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ON-LINE MONITORING OF CRATER WEAR IN SINGLE POINT CUTTING TOOL USING ULTRASONIC TE CHNIQUE

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Abstract: - On-line tool condition monitoring is essential for modern machining system, especially in the case the case of precision and unmanned machining. Knowledge of the condition and expected life of the tool are very important inputs for determining the optimal machining parameters. On-line tool wear monitoring increases the cutting tool utilization considerably and 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 online monitoring. Ultrasonic testing uses A-Scan to evaluate the depth, position and area of tool wear. Two types of wears affect the tool life namely flank & crater wear, during machining of ductile material crater wear dominates more. An integrated ultrasonic transducer (Angle probe) 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 rake face of the tool can be related to the amplitude level, Time of flight and Root mean square value. This can be used to find the crater wear of the tool.

Keywords: *Online Wear Monitoring System, Single Point Cutting Tool, Ultrasonic Machining, Integration Ultrasonic Transducer*

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I INTRODUCTION

Online tool condition monitoring is necessary for modern machining industries. It is very important that when the tool has to be changed, on-line tool condition monitoring gives the optimum utilization of tool [1]. It reduces the production time tool changing time & ultimately production cost. In order to monitor the tool condition several methods have been developed during the last few decades. Mainly they are classified into two direct method and indirect method [2]. Direct online methods for tool and process condition monitoring have been difficult to develop and implement since the tool nose and flanks are obscured from vision during cutting, several methodologies explored for sensing the tool condition online directly, none of these system are practical for the shop floor [3-5]. The indirect methods measure one or more of the parameters associated with the cutting operation such as tool force, acoustic emission, vibration [6]. The tool condition is then inferred from the values of the parameters. Ultrasonic technology is one among these methods. Ultrasounds are the sound waves that are in very high frequencies than human ears can hear [7-8]. Normally 1 to 10 MHz frequencies are used for finding surface and internal discontinuities such as laps, seams, voids, cracks, blowholes, inclusions, and lack of bond, delamination, and others. Tool life prediction and tool change strategies are now based on most conservative estimates of tool life from past tool wear data [9]. Hence, usually tools are underutilized. In an unmanned factory, this has the effect of increased frequency of the tool changes and therefore increased cost [10]. Advances in adaptive control now call for more sensitive ways of measuring tool wears. Gradual wear develops on the tool in two locations: Rack face and flank face. The chip flows across the rake face, resulting in severe friction between the chip and rake face, and leaves a scar on the rake face that usually parallels to the major cutting edge [11]. The crater wear can increase the working rake angle and reduce the cutting force, but it will also weaken the strength of the cutting edge [12]. Wear on the flank (relief) face is called Flank wear and results in the formation of a wear land. Wear land formation is not always uniform along the major and minor cutting edges of the tool. Flank wear most commonly results from abrasive wear of the cutting edge against the machined surface. The objective of this experimental study is to observe and to optimize the feasibility of the system for on-line monitoring of tool wear.

II. EXPERIMENTAL SET-UP

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

Fig.1 Experimental setup representation of USM 35X device

2.1 ULTRASONIC METHODOLOGY

Gradual tool wear manifests in two locations, flank and 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 flank of a new tool can be broken down in two wave packets [13]. 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 that strikes the rake face is internally reflected to the top surface or flank 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 nose signal, which is manifested by longer time of flight (TOF).In the course of cutting and due to wear, a flat spots begin to develop at the tool nose and the rake this change in the geometry of the tool serve 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 crater 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 crater is a comparatively slow process about minute or perhaps hours in some cases. Determining gradual wear requires comparing the integral of the absolute value of the waveform to that of new tool (base waveform) [14]. Several tool wear tests were conducted to evaluate gradual wear measurements of the nose and the crater. The work material and cutting parameters were:

Table.1 Work Material and Cutting Parameters

1.	Work Material	Aluminum
2.	Bar Geometry	30mm Dia X 100 mm length
3.	Cutting Speed	1200 Rpm
4.	Feed	60 mm/min
5.	Depth Of Cut	0.5mm/Rev

2.2 THEORITICAL BACKGROUND

An ultrasonic system for on-line measuring of gradual wear during turning operation was developed by Nayfeh, this method relies on inducing ultrasonic waves in the tool that propagates 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 orientation of the reflecting surfaces [15]. 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 each reflecting interface with in an area. This paper describes the methodology to measure the wear land by A-scan display. The relationship between crater wear and various ultrasonic parameters like Time of Flight (T.O.F), Amplitudes, reflection coefficient, pulse width and root mean square of the signal.

