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Diamond & CBN Applications and Abrasive Machining of Brittle Materials

THE APPLICATION OF ACOUSTIC EMISSION (AE) TECHNIQUES ON THE DRESSING OPERATION USING SYNTHETIC DIAMONDS AND SINTERED TOOLS

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INTRODUCTION

According to several authors the dressing operation is directly responsible for the grinding wheel topography, which is one of the factors of great importance on the chip formation during the grinding operation [1-3]. In this way, the dressing tool and its performance during the dressing operation seems to have significant influence on the grinding final results, in terms of surface finishing and material removal rate [4].

Grinding wheel life, cycle time and quality output are the main factors affected by the dressing operation [5-6]. Due to its importance, dressing tools and processes have been studied regarding performance improvement, cost reduction and reability [8-11]. As a result, new tool design like plane dressers, clusters and rotary technologies have been introduced in industrial environment [5].

The aim of the present work is to investigate the relation between the dressing parameters and the grinding wheel sharpness using Acoustic Emission (AE) techniques. In addition, this work evaluates the influence of the contact area (between the dresser and the grinding wheel) on the sharpness of the working surface and also on the AE root-mean-square (AE RMS) level. Two types of dressing tool were used, one single point made with a natural stone and two others with synthetic diamond bars, called here constant width dressing tools (CWDT).

THE DRESSING OPERATION AND ITS PARAMETERS

When using conventional grinding wheels, i.e., those employing conventional abrasives, such as Al_2O_3 and SiC, for instance, the dressing is made in order to correct the wheel geometry and to renew the working surface sharpness. Figure 1 shows scquematically some of the main parameters used to describe the dressing operation.

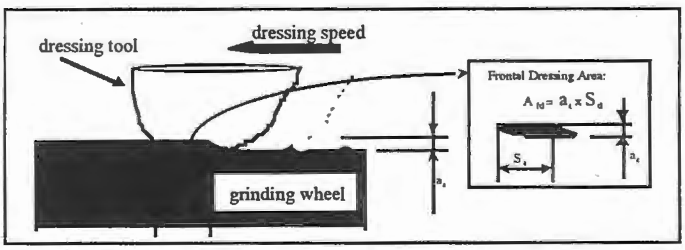


Figure 1 - The dressing operation with a single point dressing tool, showing the forntal dressing area.

During the dressing operation, the depth of cut (a_d), defines an apparent width of dressing (b_d) on the dressing tool. These two parameters defines, in a certain way, the geometric working profile of the dresser. This width varies as the dresser wears out, when using a single point diamond stone. If the dresser uses synthetic diamond bars, aligned, the width is more kept constant all along its useful life time.
With the wheel rotating and the dresser moving along its surface, a thread is created with a pitch (S_d). Using the apparent width (b_d) and pitch (S_d), the overlapping dressing ratio U_d is defined by the expression:

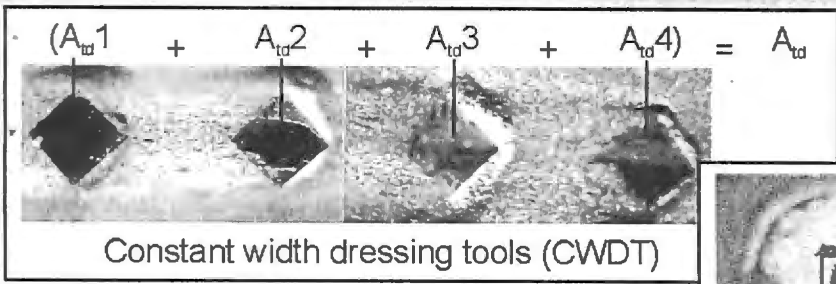
(2.1)

