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Tool Life Estimate during Turning of EN24 against Coated Carbide Insert using Vibration Signal

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ABSTRACT: Tool life monitoring using condition based maintenance which seeks optimum utilization of the process without altering the quality is the focus of ongoing work. To assess the status of single point cutting tool, viz-a-viz, tool wear and develop a trend; capable of predicting life of tool in terms of measured parameter like force, pressure, voltage, vibration, etc are used. Work material En24 is turned using coated carbide inserts, while maintaining cutting parameters in accordance with ISO 3685 -1993; flank wear is particularly studied since it determines the diametric accuracy of machining, stability and reliability compared to the crater wear, a complete model describing the variation in cutting forces of which being not available. Vibration signatures, a tool to indicate the internal health of machine tool with good response time catering information of running conditions in terms of displacement velocity or acceleration measurable at suitable location is used a key method, and the outcome of research carried which exhibits relationship between tool wear and tool vibration acceleration, time and tool wear and number of cuts and tool wear; intends in trend generation to monitor the health of the tool.

Keywords: Turning, Tool Wear, Vibration, Flank Wear, En-24 Steel, Coated Carbide Inserts

I. INTRODUCTION

Condition monitoring lends hand in maintaining and up keeping facilities, machines, material, tool, etc; the major concern in an automated system, which reputes as one obtaining highest productivity. [2][3][4]Useful life of the tool during which it assists in producing the desired size and surface quality, can also be observed using condition monitoring; which otherwise would lead to risking the quality and hence usefulness of the work. Of many types of tool we ard escribable in terms of flank, crater, nose etc; due to its influence on tool life and ease of measurement, flank wear is significant. Also a complete model that can determine the accuracy of machining, stability and reliability is available only for flank wear. Hence the width of flank wear land is a To establish a relation between trend plot of tool wear v/s tool vibration amplitude; via correlation with vibration signals generated during turning, is the main objective intending to assess the useful life of tool in minutes. [1][6] A maximum flank wear of 0.6mm, as per ISO 3685:1993; a reference value upon reaching suitable tool wear measure and a predetermined value of flank wear as per ISO 3685:1993 is regarded as criterion.[7][8][14][15][16] As recommended the common criteria for high speed steel tools as shown in figure 1 are i) the maximum width of the flank wear land VB, max = 0.6 mm if the flank wear is not regularly worn, scratched, chipped or badly grooved in zone B ii) The average width of the flank wear land VB = 0.3 mm, if the flank wear land is considered to be regularly worn in zone B or else catastrophic failure. The above said conditions remain same even for sintered carbide tools and tools of ceramics as well. [9][10][12][13].

II. OBJECTIVE

which decision pertaining tool rework/ replacement could be taken.[7][14][15][16] Frequency analysis of the output signals is used for assessing the condition of tool on-line. [5] Tool life could be effectively monitored without disturbing the turning process. Types of wear are shown in figure 2.

