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REAL TIME OPTIMIZATION OF MACHINING PARAMETERS BY CUTTING TOOL CONDITION MONITORING TECHNIQUE IN TURNING

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Abstract:

Tool flank wear is a critical phenomenon which influences the quality of the machined component. In this work, an attempt has been made to create artificial flank wear using the CNC turner equipped with FFT analyzer to study machining parameters on tool wear. Also using artificial worn tool, cutting experiments were performed and signals are captured. The development of practical and reliable condition monitoring system for detecting flank wear in turning operation is essential for realization of intelligent and flexible manufacturing systems. The major objective of this work is to develop self-adjusting machining functions under various working conditions with minimum operator supervision. Experimental tests were conducted by varying process parameters such as depth of cut, cutting speed and feed rate using carbide tipped insert tool on Al based MMC work piece material. Vibration data during the metal cutting process was recorded using two accelerometers. Power spectral analysis was carried out to test the level of significance through regression analysis. Results obtained were analyzed the influence of tool wear with respect to different machining process parameters. Since tool life and tool quality are decisive criteria for the successful machining operations in industrial production.

Key Words: Tool Condition Monitoring (TCM), FFT analyzer, CNC turner, MMCs & Machining Parameters

1. Introduction:

Manufacturing process aspects must be carefully examined and controlled during the metal cutting operation. The various CNC turner operation involves the contact between work-piece, tool, and the chip which imposes various cutting forces-on the cutting tool resulting in gradual tool wear. The purpose of monitoring the machining operations is fundamental requirement, relevant to the performance of the machine tool, progression of tool wear, dimensional tolerances, surface texture (roughness, waviness) [9], tool deflection, and other features of the work piece and the chip shapes and formation. Tool wear is an especially severe problem when machining aerospace materials because of their high shear strength, work hardening tendency, highly abrasive particles, tendency to weld and form a built-up edge, and low thermal conductivity [1]. The cutting tool often bears extreme thermal and mechanical loads close to the cutting edge, leading to rapid tool wear. Therefore, tool wear is not repeatable and has a tendency to breakage of the cutting edge. Tool condition monitoring under such conditions seems to be especially important. Various cutting tool monitoring techniques [2] have been presented in the literature by various investigators which deal with the issues of detecting edge chipping, fracture, tool wear and surface finish. Many sensors were adopted in the area of metal cutting tool condition monitoring system namely, touch sensors, power sensors, acoustic emission sensors [2–5]. In the present study, artificial tool wear has been created (externally) using CNC turner machine in a controlled manner. This is similar to a real flank wear experienced by the tool during machining process. Characteristics of the surface topography of a machined work piece depend on the condition of the cutting tool including tool geometry, cutting tool material, work piece material, cutting conditions (with or without cooling) and machining parameters (cutting speed, feed rate and depth of cut). In general, the single point turning tool is subjected to different types of wear such as flank wear, crater wear, nose wear and chipping. Out of these wears, flank wear is considered in the present work. While creating artificial flank wear, the following important cutting tool geometrical parameters are taken into consideration like rake angle, clearance angle, length of the flank wear and radial wear length [6]. The fig.1 shows the typical flank nomenclature. The relation between flank wear and radial wear is given by

$$r_f = \frac{h_f \tan \alpha_0}{1 - \tan \gamma_0 \tan \alpha_0} \quad \ldots\ldots\ldots\ldots (1)$$

where, r_f is radial wear, h_f is flank wear, γ_0 is clearance angle and α_0 is rake angle.

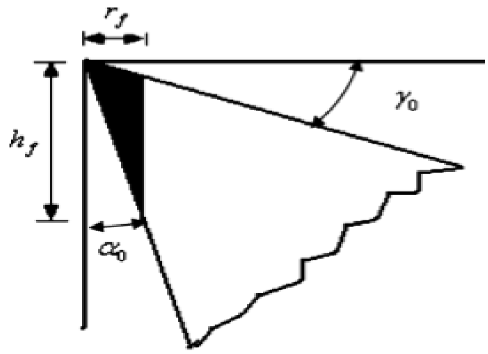

Figure 1: Flank wears form

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2. Fabrication of MMCs by Stir Casting Technique:

The work piece material used for present work was Al Alloy 6061 MMC fabricated by using stir-casting process technique. Stir casting is an accepted technique that is economically possible for mass productions [7]. This may be handled terribly simply with the assistance of stirrers; the speed of stirrer provides advantages for bonding ability in metal mixture. Table I Shows the various reinforcement material compositions by its % of Volume of Al alloy 6061based MMCs material.