2.3 Study of Ultrasonic Flaw Detector (USM 35X)

2.3.1 Introduction of USM 35X

USM 35X is widely used ultrasonic equipment in NDT field. It a compact, light in weight and user-friendly digital ultrasonic flaw detector. USM 35X has a color LCD display, it provides wide viewing angle and allows fast scanning speed. Fully charged battery gives continues working of eight hours and charging time is just 2 1/2 hours.

2.3.2 Working of USM 35X

USM 35X is a single ultrasonic testing instrument used for the inspection of homogeneous material for inclusions, porosity and other discontinuities that could affect the performance of material and components. It can be also used for thickness gauging of homogenous material, requiring access from only one side of the test piece. High frequency sound waves are introduced in to the test material part from a transducer/ probe that is usually coupled to the test piece by water or some other coupling fluid. The transducer converts the electrical signal to ultrasonic sound and vice-versa. A short burst of ultrasound is introduced in to the test material so some or all energy is reflected by discontinuities. The reflection of ultrasound energy is function of ratio between the acoustic impedance of discontinuity and base material the greater the impedance ratio the more sound energy will be reflected.

Thickness gauging with USM 35X operates on the principle of time of flight measurements. The principle utilizes the precise timing of the transmit time of a short burst of ultrasound energy through material under test. The ultrasound waves travel of the far side of the test piece and reflects back to the transducer and measurement is obtained.

2.3.3 Attenuation Coefficient

Attenuation is measured by observing the amplitude decay of a sequence of reflections.

αL= ln (Ainitial / Afinal)

αdbL= 8.686 ln (Ainitial / Afinal)

Where

α is the attenuation constant in Nepers,

αdb is the attenuation constant in decibels,

L is the distance traveled and

A is the amplitude in volts

Although you could also measure the distance traveled by measuring the change in amplitude, time of flight is much easier and more accurate measure. Instead, attenuation is used measure the homogeneity, volume fraction of the dispersed particles, or other absorptive or scattering qualities of a material.

2.3.4 Reflection Coefficient

When ultrasonic waves are incident at right angle to the boundary of two media of different acoustic impedance, then some of the energy is reflected and the balance is transmitted across the boundary.

Rc = (Afinal / Ainitial)

Where Rc = reflection coefficient.

2.3.5 Root Mean Square (RMS)

Square root of the mean square value of a random variable. In other words, we can define the root mean square is a statistical measure of the magnitude of a varying quantity. It can be calculated for a series of discrete values or for a continuously varying function.

Root Mean Square = (((X1)2 + (X2)2 + (X3)2 +……….+ (Xn)2 /N))1/2

Where,

N= sample size (number of scores)

X= individual score

Cutting tools are subjected to an extremely severe rubbing process. They are in metal-to-metal contact between the chip and work piece, under conditions of very high stress at high temperature. The situation is further aggravated (worsened) due to the existence of extreme stress and temperature gradients near the surface of the tool.

During machining, cutting tools remove material from the component to achieve the required shape, dimension and surface roughness (finish). However, wear occurs during the cutting action, and it will ultimately result in the failure of the cutting tool. When the tool wear reaches a certain extent, the tool or active edge has to be replaced to guarantee the desired cutting action.

2.3.6 Tool Wear Phenomena

As we have learned in the level-300 course "Manufacturing Science 1", orthogonal and oblique cutting sections, the shear stress and normal stress involved in metal cutting is much higher than that used in Engineering Mechanics. The high contact stress between the tool rake-face and the chip causes severe friction at the rake face, as well, there is friction between the flank and the machined surface. The result is a variety of wear patterns and scars which can be observed at the rake face and the flank face

2.3.7 Probes/ Transducer

The conversion of electrical pulses to mechanical vibrations and the conversion of returned mechanical vibrations back into electrical energy is the basis for ultrasonic testing. The active element is the heart of the transducer as it converts the electrical energy to acoustic energy, and vice versa.