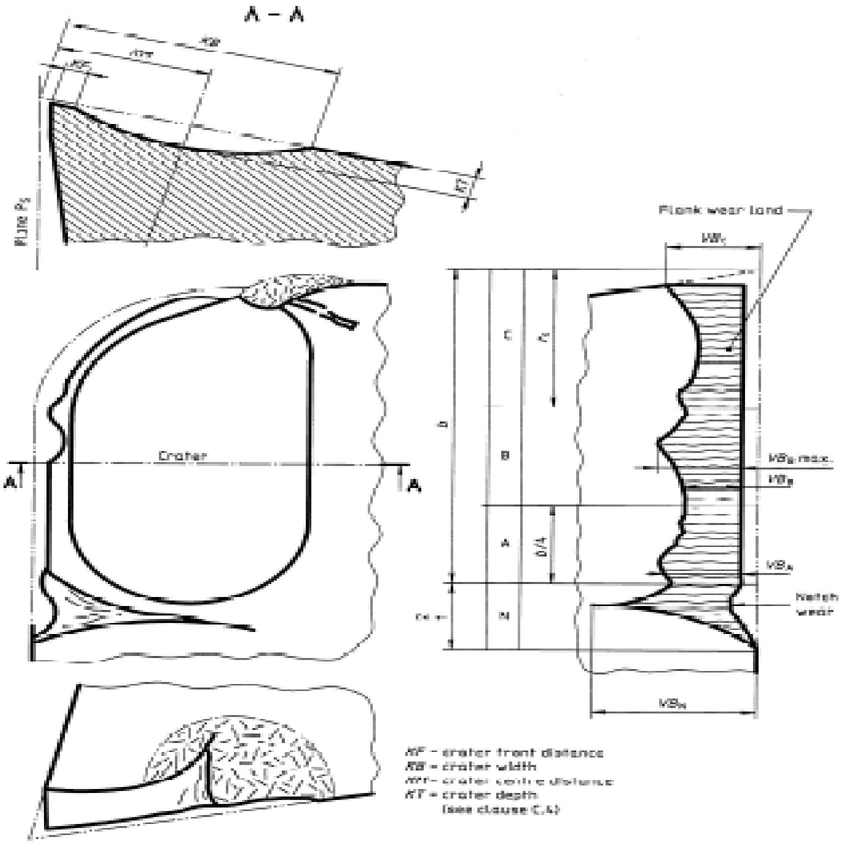

Fig 1: Types of wear on turning tools.

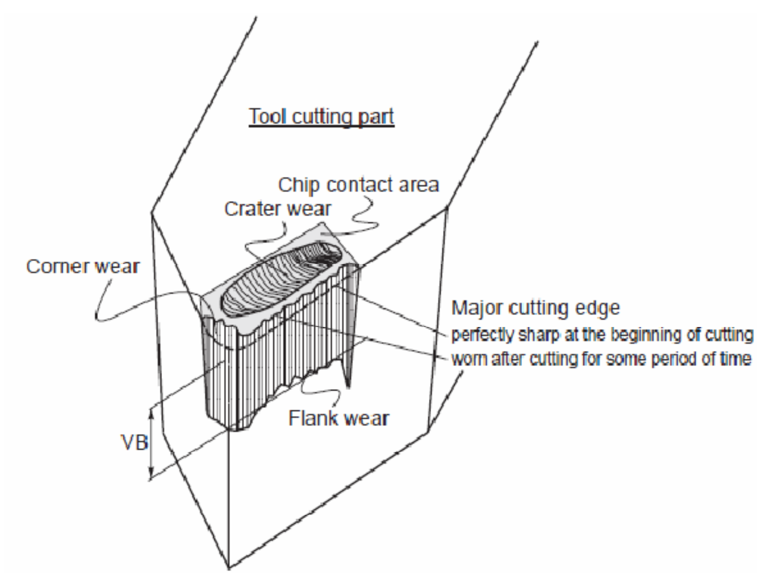

Fig 2: Different types of wear of cutting tool.

III. METHODOLOGY

A. Work Material

EN-24 is cut to the sizes of 30 mm diameter and 300 mm length for turning operation without built-up edge formation on the tool tip and turned at cutting speeds selected. The combinations for the various process parameters to conduct experimentation are as shown in figure-3. The description of each of the process parameters are explained in Section 5

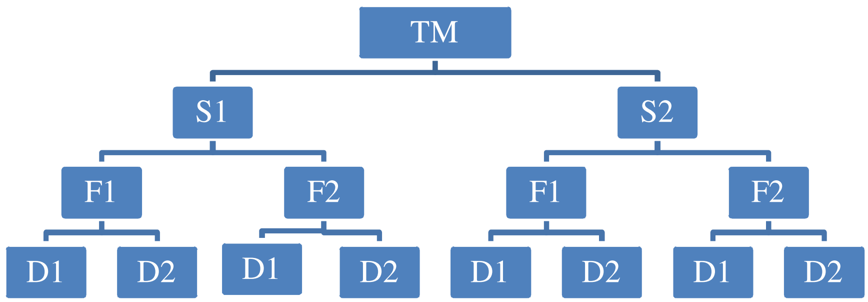

Fig 3: Process parameter combination Tree.

B. Cutting Tool

Coated carbide inserts are used for machining purposes to obtain good surface finish.

C. Operating Conditions

Two speeds: 630 rpm (59.37 m/ min) and 800 rpm (75.398 m/ min)
Two feeds: 0.07 mm/rev and 1.0mm/ rev
Two depths of cut: 0.4 mm and 0.8 mm

The above mentioned parameters are set in various combinations and turning was carried out.