Table 1: Shows Various Reinforcement Material Composition by Its % of Volume in Al 6061 Alloy Based MMC

Constituents	% by Vol.
Al6061 alloy	77%
TiB_2	8%
Ni	2%
Fly-ash	4%
Al_2O_3	3%
Mg	2%
Hexachloromethene	4%

3. Experimentation:

According to Eq. (1), the value of depth of cut (h_f) and radial distance (r_f) are calculated to create flank wear in the range of 0.2 mm to 0.65 mm. Opted machining parameters values were presented in the table II, in terms of cutting speed, feed rate as well as depth of cut to create exact shape of flank wear. In this study of work, optical microscope was used to capture the image of worn out area of the cutting tool flank. The Fig. 2 shows the CNC turner set-up for the experimentation. The accelerometers were placed in the turning centre, one was placed in the cutting direction on the tool holder, and the other one was placed in the feed direction for measuring vibration amplitude in terms of accelerations, during the conducting experimentations on Al alloy based MMC material. The experiments have been carried out by using the standardized Taguchi based experimental design, with three levels (designated by: 1; 2 and 3) of three main cutting parameters, namely, cutting speed , feed rate and depth of cut [8]. The necessary number of experimental test runs is nine. According to theTaguchi L9 orthogonal array, the number of experiments will be 27. Table III shows machining variables corresponding to the individual experiment.

Table 2: Selected Machining Variable

Variables	Units	Levels		
Cutting Speed	m/min	250	400	650
Feed rate	mm/min	100	300	450
Depth of cut	mm	3	4	5

Table 3: Experimental Data for Various Process Parameters

Ex. No	Cutting Speed, m/min	Feed Rate, mm/min	Depth of Cut, mm
1	650	450	5
2	650	450	4
3	650	450	3
4	650	300	5
5	650	300	4
6	650	300	3
7	650	100	5
8	650	100	4
9	650	100	3
10	400	450	5
11	400	450	4
12	400	450	3
13	400	300	5
14	400	300	4
15	400	300	3
16	400	100	5
17	400	100	4
18	400	100	3
19	250	450	5
20	250	450	4
21	250	450	3
22	250	300	5
23	250	300	4
24	250	300	3
25	250	100	5
26	250	100	4

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27	250	100	3

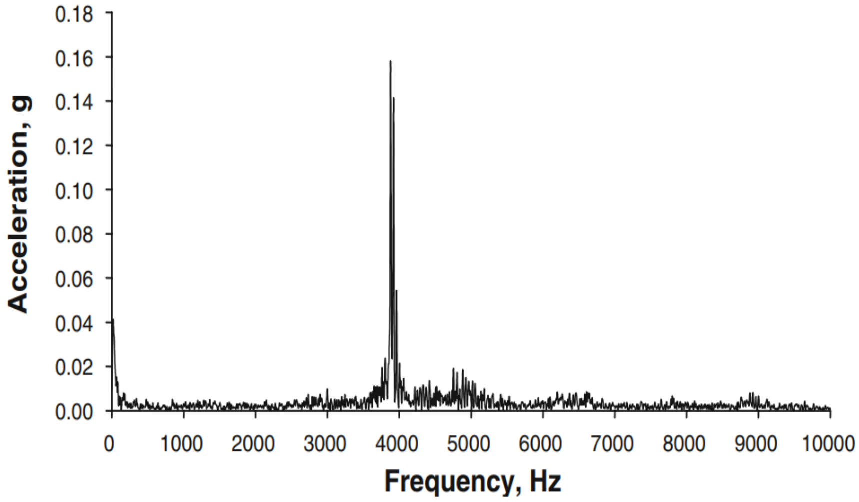

Figure 2: Cutting speed=650 m/min, feed=450 mm/min and depth of cut=3 mm for flank wear 0.3 mm. Response of the accelerometer in cutting direction

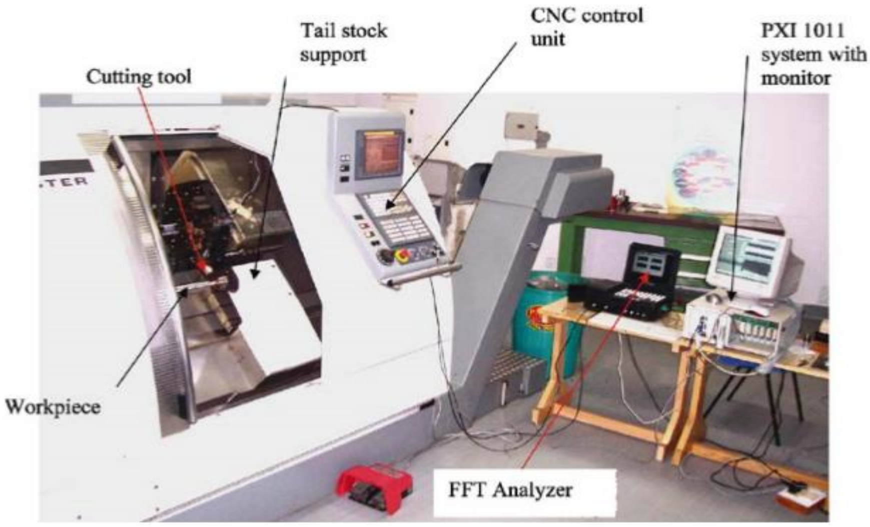

Figure 3: Shows the CNC turner set-up for the Experimentation work.

