CORRELATING SURFACE ROUGHNESS AND ACOUSTIC EMISSION SIGNALS WITH THE RELATIVE POSITION BETWEEN TOOL AND WORKPIECE DURING CYLINDRICAL TURNING

Fábio Fialho do Nascimento
Departamento de Engenharia Mecânica, Universidade Federal da Bahia, Rua Aristides Novis, 2, 5º andar, Federação, Salvador/BA, CEP. 42.210-630
f_fialho@terra.com.br

Anderson Clayton Alves de Melo
Departamento de Engenharia Mecânica, Universidade Federal da Bahia, Rua Aristides Novis, 2, 5º andar, Federação, Salvador/BA, CEP. 42.210-630
acamelo01@yahoo.com.br

Álisson Rocha Machado
Faculdade de Engenharia Mecânica, Universidade Federal de Uberlândia, Avenida João Naves de Ávila, 2121, Santa Mônica, Uberlândia/MG, CEP. 38.400-100
alissonm@mecanica.ufu.br

Abstract. *Results obtained from dry cylindrical turning of ABNT 1045 steel bars, where surface roughness and VRMS signals of acoustic emission monitored at different regions over the workpiece are presented. The workpiece was fixed using the chuck and the dead center of the tailstock. During trials the main cutting parameters were kept constant and the tool wear neglected. Thus, the only entrance variable was the tool position on the workpiece. It was observed that there is a proportional relationship between the intensity of the acoustic emission signals and the surface roughness values. Furthermore, it was verified that the set-up conditions and stiffness of the workholding system cause influence on the machined surface quality.*

Keywords: *Monitoring, Acoustic Emission, Surface Roughness, Turning.*

1. Introduction

Acoustic emission (AE) is defined as a transient elastic wave generated by a sudden release of energy from one or more sources located inside a material when it is subjected to a state of stress. This release of energy is associated with the abrupt redistribution of internal stresses and as result of this, a stress wave is propagated throughout the material (Ravindra *et al.*, 1997). According to Matsumoto and Diniz (1998), the frequency range of acoustic emission signals varies from 50 to 1000 kHz, permitting detection of occurrences that emit high frequency signals, for example, the appearance of a crack inside a material.

The monitoring of machining processes using acoustic emission sensors is a practice that has been largely used in the last years, both in the research laboratories and in the industry. There are many advantages in using acoustic emission for monitoring machining processes. In this case, it can be highlighted that the frequency range of acoustic emission signals are much higher than that from the machine vibrations and environmental noises. This fact becomes interesting, because the high frequency signals generated during the cut at the secondary and primary shear zones and at the interface between flank face and the machined surface or due the cutting tool breakage, can be monitored without suffer interferences caused by vibration signals. Thus, it is possible to use AE signals for indirectly to monitor tool wear (and, consequently, the surface roughness), because the progress of the tool wear causes increase in the AE level.

Several researchers have worked on monitoring of machining processes using acoustic emission. Publications by Diniz *et al.* (1991) and Li (2001), that have applied AE in turning; Webster *et al.* (1994), Kwak and Song (2000) and Oliveira and Dornfeld (2001), in grinding; and Diei and Dornfeld (1987), in milling, can be highlighted.

In this paper, results obtained from the monitoring of surface roughness (Ra) and AE signals in several segments on cylindrical bar of ABNT 1045 steel during turning are presented. In this case, trials using a steel bar with diameter equal to 100 mm were carried out. Results show that there was a proportional relationship between the two measured variables (AE and Ra) and that, during turning process, the dynamic condition between cutting tool and workpiece depends on the relative longitudinal position between cutting tool and workpiece. Furthermore, it was observed that near the chuck the dynamic condition is not the same of the one near the tailstock, being this last condition more favorable to the appearance of self-exited vibrations (vibrations caused by dynamic instability in the tool-workpiece system – Stemmer, 1987) that causes a worse surface roughness.

2. Experimental Details

For carrying out the trials, it was used the conventional cylindrical turning, where a bar of ABNT 1045 steel with diameter of 100 mm and length of 380 mm were machined. The bar was divided in 37 segments of 8 mm each (Figures 1 and 2) for monitoring AE and Ra along the bar. It was kept fixed at one of its extremities by the chuck and susteined at the other by the dead center of the tailstock, according to Figures 1 and 2.

Cemented carbide cutting tools coated with TiN and having a nose radius equal to 0.4 mm were mounted on a tool holder ISO DSBNR2525M12, both manufactured by Sandvik-Coromant. Due to the brevity of the trials, the tool wear was practically zero, and therefore neglected.

The main cutting parameters were kept constant at: cutting speed, v_c = 105 m/min; depth of cut, a_p = 0.7 mm and feed rate, f = 0.1 mm/rev.