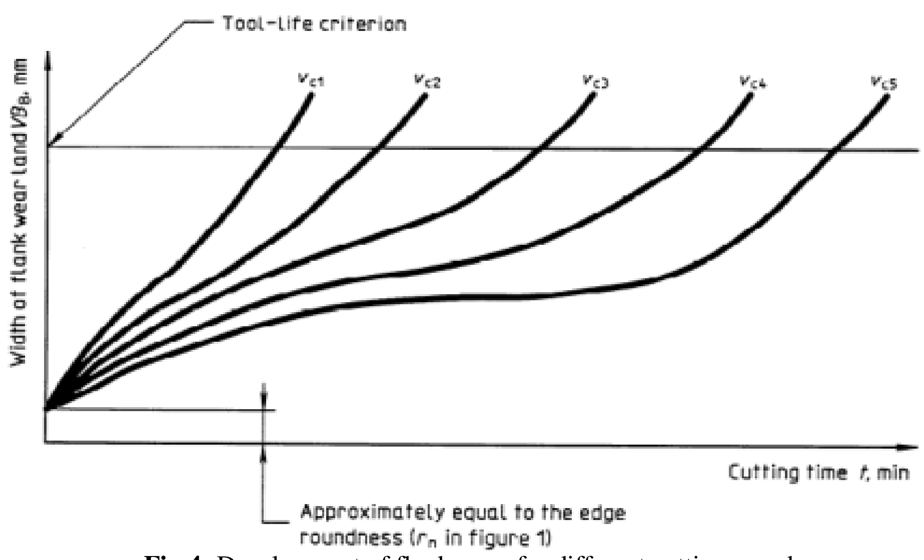

Fig 4: Development of flank wear for different cutting speeds.

At different cutting speeds, tool wear rate varies as shown in figure 4 [14][13]; to observe these variations above mentioned two sets of operating conditions are set for trailing while experimentation.

D. Data Collection

In each trial, the following data is collected
Cutting time in minutes
Number of cuts
Vibration acceleration in g's from the vibration signatures obtained from the IRD Model 880 Vibration analyzer at the operating frequency of the tool which has been found before the commencement of the experimentation. The Vibration acceleration is picked up by the accelerometer IRD 970 whose probe is held very closely to the tool tip while turning.

Progressive flank wear is measured at the end of each cut using tool maker's microscope

With the references of ISO 3685-1993, the above process is to be carried out until the tool has reached the width of flank wear of 0.6 mmthe number of trials and various combinations are planned under different operating conditions using Taguchi's L8 orthogonal array.

IV. EXPERIMENTAL SET UP

18 Speed Automatic Kirloskar lathe was used for conducting the experimentation of turning operation. The cutting tool used was coated cemented carbide inserts against the work material 0.5% carbon tool steel En24. The operating conditions were set at 2 speeds and 2 depths of cut. The vibration analyzer IRD model 880 with provision to obtain vibration signature in the form of print out was used. To sense the pickup and vibration an IRD model 970 accelerometer was used. A tool maker's microscope was used to measure the flank wear after each trial. The experimental set up is shown in figure 5.

