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Acoustic Emission Method For Selection Of Optimum Cutting Parameters In Turning Using Different Fluids: A Review

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Abstract:
Research during the past several years has established the effectiveness of acoustic emission (AE) based sensing methodologies for machine condition analysis and process monitoring. AE has been proposed and evaluated for a variety of sensing tasks as well as for use as a technique for quantitative studies of manufacturing processes. Optimum selection of cutting conditions importantly contribute to the increase of productivity and the reduction of cost, therefore utmost attention is paid to this problem in this contribution. In this paper we proposed AE as non-contact and indirect technique for in-process surface roughness assessment in turning. Three cutting conditions dry cut, cutting with water as coolant and normal coolant will be used. The materials in study are mild steel and EN8. Three cutting parameters namely feed rate, depth of cut, cutting speed will optimized with consideration with surface roughness. AE signals will be acquired from tool post jig. Surface roughness of finished surface will be measured. Taguchi method will be used find optimal cutting parameters for surface roughness (Ra) in turning. The L-9 orthogonal array, the signal-to-noise ratio and analysis of variance are employed to study the performance characteristics. Regression models will be developed and will be validated to predict the surface roughness and AE Signal value.

Key words: Acoustic Emission (AE), Surface roughness, Taguchi Method, DOE, L-9 array

1.Introduction

1.1.Acoustic Emission

Acoustic Emission, according to ASTM, refers to the generation of transient elastic waves during the rapid release of energy from localized sources within a material. The source of these emissions in metals is closely associated with the dislocation movement accompanying plastic deformation and the initiation and extension of cracks in a structure under stress. Other sources of Acoustic Emission are: melting, phase transformation, thermal stresses cool down cracking and stress build up acoustic emission phenomena in non-distractive testing and tool monitoring. Acoustic emissions have become an important tool for instrumentation and monitoring due to the great advances in signal classification, instrumentation, and sensors.

1.1.1 AE Signal Source

Research has shown that AE, which refers to stress waves generated by the sudden release of energy in deforming materials, has been successfully used in laboratory tests to detect tool wear and fracture in single point turning operations. Dornfeld (1989) [1] pointed out the following possible sources of AE during metal cutting processes (see Fig. 1)

- Plastic deformation during the cutting process in the work piece;
- Plastic deformation in the chip;
- Frictional contact between the tool flank face and the work piece resulting in flank wear;
- Frictional contact between the tool rank face and the chip resulting in crater wear;
- Collisions between chip and tool;
- Chip breakage;
- Tool fracture.

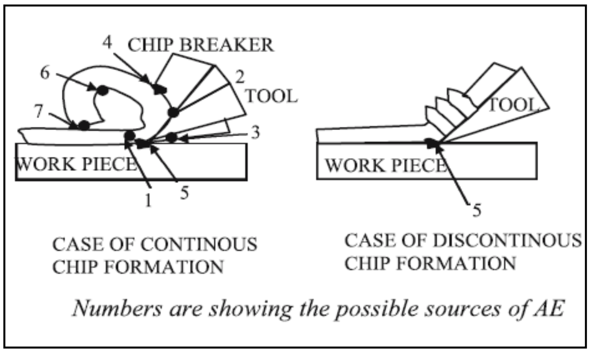

Figure 1: Sources of AE

1.1.2 AE signal

Based on the analysis of AE signal sources, AE derived from metal turning consists of continuous and transient signals, which have distinctly different characteristics. Continuous signals are associated with shearing in the primary zone and wear on the tool face and flank, while burst or transient signals result from either tool fracture or chip breakage. Therefore, from (a) to (d) sources generate continuous AE signals, while from (e) to (g) generate transient AE signals (see Fig. 2). The AE signal types in cutting process shown in Fig.2.

1.2.Surface Roughness

Surface Roughness (finish) is one of the crucial performance parameters that have to be controlled within suitable limits for a particular process. Therefore, prediction or monitoring of the surface roughness of machined components has been an important area of research. Surface roughness is harder to attain and track than physical dimensions are, because relatively many factors affect surface roughness.

