TIME DOMAIN ANALYIS OF ACOUSTIC EMISSIONS SIGNAL FOR MILLING PROCESS

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ABSTRACT

This thesis is to investigate the machining surface roughness by using acoustic emission (AE) method. The objectives of this project is to acquire AE data of the experiment by operating milling process, to study the correlation of AE parameter with work piece surface roughness (R_a) and to cluster AE data by using time domain analysis such as global statistical parameter and clustering method for online machining condition monitoring. In order to done this experiment, there is method to be taken. Firstly is the experimental setup. Computational Numerical Control (CNC) milling machine will be use through this project conduct the face milling. Machining parameter set for depth of cut, cutting speed and feed rate. Surface roughness being measure by using perthometer. USBwin for AE Node used for data acquisition. The material used is Hayness 188 alloy and carbide-coated as the cutting tool. Before experiment is started, the AE system need to be tested by using pencil break test to check whether AE system can receive AE signals properly. When lead of pencil break, it will generate as equal as AE signals emit during experiment. For data analysis, AE signal can be cluster based on surface roughness. For clustering analysis, it is related to its signal properties. Method used to cluster the signals is global statistical parameter such as root mean square (RMS), skewnes, kurtosis, peak value and variance. Based on experiment data, the pattern of AE parameter with time domain analysis can be concluded by clustering method. The analysis shows that AE signals data can be cluster by global statistical parameter according to its surface roughness measurement. Between all global statistical parameter, we can see that peak value, RMS and variance can show the significant pattern on clustering. As the project is success, data collected surface roughness monitoring can be made and be used in industry. So, this method can be use as an alternative method in industry to decrease the time used and the cost needed.

ABSTRAK

Tesis ini adalah untuk menyiasat kekasaran permukaan bahan yang telah dimesin dengan menggunakan kaedah pancaran akustik (AE). Objektif projek ini adalah untuk memperoleh data eksperimen oleh proses mencanai, mempelajari kaitan antara AE parameter dengan kekasaran dan mengkelaskan data AE dengan menggunakan analisis domain masa seperti parameter statistic global dan kaedah pengelompokan untuk pemantauan kaedah pemesinan yang sedang beroperasi. Beberapa langkah diperlukan untuk menjalankan eksperimen ini. Yang pertama adalah persediaan eksperimen. Mesin kawalan berangka computer (CNC) akan digunakan dalam eksperimen ini dalam menjalankan pencanaian muka. Parameter mesin telah ditetapkan seperti kedalaman memotong, kelajuan memotong dan kadar suapan. Kekasaran permukaan diuji dengan menggunakan perthometer. Bahan yang digunakan adalah Hayness 188 aloi dan carbide bersalut sebagai alat pemotong. Sebelum eksperimen dijalankan, system AE perlu diperiksa dengan menggunakan ujian pensil untuk memastikan system AE boleh menerima signal AE dengan baik. Untuk analisis data, signal AE boleh dikelaskan mengikut kekasaran permukaan. Untuk pengkelasan analisis, ianya berkaitan dengan butiran signal. Kaedah yang digunakan untuk mengkelaskan signal adalah parameter statistic global seperti punca min kuasa dua (RMS), kepencongan, kurtosis, nilai puncak dan varians. Daripada semua data terkumpul, pemantauan kekasaran poermukaan boleh diuji dan digunakan dalam industry. Berdasarkan data eksperimen, corak parameter AE dengan domain masa dapat disimpulkan dengan menggunakan kaedah pengelompokan. Analisis menunjukkan data boleh dikelompokkan dengan menggunakan parameter statistical global berdasarkan keadaan permukaannya. Di antara semua parameter statistik global, kita boleh lihat RMS varians dan nilai puncak boleh memberikan bentuk yang lebih tepat dalam pengkelasan. Oleh itu, kaedah ini boleh digunakan sebagai kaedah alternative dalam industry untuk mengurangkan masa dan kos yang diperlukan.

