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Rock Strength and Deformability Characterisation and Assessment for  
Drilling Performance Estimation

By

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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.

## TABLE OF CONTENTS

<b>STATEMENT OF ORIGINALITY .....</b>	<b>1</b>
<b>SUMMARY .....</b>	<b>2</b>
<b>TABLE OF CONTENTS .....</b>	<b>5</b>
<b>LIST OF FIGURES .....</b>	<b>9</b>
<b>LIST OF TABLES .....</b>	<b>14</b>
<b>ACKNOWLEDGEMENTS .....</b>	<b>16</b>
<b>THESIS DISSERTATION.....</b>	<b>18</b>
<b>CONCLUSIONS .....</b>	<b>31</b>
<b>REFERENCES.....</b>	<b>33</b>
<b>PUBLICATION IN JOURNALS .....</b>	<b>34</b>
<b>STATEMENT OF AUTHORSHIP .....</b>	<b>35</b>
<b>PRE-PEAK AND POST-PEAK ROCK STRAIN CHARACTERISTICS DURING UNIAXIAL COMPRESSION BY 3D DIGITAL IMAGE CORRELATION .....</b>	<b>36</b>
<b>ABSTRACT .....</b>	<b>36</b>
<b>KEYWORDS.....</b>	<b>37</b>
<b>INTRODUCTION .....</b>	<b>37</b>
<b>EXPERIMENTAL STUDY.....</b>	<b>40</b>
<i>Rock type and core preparation.....</i>	<i>40</i>
<i>Speckle pattern preparation .....</i>	<i>41</i>
<i>Rock instrumentation.....</i>	<i>41</i>
<i>Loading set-up and testing method.....</i>	<i>42</i>
<i>3D digital image correlation method.....</i>	<i>44</i>
<i>3D digital image correlation set up and measurement .....</i>	<i>44</i>
<b>TEST RESULTS AND DISCUSSION.....</b>	<b>47</b>

<i>Rock stress-strain characteristics</i> .....	47
<i>Post-peak strain measurement method</i> .....	49
<i>Field strain patterns</i> .....	51
CONCLUSIONS.....	52
ACKNOWLEDGEMENT .....	54
REFERENCES .....	54
LIST OF SYMBOLS AND NOMENCLATURE.....	59
LIST OF FIGURES .....	60
LIST OF TABLES .....	77
<b>STATEMENT OF AUTHORSHIP .....</b>	<b>78</b>
<b>FRACTURE ENERGY-BASED BRITTLENESS INDEX DEVELOPMENT AND BRITTLENESS QUANTIFICATION BY PRE-PEAK STRENGTH PARAMETERS IN ROCK UNIAXIAL COMPRESSION .....</b>	<b>79</b>
ABSTRACT .....	79
KEYWORDS.....	80
INTRODUCTION .....	80
EXPERIMENTAL STUDY.....	84
<i>Rock material and preparation</i> .....	84
<i>Rock instrumentation</i> .....	85
<i>3D Digital Image Correlation method</i> .....	86
<i>Loading set-up and testing method</i> .....	87
COMPRESSIVE TEST RESULTS .....	88
<i>Lateral-strain controlled test</i> .....	88
<i>Complete average stress-strain curves</i> .....	89
<i>Pre-peak stress-strain quantities</i> .....	91
<i>Post-peak local strain features</i> .....	92
FRACTURE ENERGY IN COMPRESSION.....	93
ENERGY-BASED BRITTLENESS INDEX.....	96
CONCLUSIONS.....	99
ACKNOWLEDGEMENT .....	100
REFERENCES .....	100
LIST OF FIGURES .....	105
LIST OF TABLES .....	135
<b>STATEMENT OF AUTHORSHIP .....</b>	<b>139</b>

