Impact of Abrasive Wear on Drilling Tools

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Abstract

This paper presents the experimental results of shore hardness index and cone indenter hardness and average grain size and continuous abrasive index on the impact abrasive index. A good correlation was found with combined parameters. These results can predict during life of drilling tools, and then avoid the breakdown.

Keywords
Wear, Abrasiveness, Drilling, Tools

1. Introduction

A wide range of problems occur in mining caused by the harsh environmental conditions that are hostile to equipment operation. Many mineral constituents of the rocks encountered are harder than the materials used in the construction of the equipment. Broken rock fragments with very sharp edges can be produced by blasting or natural fracturing, while abrasive dusts can also be generated. Often copious quantities of water are used for dust suppression, drill bit flushing and cutter pick cooling. This water can become contaminated with acids and salts originating from the oxidation of pyrites, from blasting fumes and minerals associated with fissure water. All these parameters were correlated so then to find that there is a good relationship between them.

2. Wear Mechanisms

There are several types of wear mechanisms and more than one mechanism may be present resulting in synergistic effects. Although corrosion is not strictly a wear mechanism, it is a major contributor to the wear process [2].

2.1. Abrasive wear

The three generally accepted modes of abrasive wear are :

1. *Two body, low stress abrasion,* caused by the gouging or shearing action of abrasive panicles sliding over surfaces and removing wear debris, without reducing the size of the abrading material.
2. *Two body, high stress abrasion,* with the effect of impact causing gouging, deformation and material loss.

3. *Three body, high stress abrasion,* caused by an abrasive solid present between two surfaces in relative motion that wears the surfaces by a grinding action, through gouging, deformation and fracture.

2.2. Determination of Hardness and Abrasiveness

A number of methods have been investigated for the determination of hardness and abrasiveness of rock and these can be divided into two specific groups:

a) Petrological Methods and
b) Mechanical Methods.

Many tests have been designed to determine the abrasiveness of rocks and most of these are designed for some particular purpose or geographical location.

Most of the mechanical hardness rock tests have been based on standard metallurgical hardness test equipment such as the penetrometer tests by Vickers, Brinnel and Rockwell. The Vickers hardness test has been adapted to fit petrological microscopes and used to determine the hardness of individual minerals [3].

In an attempt to reduce the number of anomalies associated with this phenomenon, two new tests were investigated, these were [5] :

a) The Dynamic Impact Test, Fig 1, and
b) The Continuous Abrasive Wear Test, Fig 2.

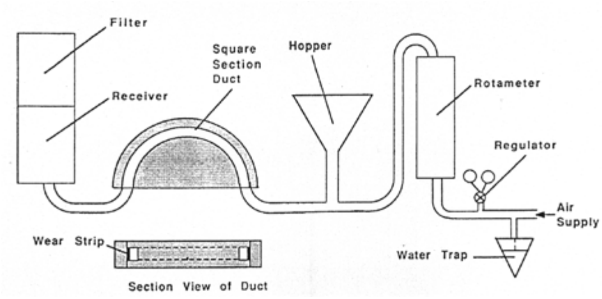

Fig 1. Dynamic Impact Test

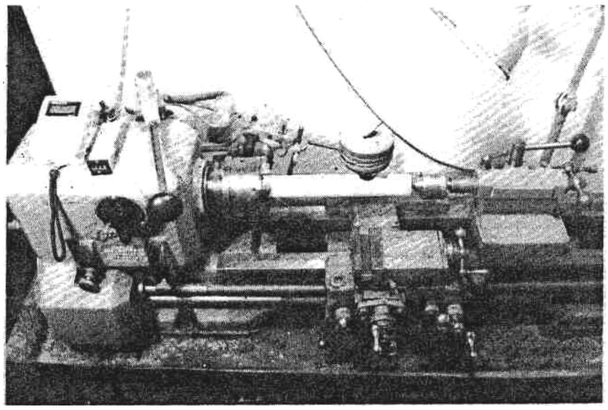

Fig 2. Continuous Wear Test

3. Statistical Analysis of Test Results

In order to better understand the relationships to abrasive wear a statistical analysis of the data was carried out. All data, including computer monitored data from actual diamond sawing trials were analyzed to determine relative correlations between the various parameters and actual cutting forces and wear rates. Factor analysis showed that strength and deformation parameters have little effect on the abrasive wear potential of the rocks tested and although a tentative wear relationship was found with the angle of friction ($R = 0.625$) (correlation coefficient).