The acoustic emission signals were acquired using the signal conditioner DM-42 manufactured by Sensis. In this case, the acquisition rate was settled in 1kHz and a highpass filter of 50kHz was used. All this apparatus was connected to a data acquisition board NI 6036E (Fig. 1). The acoustic emission sensor was fastened on the tool post, as detailed in Fig. 1. For each segment (from 1 to 37) data files containing the numerical values of the acoustic emission signals (in VRMS) with approximately 14,000 points were obtained.

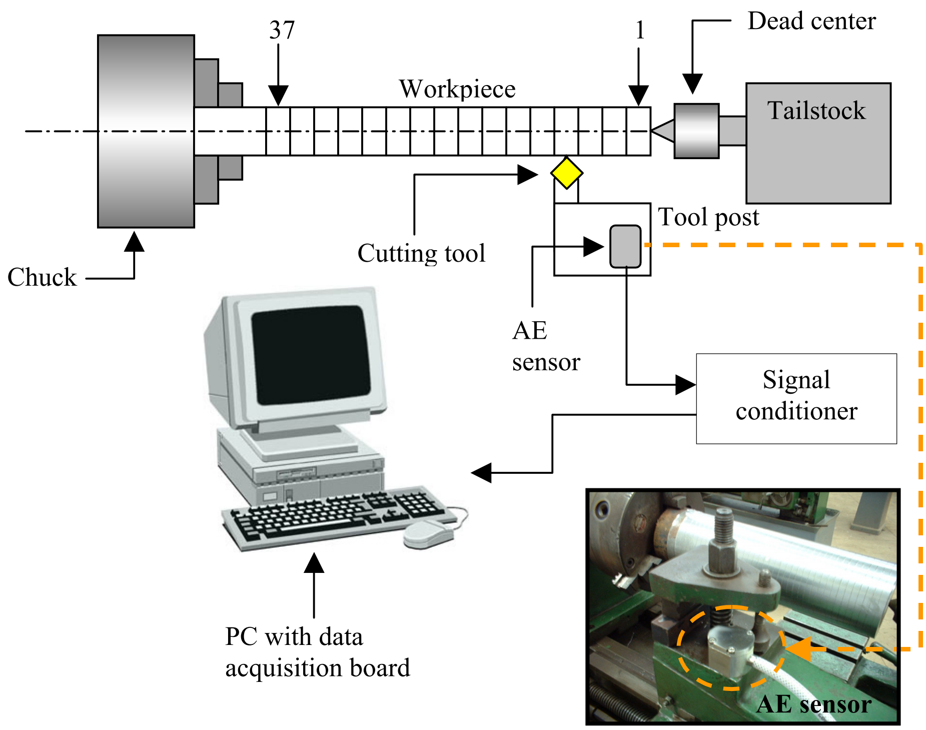

Figure 1. Experimental apparatus.

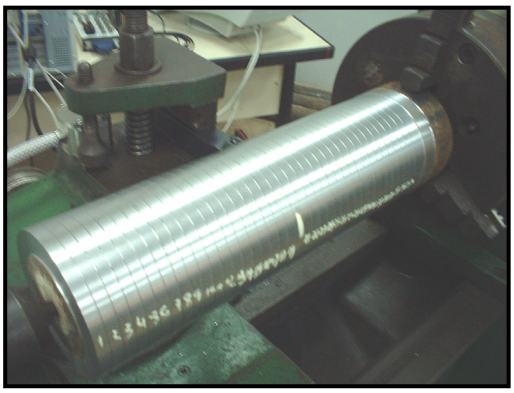

Figure 2. Bar used on the trials. The picture shows the divisions between each segment (from 1 to 37). The divisions were made to facilitate the identification of the acquired signals in each segment.

After machining, the parameter "Ra" was measured on each segment. For measuring this parameter, a portable surface roughness tester Mitutoyo SJ-201P was used. In this case a cut-off length equal to 0.8 mm and an evaluation length equal to 4 mm were set. Three measurements on the bar's circumference separated by an angle of 120º were done. The roughness value considered for each segment was the average of the three measured values.

3. Results and Discussion

Figure 3a presents a typical behavior of the acoustic emission signal during machining of a segment. It can be observed that at the extremities of the segment the values of AE are practically zero. This is due to the slots made on the workpiece surface to separate the segments. It can be also observed that the typical signal is composed by "continuous type AE signals" and by "burst type AE signals" or "transient AE signals". This observation was already cited by some researchers (Blum and Inasaki, 1990; Li, 2002; Matsumoto and Diniz, 1997). Continuous signals are associated with plastic deformation in soft materials, while burst or transient signals result from the appearance of a crack (Schofield, 1972; Dunegan and Green, 1971). According to Blum and Inasaki (1990), chip impacts against the workpiece, the cutting tool, the tool holder, etc., can also generate transient signals. In the present research, it is believed that the majority of the peaks observed was a consequence of chip impacts during the trials and due to the fracture of them.

