DIGITAL SIGNAL PROCESSING OF ACOUSTIC EMISSION SIGNAL FOR MONITORING THE DRESSING OPERATION

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Abstract. *Dressing is a "resharpening" or renewing of abrasive grains, what consists in removing, or fracturing, worn and unsharpened grains, or cleanse wheels replete of metal chips. However, there is a lack of trustworthy indicative methods of a proper dressing, in order to prevent excessive wear of the wheel during the operation. The objective of the present work is to assess the influence of the cutting fluid on the acoustic emission (AE) RMS signal in the operation of dressing. Experimental tests were carried out in a surface grinder, making use of a single tip diamond dresser and a conventional alumina wheel, developing signal acquisition of raw acoustic emission signals. They were collected at a rate of 2.0 million samples per second and then mathematically treated. From the results obtained from the digital processing, it was observed that the raw acoustic emission spectrum contains important components only in a range of 50 kHz to 300 kHz. It can be clearly observed by the acoustic emission RMS signal graphics that fluid jet distribution can substantially influence on dressing analysis, including a reduction in AE signal level when the fluid pressure is higher in a given wheel region. That phenomenum can generate erroneous interpretations about the wheel surface after dressing. Several digital filters were implemented, and the 70 kHz high-pass filter applied to the AE raw signal showed itself very appropriate to elimiate influence from cutting fluid in the AE signal during dressing. Furthermore, tests and analysis can also detect a failure intentionally induced on the wheel, and the selected filter was also effective in that simulation.*

***Keywords**: dressing, acoustic emission, cutting fluid, digital filter*

1. INTRODUCTION

Grinding is a machining process broadly used in industry, what causes a need of a proper execution management. In order to keep the ideal conditions in grinding, there is a need to dress the grinding wheel in frequent intermissions in order to remove the worn grains on wheel surface (Hassui et. al, 1998). However, the lack of reliable methods of an appropriate dressing, preventing excessively wheel wear makes the process a subject of extensive researches, seeking its optimization.

Dressing operation consists in transversely moving the dresser to the rotating grinding wheel. The dresser penetration in a settled depth of dressing (a_d), implicates on a dressing actuation width (b_d), which can be determined by measurement of the dresser tip with a profile projector, for instance (Oliveira et. al., 2002).

The acoustic emission is used for monitoring the process, which shows itself highly useful for this operation and should be more utilized as the real-time automated monitoring systems for grinding take place in industrial processes (Dornfeld et. al, 2004).

It is still less known the influence of dressing in grinding, because the dresser geometry is a factor of great influence, which is not often taken into account. The majority of past researches use the depth of dressing (a_d) and dressing infeed rate (S_d) as process variables.

According to Hassui (1998), there are two resulting effects of dressing operation: macro-effect and micro-effect. The first is formed by means of the dresser shape, the depth of dressing and dressing infeed rate. This phenomenon determines the position in which the abrasive grains edges are located. It can be said the macro-effect is the "thread" originated by the dresser at the wheel surface. Fig. 1 represents the dressing process chart.