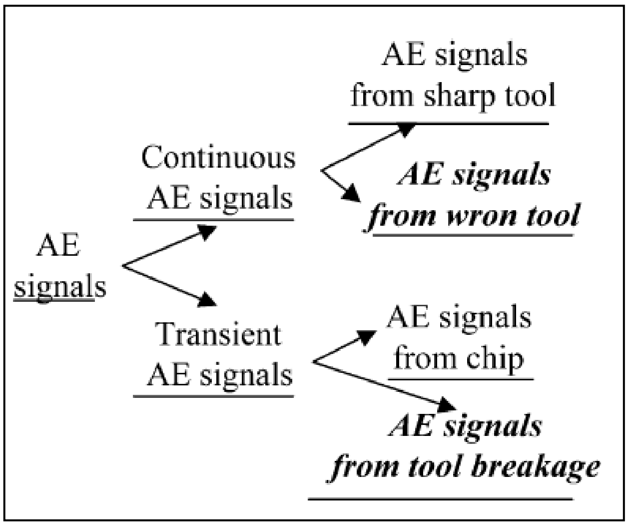

Figure 2: AE signal

Surface roughness is caused by:

The feed marked or ridges left by the cutting tool, and

The fragments of built-up edge shed on the work surface in the process of chip formation. Surface finish can be improved by reducing the height of the feed ridges and the size of the built up edge.

2. Litreture Review

Stefan pitter et. al.[2] concluded that acoustic emission signals are one of the promising source for in-process surface roughness assessment in turning. Approximate relationship between statistical measurement of acoustic emission signals and surface roughness parameters have been modeled earlier for different experimental situation. In addition to cutting feed, and cutting speed simple statistics derived from acoustic emission signals produce useful information for surface roughness assessment. Speed, feed and RMS value of AE are clearly correlated with the surface roughness parameters. The degree of correlation of RMS of AE seems to be better correlated than speed and RMS is the best possible choice to classify each of three roughness parameters apart from feed.

T. Tamizharasan et. al. [3] had developed a mathematical model using multiple regression analysis and artificial neural network (ANN) model for artificial intelligent model. They found that depth of cut is most significant parameter followed by cutting speed, hardness of material and lastly feed rate. The mathematical model developed by multiple regression method shows accuracy of 97.41% which is reliable to be used on AE signal prediction. The result from this research is useful to be implemented in industry to reduce time and cost in AE signal prediction.

R S Pawade et. al. [4] have found that analysis of AE Signal during the machining could help to determine the quality of the machine surface. Frequency amplitude of the AE signal is influence by the cutting speed. The feed rate and edge geometry are found to influence the number of count generated during machining deformation.

T S Reddy et. al.[5] have done the turning operation using HSS tool on mild steel. The result shows significance relation between surface roughness and AE signals parameters. The conclusions are made for predicting surface roughness by suggesting consistence values and ranges for on-line monitoring of AE signals parameters.

J Bhaskaran et. al.[6] in study of hard turning, used the skew and kurtosis parameters of AE signals to monitor tool wear. The moment parameters of AErms signals such as skew and kurtosis can be used to reliably monitor the tool wear and surface roughness.

G. Priyadarshini et. al.[7] found that lower feed rate/rev, AErms Value was less and surface roughness of machined surface was also less. Analysis reveal that the acoustic emission while metal machining can be very useful in identifying relative surface quality of the product and hence selection of proper cutting parameters. Acoustic emission technique can be effectively used in online condition monitoring of machining parameters.

Nitin Sharma et. al.[8] have used Taguchi method to find the optimal cutting parameters for surface roughness (Ra) in turning of AISI-410 steel bars usinf tin coated inserts. The four cutting parameters namely insert radius, depth of cut, feed and cutting speeds are optimized with consideration of surface roughness. The analysis reveals that feed rate has the most significant effect on Ra. They found that parameter design of the Taguchi method provides a simple systematic and efficient methodology for the optimization of the cutting parameters.

