ON-LINE MONITORING OF FLANK WEAR IN SINGLE POINT CUTTING TOOL USING ULTRASONIC TECHNIQUE

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ABSTRACT

The condition of tool and the cutting process 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 have yet been established for industrial use. This is mainly due to the complexity of the machining process and uncertainty in the correlation between the process parameters and tool wear. So promising methods are yet to be developed for detecting the tool wear. Ultrasonic technique is proposed for detecting the tool wear in machining process by on-line monitoring. Ultrasonic testing uses A-scan to evaluate the depth, position and area of tool wear. An integrated ultrasonic transducer operating at a frequency of 1-20 MHz is placed in contact with the tool. The change in amount of reflected energy from the nose and the flank of the tool, amplitude level, TOF and pulse width can be related to the wear of the tool.

Keywords: condition monitoring; Tool wear; ultrasonic sensing; ultrasonic attenuation; ultrasonic reflection coefficient; peak to peak amplitude; time of flight; pulse width.

1. INTRODUCTION:

In recent years the manufacturing systems have undergone dramatic changes. One of the most significant developments has the trend towards cost saving and unattended operation, which also results in improved product quality in conjunction with reduced production time. So the need for detecting the tool condition on on-line is very much increased in order to guarantee higher reliability of these systems. Several methods have been developed for on-line tool wear monitoring but none has achieved significant use in industries [3].

Tool life prediction 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. Advances in adaptive control now call for more sensitive ways of measuring tool wears. It has been proved that on-line tool wear monitoring using ultrasonic technique is more sensitive and promising when compared with other techniques [7]. Gradual wear develops on the tool in two locations: the major flank and the face. Flank wears mainly results from the cutting action and to a lesser extent is due to friction between the newly machined surface and the tool flank. Wear on the face of the tool is termed as crater wear and is located at tool-chip interface. Small amounts of material are gradually removed from the tool face in part due to the friction generated between the flowing chips and the tool face. In time, a crater is generated in the face of the tool, hence the name crater wear. In general and under normal cutting conditions, flank wear develops much faster than crater wear, as such; tools tend to fail due to flank wear long before crater wear becomes significant. Therefore, flank wear (wear land height) is the more common measure of tool life under normal cutting conditions.

Several monitoring methods have been developed during the last few decades by many researchers. These methods may be classified in it two groups direct and indirect [4]. Direct methods are based upon direct measurements of the worn area of the tool using optical sensors, vision systems [6], microprobes, etc. These methods have the advantage of high measurement accuracy, but cannot be easily adopted for on-line applications mainly because of coolant and chips flow on the work piece.

Various indirect methods have also been developed in which the state of the wear is estimated from measurable parameters such as cutting forces [7},

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vibration, acoustic emission [8], cutting temperature and surface roughness. However few reliable indirect methods have yet been established for industrial use. This mainly due to complexity of machining process and the uncertainty in the correlation between the process parameters and tool wear.

An ultrasound on-line measurement of gradual wear of the flank during the turning operation was developed by Abu –Zahra and Nayfeh [3,4]. The method relies on inducing ultrasound waves in the tool, which propagates the length of the tool and are reflected by nose and flank surfaces. The amount of reflected energy is correlated with wear land height.

This paper considers the various ultrasonic parameters like time of flight (T.O.F), amplitudes, reflection coefficient, pulse width and root mean square of the signal (R M S) to quantify the wear land height and width that supports and refines the results obtained by Abu-zahra[4]. It shows that the better correlation exist between the wear and ultrasonic parameters.

2. THEORETICAL BACKGROUND:

An ultrasonic system for on-line measuring of gradual wear of the flank during turning operations was developed by Nayfeh[97], this method relies on inducing ultrasonic waves in the tool which propagate the length of the tool and are reflected by the nose and flanks, the amount of energy reflected is a function of several parameters, among which are the areas and orientation of the reflecting surfaces. It was shown that linear correlation exits between the levels of the reflected ultrasonic energy and the wear land height. However every tool tested the correlation was shown to be tool dependent.

In A-Scan Display, X-represents time of flight of the pulses converted in to distance traveled by the pulses (depth of penetration); Y-axis represents the amplitude of echoes. The information available in A-scan is one-dimensional. The B-Scan presentation gives a cross sectional views of the part being tested and shows the length and depth of the flaw in the test material. In C-scan display records echoes from the internal portions of test pieces as a function of position of each reflecting interface with in an area.

This paper describes the methodology to measure the wear land by A-scan display .The relationship between flank wear and various ultrasonic parameters like time of flight (T.O.F), amplitudes, reflection coefficient, pulse width and root mean square of the signal (R M S) are derived.

3. EXPERIMENTAL DETAILS:

The experimental setup is shown schematically in fig. 1. The hardware used is available commercially; consequently certain limitations are imposed on the capabilities and performance of the experimental setup.