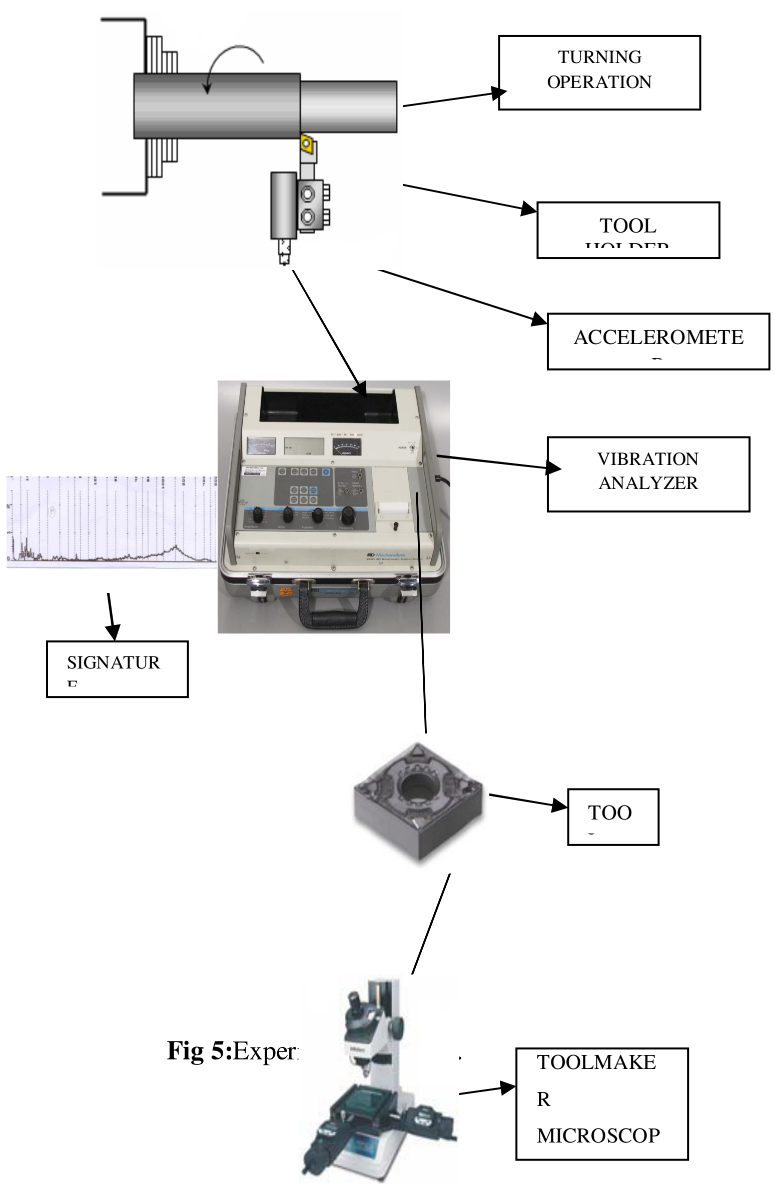

Fig 5: Exper

V. PROCESS PARAMETERS

Table1: The process parameters

Tool – Coated carbide insert ISO code: CNMG 12 04 08 TTS	T
Tool Holder	PCLNR 1616
Work material- Tool Steel En24 (0.5%C)	M
Speed 1: 630 rpm	S1
Speed 2: 800 rpm	S2
Feed 1: 0.07 mm/ rev	F1
Feed 2: 0.1 mm/ rev	F2
Depth of cut 1: 04 mm	D1
Depth of cut 2: 08 mm	D2
Tool Overhang	40 mm
Cutting Environment	Dry Cutting

VI. EXPERIMENTATION TRIALS

Using Taguchi's L8 orthogonal array, It was possible to optimize the combinations of too, material, speed, feed and depth of cut and number of trials to 8. They are as follows.

S1F1D1
S1F2D1
S2F1D1
S2F2D1
S1F1D2
S1F2D2
S2F1D2
S2F2D2

VII. FREQUENCY ANALYSIS

First, the natural frequency of the tool holder was determined by the impulse response testing method and it was found that the natural frequency of vibration was 44.5 kHz for tool holder with overhanging length of 0.06 mm. the conformity was obtained experimentally during idle running it was found to be 50 kHz. During machining after several repetitions, the vibration acceleration due to tool was found in the frequencies at about 200 kHz as shown in the figure 6. A prominent in the vibration signatures was found in all the repetitive trials. This can be attributed to the tool vibrations since the accelerometer was attached at the closest distance to the tool tip by strong magnetized stud.

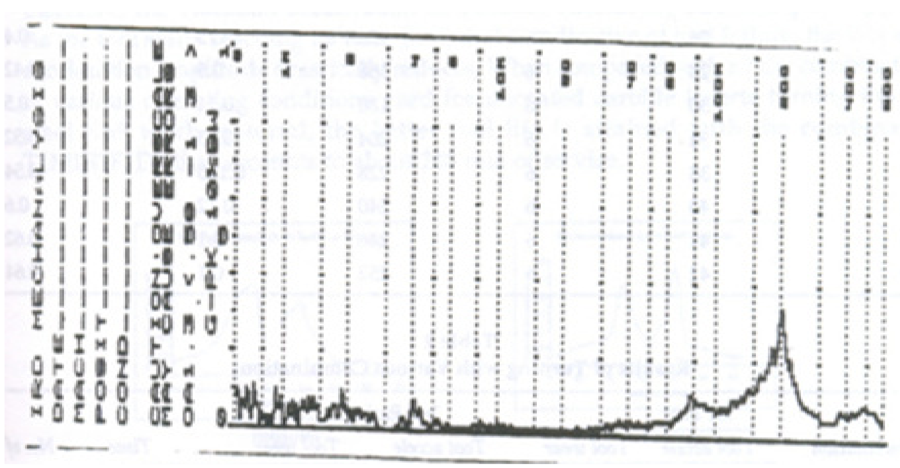

Fig 6: Tool Signature during Machining

VIII. EXPERIMENTATION AND RESULTS

Turning, on lathe with 80 HRC hardness coated carbide insert on work material En24, 220 BHN of hardness during experimentation with parameters as time, tool acceleration and flank wear being measured at the end of each cut. The data is shown in table 2.