2.3.8 Calibration Ranges

Min.: 0 to 0.5 mm +10 % (steel), 0 to 0.02” +10 % (steel)

Max.: 0 to 9,999 mm +10 % (steel), 0 to 390” +10 % (steel) within the frequency range from 0.2 to 1 MHz / 0.5 to 4 MHz, 0 to 1,420 mm +10% (steel), 0 to 56” +10 % (steel) within the frequency range from 0.8 to 8 MHz / 2 to 20 MHz

2.3.9 Sound Velocity

1,000 to 15,000 m/s, 40 to 600 inch/ms variable in steps of 1 m/s, 0.1 inch/ms and fixed programmed values

2.3.10 Display Delay

From -10 to 1,000 mm, -0.3 to 40” (340 μs)

a. Probe Delay

0 to 200 μs

b. Auto Calibration

Measurement and setting of sound velocity and probe delay using two known calibration echoes

(2-point calibration)

c. Pulse Intensity

220 pF, 1 nF

d. Damping

50 ohms, 500 ohms (1,000 ohms in TR mode)

e. Pulse Repetition Frequency

4 to 1,000 Hz, variable in 10 steps

f. Frequency Ranges (-3 dB)

0.2 to 1 MHz / 0.5 to 4 MHz / 0.8 to 8 MHz /

2 to 20 MHz

g. Gain

0 to 110 dB, variable in steps

h. Gain steps

0.5 / 1 / 2 / 6 / 12 dB (or user-adjustable),

Step 0 is Locked

i. Fine Gain

4 dB, continuously variable in 40 steps

j. Rectification

Full-wave, negative and positive half-wave, RF mode

K. Reject

Linear, 0 to 80 % screen height

Variable in steps of 1 %

III MONITOR GATES

2 independent gates in color bar mode, start and width variable over the entire calibration range, response threshold of 10 to 90 % screen height variable in steps of 1 % (coincidence and anti-coincidence), alarm signal via LED and connectableinternal horn, Gate A switchable as interface gate for Gate B, gate magnifier (Zooming of Gate Range Over the entire display range)

Sound Path Measurement

Digital display of sound path (projection distance, depth) between initial pulse and the first echo in the gate, or between the echoes in the two gates, measurement always at the intersection point with the echo flank or echo peak

Measurement Resolution

0.01 mm within a range up to 99.99 mm/0.1 mm within a range from 100 to 999.9 mm/1 mm above 1,000 mm, 0.001” within a range up to 9.999”/0.01” above 10”With evaluation in the frozen A-scan: 0.5 % of the calibration range setting

3.7 Amplitude Display

In % screen height

USM 35X DAC: additionally in dB above DAC or TCG

USM 35X S: additionally in dB above DGS curve or ERS

Displayed Reading

Sound path, (reduced) projection distance, depth, amplitude for every gate, user configurable at four positions of measurement line and of the zoomed display in the A-scan

a. A-Scan Functions

Manual or automatic A-scan freeze, A-scan comparison, echo dynamics (envelope), peak echo storage

b. Color Functions

Patented color-coded display of legs in angle testing, adaptation of background color to the light conditions of test environment, color display of monitor gates and of registration curves (DAC, TCG, DGS) for direct recognition, messages and alarms in red channel

IV. RESULTS AND DISCUSSIONS

4.1 EXPERIMENTAL PROCEDURE

USM 35X equipment was calibrated using test piece of 25 mm thickness, single probe, 10 MHz frequency transducer using A-Scan.

STEP 1

The Reference measurement procedure was as follows:

1.The calibrated work piece is placed in position.

2.The cable is used to connect the angle probe (70°)to the receiver of USM 35X

3.The probe is placed in the calculated position

4.Scanning carried out to get the nose signal.

5.Nose signal & Crater area signal are noted.

6.This signal is taken as the Reference signal.

STEP 2

The Gradual measurement procedure was as follows:

1.The calibrated work piece is placed in position.

2.The cable is used to connect the angle probe (70°)to the receiver of USM 35X

3.The probe is placed in the calculated position

4.Nose signal & Crater area signal got by giving print out.

5.This is the first signal.