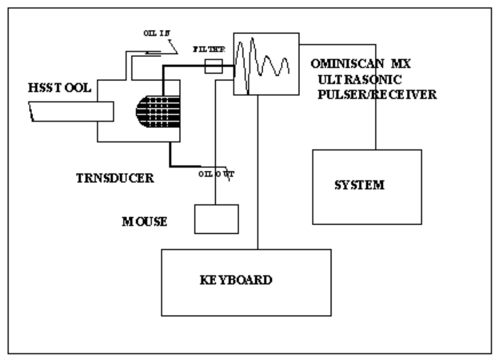


Fig.1. Schematic representation of the system

The shape of the ultrasonic transducers selected for this research dictates the cutting tool geometry. The transducer uses is a panametrics (V-112-rm) round shaped transducer operating at a frequency of 10 MHz. Propeleyene glycol is pumped through the tool holder to serve as the coupling medium of the transducer to the tool. In addition, slow circulation of the fluid cools the transducer during cutting. An ultrasonic pulser / receiver operated in burst mode, i.e., short duration spikes, and activate the transducer. The tool used in the experiments is high speed steel tool (HSS) 15 mm thick and 100 mm long and with side clearance angle of one degree, for accelerated wear testing.

3.1 THE ULTRASONIC METHODOLOGY:

Gradual tool wear manifests in two locations, which are the primary and secondary flanks, and the crater area. The present tool-transducer configuration can detect the first waveform. The second form, crater, can only detected when it is very severe. The contents of the ultrasonic wave returning from the nose and the flanks of a new tool can be broken down in two wave packets as illustrated in fig .2. The first is the reflection of the nose of the tool and surrounding areas of the flanks. The first reflection is an internally reflected wave, which corresponds to the energy that strikes the flanks at the point of the nose curvature. The wave, which strikes on the flank face, is internally reflected to the top surface or rake face, which is then reflected back, along a different path to the transducer. In the case of second reflection, the travel path is shorter than the path to the nose signal, which is manifested by longer time of flight (TO F).

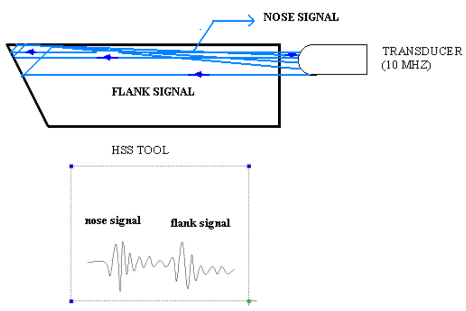


Fig 2 . Reflection of Ultrasonic waves for a new tool

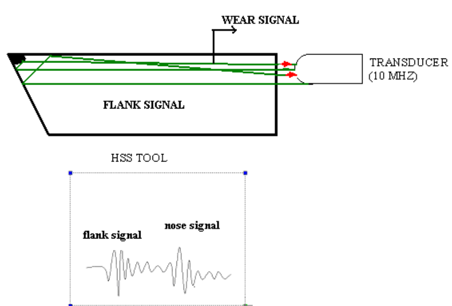


Fig.3.Reflection of Ultrasonic waves for the same tool with wear land.

In the course of cutting and due to wear, a flat spots begin to develop at the tool nose and the flank, this change in the geometry of the tool serves to change the total amount of reflected ultrasonic energy. In this case, the flat areas are more favorable reflector. As such, the total amount of reflected ultrasonic energy increases with gradual wear for both components of the wave. In the ideal case, the increase in the reflected energy obeys the square law. In the case of turning, the principles does not strictly hold since the reflecting surfaces are marred and are at off angles from the normal to the transducer, thus resulting in complex wave interactions.

No effort was made to isolate the nose from flank wear, since they are directly related to each other. In addition, isolating the individual wear contributions to the individual ultrasonic echoes is not possible.

Gradual wear of the nose and flanks is a comparatively slow process, on the order of minute or perhaps hours in some cases. Determining gradual wear requires comparing the integral of the absolute value of the wave form to that of new tool (base wave form).

Several tool wear tests were conducted to evaluate gradual wear measurements of the nose and the flanks. The work material and cutting parameters were:

Work material —EN 29 HARDENED STEEL.
Bar geometry —30 mm in diameter.
Cutting speed —600 rpm.
Feed —60 mm/min
Depth of cut —0.5 mm/rev.

4. RESULTS AND DISCUSSIONS:

The gradual wear measurements procedure was as follows:

(1) An ultrasonic waveform is recorded for a new cutting tool (H S S). The recorded wave was considered as a base (reference) wave— no tool wear was developed at this stage.

(2) The tool was then engaged in cutting action for 1 min before it was disengaged for the first wear measurement.

(3) After disengaging the tool, the tool was left and an ultrasonic waveform was recorded. The tool is then taken off the lathe, and the wear land height and width were measured with toolmaker's microscope.

(4) The tool was mounted back, and the tool was engaged in cutting for some time. Steps 3 and 4 were repeated until the wear land height reached 0.5—1 mm.

From the recorded wave form the TOF is measured in time path mode. Ultrasonic pulse is sent through an object and then reflected (or transmitted); the wave transit time can be measured, and is called the time of flight. The time of flight reduces with increase in wear land. This parameter is compared with wear land width.