The graphs of tool acceleration v/s tool wear are shown in figure 7. The results of various combinations are plotted in graphs 1 to 8, and from these it is seen that 2 peaks are obtained for each combination at different frequencies until maximum flank wear width of 0.6 mm is reached for coated carbide insert. This can be a base of establishing the relationship between vibration, acceleration amplitude and flanks wear. When anew, due to point contact of the cutting tool with the work piece there will be less friction between the tool and work piece, due to which the amplitude of vibration will be less while due to heaviness of work piece during early cutting stage, there will be an increase in vibration acceleration amplitude. The system characteristics are represented by this initial increase in the vibration acceleration amplitude. As the diameter and hence the mass of the work piece decreases, a corresponding decrease in vibration amplitude is observed. further increase in the tool wear brings a bit more surface contact work piece with tool due to which friction increases and therein the vibration acceleration amplitude as well, then the second peak appears. As the tool starts reaching its wear limit that is indicative of tool failure, the vibration acceleration amplitude drastically reduces. When compared with all the combinations of various operating conditions used for coated carbide inserts turning the tool steel En24 work material, the better tool life is attained with TMS1F1D1 that accounts to about 258 min of service.

Table 2:Data collected during experimentation during turning of combination TMS1F1D1.

Sl. No.	Cumulative No of cuts	Time for one cut (min)	Cumulative time (min)	Tool acceleration in g's	Progressive flank wear (mm)
1	2	6	12	0.15	0.04
2	4	6	24	0.18	0.09
3	6	6	36	0.18	0.12
4	8	6	48	0.2	0.15
5	10	6	60	0.28	0.18
6	12	6	72	0.52	0.22
7	14	6	84	0.3	0.24
8	16	6	96	0.25	0.26
9	18	6	108	0.2	0.28
10	20	6	120	0.18	0.3
11	22	6	132	0.25	0.33
12	24	6	144	0.3	0.35
13	26	6	156	0.5	0.38
14	28	6	168	0.57	0.41
15	30	6	180	0.35	0.44
16	32	6	192	0.23	0.47
17	34	6	204	0.23	0.5
18	36	6	216	0.18	0.54
19	38	6	228	0.18	0.57
20	40	6	240	0.2	0.62

Table 3: Results of Turning with Various Combinations.

Combination	1st Peak		2nd Peak		Time in min	No. of Cuts
	Tool Acceleration in g's	Tool Wear in mm	Tool Acceleration in g's	Tool Wear in mm		
Coated Carbide Insert- En24 Tool Steel						
TMS1F1D1	0.52	0.22	0.57	0.41	240	40
TMS1F2D1	1.2	0.22	1.3	0.4	204	34
TMS2F1D1	0.31	0.24	0.31	0.45	190	38
TMS2F2D1	1.2	0.2	1.25	0.56	152	38
TMS1F1D2	1.0	0.23	1.1	0.5	140	28
TMS1F2D2	0.65	0.32	0.62	0.54	120	30
TIMS2F1D2	0.65	0.35	0.55	0.55	78	26
TIMS2F2D2	0.62	0.25	068	0.39	60	20