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LIST OF ABREVIATIONS

AE	Acoustic Emission
CM	Condition Monitoring
CNC	Computer Numerical Control
DSP	Digital Signal Processing
DUS	Digital Ultrasonic System
f	Feed
FCG	Fatigue-crack Growth
LCF	Low-cycle Fatigue
N	Rpm
NDT	Non-destructive Testing
P	Parameter
PC	Personal Computer
PCA	Principal Component Analysis
R_a	Surface Roughness
RMS	Root Mean Square
SD	Standard Deviation
SNR	Signal-to Noise ratio
UT	Ultrasonic Testing
UV	Ultraviolet
v	Cutting Speed
w	Depth of Cut

WPT	Wavelet Packet Transform
WT	Wavelet Transform

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Nowadays, industrial demands for machining systems to increase the productivity and quality of products in milling process requires advance investigations of monitoring techniques where can determine the failure earlier. Monitoring and analyzing of failures and quality that happen on milling process will help how to predict cutting tool life and breakage in the work piece (Dornfeld, 1985). This project is focused on the detection and prediction of the occurrence of process malfunctions at work piece surface integrity levels using Acoustic Emission (AE). AE has been employed predominantly for tool condition monitoring of continuous machining operations like drilling or turning, but relatively little attention has been paid to monitor interrupted processes such as milling and especially to detect the occurrence of possible surface anomalies (Dornfeld, 1985).

The purpose of this project is to monitor time domain analysis of AE signal during machining process at different surface quality. The research focused to determine AE signal that released during machining process along with surface roughness of the work piece. Those signals will then analyse using time domain analysis by using global statistical method and clustering method in order to study the characteristics of the AE signal at different surface quality machining (Deniz et al, 1992).

Industries nowadays usually focused on the quality and productivity of product that considering improving the products and avoiding major losses of machining process. A lot of research in the process malfunctions of tool and work piece have done to increase the productivity of the product and reduce the manufacturing costs and times in production lines (Dornfeld, 1991).

For example, the manufacturers usually focused on the quality and productivity of the product in their factory. In the production lines, the problems that always occur are malfunctioning of machine or the product defect. To increase the productivity and increase the quality of product, they made several experiments and simulations to decrease the failure events. For milling process, the manufacturers control the cutting speed during the production. They used related formulas to get the best cutting speed and some of the product defect can be decrease. But, it is only occur on material that have low strength properties such as aluminum and steel. Thus, for materials that have high strength properties such as Hayness alloy, a new method should be created so that manufacturing industries can manufacture faster and produce high quality product.

1.2 PROBLEM STATEMENT

In industries, manufacturers focused on the quality and productivity of the product. To increase the productivity, offline condition monitoring have been implemented during the past decades. Surface roughness is one of the important parameters to determine the quality of product. The mechanism behind the formation of surface roughness is very dynamic, complicated and process dependent. Several factors will influence the final surface roughness in computer numerical control (CNC) milling operations such as controllable factors for spindle speed, depth of cut and feed rate while for uncontrollable factors for tool geometry and material properties of both tool and workpiece. For data analysis, some of the operator past decades used conventional method offline condition monitoring. It is based on the collection of data by means of a handheld data logger and the subsequently downloading the information to a database for further analysis. It also increase the cost of the process. By contrast, online condition monitoring provide some level of permanent connections to the monitored plant (Toenshoff, 2000).

Thus, this research will preferred online condition monitoring technique where full protection of material is required. The advantage of online condition monitoring is that the monitoring intervals can be increase without incurring additional labour cost. This allows for better fault detection and permits collection from dangerous and hazardous areas without incurring risk to operator. This type of monitoring is also made more economical, as the time domain can be transferred over great distance using this technique (Inasaki, 1998).

1.3 OBJECTIVES OF THE RESEARCH

a) To develop method monitoring AE using time domain analysis.

b) To use online condition monitoring AE signal to detect the characteristics of AE signal for different surface roughness

c) To acquire AE data release from low speed face milling process for material Hayness 188 alloy.

1.4 PROJECT SCOPES

a) Using HAYNESS 188 alloy as a material or work piece.

b) Using carbide coated for cutting tool.

c) Using face milling machine conduct by acoustic emission.

d) Using single channel sensor system for AE sensor system

e) Using clustering method parameter based on global statistical parameter to cluster the signal at different surface quality in time domain analysis.

1.5 HYPOTHESIS

The expected result for this research is that global statistical parameter can differenciate the surface quality level using clustering method by AE analysis based on condition monitoring. Since the signal receive is different for different machining parameter used, so the pattern of clustering data will be different too.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will briefly explain about the theory of machining, theory of acoustic emission, clustering methods and literature based on other research.