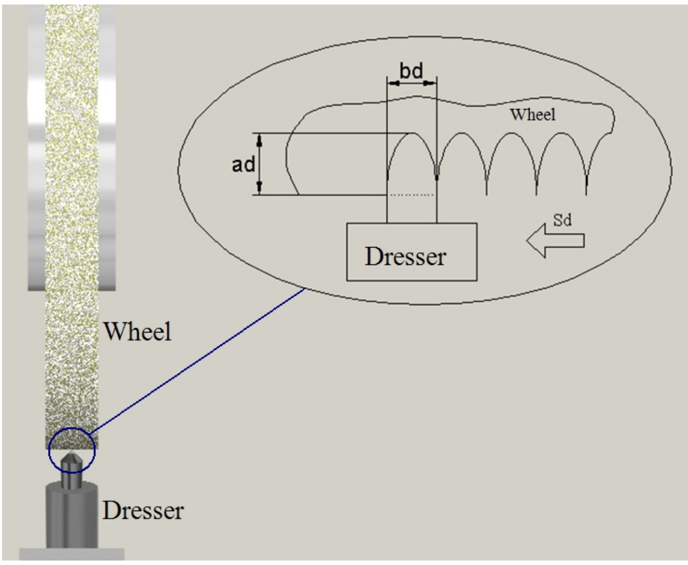


Figure 1. Dressing process chart

Micro-effect represents the dresser action over the abrasive grains, by fracturing, plucking up or melting them, the latter when in laser dressing. In this case, the increase in aggressiveness occurs due to friability, the capacity of retaining grains on the wheel structure, and the means of solidification of the abrasive material. When high values of a_d and S_d are used, substantial portions of the grains are broken and sharper edges formed, causing aggressive macro and micro-effects, thus resulting in a high removal rate capacity of the grinding wheel.

According to König apud Aguiar (1997), the sharpening form usually utilized by adjusting the dresser feed in function of its type is inappropriate, because it does not take into account the dressing actuation width at the time of the operation. This parameter varies according to the dresser tip wear during several dressing operations.

König (1980) defined the parameter designated as overlapping ratio (U_d) as being the relation between the dressing actuation width (b_d) and the dressing infeed rate (S_d), according to the expression:

$$U_d = \frac{b_d}{S_d} \tag{1}$$

Dressing conditions influence directly on material removal rate, which affects the surface roughness of the machined part. In rough dressing, for example, where overlapping ratio is low and the number of active edges is reduced, there is an increase in the groove depths which, consequently, induces higher surface roughness values.

The application of cutting fluid in machining processes is becoming increasingly more important when is desired to have higher removal rates, a better final product quality and higher life cycles of grinding wheels. To select the best fluid for a given application and an efficient way to do so are meaningful ways to increase productivity, being as important as the wheel selection. A satisfactory application can reduce the incidence of burns due to a diminution of the specific energy and temperatures at the contact zones (Malkin apud Webster et. al., 1995), improving the process and diminishing the amount of burnt workpieces.

It is important the use of cutting fluid in processes such as grinding and dressing, avoiding excessive tool wear, lubricating and cooling the contact zone. This work aims to analyze the influence of irregular distribution of cutting fluid in dressing over acoustic emission (AE) signals, proposing a method based on digital filters to eliminate or soften those effects.

2. MATERIALS, METHODS AND RESULTS

With the objective of investigating the influence of cutting fluid on the acoustic emission signals in the dressing operation, experiments were conducted in a surface grinder using an alumina wheel (38A220KVS, with dimensions of 355.6×25.4×127 mm, and maximum rotation of 1775 rpm), and a single tip diamond dresser.

For each experiment, it was measured the dressing actuation width (b_d) with a profile projector, adjusting the dresser speed in ways that the overlapping ratio U_d remained constant. The grinding wheel peripheral velocity was kept constant at 30 m/s.

The tests were carried out with and without cutting fluid in order to observe the behavior of the acoustic emission signal in both situations. The fluid flow rate was kept also constant across the experiments ($P_{máx}$ = 28.417 Pa with $Q_{máx}$ = 0.33 l/s).

In order to achieve an irregular distribution of cutting fluid across the wheel periphery, it was built a nozzle with flat output geometry, however in ways that the fluid presented higher pressure in one extremity, obtaining a result as illustrated in Fig. 2. It can be observed a clean region in one wheel extremity, where the cutting fluid reached it with higher pressure, and, therefore, obtaining the intended effect for the present study purpose.