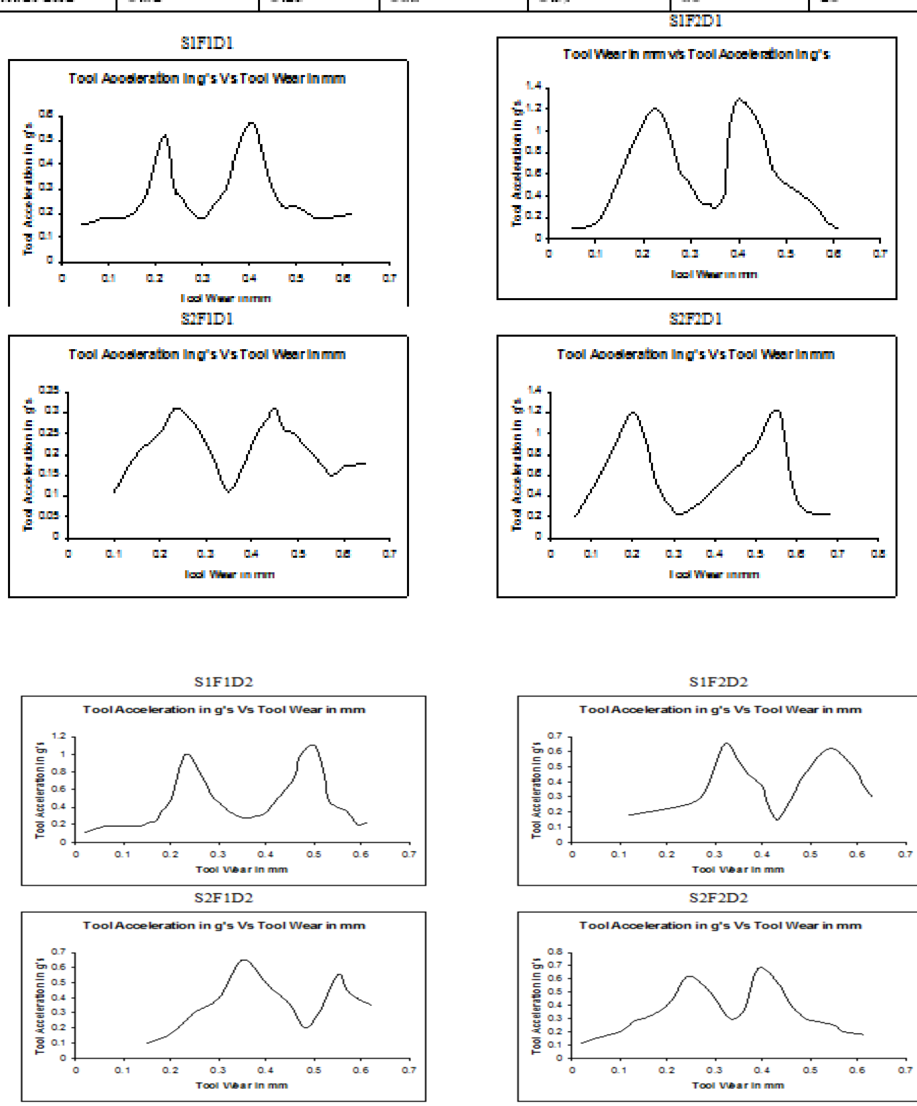

Fig 7: Graphs of tool acceleration v/s tool wear for coated carbide insert on En24.

VIII. REGRESSION ANALYSIS

Regression analysis was carried out for experimental results of tool wear v/s tool acceleration and regression trend was obtained for all combinations. The mapping of experimental and regression trends are shown in figure 8. The regression equation that defines that trend was found to be a polynomial of 8th order. The regression values were obtained for all the input values of tool wear. Using the experimental and regression data the coefficient of determination R2 was calculated. These values were found to be more than 0.9 for almost all combinations, which are depicted in table 3. [11]