STEP 3

The Gradual measurement procedure was as follows:

1. The calibrated work piece is placed in position.

2. The cable is used to connect the angle probe (70°)to the receiver of USM 35X

3. The probe is placed in the calculated position

4. Nose signal & Crater area signal got by giving printout.

5. This is the second signal.

STEP 4

The gradual measurement procedure was as follows:

1. The calibrated work piece is placed in position.

2. The cable is used to connect the angle probe (70°)to the receiver of USM 35X

3. The probe is placed in the calculated position

4. Nose signal & Crater area signal got by giving print out.

5. This is the third signal.

STEP 5

The gradual wear measurement procedure was as follows:

1. The calibrated work piece is placed in position.

2. The cable is used to connect the angle probe (70°) to the receiver of USM 35X

3. The probe is placed in the calculated position

4. Nose signal & Crater area signal got by giving print out.

5. This is the second signal.

4.2 UT PARAMETERS

Time of Flight

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 flight.

Where V= velocity of the material

Table:2 Crater Wear Width Vs Time of Flight

S.NO	Crater Wear Width	Time of Flight
1	0	34
2	122	32
3	205	27
4	264	24
5	302	21

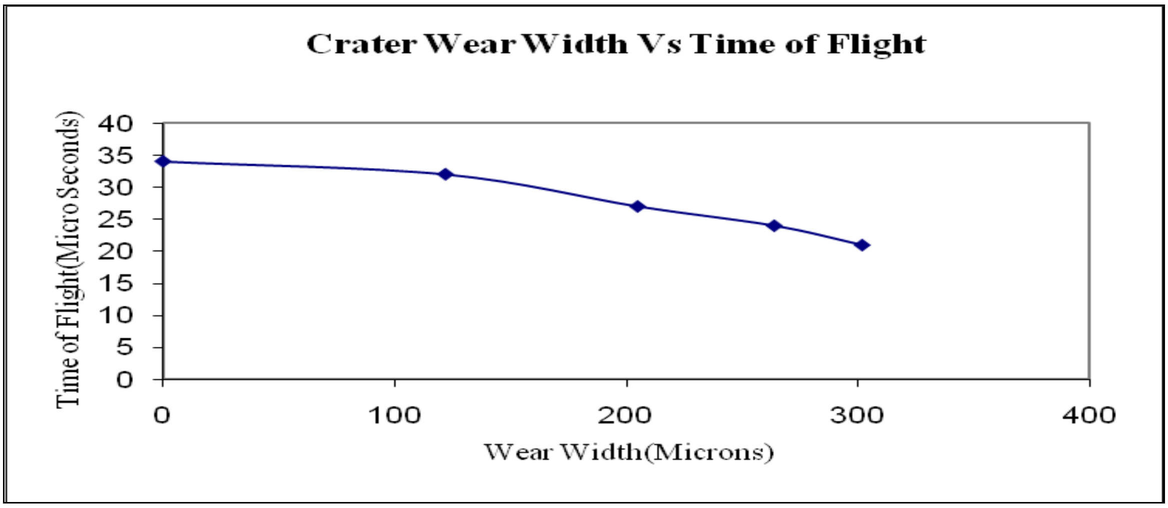

Fig.2 Crater Wear Width Vs. Time of Flight

From the figure 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.

Peak Amplitude

It is noted that the amplitude of the nose and crater signal increases with the crater wear depth Since ultrasonic is more sensitive when it hits the flat spots. Due to the same reason the pulse width also increases with wear depth.

