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Optimum Drilling States in Down-the-Hole Percussive Drilling: An Experimental Investigation

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Abstract : Down-the-hole (DTH) percussive drilling is an excavation method that is widely used in the mining industry due to its high efficiency in fragmenting hard rock formations. A DTH hammer system consists of a fluid driven (air or water) piston and a drill bit; the reciprocating movement of the piston transmits its kinetic energy to the drill bit by means of stress waves that propagate through the drill bit towards the rock formation. In the literature of percussive drilling, the existence of an optimum drilling state (Sweet Spot) is reported in some laboratory and field experimental studies. An optimum rate of penetration is achieved for a specific range of axial thrust (or weight-on-bit) beyond which the rate of penetration decreases. Several authors advance different explanations as possible root causes to the occurrence of the Sweet Spot, but a universal explanation or consensus does not exist yet. The experimental investigation in this work was initiated with drilling experiments conducted at a mining site. A full-scale drilling rig (equipped with a DTH hammer system) was instrumented with high precision sensors sampled at a very high sampling rate (kHz). Data was collected while two boreholes were being excavated, an in depth analysis of the recorded data confirmed that an optimum performance can be achieved for specific ranges of input thrust (weight-on-bit). The high sampling rate allowed to identify the bit penetration at each single impact (of the piston on the drill bit) as well as the impact frequency. These measurements provide a direct method to identify when the hammer does not fire, and drilling occurs without percussion, and the bit propagate the borehole by shearing the rock. The second stage of the experimental investigation was conducted in a laboratory environment with a custom-built equipment dubbed Woody. Woody allows the drilling of shallow holes few centimetres deep by successive discrete impacts from a piston. After each individual impact, the bit angular position is incremented by a fixed amount, the piston is moved back to its initial position at the top of the barrel, and the air pressure and thrust are set back to their pre-set values. The goal is to explore whether the observed optimum drilling state stems from the interaction between the drill bit and the rock (during impact) or governed by the overall system dynamics (between impacts). The experiments were conducted on samples of Calca Red, with a drill bit of 74 millimetres (outside diameter) and with weight-on-bit ranging from 0.3 kN to 3.7 kN. Results show that under the same piston impact energy and constant angular displacement of 15 degrees between impact, the average drill bit rate of penetration is independent of the weight-on-bit, which suggests that the sweet spot is not caused by intrinsic properties of the bit-rock interface.

Keywords : optimum drilling state, experimental investigation, field experiments, laboratory experiments, down-the-hole percussive drilling
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