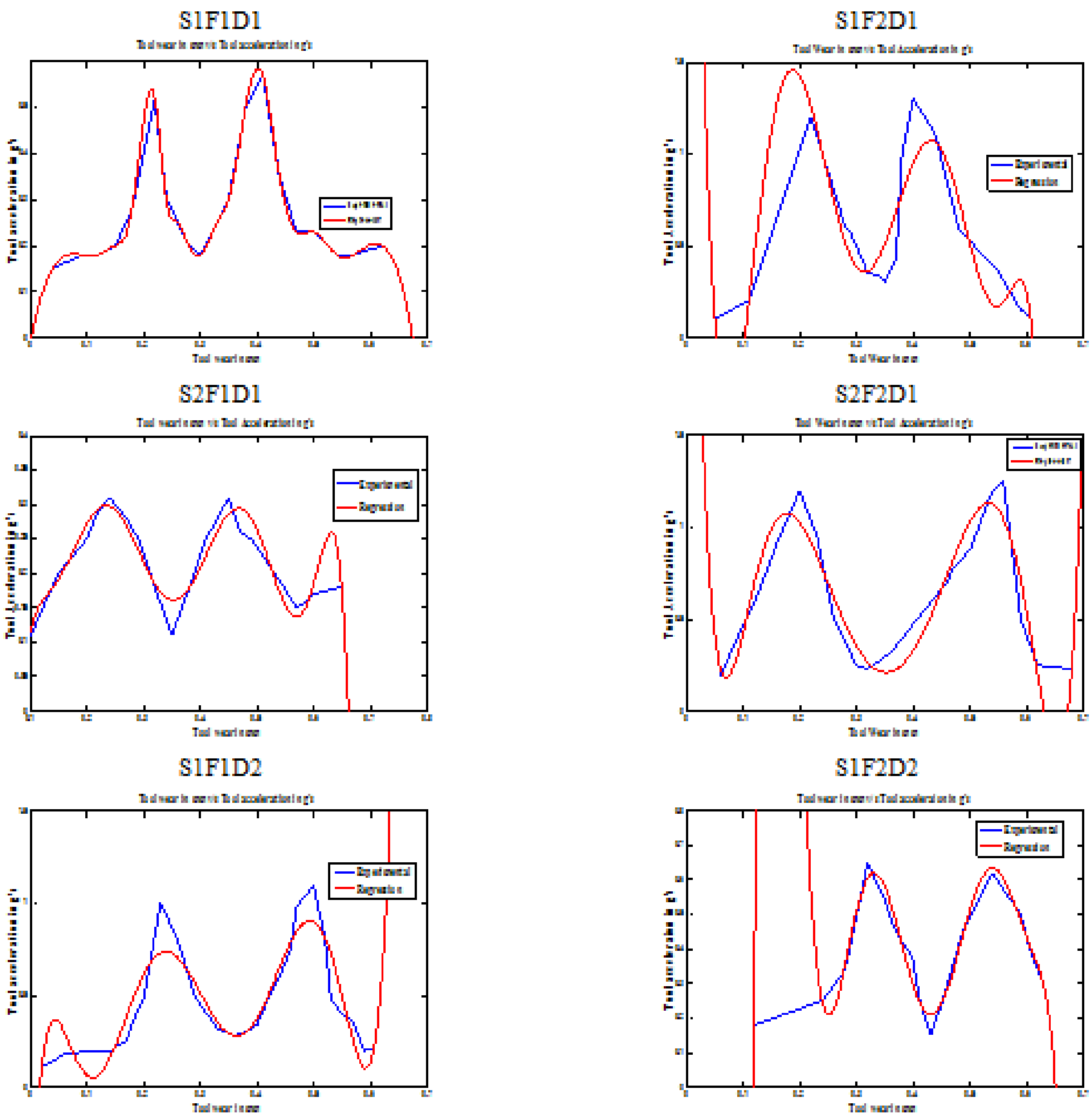

Fig 8: Regression graphs of tool acceleration v/s tool wear for coated carbide insert on En24

Table 4:R Squared values for various combination

Constants / Combinations	Regression Co-efficient of Determination R2
TMS1F1D1	0.927
TMS1F2D1	0.9199
TMS2F1D1	0.8906
TMS2F2D1	0.8921
TMS1F1D2	0.8392
TMS1F2D2	0.9549
TMS2F1D2	0.9467
TMS2F2D2	0.7783

IX. CONCLUSIONS

The results of the research conducted with En24 work material machined against coated carbide inserts yields very positive results of using vibration monitoring technique to be used as an on-line tool condition monitoring technique.

The graphs plotted from the results of experimental work carried out provide us the trends in which it is possible to know how tool flank wear progresses towards failure. This is possible to conclude even without disturbing the machining process with the use of trend developed which is the correlation of vibration amplitude of the tool during machining and the tool wear.

It is observed from all the graphs of tool acceleration in g's Vs tool wear in mm during the turning of tool steel En24 using coated carbide insert for various operating conditions used in the present research work that there are two peaks emerging at different frequencies before the carbide insert reaches the maximum flank wear of 0.6 mm in reference with ISO 3685. The second peak can be considered as the warning peak as it occurs before the maximum tool wear is reached.

The regression analysis shows the co-efficient of determination and co-efficient of correlation as high as 90% and above. This implies how closely the regression values recline along with experimental values.

The trend helps us in timely replacement of the cutting tool so that the quality of the work under machining is no deteriorated. This attribute becomes very important during precision manufacturing and when there is risk of losing a fairly costly material for not reaching the specified quality standards.

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