This parameter is, in fact, an attempt to better define the kinematics of the interaction between the dresser tip and the grinding wheel.
Combining the parameters a_d and b_d one can obtain a projection of the frontal dressing area (A_{fd}), as can be observed in the Figure 1. Due to the difficulties in calculating accurately the frontal dressing area (A_{fd}), it can be conveniently approximated by the value $S_d \times a_d$ [5]. This value will be more accurate as the area approximates a parallelogram (see detail in Figure 1). This area can grow up to the limit where the dressing pitch equals the value of b_d. Values of S_d bigger than b_d cannot be used since part of the wheel surface is not dressed. In other words, the minimum possible value for U_d is 1.0, in order to guarantee that all the working surface is being dressed

Another area can be defined on the tip of the dressing tool. It is the top dressing area A_{td}, as shown in Figure 2. In a single point dresser it can be measured using a microscope or a profile projector. When using dresser with diamond bars it can be calculated by the cross section area of the diamonds, times the number of them present on the dresser.

GRINDING WHEEL SHARPNESS

Several methods have been developed for evaluating the grinding wheel sharpness. Some of the first approaches attempt to relate topographic parameters with the wheel



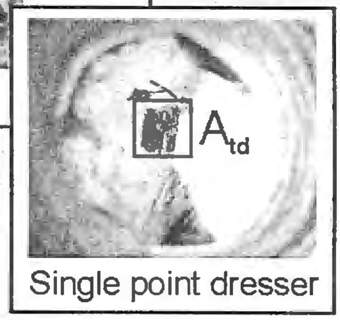


Figure 2 - Top dressing area A_{td}.

sharpness. Many of these methods involve counting the number of cutting edges on the wheel surface, for instance. More recently, however, methods have been created in which the approach is to assess the influence of the wheel topography on the results of the operation [7]. Some of these methods involved a test using standard equipment and cutting conditions [8-11].

In spite of the great number of works on the wheel sharpness evaluation, there are still some difficulty, mainly with the repeatability of the results obtained with the proposed methods, either with static or dynamic parameters [7]. One of the most direct and simple method to evaluate the wheel sharpness is first proposed by Nakayama and Takagui in 1980 [8-10]. This method brings about the possibility of evaluating the wheel sharpness in a very rapid and simple way, using a standard ground specimen. A linear relation can be found, whose slope is proportional to the wheel sharpness ***K*** **(mm^3/Ns)**. In this method the wheel topography with all the cutting edges are assessed at once.

In the first proposal the specimen is a ball bearing, made of hardened steel. There was, however, some difficulties to assess the grinding wheel sharpness performance on different workpiece materials, since a sphere is not a easy geometry to manufacture. Aware of this problem, in 1991, a variation of the initial Nakayama method is proposed, in which a disk replaces the ball bearing (the Method of the Ground Disk) [11]. In this version, the calculation and also the assessment is made by a computer, with the objective of making the method more rapid and automated. This method is used in this research in order to evaluate the sharpness of the wheel working surface, measuring a parameter known as ***K*** ($mm^3/N.s$) [2] [5] [11] .

ACOUSTIC EMISSION (AE)

Acoustic Emission (AE) could be defined as transient waves of stress generated by the sudden liberation of the deformation energy, or most generally, the friction energy of one or several sources located in a structure [12]. The main sources of AE can be divided into four groups: dislocation movements, phase transformations, mechanisms of friction and crack formation [14]. Since the use of sensors for the measurement of the AE energy is a passive and nondestructive technique, it can be used to monitor crack propagation and failure prediction in loaded structures. This technology has been gaining a variety of applications since the beginning of the century [12-17].

Several research works have been published showing the applications of AE to monitor tool wear on machining operations and on several other production processes, as well. For instance, references [18] and [19] demonstrate that the RMS (root-mean-square) level of the AE signal during turning operation has a strong correlation with the tool wear. Additionally, it can be found a number of other works showing the efficiency of the AE signal to evaluate tool wear in a variety of machining processes [20-24]. Moreover, AE has been also reported to be capable of predicting tool failure in process [25-31].

On the grinding wheel dressing, the shocks between the abrasive grains and the diamond on the dresser creates strong stress waves, which travels along the dresser and the machine parts in a large band of frequencies. The energy of these waves can be detected by an AE sensor. Some works using the AE RMS level has already shown that it is proportional to the main dressing parameters (S_d, a_d) [32] and [33]. The final result presented by reference [35] is in the Figure 3.