Suleman et. al.[9] have investigated the influence of depth of cut, feed rate and spindle speed on surface roughness during turning of mild steel. Analysis of variance (ANOVA) is used to analyze the influence of machining parameters on surface roughness. Multiple linear regressions, mathematical model correlating the influence of machining parameters on surface roughness during the process were developed and validated.

3. Taguchi Method

Taguchi has developed a methodology for the application of designed experiments, including a Practitioner's handbook. This methodology has taken the design of experiments from the exclusive world of the statistician and brought it more fully into the world of manufacturing. His Contributions have also made the practitioner work simpler by advocating the use of fewer Experimental designs, and providing a clearer understanding of the variation nature and the economic consequences of quality engineering in the world of manufacturing [10,11]. Taguchi introduces his approach, using experimental design for designing products/processes so as to be robust to environmental conditions; designing and developing products/processes so as to be robust to component variation; minimizing variation around a target value.

The philosophy of Taguchi is broadly applicable. He proposed that engineering optimization of a process or product should be carried out in a three-step approach, i.e., system design, parameter design, and tolerance design. In system design, the engineer applies scientific and engineering knowledge to produce a basic functional prototype design, this design including the product design stage and the process design stage. In the product design stage, the selection of materials, components, tentative product parameter values, etc., are involved. As to the process design stage, the analysis of processing sequences, the selections of production equipment, tentative process parameter values, etc., are involved. Since system design is an initial functional design, it may be far from optimum in terms of quality and cost

The objective of the parameter design [12] is to optimize the settings of the process parameter values for improving performance characteristics and to identify the product parameter values under the optimal process parameter values. In addition, it is expected that the optimal process parameter values obtained from the parameter design are insensitive to the variation of environmental conditions and other noise factors. Therefore, the parameter design is the key step in the Taguchi method to achieving high quality without increasing cost.

Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. A loss function is then defined to calculate the deviation between the experimental value and the desired value. Taguchi recommends the use of the loss function to measure the performance characteristic deviating from the desired value. The value of the loss function is further transformed into a signal-to-noise (S/N) ratio h. There are three categories of the performance characteristic in the analysis of the S/N ratio, that is, the lower-the-better, the higher-the-better, and the nominal-the-better. The S/N ratio for each level of process parameters is computed based on the S/N analysis. Regardless of the category of the performance characteristic, the larger S/N ratio corresponds to the better performance characteristic. Therefore, the optimal level of the process parameters is the level with the highest S/N ratio ρ Furthermore, a statistical analysis of variance (ANOVA) is performed to see which process parameters are statistically significant. With the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. In this paper, the cutting parameter design by the Taguchi method is adopted to obtain optimal machining performance in turning.

- Nominal is the better: $S/N_T = 10 \log(\frac{y}{S_y{}^2})$ (1)
- Larger-is-the better (maximize): $S/N_L = -10 \log (\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i{}^2})$ (2)
- Smaller-is-the better (minimize): ${S}/{N_S} = -10 \log (\frac{1}{n}\sum_{i=1}^{n} y_i{}^2)$ (3)

Where y is the average of observed data, $S_y{}^2$ is the variance of y, n is the number of observations and y is the observed data.

Notice that these S/N ratios are expressed on a decibel scale. We would use S/NT if the objective is to reduce variability around a specific target, S/N_L if the system is optimized when the response is as large as possible, and S/N_s if the system is optimized when the response is as small as possible. Factor levels that maximize the appropriate S/N ratio are optimal. The goal of this research was to produce minimum surface roughness (Ra) in a turning operation. Smaller Ra values represent better or improved surface roughness. Therefore, a smaller-the-better quality characteristic will be implemented and introduced in this study.

4.Conclusion

The acoustic emission while metal machining can be very useful in identifying relative surface quality of the product and hence in selection of proper cutting parameters. Acoustic emission technique can be effectively used in online condition monitoring of machining parameter. Parameter design of the Taguchi method provides a simple systematic and efficient methodology for the optimization of the cutting parameters.

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