The effects of rock hardness as determined by the Shore Scleroscope and Cone Indenter however, can be regarded as significant, furthermore, these two tests indicated good correlation with each other where $R = 0.861$ and $R = 0.733$ respectively. Good correlation was also found with wear and cutting force between the percentage of hard minerals and average grain size. The correlation between the Impact Abrasive index and the Cone indenter hardness test, was $R = 0.773$ and the correlation of the Shore hardness index with the Impact Abrasive Test was $R = 0.680$. Good correlation was found found between the Shore hardness index and average grain size $R = 0.978$.

A multiple regression equation which incorporates these hardness and mineralogical parameters is given as follows:

$$Y = 1{,}26 + 0{,}26\ X_1 - 2{,}93\ X_2 + 16{,}0\ X_3$$

Where: Y = Impact Abrasive Index

X_1 = Shore Hardness Index

X_2 = Cone Indenter Hardness

X_3 = Average Grain Size

The correlation coefficient for the above equation is, $R=0{,}994$.

Similar trends were found with other combined parameters, although, the correlation between the individual abrasive tests were not as good. This could be attributed to the different mechanisms involved with each individual test. Consequently, the following empirical equation was derived to show the relationship between the Impact Abrasive tests. Shore Hardness index. Cone Indenter Hardness Index and Continuous Abrasive index:

$$Y = 6{,}00 + 0{,}231\, X_1 + 1{,}09\, X_2 + 5{,}03\, X_3$$

Where: Y = Impact Abrasive Index

X_1 = Shore Hardness Index

X_2 = Cone Indenter Hardness

X_3 = Continuous Abrasive Index

The correlation coefficient for the above equation is, R=0,95

The analysis outlined in these equations suggest the following:
The abrasive indices do not correlate well with physical strength and deformation properties.
Abrasiveness can be correlated to whole rock hardness and petrology, including hard mineral grain size.

The individual abrasive indices cannot be easily correlated with each other.
An interrelationship however does exist between various abrasive indices when taken together with hardness and petrological properties.

3.1 Toughness

Experience has shown that toughness can significantly affect wear rates, in addition to its effect on the forces required to cause disintegration of certain rock materials. The toughness index is derived from the area under the stress/strain curve as shown in the following equation, [6]:

$$T_1 = (\sigma^2_c /2E) \times 100$$

Where T1 = Toughness Index

σ_c = Uniaxial Compresssive Index (MPa)

E = Young's Modulus of Elasticity (MPa)

Statistical analyses however, do not indicate any significant correlation between toughness and abrasiveness. The correlations between Toughness Index and Impact Abrasive, Cherchar Abrasive and Continuous Abrasive indices were given as R = 0.123, R = 0.017 and R = 0.106 respectively. The correlation with Young Modulus, Compressive Strength, Cohesive Strength, Hardness and Hard Mineral Constituents are given as R = 0.897, R = 0.969, R = 886, R = 0.708, R = 0.904. This indicates that wear could result from fatigue failure rather than an abrasive mechanism and therefore, worthy of consideration, especially with regard to the impact mechanisms employed with jaw crushers and percussive drilling etc. [1].

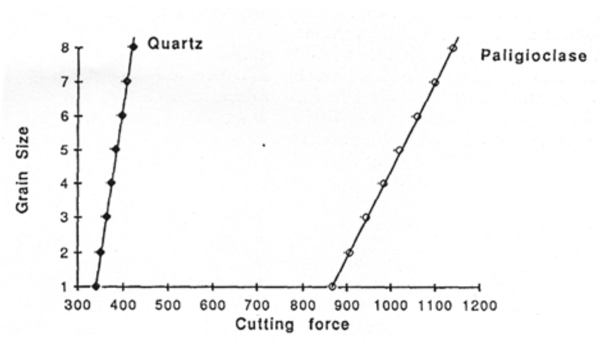

Fig 3. Effect of Grain Size on Cutting Force

3.2.Diamond Wheel Sawing of Hard Rocks [4]

A project to determine the predicted cutting forces and wear rates on diamond sawing of 8 different granite rock types was recently carried out and the statistical analysis of all the data indicated that prediction of these parameters was possible. Figure 3 illustrates the effects of hard mineral constituent grain size on cutting forces and Figure 4 shows the effect of whole rock hardness determined by the Shore hardness method on cutting force requirements. Figure 5 indicates the cutting force requirements measured and the predicted cutting forces from the following equation:

$$N = 211 + 8{,}86X_1 + 10{,}2X_2 - 1{,}93X_3 + 11{,}4X_4 - 2{,}12X_5 + 38{,}3X_6$$

Where: N = Cutting force required,

X_1 = Shore Hardness Index,
X_2 = Cone Indenter Hardness,
X_3 = UCS (MPa),
X_4 = Mean Quartz Grain Size (mm),
X_5 = Quartz Percentage,
X_6 = Plagioclase Grain Size (mm),

The correlation coefficient for this equation was: R = 0,993

Figure 6 illustrates a similar approach to the prediction of wear rates. The results of these trials indicate that where reliable and accurate data acquisition is possible, the production of useful predictive equations for future development and design parameters are practical.