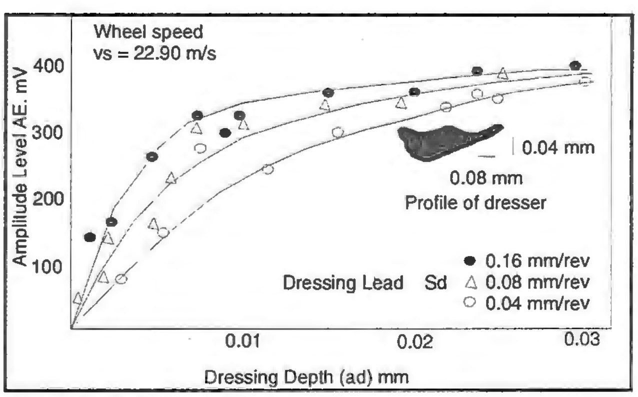


Figure 3 - Influence of the Dressing parameters on the EA signal [35].

Figure 3 shows that AE level is directly proportional to a_d up to the value of

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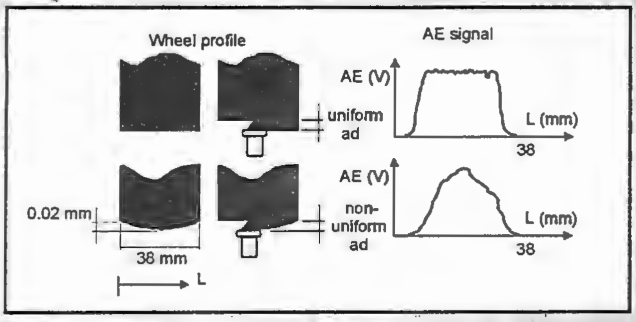

Figure 4 – Variation on the AE RMS level according to the depth of cut (a_d) [35].

0.01 mm. Higher values of a_d seems to cause much less increase on the AE level, leading to an apparently limit value. The influence of S_d on the AE level is shown to be less intense, but there is still some relation between them.

The AE RMS level can also be used to guarantee the uniform dressing depth of cut (a_d) over all the wheel width. Figure 4 shows the relation between the AE level and the variation on the dressing depth of cut (a_d).

There are also a number of successful applications of AE to monitor the dressing operation described in references [32-37].

EXPERIMENTAL WORK

The experimental work developed can be divided in two parts. In the first one a single point dresser made with natural diamond was used. Relation between dressing parameters and sharpness were evaluated, as well as, the AE RMS level. In the second part dressing tools with constant width, made with synthetic and geometrically regular diamond stones, are used to evaluated the same relations.

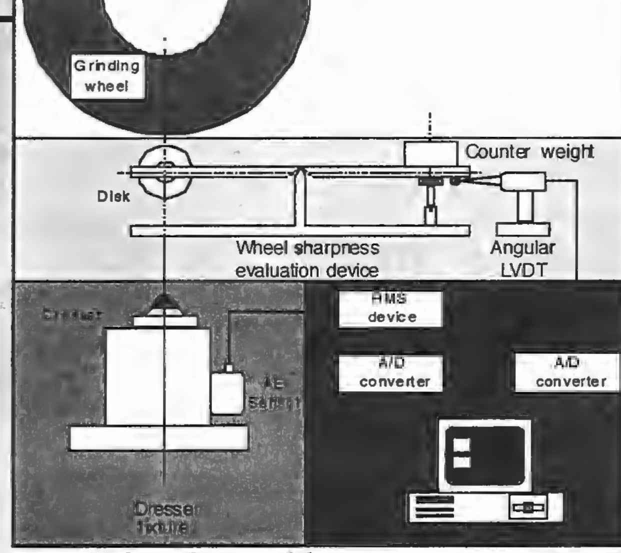

Figure 5 - General set-up of the experiments.