<b>ROCK CUTTING CHARACTERISTICS ON SOFT-TO-HARD ROCKS UNDER DIFFERENT CUTTER INCLINATIONS .....</b>	<b>140</b>
KEYWORDS .....	140
INTRODUCTION .....	140
ROCK CUTTING MECHANISM .....	142
EXPERIMENTAL STUDY .....	143
<i>Rocks investigated .....</i>	<i>143</i>
<i>Uniaxial Compressive tests .....</i>	<i>144</i>
<i>Cutting tests with a single PDC .....</i>	<i>144</i>
TEST RESULTS AND DISCUSSION .....	145
<i>Rock strength characteristics .....</i>	<i>145</i>
<i>Intrinsic specific energy from PDC cutting .....</i>	<i>146</i>
CONCLUSIONS .....	147
ACKNOWLEDGEMENT .....	148
REFERENCES .....	148
LIST OF FIGURES .....	151
LIST OF TABLES .....	158
<b>STATEMENT OF AUTHORSHIP .....</b>	<b>161</b>
<b>ROCK DRILLING PERFORMANCE EVALUATION BY AN ENERGY DISSIPATION BASED ROCK BRITTLENESS INDEX.....</b>	<b>162</b>
ABSTRACT .....	162
KEYWORDS.....	163
INTRODUCTION .....	163
NEW ENERGY-BASED BRITTLENESS INDEX .....	167
PDC CUTTING PERFORMANCE.....	169
<i>Cutting experiments conducted in the present study .....</i>	<i>169</i>
<i>Intrinsic specific energy from PDC cutting .....</i>	<i>171</i>
<i>Intrinsic specific energy and brittleness index .....</i>	<i>172</i>
ROTARY DRILLING PERFORMANCE .....	172
<i>Drilling experiments from literature .....</i>	<i>172</i>
<i>Intrinsic specific energy from rotary drilling .....</i>	<i>173</i>
<i>Intrinsic specific energy and brittleness index .....</i>	<i>175</i>
PERCUSSIVE DRILLING PERFORMANCE.....	176
<i>Drilling experiments from literature .....</i>	<i>176</i>
<i>Penetration rate and brittleness index .....</i>	<i>176</i>



CONCLUSIONS.....	178
ACKNOWLEDGEMENT .....	179
REFERENCES .....	179
LIST OF FIGURES .....	185
LIST OF TABLES .....	201

## LIST OF FIGURES

### **Pre-Peak and Post-Peak Rock Strain Characteristics during Uniaxial Compression by 3D Digital Image Correlation**

Figure 1.1 Classification of class I and class II behaviour of rock failure in uniaxial compression (Hudson et al. 1971).....	60
Figure 1.2 Identification of the compression zone damage model and deformation of a specimen loaded in uniaxial compression (Vasconcelos et al. 2009).....	61
Figure 1.3 Experimental set up: servo-controlled closed-loop testing system and two-camera stereo system for 3D DIC in uniaxial compression loading .....	62
Figure 1.4 Strain gauge instrumentation arrangement and typical failure pattern of Hawkesbury sandstone. A, B, C, D and E refer to the location of strain gauges .....	63
Figure 1.5 Typical time history of a) loading and strains and b) loading rate and strain rate in uniaxial compression tests with lateral-strain rate feedback signal .....	65
Figure 1.6 Recovering the third dimension by using two cameras (Sutton et al. 2009).....	66
Figure 1.7 a) Calibration procedure for the stereo cameras left and right pair imaging and b) location of the virtual extensometers within the area of interest and rock at the end of the compression test.....	67
Figure 1.8 a) Stress-axial strain curves from platen displacement, external LVDT and DIC measurements (DIC-E0) and b) Stress-lateral strain curves from lateral extensometer and DIC measurements (DIC-E5 and E6) ..	69

Figure 1.9 Typical stress-strain curves with axial strains obtained from external LVDT and strain gauges..... 70

Figure 1.10 Typical stress-strain curves obtained from DIC for virtual extensometers DIC-E0, DIC-E1 and DIC-E2 ..... 71

Figure 1.11 Field of axial strains developed at different stress levels in a) pre-peak regime and b) and c) post-peak regime ..... 74