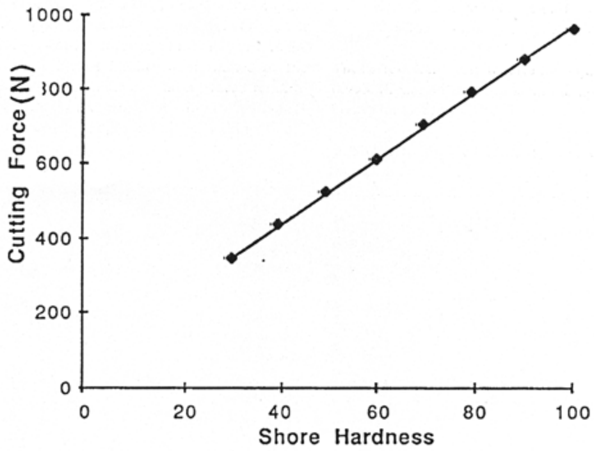

Fig 4. Effect of Slope Hardness on Cutting Force Requirements

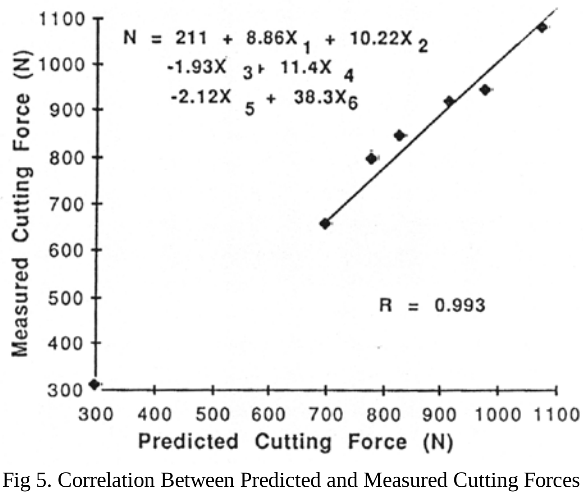

Fig 5. Correlation Between Predicted and Measured Cutting Forces

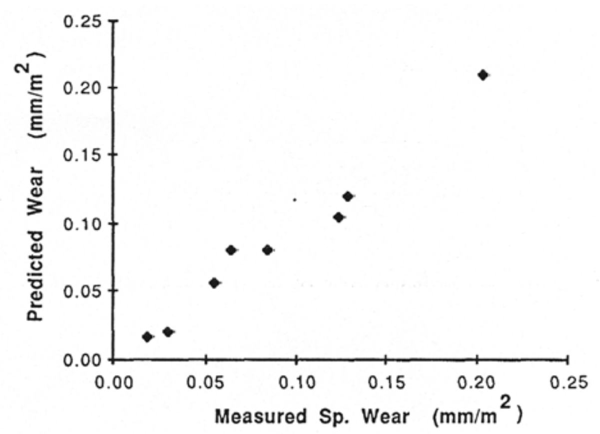

Fig 6. Relationship Between Measured and Predicted Wear

3.3 *Designing for Wear Elimination*

Previous experience may not be relevant to new technological advance. There must be considerable cross-fertilization of ideas between equipment designers, end-users, material scientists and mineralogists. When planning a new working method it must be recognized that most units in the extractive industries must operate within a system. The design of separate units or sub-systems without reference to the role they play in the total system can lead to the creation of additional wear problems. The procedure must be to eliminate wear hazards from each individual item making up the system, investigation of the interfaces between items, and identification of the possible wear points and their reduction; and finally an anti-wear audit of the system as a whole. i.e. a "design it out philosophy".

4. Conclusion

The cost of "anti-wear" investigations is very small compared with the huge capital sums invested in modern mining operations and the consequential losses when they are out of operation. These investigations can prevent costly mistakes in equipment selection and possibly in identifying alternative methods of operation. Anti-wear management can save a lot of money and turn a potential loss-maker into a profitable organisation.

Even though a conclusion may review the main results or contributions of the paper, do not duplicate the abstract or the introduction. For a conclusion, you might elaborate on the importance of the work or suggest the potential applications and extensions.

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