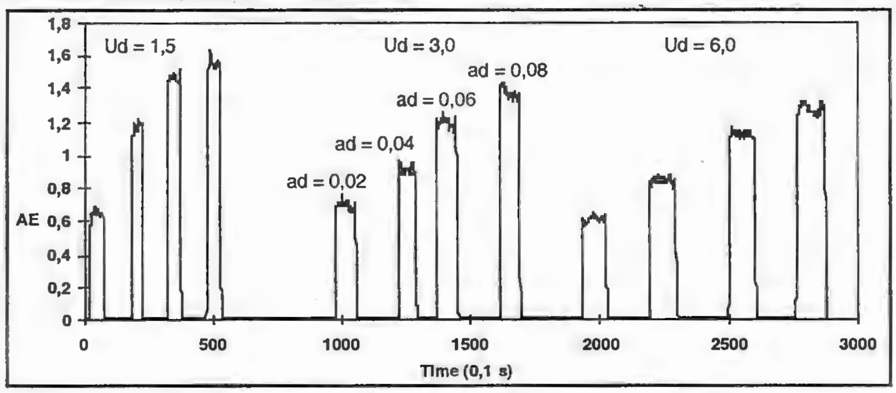

Figure 6 – Gain adjustment of the BM12 - AE measurement device .

The general set-up used is shown squematically in Figure 5. It used a device for wheel sharpness evaluation (Method of the Ground Disk), a dresser fixture with a AE sensor attached and also a microcomputer set with an analogue/digital converter.

The wheel sharpness evaluation device and the dresser fixture were placed on the magnetic table of the surface grinding machine, under the wheel. The experiments were carried out following always the same sequence, i.e.:

The grinding wheel surface was made blunt by setting a very mild dressing condition, i.e. U_d = 8.0 and a_d = 0.04mm. The wheel was dressed in spark out.

The dressing conditions were set to the experiment and the wheel was dressed, with the AE signal being recorded by the microcomputer,
The sharpness was measured using the wheel sharpness evaluation device.
The whole sequence was repeated setting up a new dressing condition.
The order in which the experiments were carried out, followed a random table aiming at minimise any possible bias on the results.

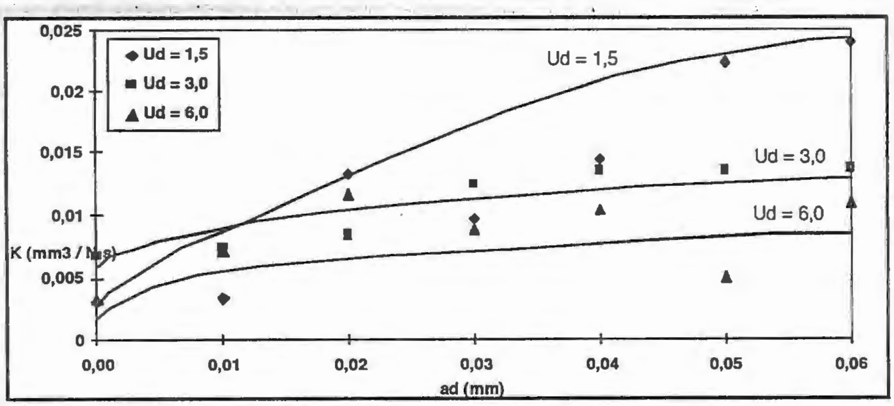

Figure 7 – Wheel sharpness as a function of the depth of cut a_d for different values of overlapping ratio U_d.

5.1 – EQUIPMENT
Machine: surface grinding machine TRIPET.
Grinding wheel: 80 K V 5 - 250 mm diameter and 25 mm width.
Grinding wheel speed: 33 m/second.
AE sensor: Sensis piezoelectric, response flat up to 200 kHz.
AE device Sensis BM12, set with a 40 dB amplifier and a 5 kHz high pass filter.
The gain was adjusted for the experiment in such a way that it could be used up to the strongest dressing condition without reaching the maximum level of the RMS signal. The result of this adjustment is shown in Figure 6.

