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Effect of operating variables on specific wear rate of diamond sawblades in sawing of granites

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ABSTRACT

In this study, it was aimed at investigating the wear performance of sawblade in processing of granites. In the experimentations, a computer controlled sawblade was used and the experiments were performed with the same-direction cutting mode. Specific Wear Rate (SWR, μm/m^2) was selected as the criteria for sawblade wear performance. Effect of each operating variable on SWR was determined. Results showed that the SWR increased with respect to the increase in peripheral speed and traverse speed, and decreased with the increasing of cutting depth and flow rate of cooling fluid. Peripheral speed was determined as the most significant operating variables affecting the SWR.

1. Introduction

Trade of granites as a construction and decorative material is continuously increasing worldwide due to their high resistance against to environmental effects and attractive aesthetic properties. As a result of growing demand, processing of granites by using diamond segmented circular sawblades has found a wide application in the stone industry [1]. Sawblade wear in rock cutting is a major factor in determining the cutting cost and cutting method selected. Significant savings could be achieved by effective control of saw wear [2]. Some factors affected the sawblade wear performance can be ranged as diamond and matrix properties (diamond type, diamond concentration, grit size, hardness of the metal bond formulation), segment manufacturing method, sawing conditions (peripheral speed, traversing speed, cutting depth), sawing mode (up-cutting, down-cutting), physico-mechanical and mineralogical properties of the rock to be cut, cooling efficiency (coolant type and flow rate), condition of the sawing machine and the skill of the operator. As can be understood, all these parameters indicate the complexity of the system [3]. The present study concentrated on a particular group of rocks (granites). The study aimed at investigating effect of operating variables on SWR.

2. Materials and Methods

For the execution of experiments, three granite having different percentages of minerals and substantial market potential were selected from a stone processing plant and dimensioned according to the requirements of experimental studies. The selected rocks include Giallo Fiorito, Porto Rosa and Crema Lal. The samples have a length of 30 cm and 10 cm x 3 cm section. Some physico-mechanical properties of the rocks are presented in Table 1. It may be important to note that in practice, there are serious difficulties of supplying enough samples having suitable dimensions, preparing and testing for their mechanical properties such as uniaxial compressive and bending strength. For these reasons, the uniaxial compressive and flexural strengths of the tested rocks were provided by the stone processing company where the tested rocks were supplied. Density (kN/m^3), water absorption by volume (%), porosity (%), ultrasonic velocity (m/s), Schmidt hammer hardness, Shore hardness were determined according to related ISRM [4] suggested methods. For the detailed procedure of Shore hardness and Cerchar abrasive index, related papers [5, 6] can be investigated.

The cutting tests were performed on a high precision experimental cutting machine (Figure 1). The diamond sawblade used in the tests was of 40 cm diameter, having 28 impregnated diamond segments (circumferential length 40 mm, width 3.5 mm and height 10 mm). The diamonds were sized at 40/50 US mesh with a concentration of 30 which is recommended for the sawing of hard materials. Sawblade movements, forward–backward in the horizontal plane and up–down in the vertical plane, were driven with two 0.75 kW AC motors, while the turn of the disc were driven with 4 kW AC motor. Moreover, 0.75 kW AC motor was used to move the wagon through the cutting line.

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Table 1. Some physico-mechanical properties of rocks used in the sawing tests

Rock Properties	**Giallo Fiorito**	**Porto Rosa**	**Crema Lal**
Uniaxial compr. strength (MPa)	167.65	107.94	231.34
Density (kN/m^3)	26.60	26.40	25.9
Bending strength (MPa)	22.06	15.00	19.42
Water absorption by volume (%)	0.28	0.30	0.86
Porosity (%)	0.80	1.50	1.50
Ultrasonic Velocity (m/s)	3917	4196	4140
Cerchar abrasion Index	4.166	4.508	5.2
Schmidt hammer hardness	48	51	56
Microhardness (HV)	543.47	538.73	539.55
Shore hardness	73.55	81.85	75.6
Mohs hardness	5.7	6.0	4.5

Figure 1. Experimental set-up

Various methods have been used for measurements of segment wear of sawblades. Laser measurement, one of the commonly used methods, has been preferred especially in recent years due to their high precision. In this method, sawblade is removed and then fixed on a unit to measure wear. Removal and installment of sawblades cause a loss of time especially in the applications where many test are conducted. In the current study, an alternative wear measuring design was developed. New design (Figure 2) provides opportunity to measure the sawblade wear without the need to removing of disc.