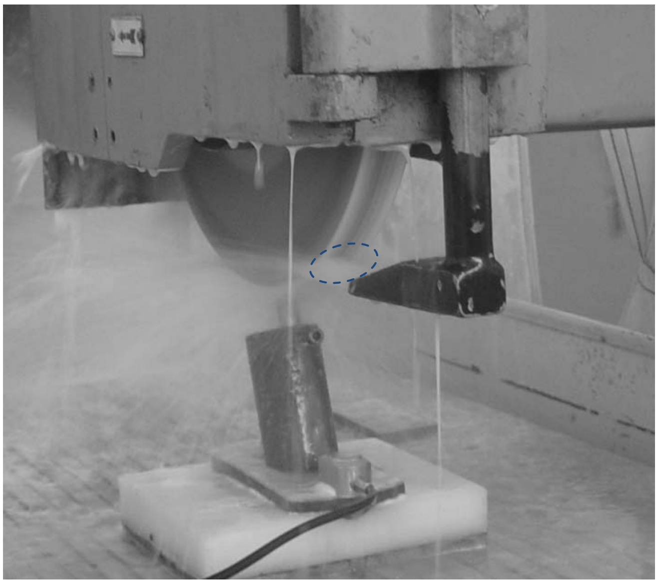


Figure 2. Irregular cutting fluid flow during dressing operation

Additionally, it was developed an experiment where a wheel failure was simulated. For that purpose, a single tip dresser was used to obtain a 60 µm groove at the center of the wheel, according to Fig. 3. This experiment was carried out only with cutting fluid.

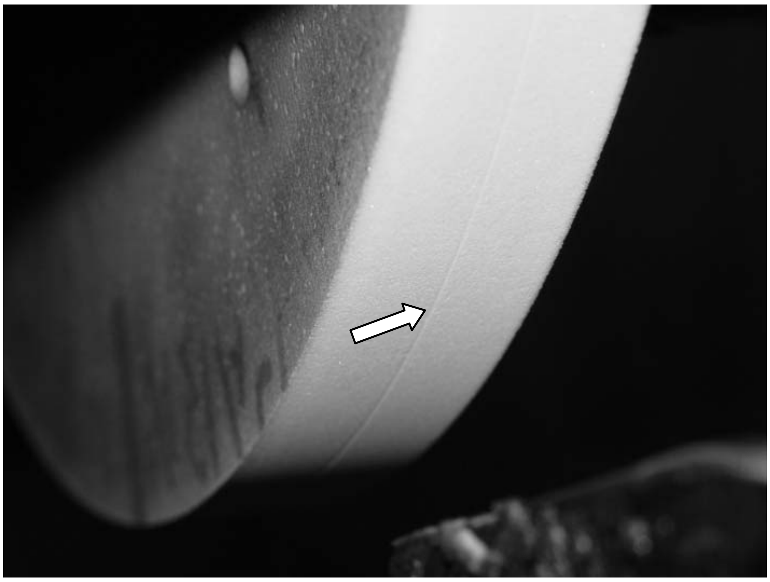


Figure 3. Wheel with induced failure

Acoustic emission signal was monitored by a DM42 Sensis sensor and module, configured with a 50 kHz high-pass filter. The acquired signal was the raw signal at a frequency of 2 millions samples per second. For that goal, it was used a PCI-6111 National Instruments board, installed in a PC microcomputer, and a LabVIEW software developed routine.

Table 1 shows the information about the conducted experiments such as depth of dressing, using of cutting fluid, number of passes and wheel condition before the experiment. In the case of experiments 3 and 5, the wheel after dressing was used to machine an ABNT 1020 steel workpiece in order to obtain a worn wheel. In experiment 7, a groove was obtained at the center of the dressed wheel. The objective of this last test was to simulate a failure on the wheel to be corrected by cleaning and dressing. Other tests were developed but not shown here for lack of space.

Table 1. Tests conditions

	Test 3	Test 5	Test 7
Depth of dressing (a_d)	20 μm	20 μm	40 μm
Cutting fluid	With	Without	With
Number of passes	15	15	3
Wheel condition	Worn by machining	Worn by machining	Dressed with central groove

2.1. AE signal frequency analysis

With the objective of knowing the frequency content of the acoustic emission signal for each experiment, routines were built using the Matlab software and employing a function relative to the Fast Fourier Transform (FFT). Figure 4 was created based on this procedure. It was obtained from three points chosen at the start, middle and end of the analyzed pass, showing the acoustic emission raw signal spectrum of test 3 and pass 14.

