CHAPTER 1

INTRODUCTION

One of the most important activities in the manufacturing industry is machining, which includes turning, milling, grinding, drilling etc. The recent trend in manufacturing technology is the development of automatic machining system requiring no supervision or little supervision. Machine tool automation requires monitoring techniques to ensure the condition of machine and workpiece quality. Among several areas of active interest, online monitoring of the state of the cutting tool and the surface roughness of machined workpiece become crucial from this context. Unscheduled downtime, resulting in reduced productivity and profitability, can be caused by the excessive wearing and/or breakage of the cutting tool during machining. In automatic operations, the tool must be removed from the cutting process just before it fails, otherwise the parts produced become out of the allowable tolerance. In fully automated or lightly staffed machining environments, timely determination of the wear state of cutting tools and workpiece roughness are essential to the improvement of productivity and cost effectiveness. Monitoring of tool wear and surface roughness is recommended while dealing with mass production.

The condition of tool and the cutting parameters are the essential inputs to any productivity improvements in unmanned machining. Generally tool replacement and tool wear compensation strategies are based on previous experiences or tool history. On-line monitoring of tool increases the cutting tool utilization by 20% and also gives better surface quality; however, few
reliable and robust indirect methods are available for industrial use. This is mainly due to the intricacy involved in machining process and uncertainty in the correlation between the process parameters and tool wear.

Another parameter concerned in machining process is surface roughness which is an essential parameter used to describe the quality of machined work piece and an indication of tool wear. The roughness of a surface defines how that surfaces feels, how it looks, how it behaves in a contact with another surface and how it behaves for coating or sealing. For moving parts, the roughness determines how the surface will wear, how well it will retain the lubricant and how well it will hold a load. In the manufacturing industry, surface must be within certain limits of roughness. Therefore, monitoring the surface roughness is vital for quality.

In the direct contact surface roughness measurement, the stylus motion perpendicular to the surface is registered. The registered profile is then used to calculate the roughness descriptors. This method requires interruption of machining process. Therefore, an indirect method is needed for monitoring the surface roughness in real time. But there is no absolute, robust way for online prediction of roughness in practice. A promising condition monitoring system is yet to be developed for detecting the tool wear and surface roughness for an automated industry.

1.1 INTRODUCTION TO CONDITION MONITORING

Condition monitoring is determining the health and condition of equipments, machines and systems by observing, checking, measuring or monitoring certain parameters/signals. A general impression occasionally noted is that once the planning, design, manufacture, erection and commissioning are done successfully and the plant or equipment goes for regular operation, the rest is a matter of planned or periodic maintenance
schedules to upkeep the plant or equipment. This is assumed on the basis that, in such cases the general wear and tear can be predicted.

All machines or equipments emanate or indicate both “primary signals” and “secondary signals”. Primary signals are generally those signals or parameters which are required to assess the performance of the equipment. Monitoring of primary signals is termed as “performance monitoring” or “performance trend monitoring”.

Performance monitoring covers the following area,

- Measuring the variations in the absolute value of the system in terms of quality and quantity
- Measuring the system's input output relationship.
- Measuring and simultaneously comparing the output parameters within a set of standard operating conditions. The direct measurement of flow/pressure of a pumping system is an example for performance monitoring. (Rao 1996)

All other signals, which appear as loss outputs like vibration, sound, thermal, chemical and physical changes, are termed as “secondary signals”.

Monitoring of primary signals alone does not help in efficient assessment of health and condition of the machines. As secondary signals are generally a result of loss in output, monitoring of these signals becomes inevitable for equipment health monitoring and technical diagnostics.
1.2 MOTIVATION FOR THE PRESENT RESEARCH

Condition monitoring system (Figure 1.1) is almost essential and by measuring emanated signals at the correct locations in correct manner, it is possible to judge the physical condition of plants and equipments through which timely actions can be initiated. Every defect or malfunction in equipment indicates significant frequencies or signals, which can be identified and measured/compared by suitable instruments/devices. As a rough estimate, about 70% of damages can be characterized by such signals (Sushil Kumar Srivastava 1998). On-line condition monitoring systems are generally continuous with provision to bypass. Continuous monitoring instruments are generally connected with micro-processor or computer.