Figure 1.12 Field of shear strains developed at different stress levels in a) pre-peak regime and b) post-peak regime ..... 76

**Fracture Energy-Based Brittleness Index Development and Brittleness Quantification by Pre-Peak Strength Parameters in Rock Uniaxial Compression**

Figure 2.1 a) Rock instrumentation (Massangis limestone) and rocks at the end of the test (Tuffeau limestone, Hawkesbury sandstone and Alvand granite) and b) servo-controlled closed-loop testing system and 3D DIC set up ..... 106

Figure 2.2 Normalised stress-strain relations of Hawkesbury sandstone under axial-load, axial-strain and lateral-strain control (the origin of the curves were shifted horizontally to not overcrowd the figure)..... 107

Figure 2.3 Typical time history of a) loading and strains and b) loading and strain rates in uniaxial compression tests (Hawkesbury sandstone) with lateral-strain control feedback ..... 108

Figure 2.4 Typical stress-strain curves with axial strains obtained from external LVDT and strain gauges in Hawkesbury sandstone..... 109

Figure 2.5 Typical complete stress-strain curves for different rocks under lateral strain-rate control ..... 111

Figure 2.6 Pre-peak stress-strain quantities: a) tangent Young’s modulus and b) crack damage stress relations with peak stress for different rock types. Numbers 1 to 8 refer to the rock type in Table 2.1 ..... 112

Figure 2.7 a) Stress- strain curve and b) Field of axial strains in pre-peak regime ( $0.29q_{peak}$ ,  $0.52q_{peak}$ ,  $0.67q_{peak}$  and  $q_{peak}$ ) and c) post-peak

regime ( $0.70q_{peak}$ , $0.60q_{peak}$ , $0.45q_{peak}$ and $0.15q_{peak}$ ) of Hawkesbury sandstone .....	115
Figure 2.8 a) Stress- strain curve and b) Field of axial strains developed in pre-peak regime ( $0.81q_{peak}$ and $q_{peak}$ ) and post-peak regime ( $0.70q_{peak}$ and $0.45q_{peak}$ ) of Tuffeau limestone .....	117
Figure 2.9 a) Hawkesbury sandstone specimen and location of local virtual extensometers, b) Local stress-strain curves and c) Locally consumed energy by extensometers E(A), E(B) and E(C) and average consumed energy by $E_0$ .....	120
Figure 2.10 a) and b) Strain energy of rock in compression and c) Strain energy quantities versus peak stress for different rocks. Numbers 1 to 8 refer to the rock type in Table 2.1 .....	122
Figure 2.11 Brittleness index $B1$ relations with a) peak stress, b) crack damage stress and c) tangent Young's modulus for different rock types. Numbers 1 to 8 refer to the rock type in Table 2.1 .....	124
Figure 2.12 Brittleness index $B2$ relations with a) peak stress, b) crack damage stress and c) tangent Young's modulus for different rock types. Numbers 1 to 8 refer to the rock type in Table 2.1 .....	126
Figure 2.13 Brittleness index $B3$ relations with a) peak stress, b) crack damage stress and c) tangent Young's modulus for different rock types. Numbers 1 to 8 refer to the rock type in Table 2.1 .....	128
Figure 2.14 Brittleness index $BU - I$ relations with a) peak stress, b) crack damage stress and c) tangent Young's modulus for different rock types. Numbers 1 to 8 refer to the rock type in Table 2.1 .....	130
Figure 2.15 Brittleness index $BU - II$ relations with a) peak stress, b) crack damage stress and c) tangent Young's modulus for different rock types. Numbers 1 to 8 refer to the rock type in Table 2.1 .....	132
Figure 2.16 Brittleness index $BU - III$ relations with a) peak stress, b) crack damage stress and c) tangent Young's modulus for different rock types. Numbers 1 to 8 refer to the rock type in Table 2.1 .....	134