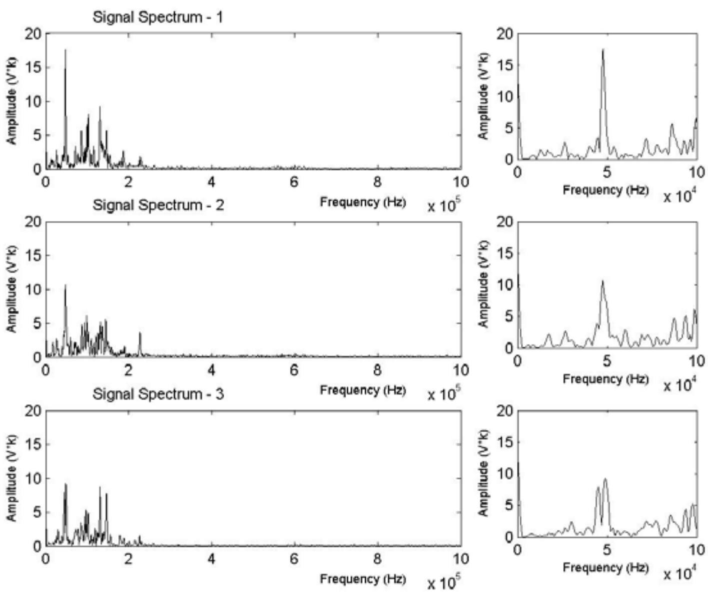


Figure 4. Pass 14 from test 3, a_d=20μm, with cutting fluid

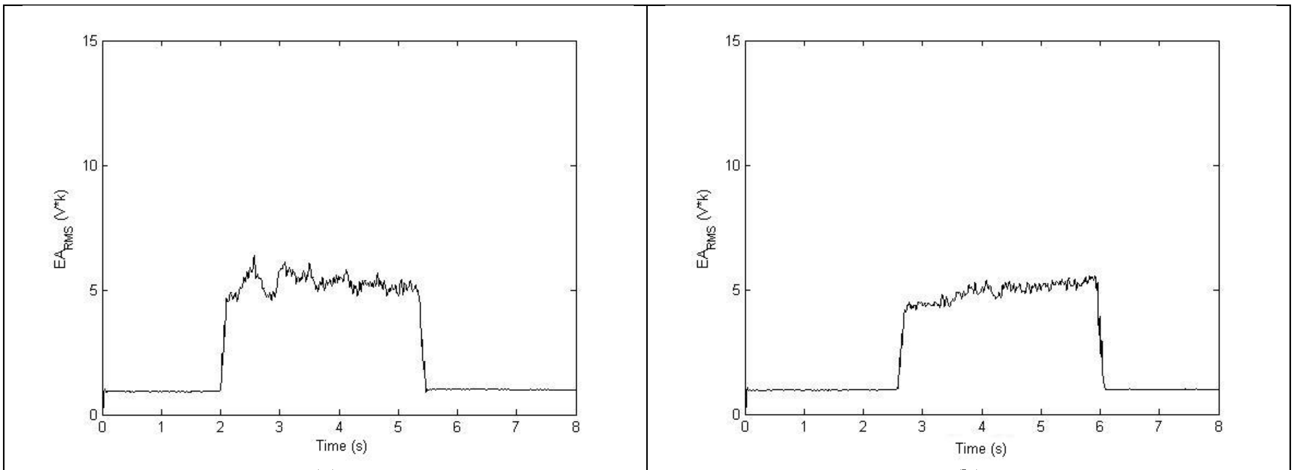
It can be observed in Fig. 4 that frequency content for the acoustic emission signals acquired lies in the range between 50 kHz and 300 kHz, being the amplitudes of higher and lower frequencies negligible. Also, the frequencies in the range of 20 kHz and 100 kHz are shown on the right side of Fig. 4, and it will help to explain the choice of cut-off frequencies in the following sections.