Monitoring of tool wear and tool change strategies are now based on most conservative estimates of tool life from past tool wear data. Hence usually tools are under utilized. In an unmanned factory, this has the effect of increased frequency of the tool changes and therefore increased cost. Several monitoring methods for mass production have been developed during the last few decades by many researchers. Another important parameter in machining is surface roughness of workpiece that also exposes the tool wear indirectly. With increasing demands for higher productivity and quality, there has been increased interest in monitoring all aspects of the machining process. However few reliable indirect methods have been established for industrial use. This is mainly due to the complexity of machining process and the uncertainty in the correlation between the process parameters with tool wear & roughness. This motivates to develop a reliable technique for the prediction of tool wear and roughness.
1.3 SCOPE OF THE PRESENT RESEARCH

Ultrasonic testing is a versatile NDT method that can be applied to a wide variety of material analysis applications. While ultrasonic NDT is perhaps better known in its more common applications for thickness gauging, flaw detection and acoustic imaging. High frequency sound waves can also be used to discriminate and quantify some basic mechanical, structural, or compositional properties of solids and liquids. From this point of view, it can be seen that the use of ultrasound is well established as a NDT tool, and much information can be obtained about the specimen being tested by ultrasonic inspection. This capability of ultrasonic technique extends its application in condition monitoring. Even though many works have been carried out in the area of tool wear and roughness monitoring, very few research work have focussed on the use of ultrasonic technique in condition monitoring.

The presented work considers the ultrasonic parameters in time and frequency domain, which contributes in prediction of crater and flank wear. The various ultrasonic signal parameters time of flight, amplitude, pulse width and root mean square of the signal (R M S) are used to quantify the wear land height and width that improves the accuracy of the system. This multiple parameter measurement eliminates the limitations in previous studies.
(Taysir H Nayfeh et al 1995) where the amplitude of signal alone was used as a representative parameter. This multiple parameter approach improves the reliability of measurements.

Here, a new method for normalizing the ultrasonic signals is presented. In previous studies (Nidal 1997), a consistent calibration mark cut in the lower corner of the tool nose is used to generate a calibration echo. The calibration echo is affected by the same variations as of the gradual wear. This is used to normalize the nose and flank echoes. It is very much objectionable to machine the insert edge by EDM for monitoring purpose which adds the work. Practically, it is not advisable to sacrifice an edge that adds to the cost. In the presented new approach, the hole provided in the insert to hold it in the tool holder is used as a reference echo. This is used to normalize the nose and flank echoes. End flank surface echo is used as a normalizing signal in H.S.S tool. It moves the ultrasonic system towards industrial application.

The analytical model was derived for tool wear in earlier work (Nidal et al 2000) where, the physical laws governing the propagation and reflection of ultrasonic waves along with geometrical analysis of wear area were used in deriving the mathematical model. The statistical multiple regression can be used for prediction of tool wear as proposed in previous studies (Taysir H Nayfeh et al 1995). But for online monitoring and control, regression or analytical models (Nidal et al 2000) may not be suitable, because the propagation of tool wear and respective ultrasonic signal are complex and dynamic in nature. So an adaptive neuro-fuzzy inference system (ANFIS) is presented to monitor and identify the state of tool wear online. The time domain parameters and the spectral parameters of the reflected ultrasonic waves are used as inputs to ANFIS, which in turn outputs the wear height/depth of tool.
The analysis is carried out by a carbide insert and H.S.S tool with different approaches. The ultrasonic probe is placed by the side of the insert to approach the crater wear directly. In HSS tool the flank wear is monitored by placing the probe at the back of the tool.

The spectral analysis of the ultrasonic signal provides a different approach for tool wear monitoring. A new modelling framework for tool wear monitoring in turning process using ANFIS is presented. This eliminates the restrictions in statistical and analytical modelling due to its limitations in online. Finally, a decision making algorithm (DMA) is presented which decides the state of wear. This technique was further extended for surface roughness measurement in grinding and end milling, as the instrumentation and methodology were almost similar for tool wear and surface roughness monitoring. Though the instrumentation and methodology are same, the setup, analysis and presentation are modified accordingly. This enables a single ultrasonic system with multi-channel used for tool wear monitoring in turning, surface roughness monitoring in end milling and grinding.