2.2 MACHINING

Almost all the process used to shape metals it is in machining process that the conditions of operation are most varied and almost all metals and alloys are machined either hard or soft, either cast or wrought, either ductile or brittle. As regards size, the components from watch parts to aircraft wing spars, over 30 meters long are machined and many different machining operations are used such as the cutting speed may be as high as 3500 m min^{-1} (11,500ft/min) for aluminum wing panels (Trent and Wright, 2000).

Machining is the removal of the unwanted material from the work pieces to obtain a finished product of the desired shape, size and the surface quality (El-hofy, 2007). In fact, machining ranges from relatively rough cleaning of castings to high-precision micromachining of mechanical components still need the narrow tolerances. The existing of new tool materials open a new era to the machining industry where machine tool development took place. For nontraditional machining techniques, it offers alternative methods for machining parts of complex shape in harder, stronger and tougher materials that were difficult to cut by traditional methods. Nowadays, micromachining has become famous for machining three-dimensional shapes and structures as well as devices with dimensions in the order of micrometers.

2.2.1 Milling

Milling is a machining process where the cutting tools turning out a rotary motion and the workpiece a rectilinear motion (El-hofy, 2007) and the process is used to machine the slots, countered surfaces and external surfaces by use multi-toothed milling cutters or end mills. Milling cutters also available for many types of surfaces of revolution, machining threads, cutting off metals and for cutting gears as shown in **Figure 2.1**.

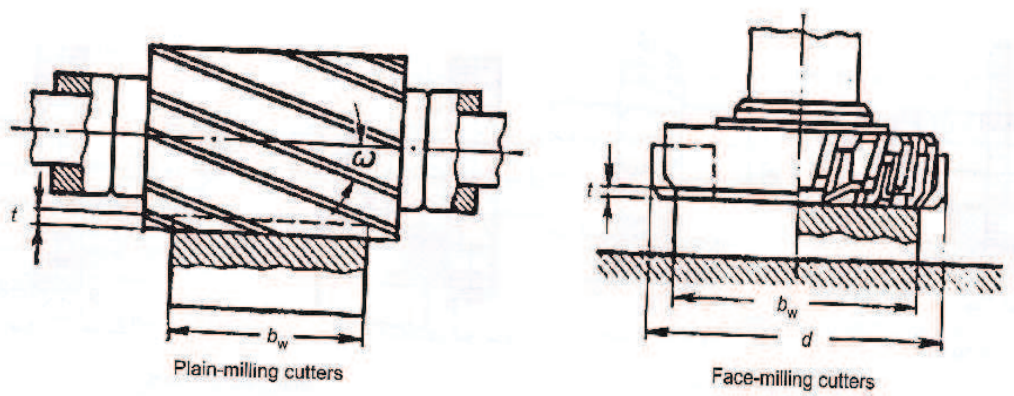

Figure 2.1: Plain- and face-milling cutters

Source: Arshinov, 1970

The milling machine comes in two basics types which are vertical where the cutting tool is normally inserted into a mounting device on the spindle and is held vertically while the other one is horizontal type where the cutting tool is either mounted directly into the spindle and held horizontally or it is mounted on an arbor supported and rotated by the spindle at one end and supported at the other end by a detachable device (Meyers and Slattery, 2001). Both machines are similar in operating control, features and metal removal characteristics but for the horizontal machine its structually is usually much heavier and more powerful than its vertical counterpart. For vertical mill it is more versatile and low in costing with basic yet highly attractive and have the characteristics that help account for the fact it is much more popular than its muscular relative. Their primary functions are to machine slots and to face materials or to create flat and smooth surface (Meyers and Slattery, 2001).

The most important feature of all milling operations is that the action of each cutting edge is discontinuous. Each tooth is cutting less than half of revolution of the cutter and on other time for only a very small part of the cycle (Trent and Wright, 2000). It also is subjected to periodic impacts as it makes contact with the work so that it is stressed and heated during cutting part of the cycle and followed by a period when it is unstressed the allowed to cool. Often the cutting times are in a small fraction of a second and are repeated several times a second that involving both thermal and mechanical fatigue of the tool. The milling cutters design is greatly influenced by the problem of getting rid of the chips. The **Figure 2.2** shows the cutters. **Figure 2.2** (a) show the cutter for up milling process, and followed by figure 2.2 (b) show the cutter for climb milling process.