2.2. Root Mean Square value of the AE without filter, in the AE raw signal

2.2.1. With cutting fluid

Possessing the data archives generated for each test, routines were also built using Matlab software in order to filter and to obtain initially the root mean square (RMS) signals from the raw signal acquired. To calculate the root mean square value, 2048 points were used in the digital processing, in other words, each point of RMS computed corresponds to 2048 points in raw signal.

Figure 5 shows the RMS acoustic emission signal graphs, from test 3 and passes 1 and 14, respectively. Those signals were filtered out using a fourth-order Butterworth low-pass filter, with a cutoff frequency of 20 Hz, in order to observe clearly the important signal variations. It is also significant to emphasize that at this stage no filters on the acoustic emission raw signal were used, but only a low-pass filter on the AE RMS signal for a better graphical visualization.



(a) (b)

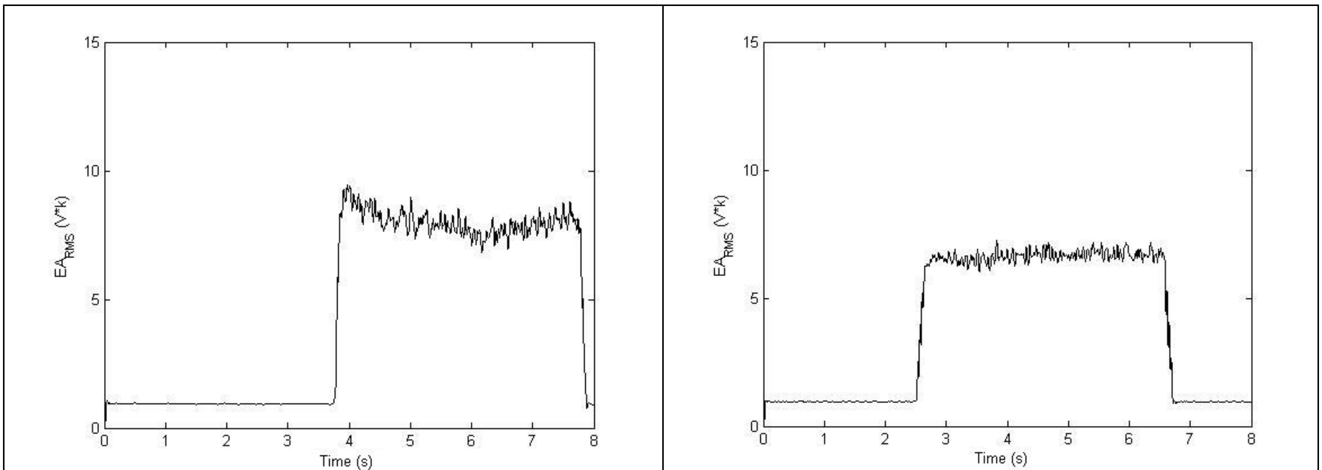
Figure 5. Pass 1 (a) and 14 (b) from test 3, $a_d = 20$ µm, with cutting fluid

It can be observed in Fig. 5 (a) that the AE signal is quite irregular across the pass, indicating that the wheel profile is not uniform and, therefore, it should be cleaned and dressed. Figure 5 (b) shows that the AE signal still presents irregularity. On this pass a perfectly uniform wheel was expected, due to the fact that an amount of 280 µm was removed. It can be also observed on this pass a lower AE value at the beginning of the pass, that is, a region where the fluid jet was stronger.

The need of verifying the influence of the cutting fluid jet on the acoustic emission signal was apparent after noticing the observed phenomenon. Thus, additional tests without cutting fluid were planned.

2.2.2. Without cutting fluid

Figure 6 illustrates the RMS acoustic emission signal graphs from experiment 5 and passes 1 and 14, respectively. Again the signals were filtered out using a fourth-order Butterworth low-pass filter, with a cutoff frequency of 20 Hz, in order to observe clearly the important signal variations. It is important to point out that at this stage no other digital filter on the raw acoustic emission signal was used.