In the manufacturing industry, surface must be within certain limits of roughness. In the direct contact method, measurements are obtained using a stylus drawn along the surface to be measured for defined sampling length. This technique may be useful in 100% inspection of parts but not in 100% inspection of entire surface of the work piece. But ultrasonic technique scans the entire surface of the workpiece.

An ultrasonic longitudinal wave propagating through the work piece will lose energy for variety of reasons. The surface roughness of work piece attenuates the ultrasound waves and this scattering is a measure of surface roughness. This behaviour can account for a loss in amplitude as well as change in reflected echo of ultrasonic waves. Such energy loss of the ultrasonic waves is treated very thoroughly in several of the references.
This work concentrates on the ultrasonic parameters, peak amplitude, time of flight and RMS value of reflected ultrasonic signal. This multiple parameter measurement improves the reliability of measurements and eliminates the limitations of previous studies (Scott 1996) where the amplitude of signal alone was used as a representative parameter. The presented work also combines the merits of the usage of normal probe and coolant circulation as coupling medium which were presented by different authors (Scott 1996 and Abdelhay 2004). This eliminates the problem with the back surface and non-normal incidental probe. In addition to this, the power spectrum analysis provides very useful information about the surface conditions.

As mentioned earlier, an Adaptive Neuro-Fuzzy Inference System is used to monitor and identify the surface roughness online. The time domain parameters and the spectral parameters of the reflected ultrasonic waves are used as inputs to ANFIS, which gives predicted surface roughness. The problems in probe approach distance and the effect of back wall is solved in this work. A decision making algorithm (DMA) is presented which is used to take a decision on acceptance of the part.

1.4 BENEFITS OF ONLINE MONITORING OF TOOL WEAR

- Timely replacement of tool
  In current shop floor practice, tools are replaced at the end of pre-determined machining times based on past tool life data. With this policy, tools could either be replaced before the end of their useful life or after considerable damage to work piece due to wear or fracture. So predictions of real measurement of tool wear can eliminate the above stated problems which will improve the tool utilization.

- Plays a vital role in automated production.
The recent trend in manufacturing process is the development of automatic machining system requiring no supervision or little supervision. For an unattended operation, detection of tool condition on-line is essential in order to guarantee higher reliability of the machining system.

- Improves machined Surface quality
  Better surface quality can be confirmed in every instant of the machining process.

- Reduction in cycle time and cost
  It has been estimated that the manufacturing system with online tool wear monitoring will have a cost saving of 9% - 15% and cycle time savings of 3% – 5%

1.5 BENEFITS OF ONLINE MONITORING OF SURFACE ROUGHNESS

- Minimization of cost by eliminating separate inspection process
  Online monitoring of surface roughness completely eliminates the separate inspection process. So the space, labours and material handling time associated with inspection process is reduced.

- 100% inspection of all machined surface: Ultrasonic technique scans the entire surface of the workpiece, so 100% inspection of entire surface of the workpiece is possible.

- Elimination of separate inspection process reduces lead time.

- Corrective action can be implemented to prolong machine operation, thereby increasing machine utilization, equipment, and machine life. Online control of roughness
can be performed by the obtained roughness measurements

- Significant cost savings are guaranteed, as highlighted by the aforementioned benefits.

1.6 ORGANISATION OF THESIS

Chapter 1 describes the basics, importance and benefits of condition monitoring system for tool wear and surface roughness.

Chapter 2 discusses the previous studies in tool wear and surface roughness monitoring and introduces the presented ultrasonic system.

Chapter 3 briefs the theory of tool wear and surface roughness.

Chapter 4 provides the basics of ultrasonic measurement and ANFIS modelling.

Chapter 5 discusses the overview of the ultrasonic methodology developed in this work.

Chapter 6 elaborates the experimental details, procedure and results of crater and flank wear monitoring.

Chapter 7 describes the ANFIS modelling for crater and flank wear.

Chapter 8 elaborates the experimental details, procedure and results of surface roughness monitoring in grinding and end milling.

Chapter 9 describes the ANFIS modelling for surface roughness in grinding and end milling.

Chapter 10 presents the decision making algorithm for tool wear and surface roughness monitoring.

Chapter 11 briefs the overall conclusions drawn in the work and suggestions for future work.