Wear performance of the sawblade was evaluated in terms of Specific Wear Rate SWR (μm/m^2), which is defined as the ratio of radial wear of the sawblade segment surface to the sawn area. Sawblade turned in peripheral speed of 1 m/s and measurements was taken during 10s. Before and after the completion of each series of sawing tests, radial wear of the sawblade was measured using ILD 2220-20 high speed laser sensor and difference between two measurements was saved as radial wear of sawblade segment surface. Properties and working principles of the laser were presented in Table 2 and Figure 3 respectively. Before any series of measurement, segment surfaces of sawblades were carefully cleaned with alcohol and then dried.

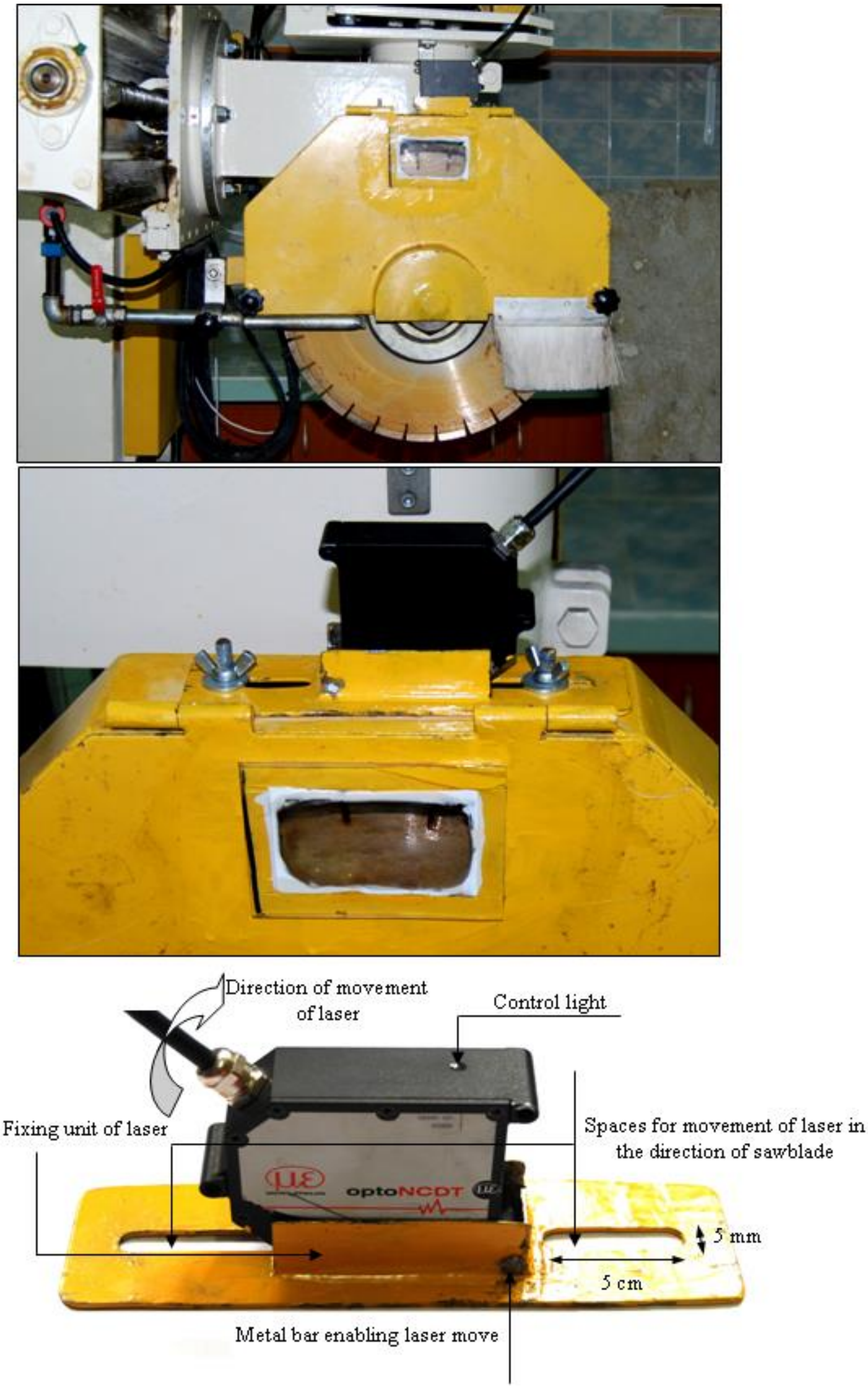

Figure 2. Wear measurement systems designed

Table 2. Properties of laser used for wear measurements

Model	ILD 2220-20
Measuring range	20 mm
Start of measuring rate	40 mm
End of measuring rate	60 mm
Linearity	6 µm
Resolution (at 20 kHz without averaging)	0.3 µm
Measuring rate	20 kHz