Table:3 Crater Depth Vs Peak Amplitude

S.No	htpeDretarC	Peak Amplitude
1	0	41
2	43	48
3	82	54
4	121	71
5	154	60

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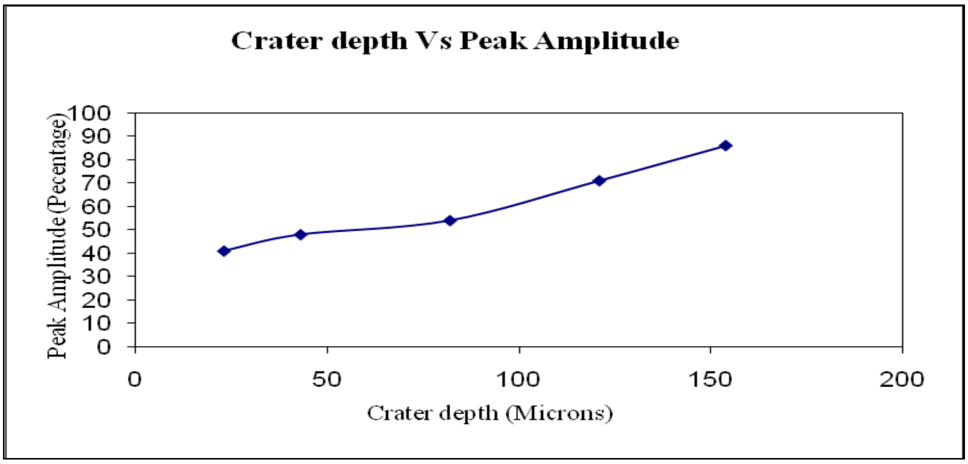

Fig.3 Crater Depth Vs. Peak Amplitude

4.3 Root Mean Square value (R.M.S)

Square root of the mean square value of a random variable. In other words, we can define the root mean square is a statistical measure of the magnitude of a varying quantity. It can be calculated for a series of discrete values or for a continuously varying function.

Root Mean Square = (((X1)2 + (X2)2 + (X3)2 +……….+ (Xn)2 /N))1/2

Table.4 Crater Depth Vs. Root Mean Square

S.No	Crater Wear Depth	Root Mean Square Value
1	0	30
2	43	40
3	82	45
4	121	50
5	154	60

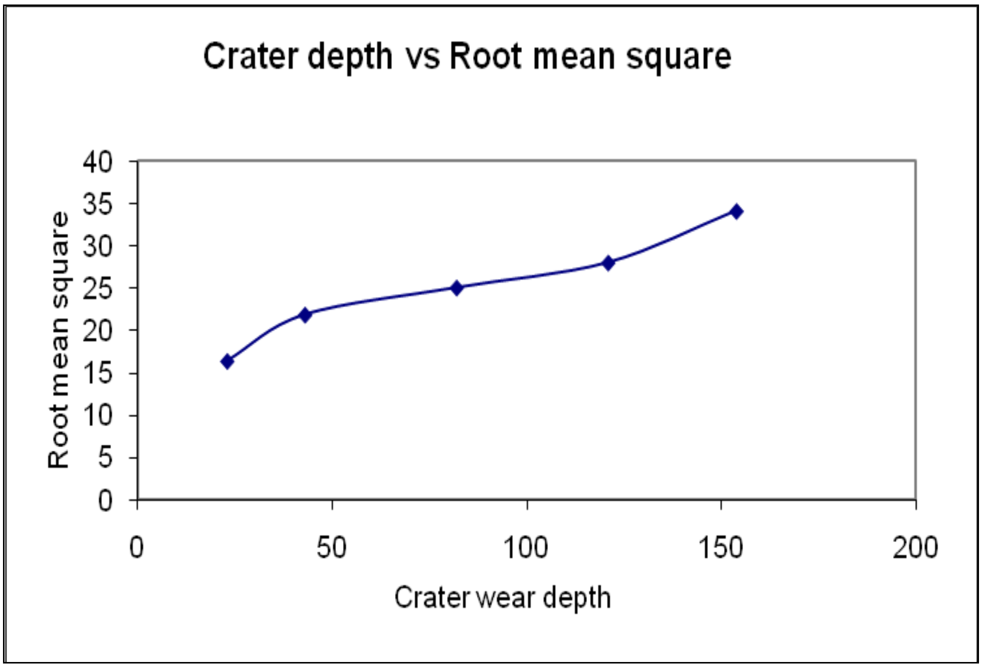

Fig.4 Crater Depth Vs. Root Mean Square

V CONCLUSION

The use of ultrasonic system to detect tool wear (crater) was proposed and the feasibility study of its practical application is investigated

The interference as follows,

•he amplitude level of ultrasonic signal during cutting process is hardly affected by crater wear land.

•The online sensing of the tool crater wear is possible by monitoring the TOF mode of ultrasonic signal.