The values of depth of cut were chosen taking into account those normally used in practical industrial applications and also in published works [33-35].

5.2 – EXPERIMENTAL PLANNING
In the first part of the experimental work a single point dressing tool with natural diamond stone was used. Three overlapping ratios (U_d = 1.5, 3.0 e 6.0) were combined with six values of depth of cut (a_d = 0.01, 0.02, 0.03 0.04 0.05 e 0.06 mm) resulting in 18 experiments. The order of these testes followed a random table. The sharpness measurement was made three times along the wheel surface and the value placed on the graph is an average. The AE RMS level was measured just once, during the dressing operation.

In the second part, three values of overlapping ratio (U_d = 1.5, 3.0 e 5.0) were used in a dressing operation with a_d = 0.04 mm, for each one of the two CWDT. The first one containing two and the second four diamonds. This resulted in 6 experiments. Sharpness ***K*** and AE RMS level were measured in the same way described for the first part.

RESULTS AND DISCUSSION

6.1. FIRST PART – Experiments with single point diamond dressing tool.
Figure 7 presents the wheel sharpness as a function of the depth of cut a_d for different values of overlapping ratio U_d.
The lines drawn on all the graphics, such as on Figure 7, are only to show a tendency and do not come from any kind of mathematical regression. Bearing that in mind, it can be observed that on the majority of the points shown in Figure 6 there is an increase on the wheel sharpness, as the dressing depth of cut, a_d, goes from 0.0 up to 0.06 mm. The values obtained when using lower overlapping ratios also shows, in general, higher values of sharpness.
Figure 8 shows the results of the AE RMS obtained from the same experiment using the single point diamond dresser.

Comparing the Figure 8 with Figure 7 it can state that both show a similar tendency. As the depth of cut increases, there is also a rise on the frontal dressing area (A_{fd} in Figure1). Consequently, the possibility of the abrasive grains become sharper grows, since the dresser tip is shocking with higher portions of the abrasive grains. The result is a working

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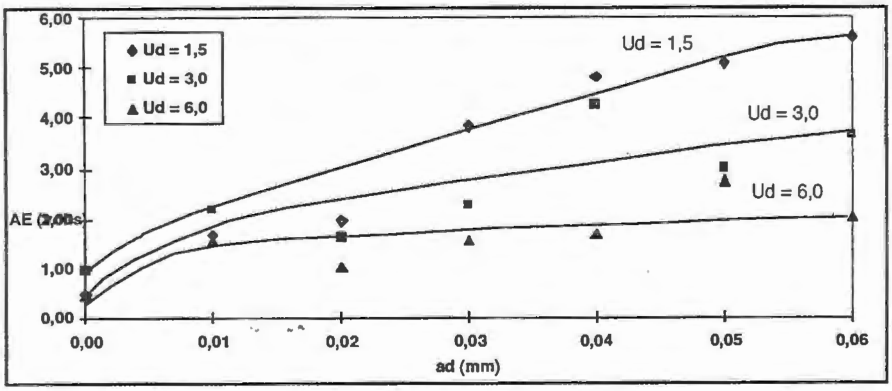

Figure 8 – AE RMS level as a function of the depth of cut a_d and the overlapping ratio U_d.

surface with higher sharpness. Moreover, a high frontal dressing area, A_{fd}, leads to stronger shocks between abrasive grains and the dresser tip. This is believed to be the cause for high AE RMS levels. The behaviour of the sharpness as a function of the frontal dressing area is shown in Figure 9.

The lines drawn in Figure 9 shows the region in which all the values of sharpness were found, as well as the overall trend. Figure 10 shows a similar picture with the values of AE RMS level.

Figure 11 shows a relation between the values of sharpness and AE RMS level obtained in the experiments with a single point diamond dresser..

The lines drawn in the Figure 11 indicates that there is a direct relation between the sharpness of the grinding wheel and the AE RMS level measured during the dressing operation. Although it seems a weak relation, it can be stated that higher AE RMS level during the dressing operation indicates that the result was a wheel working surface with high sharpness.