Figure 3b shows a set of the primitive signal used for calculating the acoustic emission value of a determined segment on the workpiece. In this case, 8,000 points (from point 5,000 to point 13,000) were considered. Naturally they are composed by continuous and transient signals. In order to get rid of the peak signals and to consider only the continuous signals in the calculation of the AE value on each segment, the Chauvenet criterium was applied. Figure 3c shows the same set presented in the Fig. 3b, after application of the Chauvenet criterium. It can be observed that the most remote points were eliminated. The arithmetic average of the points contained in this graphic was calculated to represent the AE signal on the analyzed segment. This procedure was adopted for the 37 segments on the workpiece.

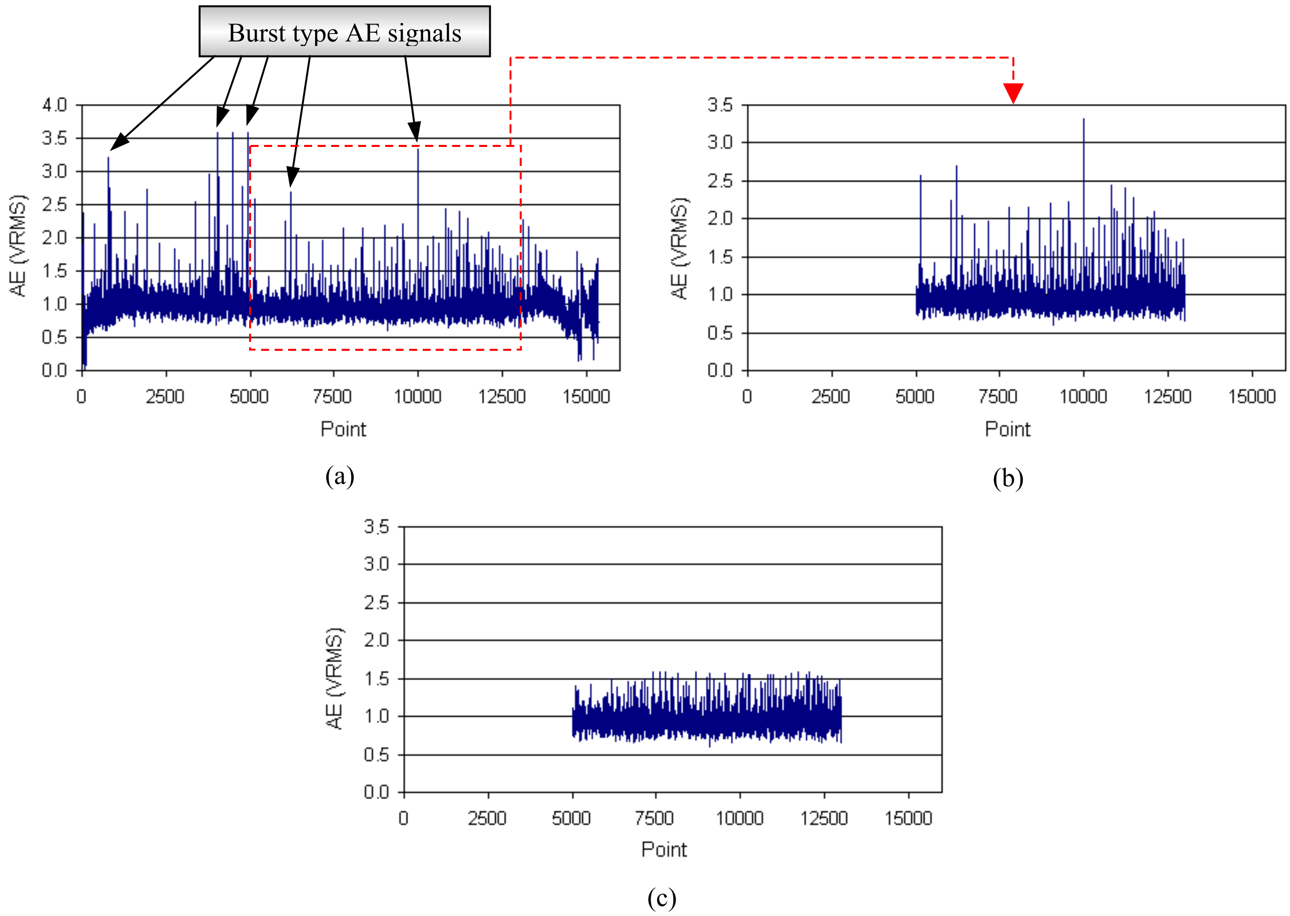

Figure 3. (a) Typical behavior of the acoustic emission signals obtained on a particular segment of the workpiece; (b) A set of the primitive signals before the application of the Chauvenet criterium and (c) After the application of the Chauvenet criterium.