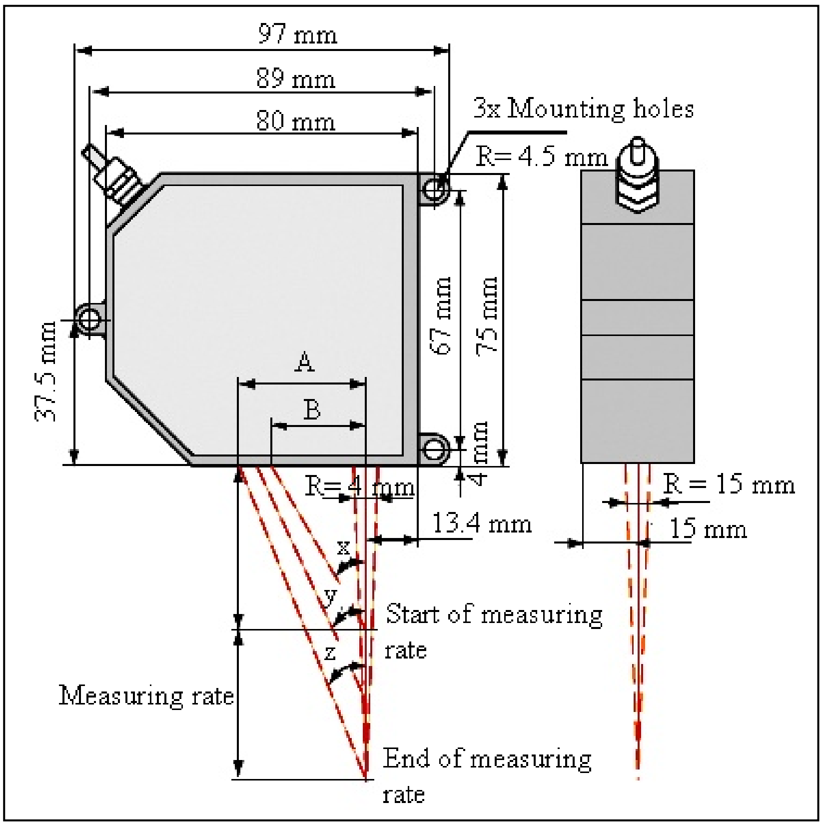

Figure 3. Working principle of laser used

Table 3. Levels of operating variables

Operating Variables	Level				
A - Peripheral Speed (m/s)	25	30	35	40	45
B - Traverse Speed (cm/min)	60	70	80	90	100
C - Cutting Depth (cm)	0.5	1.0	1.5	2.0	2.5
D - Flow Rate of the Cooling Fluids (ml/s)	50	100	150	200	250

In order to determine the levels of the operating variables for the study, preliminary cutting tests were conducted by considering instructions of diamond disc manufacturers and related studies. Consequently, valid for the type of tested rocks, the operating variables were varied at five levels presented in Table 3. Each experiment was repeated five times to increase the accuracy of the results obtained.

3. Results and Discussion

Depending on the increase in peripheral speed and traverse speed, an increase was observed in the SWR (Figure 4). It was also determined that SWR decreased with respect to the increase in cutting depth and flow rate of cooling fluid (especially for lower levels of flow rate of cooling fluid). The critical levels of the peripheral speed in terms of the SWR were determined as 35 m/s for the other rocks tested. Above the critical levels defined for the peripheral speed, dramatically increase was observed in the SWR.