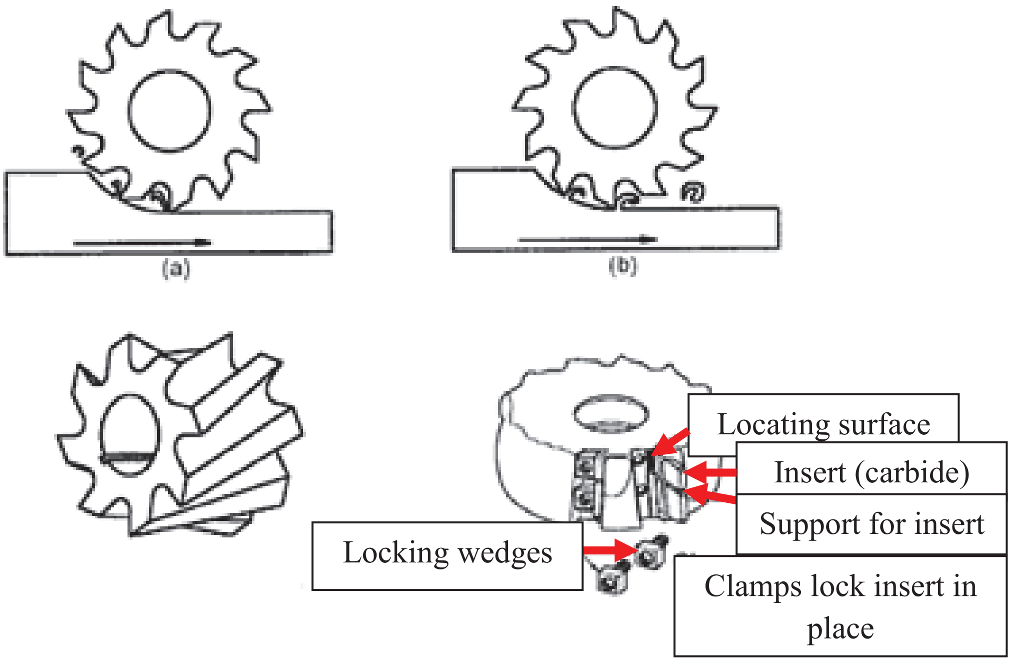

Figure 2.2: Milling cutters : (a) Up Milling, (b) Climb Milling

Source: Trent, 2000

2.2.2 Turning

Turning is a machining process which comes with a geometrically defined cutting edge, a rotational cutting motion and an arbitrary transverse translatory feed motion (Klocke, 2011). The relative movement between the work piece and tool is always take into consideration for the kinematical classification. The methods for turning also classified from various standpoints such as different objectives of the machining task lead to the distinction between finish and rough turning. In case of rough turning, a high removal rate is reached while for finish turning, the objective is to realize a high level of dimensional accuracy and surface quality via small cross-sections of undeformed chip.

The basic operation of turning is the one most commonly employed in experimental work on metal cutting where the work material is held in the chuck of a lathe and rotated (Trent and Wright, 2000). The tool held rigidly in a tool post and it moved at a constant rate along the axis of the bar. It cut away a layer of material to form a cylinder or a surface of more complex profile. This shown in **Figure 2.3**. Lathe turning showing a vertical cross-section at top right and a detail of the insert geometry at bottom right. The dynamometer platform and the remote thermocouple on the bottom of the insert are not used during today's production machining. However they are useful in many researches for routine measurement of cutting forces and overall temperature.