•The cumulative count of RMS value has a very good correlation with crater wear land. So this system can be used in online monitoring of wear in single point cutting tool.

REFERENCE:

1.Pacella, M. and Brigginshaw, D., 2020. Enhanced wear performance of laser machined tools in dry turning of hardened steels. Journal of Manufacturing Processes, 56, pp.189-196.

2.Li, B., Zhang, S., Zhang, Q., & Li, L. (2019). Simulated and experimental analysis on serrated chip formation for hard milling process. Journal of Manufacturing Processes, 44, 337-348.

3.Panda, A., Sahoo, A. K., Kumar, R., & Das, R. K. (2020). A review on machinability aspects for AISI 52100 bearing steel. Materials Today: Proceedings, 23, 617-621

4.Sánchez Hernández, Y., Trujillo Vilches, F.J., Bermudo Gamboa, C. and Sevilla Hurtado, L., 2019. Online Tool Wear Monitoring by the Analysis of Cutting Forces in Transient State for Dry Machining of Ti6Al4V Alloy. Metals, 9(9), p.1014.

5.Mohanraj, T., Shankar, S., Rajasekar, R., Sakthivel, N.R. and Pramanik, A., 2020. Tool condition monitoring techniques in milling process—A review. Journal of Materials Research and Technology, 9(1), pp.1032-1042.

6.Trujillo, F.J.; Sevilla, L.; Marcos, M. Experimental Parametric Model for Indirect Adhesion Wear Measurement in the Dry Turning of UNS A97075 (Al-Zn) Alloy. Materials 2017, 10, 152.

7.Maruda, R.W.; Krolczyk, G.M.; Wojciechowski, S.; Zak, K.; Habrat, W.; Nieslony, P. Effects of extreme pressure and anti-wear additives on surface topography and tool wear during MQCL turning of AISI 1045 steel. J. Mech. Sci. Technol. 2018, 32, 1585–1591.

8.Liang, X.; Liu, Z.; Wang, B. State-of-the-art of surface integrity induced by tool wear effects in machining process of titanium and nickel alloys: A review. Meas. J. Int. Meas. Confed. 2019, 132, 150–181

9.Hayajneh, M.T.; Astakhov, V.P.; Osman, M.O.M. An analytical evaluation of the cutting forces in orthogonal cutting using a dynamic model of the shear zone with parallel boundaries. J. Mater. Process. Technol. 1998, 82, 61–77.

10.Suneel, K., Rao, N.N., Balaji, R., Srikanth, N., Solomon, G.R. and Selokar, A., 2020. Review on Sliding Wear of Ti–6Al–4V Alloy Concerning Counterface and Sliding Conditions. In Intelligent Manufacturing and Energy Sustainability (pp. 309-318). Springer, Singapore.

11.Khattri, K., Choudhary, G., Bhuyan, B.K. and Selokar, A., 2018, March. A review on parametric analysis of magnetic abrasive machining process. In IOP conference series: materials science and engineering (Vol. 330, No. 1).

12.Balaji, R., Nadarajan, M., Selokar, A., Kumar, S.S. and Sivakumar, S., 2019. Modelling and analysis of Disk Brake under Tribological behaviour of Al-Al2O3 Ceramic Matrix Composites/Kevlar® 119 composite/C/Sic-Carbon Matrix Composite/Cr-Ni-Mo-V steel. Materials Today: Proceedings, 18, pp.3415-3427.

13.Balaji, R., Sivakumar, S., Nadarajan, M. and Selokar, A., 2019. A Recent Investigations: Effect of Surface Grinding on CFRP using Rotary Ultrasonic Machining. Materials Today: Proceedings, 18, pp.5209-5218.

14.Suneel, K., Rao, N.N., Balaji, R., Srikanth, N., Solomon, G.R. and Selokar, A., 2020. Review on Sliding Wear of Ti–6Al–4V Alloy Concerning Counterface and Sliding Conditions. In Intelligent Manufacturing and Energy Sustainability (pp. 309-318). Springer, Singapore.

15.Dinakaran, D., Sampathkumar, S. and Sivashanmugam, N., 2009. An experimental investigation on monitoring of crater wear in turning using ultrasonic technique. International Journal of Machine Tools and Manufacture, 49(15), pp.1234-1237.