The behavior of “Ra” parameter and acoustic emission signals along the workpiece length are shown in the Fig. 4.

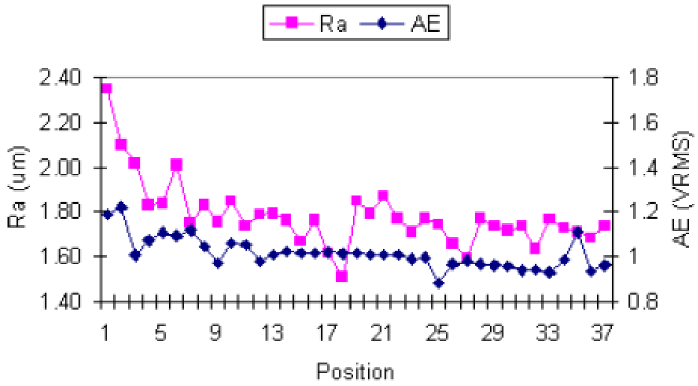

Figure 4. Roughness (Ra) and acoustic emission signal (AE) obtained from the trials.

It can be observed that the “Ra” parameter is high near the tailstock (segment 1) and drops towards the chuck (segment 37). This behavior was expected because near the chuck the rigidity of the system is higher than near the dead center of the tailstock, with higher stiffness, reducing vibrations and consequently, generating better surface roughness.

Concerning to AE signal obtained, it can be observed that the signal drops toward the chuck. This behavior is again attributed to the tool-workpiece system’s stiffness that increases near the chuck, what becomes the cut more uniform, with less vibration. Away from the chuck, and near the tailstock there is a decrease of the rigidity of the tool-workpiece system. This is confirmed by the roughness results. It is believed that the increase of vibration causes frequent increase on the contact areas at the primary and secondary shear plans, increasing the level of the acoustic emission signals, because according to Kannatey-Asibu and Dornfeld (1981), the energy contained in the AE signal is proportional to the ratio of energy consumed at the cutting zone.

4. Conclusions

The dynamic conditions between tool and workpiece during turning are more favorable near the chuck, where the system stiffness is better than near the tailstock, where higher mechanical vibrations cause the acoustic emission and surface roughness parameter to increase.

5. Acknowledgements

The authors would like to thanks to the “Fundação de Amparo à Pesquisa do Estado da Bahia” (FAPESB), FAPEMIG, CAPES, CNPq and to the “Instituto Fábrica do Milênio” (IFM).

6. References

Blum, T. and Inasaki, I., 1990, “A study on acoustic emission from the orthogonal cutting process”, Journal of Engineering for Industry, Vol. 112, pp. 203-211.

Diei, E. N. and Dornfeld, D. A., 1987, “Acoustic emission sensing of tool wear in peripheral milling”, ASME Trans., J. Eng. Ind., Vol. 109, No 3, pp. 234-240.

Diniz, A. E., Liu, J. J. and Dornfeld, D. A., 1992, “Correlating tool life, tool wear and surface roughness by monitoring acoustic emission in finish turning”, Wear, 152, 395-407.

Gomes de Oliveira, J. F. and Dornfeld, D. A., 2001, “Application of AE contact sensing in reliable grinding monitoring”, CIRP annals, Vol. 50, No 1, pp. 217-220

Kannatey-Asibu, E., Jr., and Dornfeld, D. A., 1981, “Quantitativ Relationships for Acoustic Emission from Orthogonal Metal Cutting”, Transactions for the ASME, Vol. 103, pp. 330-340.

Kwak, Jae-Seob and Song, Ji-Bok., 2001, “Trouble diagnosis of the grinding process by using acoustic emission signals”, International Journal of Machine Tools & Manufacture 41, 899-913.

Li, X., 2002, “A brief review: acoustic emission method for tool wear monitoring during turning”, International Journal of Machine Tools & Manufacture 42, 157-165.

Matsumoto, H. and Diniz, A. E., 1998, “Torneamento do Aço Endurecido Monitorado por Emissão Acústica e Corrente do Motor”, Máquinas e Metais, 72-79.

Ravindra, H. V., Srinivasa, Y. G. and Krishnamurthy, R., 1997, “Acoustic emission for tool condition monitoring in metal cutting”, Wear 212, 78-84.

Stemmer, C. E., 1987, “Ferramentas de Corte”, Florianópolis. Ed. Da UFSC, 204 pages.

Webster, J., Marinescu, I. and Bennett, R., 1994, “Acoustic emission for process control and monitoring of surface integrity during grinding”, Annals of the CIRP, Vol. 43.

7. Responsibility notice

The authors are the only responsible for the printed material included in this paper.