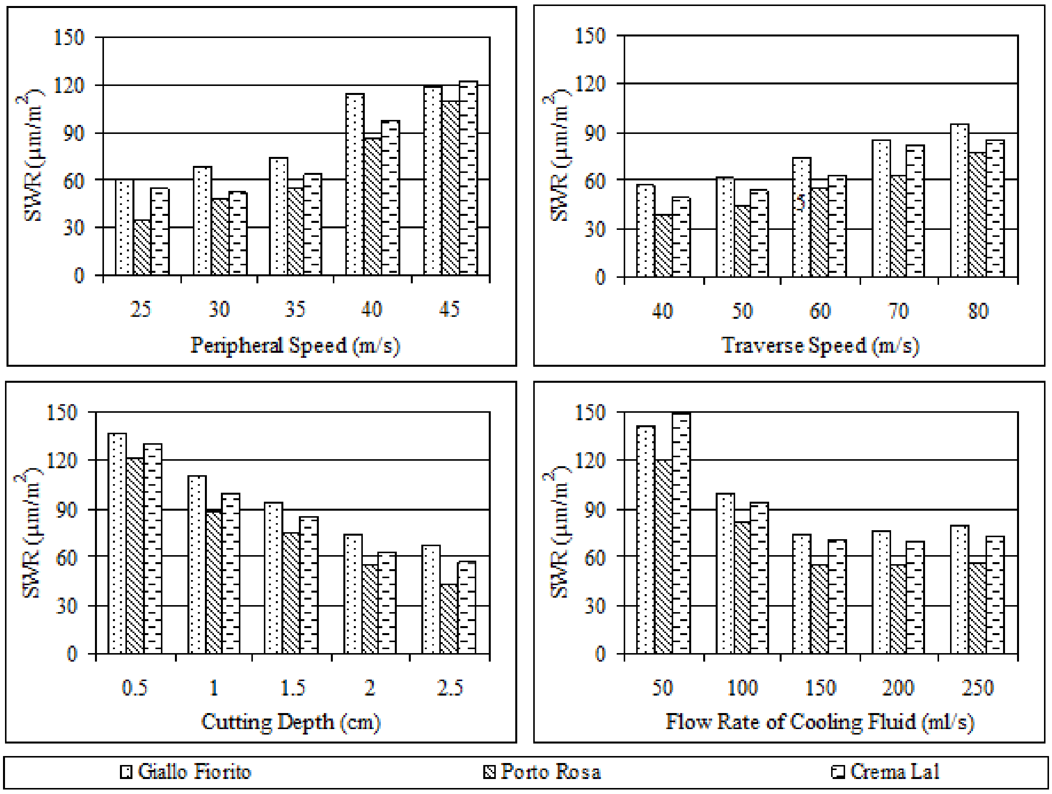

Figure 4. Relation between operating variables and SWR

As can be also seen from Fig. 4, the SWR initially decreased and then increased as a result of the increase in specific removal rate that is the quantity of the material sawn in unit time or the area cut per unit time. The critical levels of the flow rate of cooling fluid in terms of the SWR were determined as for the rocks tested. In the lower levels of the flow rate of cooling fluid (below 150 ml/s), the chips produced may not be efficiently removed from the cutting area and this may lead to get higher cutting force increasing SWR. Therefore, it is recommended that the flow rate of cooling fluid must be high enough for achieving the effective cutting in terms of SWR.

From the related figures, the most significant operating variables affecting the SWR were determined as peripheral speed. It was followed by cutting depth, flow rate of cooling fluid and traverse speed.

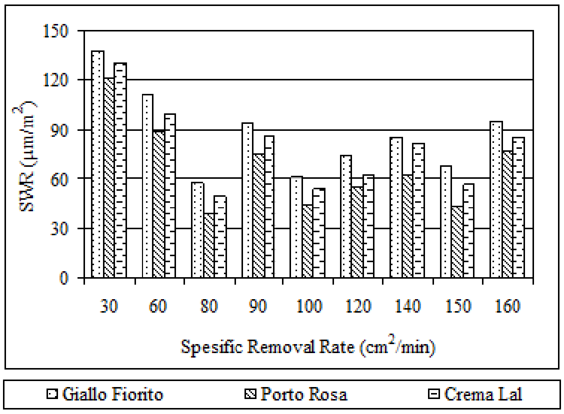

Figure 4. Relation between specific removal rate and SWR

4. Conclusions

In this study, wear performance of sawblades in processing of granites were investigated. It was determined that SWR increased with respect to the increase in peripheral speed and traverse speed, and decreased with increasing cutting depth and flow rate of cooling fluid.

The critical levels for the peripheral speed and the flow rate of cooling fluid in terms of the SWR were observed. Additionally, the most significant operating variable affecting the SWR were determined as peripheral speed. It was followed by cutting depth, flow rate of cooling fluid and traverse speed.

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