, rock failure characterised by rock brittleness is a concept yet to be investigated as there is not a unique criterion able to describe rock brittleness quantitatively nor consensus about the most suitable and reliable brittleness index to apply to different rock engineering works encountered in the field.

A new brittleness index upon fracture strain-energy quantities extracted from the area under complete stress-strain curve of rocks in uniaxial compressive tests is proposed herein to study drilling performance by rock brittleness capacity. This brittleness index takes into account post-peak instability in uniaxial compression as post-peak instability of rock during compression can be treated as a manifestation of rock brittleness. That is, an increase in the post-peak energy indicates an increase of stability (i.e. a decrease in brittleness or increase in ductility). In the same manner, a dramatic decrease of post-peak energy indicates less stability of the failure process (i.e. an increase in brittleness). In this view, advanced laboratory experiments on strength and deformability of soft-to-hard rock types (UCS is ranging from 7 to 215 MPa) were carried out. The compressive tests complied with the application of a prescribed constant lateral strain-rate as a feedback signal to control the axial load which was found to be a suitable loading rate to measure the complete stress-strain response for the rocks.

The new brittleness index developed herein describes a monotonic and unambiguous scale of brittleness with increasing pre-peak strength parameters such as crack damage stress and peak stress as well as deformation parameters such as the tangent Young's modulus of rock. This outcome becomes relevant in order to better understand material brittleness associated with the progressive fracture process characterised by the typical threshold damage stresses, peak stress and the elasticity parameters. The brittleness index scale indicates that a higher brittleness index means that rock is more brittle which corresponds to higher strength rocks.

In order to reliably estimate drilling performance both tool-rock interaction laws along with a proper rock brittleness index are required to be implemented. In this study the performance of a single PDC (Polycrystalline Diamond Compact) cutter cutting and different drilling methods including PDC rotary drilling, roller-cone rotary drilling and percussive drilling were investigated. To investigate drilling performance by rock strength properties, laboratory PDC cutting tests were performed on soft-to-hard rocks to obtain cutting parameters. In addition, results of laboratory and field drilling on different rocks found elsewhere in literature were used. Laboratory and field cutting and drilling test results were coupled with values of a new rock brittleness index proposed herein and developed upon energy dissipation extracted from the complete stress-strain curve in uniaxial compression. To quantify cutting and drilling performance, the intrinsic specific energy in rotary-cutting action, i.e. the energy consumed in pure cutting action, and drilling penetration rate values in percussive action were used. The results show that the new energy-based brittleness index successfully describes the performance of the studied cutting and drilling methods.

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