## **Rock Cutting Characteristics on Soft-To-Hard Rocks under Different Cutter Inclinations**

Figure 3.1 PDC cutting test at shallow depth of cut.....	151
Figure 3.2 Cutting force, $F_sC$ , versus cutting advancement along the rock surface for Mantina basalt at a prescribed depth of cut of 0.2 mm .....	152
Figure 3.3 a) Cutting force, $F_sC$ , versus depth of cut, $d$ , for the rocks investigated and respective intrinsic specific energy values .....	153
Figure 3.4 Cutting force, $F_sC$ , versus constant cross-section area $wcd$ for different back-rake angles for the rocks investigated.....	155
Figure 3.5 Intrinsic specific energy for a back-rake angle of 15 degrees versus unconfined compressive strength .....	156
Figure 3.6 Intrinsic specific energy relation with the back-rake angle for the rocks investigated .....	157

## **Rock Drilling Performance Evaluation by an Energy Dissipation Based Rock Brittleness Index**

Figure 4.1 Relations between compressive-to-tensile brittleness indices a) $B1$ , b) $B2$ and c) $B3$ with unconfined compressive strength. Data from literature (Howarth 1987; Paone et al. 1969; Schmidt 1972; Selim and Bruce 1970).....	186
Figure 4.2 a) and b) Strain energy of rock in compression, c) typical complete stress-strain curves for different rocks under lateral strain-rate control and d) strain energy quantities with compressive strength for different rock types .....	190
Figure 4.3 Brittleness index $BU - I$ relations with unconfined compressive strength for different rock types .....	191
Figure 4.4 a) PDC cutting test at shallow depth of cut and b) geometry of cutting and forces acting on the PDC cutter.....	192
Figure 4.5 a) Cutting force, $F_sC$ , versus depth of cut, $d$ , b) SEL for the rock investigated and intrinsic specific energy .....	193

Figure 4.6 Intrinsic specific energy from PDC cutting tests and its relation with the brittleness index $BU - I$ .....	194
Figure 4.7 Intrinsic specific energy and its relation with the brittleness index a) $B1$ , b) $B2$ and c) $B3$ from rotary drilling tests .....	196
Figure 4.8 Intrinsic specific energy from rotary drilling tests and its relation with the brittleness index $BU - I$ .....	197
Figure 4.9 Penetration rate and its relation with the brittleness index a) $B1$ , b) $B2$ and c) $B3$ from percussive drilling tests.....	199
Figure 4.10 a) Penetration rate and b) penetration rate normalised from percussive drilling tests and their relation with the brittleness index $BU - I$	200

## LIST OF TABLES

### **Pre-Peak and Post-Peak Rock Strain Characteristics during Uniaxial Compression by 3D Digital Image Correlation**

Table 1.1 Hawkesbury sandstone properties and threshold stresses for fracture damage .....	77
--	----

### **Fracture Energy-Based Brittleness Index Development and Brittleness Quantification by Pre-Peak Strength Parameters in Rock Uniaxial Compression**

Table 2.1 Rock types investigated and their physical properties .....	135
Table 2.2 Pre-peak stress-strain quantities for the rocks investigated	136
Table 2.3 Pre-peak and post-peak stress-strain quantities for the rocks investigated.....	137
Table 2.4 Brittleness indices for the rocks investigated.....	138

### **Rock Cutting Characteristics on Soft-To-Hard Rocks under Different Cutter Inclinations**

Table 3.1 Experimental program.....	158
Table 3.2 List of rock types investigated and their physical and mechanical properties.....	159
Table 3.3 List of rock types investigated and their Intrinsic Specific Energy .....	160

**Rock Drilling Performance Evaluation by an Energy Dissipation Based  
Rock Brittleness Index**

Table 4.1 Rocks investigated to develop a energy-based brittleness index  
BU – I..... 201

Table 4.2 Rocks tested for PDC cutting performance..... 202

Table 4.3 Rocks for PDC drilling performance and brittleness index 203

Table 4.4 Rocks for roller-cone drilling performance and brittleness  
index ..... 204

Table 4.5 Rocks for percussive drilling performance and brittleness index  
..... 205



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