V= total distance / time of fight.
Where= velocity of the material

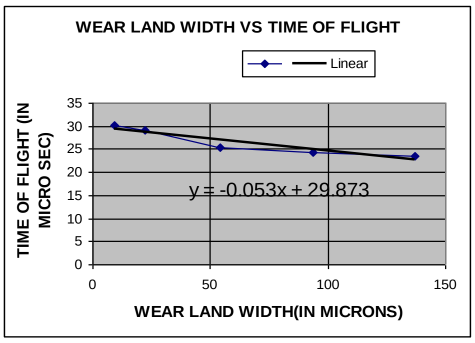


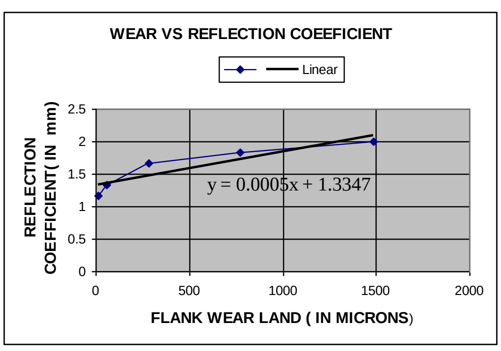
Fig 4.wear land width Vs TOF

From the fig (4) when wear land width increases time of flight reduces this is due to the fact that the travel path is shorter than the path for nose signal. This is because of appearance of flat spot on the tool nose. Thus the wear land width can be correlated with TOF with correlation coefficient 0.81.

Another ultrasonic parameter relating the wear land is reflection coefficient. It is the ratio of amplitude of echo received from the wear surface of the tool and the amplitude of echo from reference tool.

$R_c = (A_{final} / A_{reference})$

Where,



R_c= Reflection coefficient.

Fig 5.wear land area Vs Reflection coefficient

The Rc increases with increase in wear land due to some flat spots in the wear which is favorable reflector for ultrasonic waves. The value of Rc correlates the wear land area with correlation coefficient 0.91.

It is noted that the amplitude of the nose and flank signal increases with the wear land height. Since ultrasonic is more sensitive when it hits the flat spots (fig.5).Due to the same reason the pulse width also increases with wear land height (Fig.6.)

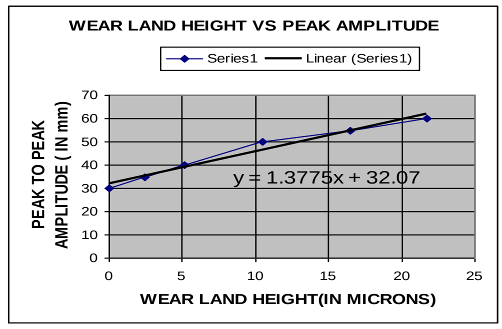


Fig 6.wear land height Vs Peak amplitude

It is observed that the increase in wear land height increases cumulative pulse width of received signals. This is because of increase in wear land height provides the plane which has lesser inclination compare with end relief angle.

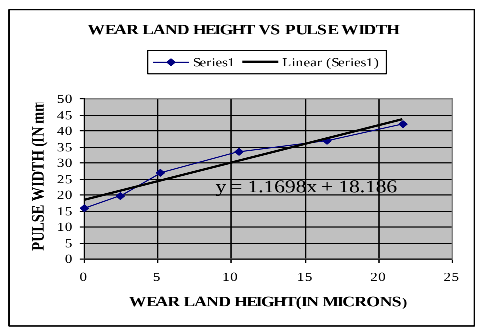


Fig 7.wear land height Vs Pulse width

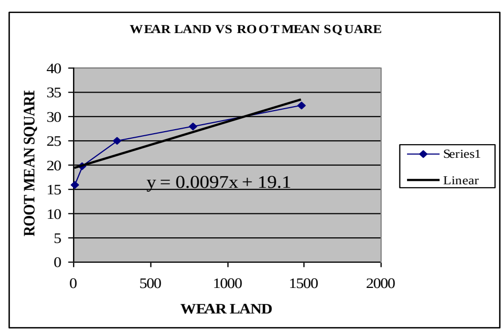


Fig 8.wear land height Vs RMS value of signal

The RMS values for the reflected ultrasonic signals are calculated. From the fig. 7, it is seen that flank wear trend is reflected in the RMS values of the ultrasonic signals with correlation coefficient 0.92.Cutting fluid are applied during all machining operations. In all cases the wear varied randomly at different measurements points, from uniform to somewhat irregular. Tool is tested beyond the standard tool life to verify the behavior of the correlation.

5. CONCLUSION:

The use of ultrasonic system to detect tool wear (flank) was proposed and the feasibility study of its practical application is investigated.
The interferences as follows,

- The amplitude level of ultrasonic signal during cutting process is hardly affected by flank wear land.
- The online sensing of the tool flank wear is possible by monitoring the TOF mode of ultrasonic signal.
- The reflection coefficient derived from the signals has a good correlation with flank wear land.
- The cumulative count of RMS value has a very good correlation with flank wear land.
- The cumulative pulse width has severely affected by the wear land height. This can be used to predict the wear land height.
  So, this system can be used in online monitoring of wear in single point cutting tool.

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