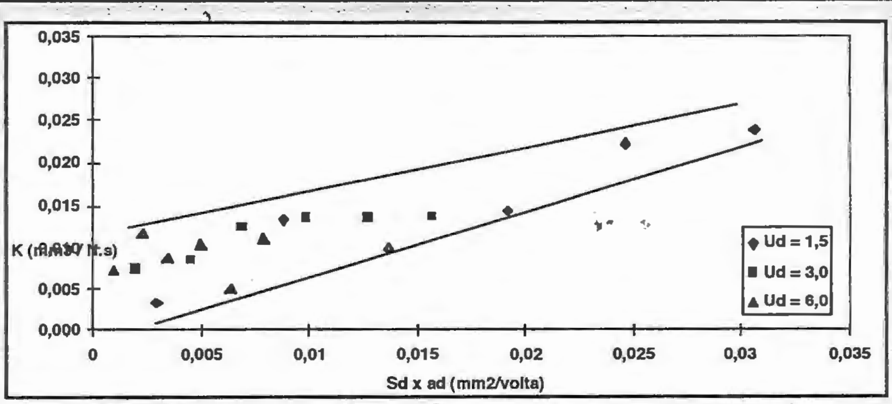

Figure 9 – Sharpness as a function of the frontal dressing area A_{fd}.

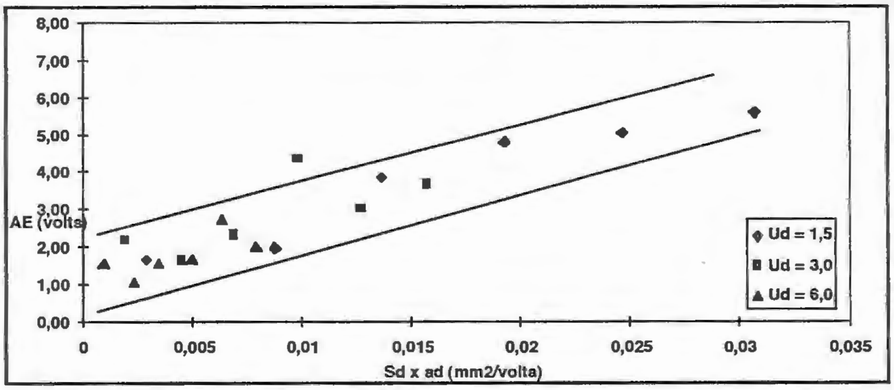

Figure 10 - EA RMS values as a function of the frontal dressing area A_{fd}.

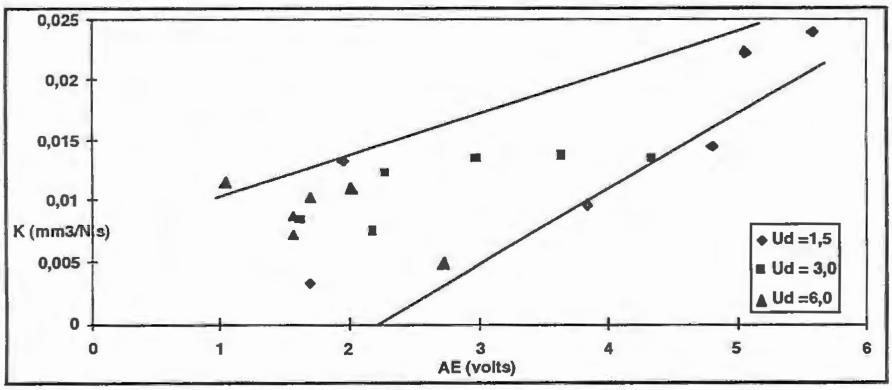

Figure 11 – Sharpness as a function of the AE RMS level.