(a) (b)

Figure 6. Pass 1 (a) and 14 (b) from test 5, $a_d = 20$ µm, without cutting fluid

Figure 6 (a) presents an irregular EA signal, meaning a worn wheel and an irregular surface, as expected. Also, in Fig. 6 (b) AE signal is very uniform, indicating dressed and cleaned wheel. It can be observed that, for test 5, the absence of cutting fluid did not cause undesired irregularities on the AE signal, as showed previously in test 3.

2.2.3. Failure simulation on wheel surface (using cutting fluid)

Figure 7 shows the RMS acoustic emission signal graph, taken from test 7 and first pass. Again the signals were filtered out using a fourth-order Butterworth low-pass filter, with a cutoff frequency of 20 Hz, in order to observe clearly the important signal variations. It is important to emphasize that at this stage no other digital filter on the raw acoustic emission signal was used.

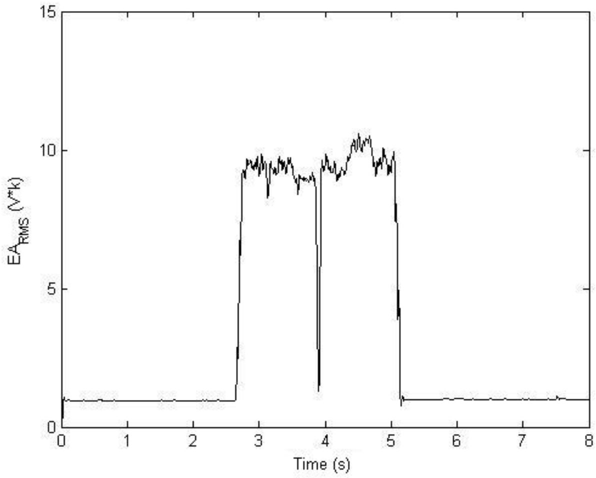


Figure 7. Pass 1 from test 7, $a_d = 40$ µm, with cutting fluid

It can be observed in Fig. 7 that AE signal behaves irregularly across the pass, even the test being carried out with a previously dressed wheel. It can be also noted a valley on the AE signal, showing clearly the 60µm groove induced on the wheel.

With the results obtained using cutting fluid, displayed in Fig. 5 and 7, the need of better investigation of the real wheel topography using AE signal was also brought to this work. In the case of result shown in Fig. 7 the noise interference is more apparent because the wheel was previously cleaned and dressed and then only AE signal variation in the groove region was expected. So, high-pass filters were applied to the AE raw signal in order to minimize or eliminate cutting fluid interference from the signal.

2.3. Cutting fluid interference elimination on the acoustic emission signal

2.3.1. Cutoff frequency selection

It can be noted in the tests that cutting fluid was used there is a reduction in AE RMS signal level in the beginning of the pass, in other words, in the region where the fluid reached the wheel with higher pressure due to the jet irregularity. Intending to eliminate this interference, routines were built using Matlab software in order to filter out AE raw signals. The filter used was a fourth-order Butterworth high-pass filter, with cutoff frequencies of 50 kHz, 60 kHz, 70 kHz and 80 kHz. The values were chosen based on the AE raw signal spectrum showed in Fig. 4, where it can be observed frequency peeks ranging from 50 kHz to 80 kHz, much likely related to cutting fluid acting on the wheel. Frequencies higher than 80 kHz can be considered related to dressing operation.

Figure 8 shows the RMS acoustic emission signal graphs from test 3 and pass 5, after filtering out the AE raw signal, using a cutoff frequency of 60 kHz and 70 kHz, respectively.