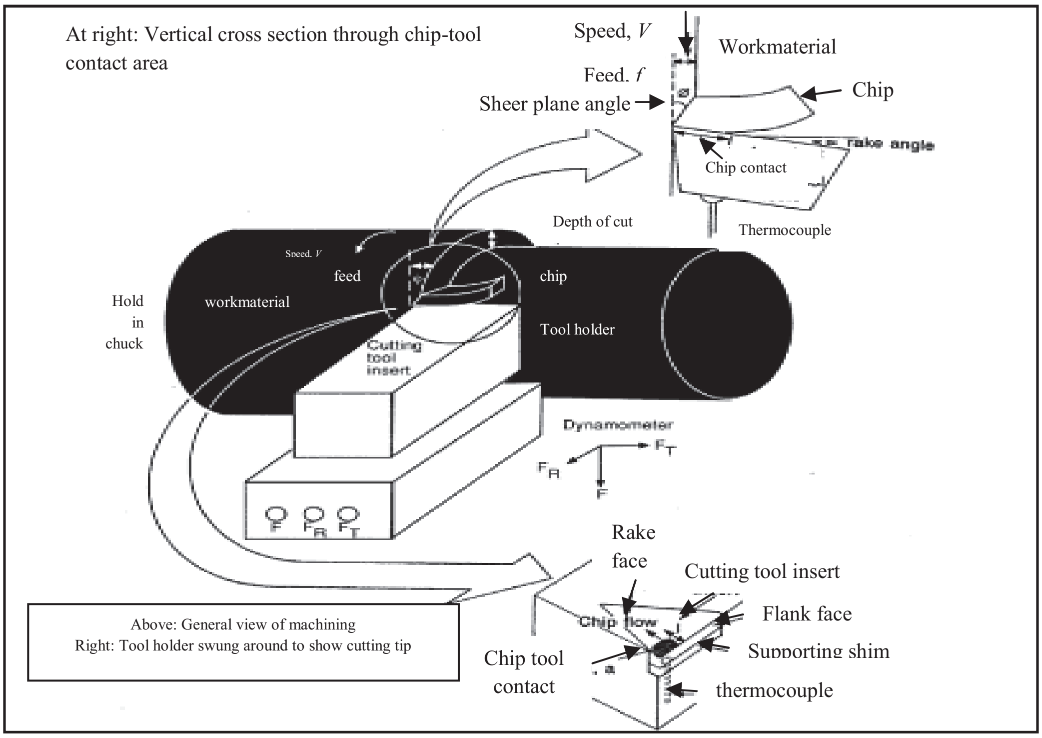

Figure 2.3: Lathe turning

Source: Trent, 2000

The cutting speed (*V*) is the rate where the uncut surface of the work passes the cutting edge of the tool and it usually expressed in units of ft/min or m/min. The feed (*f*) is the distance moved by the tool in an axial direction at each revolution of the work (Trent and Wright, 2000). The depth of cut (*w*) is the thickness of metarial removed from the bar and it measured in radial direction. These three gives the rate of metal removal and it is a parameter often used in measuring the efficiency of cutting operation.

$$\text{Feed Rate} = vfw \tag{2.1}$$

$$\text{Cutting speed } (v) = (\pi \times D \times N) / 1000 \tag{2.2}$$

Where *D* is the diameter of cutting tools and *N* is the rpm of spindle.

The feed rate and the cutting speed are the most important parameters that need to be consider in processing which can be adjusted by the operator to achieve optimum cutting conditions. The depth of cut usually fixed by the initial size of the bar used (Trent and Wright, 2000).

2.3 MATERIALS

HAYNES 188 that possesses excellent high-temperature strength, fabricability, ductility, weldability and superior corrosion resistance is a solid-solution-strengthened cobalt-based super alloy. These components are usually used in situations where low-cycle-fatigue (LCF), creep, and their combinations are the main damage mechanisms that limit service lifetimes which it is importance to investigate the elevated-temperature LCF and fatigue-crack-growth (FCG) behaviors of the HAYNES 188 alloy with and without hold time for designing high-temperature components safely and finding the potential usage of the alloy (Merrick, 1974). The fatigue lifetime depends on the temperature and on the loading waveform due to the creep damage occur (Fournier and Pineau, 1977). Generally, the lifetimes will decrease by the increase of the temperature (Burke and Beck, 1984), and the damage is caused by a combination of fatigue and creep mechanisms (Lerch and et al., 1984).

Various strain-hold tests have been performed to investigate the creep fatigue interaction behavior for many engineering materials (Berling and Conway, 1970). Some studies have examined the elevated-temperature LCF behavior of HAYNES 188 alloy (Chen and Wahi, 1998). The effects of the temperature, strain hold, cyclic frequency, and aging treatment on the LCF of HAYNES 188 alloy also have been studied (Mondel and et al., 1997) and there are few investigations of the tensile hold effect on LCF and FCG behaviors.

2.4 NON-DESTRUCTIVE TESTING

Non-destructive testing (NDT) provides techniques to assess the fall-off of a material or a structure and to detect and characterize the discrete flaws. It plays as well as role in the prevention of failure. NDT are used in processing, manufacturing and for in-service inspection. Methods of NDT are needed to reach the requirements for reliability of materials, structural components and structures. Acoustic emission, ultrasonic and eddy current were used to inspect the material or structure and to characterize the discrete flaws.