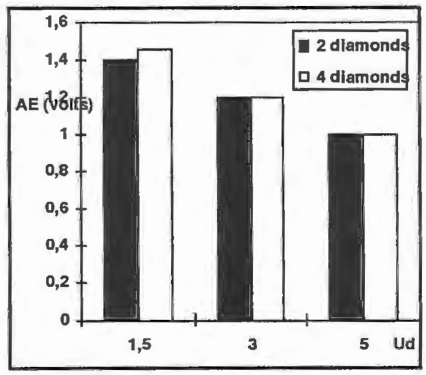

Figure 12 – AE RMS level and sharpness K as a function of the overlapping ratio U_d and number of diamonds on the dressing tool.

6.2 - SECOND PART – Experiments using constant width diamond dressing tool (CWDT).

The graphs of the Figure12 presents the results of AE RMS and sharpness, K, as a function of the overlapping ratio U_d. In all these experiments, the depth of cut, ad was kept constant (a_d = 0.04 mm) in order to be able to evaluate the effects of the top dressing area.

In Figure 12 it can be observed a negative slope relating both, the AE RMS level and sharpness K with the overlapping ratio. Regarding the sharpness K, the result confirm previous published works [8-11] and, the AE RMS level behaviour was similar to that using single point dressing tool, vis-à-vis Figure 8. On the other hand, with different number of diamonds, there is a slight difference on the values AE RMS level. This indicates that the top dressing area, A_{td}, seems to have little influence on the AE RMS signal. Contrasting, the sharpness K was significantly affected by the number of diamonds.

When the abrasive grains are broken by the first diamond on the dresser, there is a increase on the AE RMS level measured. After this shock,

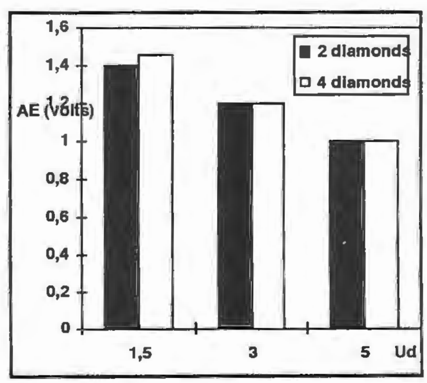

Figure 13 – AE RMS level as a function of the Sharpness K.

some sharp edges are produced, by after that there is another diamond, on the two diamond dresser, or three others on the four diamond one. It seems that the shock with the remaining diamonds did not produced a lot of increase on the AE RMS signal, but it was enough to blunt the sharp edges produced by

the first diamond. Therefore, the addition of two more diamonds onthe dresser, i.e. the increase the top dressing area, A_{td}, was sufficient to produce a lower sharpness on grinding wheel, while the increase in AE RMS level was very slight, or even not observed.

Figure 13 shows the relation found between the AE RMS level and the Sharpness K, when suing constant width dressing tools, with 2 and 4 diamonds.

Although the number of points is low , it seems that the AE RMS level is proportional to the sharpness K, independently of the size of the top dressing area A_{td}. T

CONCLUSIONS

From the results found in the present work, some conclusions can be drawn:

When using single point diamond dressing tool, the grinding wheel sharpness K was proportional to the increase in both, depth of cut a_d and overlapping ratio U_d, so was the AE RMS signal. Additionally, a direct proportionality between sharpness K and AE RMS signal was found. When high values of AE RMS level is found, a more sharp grinding wheel can be expected.

For all the dressing conditions used the frontal dressing area A_{fd} was found to be directly proportional to the sharpness K and also to the AE RMS level. It seems that the frontal dressing area is the main responsible for the sharpness and also for the higher AE RMS levels.

When using dressing tools with constant width containing two or four diamonds, results similar to those for single point tools were found, regarding the relation between sharpness K and overlapping ratio U_d, as well as AE RMS and U_d. Contrasting, when the top dressing area Atd was modified, i. e. changing from two to four diamonds, the sharpness K decreased and there no significant difference on AE RMS was observed. It can be supposed that increasing the top dressing area, the grains will result more blunt, but only the shocks between them and the first diamond on the dresser will produce significant AE RMS signal. Finally, independently of the number of diamonds on the dresser there is a direct proportionality between AE RMS level and the sharpness K.

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