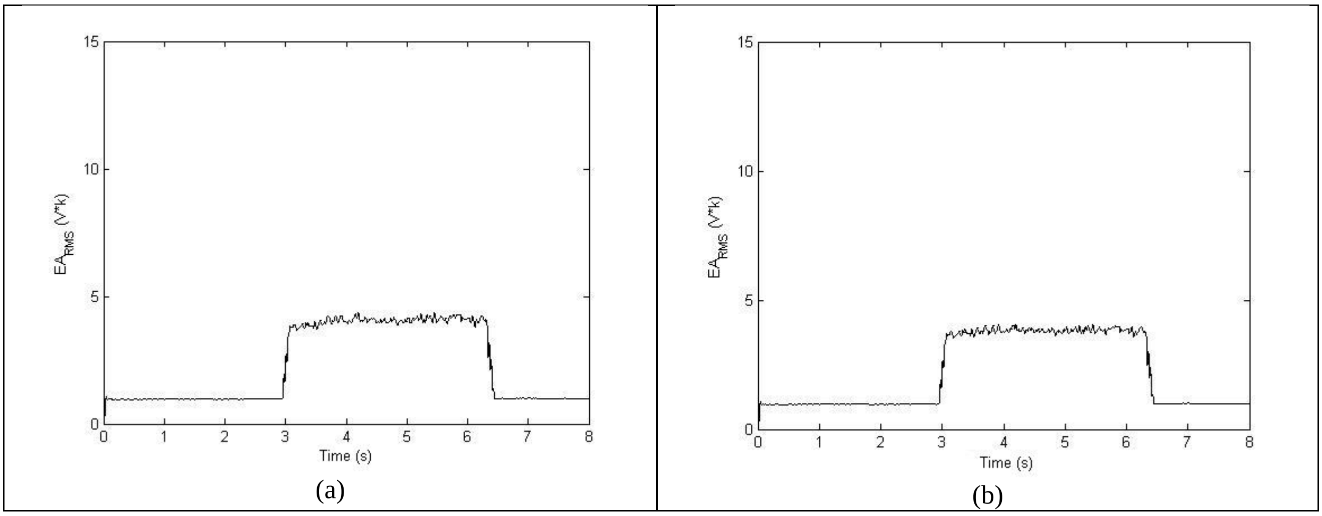


Figure 8. Pass 5 from test 3, a_d = 20 µm, filtered with a cutoff frequency of 60 kHz (a) and 70 kHz (b)

Analyzing Fig. 8 (a), it can be noticed that the interference is softened by the using of a 60 kHz cutoff frequency, however still not eliminated. In Fig. 8 (b) the application of the filter with a cutoff frequency of 70 kHz reaches complete elimination of the cutting fluid jet interference. It was chosen, then, the use of 70 kHz, which showed itself very effective in eliminating fluid interference. To choose a filter with a higher frequency would result in removing important information of dressing operation, which was the case of filter with cutting frequency of 80 kHz

2.3.2. Results verification with 70 kHz filter application

Once the cutting frequency to be used has been chosen, the filter was applied to the signals of all passes of test 3 in order to make sure none important information was lost in the AE signals. Figure 9 shows the graphs of pass 1 and 14 of test 3, respectively, after the application of high pass Butterworth filter of 4th order with cutting frequency of 70 kHz to the raw acoustic emission.