NDT was once an empirical technology based on the use of off-the-shelf equipment that produced data for correlation with benchmark results by the subjective judgment of operators. For simple application, quite acceptable results were obtained in that manner for many years. (Subhendu and et al. 1990).

2.4.1 Acoustic Emission

Acoustic emission (AE) is a transient elastic waves due to the rapid energy release from a localized source within a material when given stress. AE sources can be dislocation movements, deformation, inclusion fracture, and crack propagation. **Figure 2.4** show the AE movement process. The AE non-destructive technique is based on detection and conversion of these high frequency elastic waves to electrical signals.

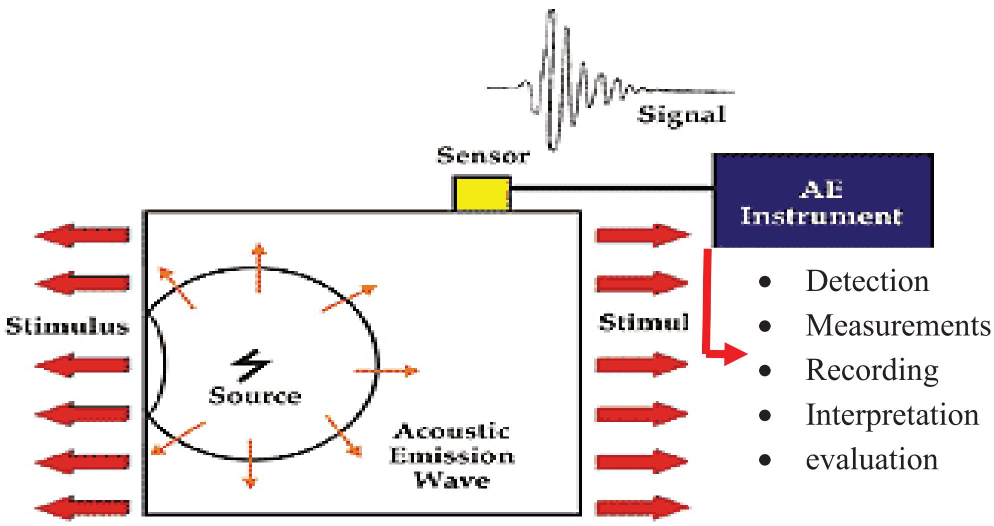

Figure 2.4: AE movement process

Source: Guo,2005

The problem of detecting tool wear and fracture of single point turning tools motivated much of this early work (Guo and Ammula, 2005). There are three major AE sources in metal cutting process (Dornfeld, 1985). One of them is the deformation and fracture of work materials in primary, secondary, and tertiary shear zones and is followed by the deformation and fracture of cutting tools between tool with chip and tool with work piece. another one source is the collision, entangling and breakage of the chips.

AE signal can be divided into two types (Inasaki, 1998). They are either continuous-type AE signal or burst-type AE signal. Continuous signal are related with shearing in the primary zone and wear on the tool flank. For burst type, it is observed during crack growth in the material, tool fracture or the chip breakage. The issue of doing AE signal processing is to eliminate the unwanted noise and to extract the feature signals which uniquely connected with the target process parameters.

The major advantage of using AE to monitor a machining process is that the frequency range of the AE signal is not interfere with the cutting operation and it is much higher than that of the machine vibrations and environmental noises (Dornfeld, 1984). The sensitiveness of the AE signal to various type of contact areas and deformation regions during cutting process has led AE signal as a basic tool for process monitoring. The friction between tool and work piece generates a continuous AE signal, and it gives rich information on a cutting process. Methods have been developed for monitoring tool wear in turning (Liu and Dornfeld, 1992) milling (Lou and Lee, 1995), drilling (Ravishankar and Murthy, 2000), grinding (Webster, 1994), etc. Once AE signatures, thresholds and bandwidth are established for a specific process configuration, the AE signal and AE root mean square (RMS) may be monitored and compared to nominal values to detect abnormal events such as tool breakage (Zheng, and Guo, 1991) or unacceptable tool wear (Dornfeld, 1991). However, few if any surface integrity parameters including residual stress, microstructure changes (Webster, 1994), and surface finish (Diniz, 1992) were on-line monitored, except a brief discussion (Toenshoff, 2000).