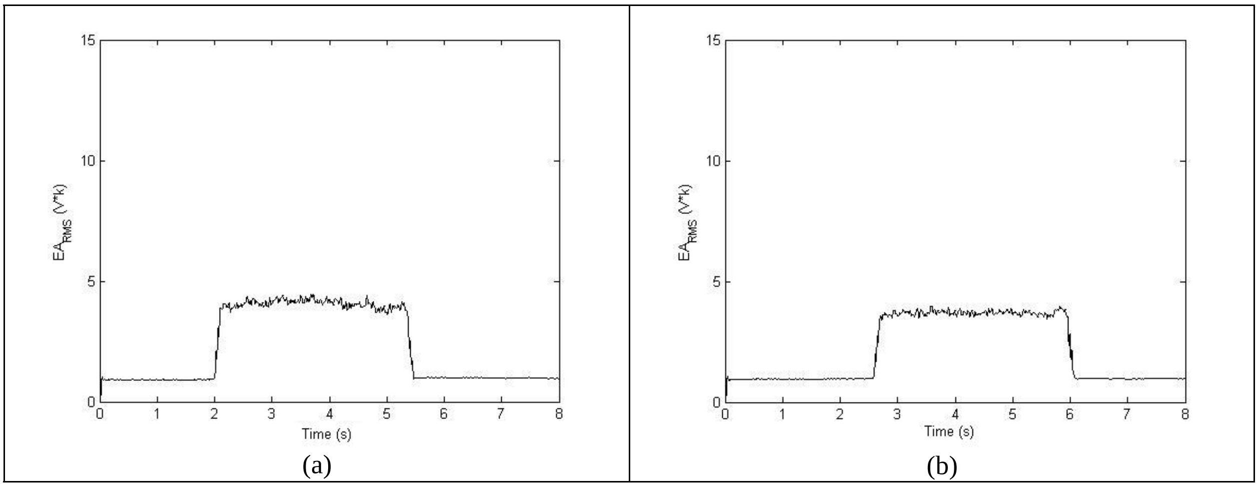


Figure 9. Pass 1 (a) and 14 (b) from test 3, a_d = 20 µm, with cutting fluid, filtered with a cutoff frequency of 70 kHz

It can be noticed that, with elimination of the interference caused by irregular pressure of cutting fluid using the digital filter, AE signal with an expected behavior is obtained for the dressing conditions adopted. It can also be observed, in the pass 1, Fig. 9 (a), some signal irregularities due to some wheel wear caused by grinding. However, in Fig. 9 (b) it can also be observed that, after 280 µm removal, the signal presents fewer irregularities, what is typical of a dressed wheel.

To confirm that no information was lost regarding the wheel topography even with utilization of 70 kHz filter to eliminate fluid interference, , the same procedure was carried out with the signals of test 7 , in which the wheel presented a induced failure (60 µm groove at the center), and the results presented in Fig. 10.

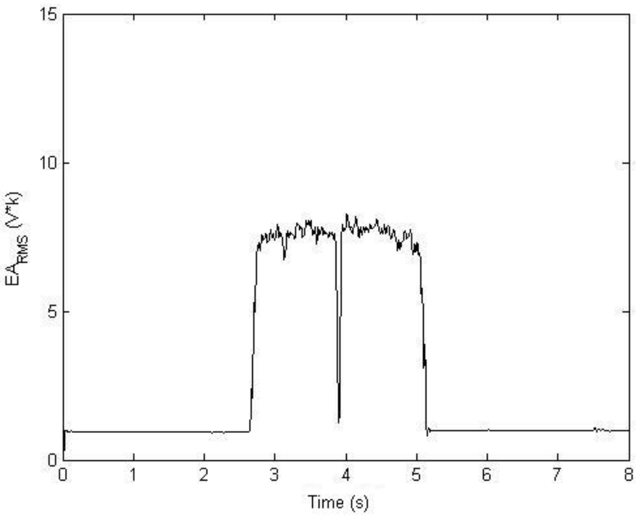


Figure 10. Pass 1 from test 7, a_d = 40 µm, with cutting fluid, filtered with a cutoff frequency of 70 kHz

It can be noted in Fig. 10 that interference caused by the fluid jet was eliminated, and it is still possible to completely detect the failure generated on the wheel. Thus, it can be found that the use of the 70 kHz high-pass digital filter did not remove significant information concerned to the dressing operation and wheel topography.

3. CONCLUSION

The present work investigated the relation between acoustic emission signal and dressing operation, with emphasis on the interference of cutting fluid jet on AE signals.

From the analysis of the AE raw signal spectrum, it has been verified that only the range from 50 kHz to 300 kHz brings information about the process.

It is concluded that cutting fluid exerts a great influence on AE_{RMS} signal, compromising the dressing operation analysis using this signal, and the high-pass filter with cutoff frequency of 70 kHz shows itself significantly effective on eliminating that interference, without removing relevant information concerned with the dressing operation. Thus, raw AE signal processing is indispensable on monitoring of dressing operation.

4. ACKNOWLEDGEMENTS

The authors are thankful for support from FAPESP – Fundação de Amparo à Pesquisa do Estado de São Paulo, process # 07/56430-2. Also, thanks go to Saint-Gobain for providing the grinding wheels for the tests.

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