The power spectrum of vibration signals is shown in Fig. 2. It is observed that 4.0 kHz is the predominant frequency in the vibration spectrum of CNC turner (as shown in Fig. 3.) The dynamic responses of accelerometer in cutting longitudinal as well as transverse direction readings were presented in the table IV and V respectively. This data is good enough to classify the flank wear at different levels.

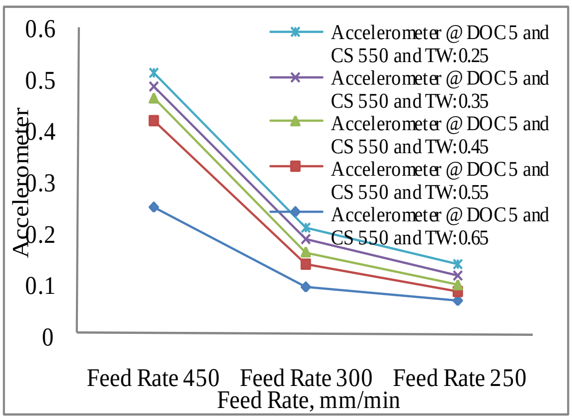

Figure 4: Influence of flank wear under the longitudinal cutting dirction at constant Cutting speed and depth of cut.

Table 4: Experimental Values of Accelerometer Under the Longitudinal Cutting Direction

Ex. No	Tool Wear, mm				
	0.65	**0.55**	**0.45**	**0.35**	**0.25**
1	0.2473	0.1723	0.0441	0.0234	0.025

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2	0.0625	0.0176	0.0228	0.014	0.0123
3	0.0514	0.0339	0.0169	0.0152	0.0078
4	0.0902	0.0441	0.0275	0.0256	0.0213
5	0.0486	0.0176	0.0147	0.0155	0.0109
6	0.0491	0.0178	0.019	0.0166	0.0072
7	0.0635	0.0176	0.0162	0.0171	0.0204
8	0.0407	0.0126	0.0116	0.0117	0.0128
9	0.0381	0.0156	0.0146	0.0149	0.0063
10	0.2893	0.2473	0.1193	0.0342	0.0254
11	0.2097	0.0297	0.0316	0.015	0.0133
12	0.0459	0.0254	0.0181	0.0173	0.0092
13	0.2673	0.0599	0.039	0.0271	0.0226
14	0.1637	0.0284	0.0187	0.0182	0.0158
15	0.0418	0.0195	0.0217	0.0186	0.0074
16	0.2033	0.0491	0.0248	0.0209	0.0207
17	0.0788	0.0212	0.0194	0.0106	0.0136
18	0.025	0.0151	0.0169	0.0154	0.0067
19	0.2793	0.2793	0.2463	0.0488	0.0296
20	0.2417	0.0682	0.0338	0.0187	0.0192
21	0.1903	0.0208	0.0235	0.023	0.011
22	0.2553	0.0764	0.0404	0.0585	0.0275
23	0.1727	0.0486	0.0207	0.0195	0.0188
24	0.1723	0.0219	0.0201	0.0188	0.0077
25	0.1203	0.0756	0.0288	0.0272	0.0255
26	0.071	0.0283	0.0195	0.0189	0.015
27	0.0329	0.0185	0.022	0.0194	0.0095

Table 5: Experimental Values of Accelerometer Under the Transverse Cutting Direction

Ex. No	**Tool Wear, mm**				
	0.65	**0.55**	**0.45**	**0.35**	**0.25**
1	0.2813	0.2593	0.0246	0.0232	0.0211
2	0.334	0.1853	0.1035	0.1028	0.1007
3	0.1628	0.0335	0.0093	0.0083	0.0075
4	0.1082	0.0781	0.0214	0.0204	0.0183
5	0.1418	0.1161	0.1019	0.1021	0.1001
6	0.0297	0.0145	0.0082	0.0075	0.0083
7	0.06	0.0372	0.0183	0.0176	0.0176
8	0.1378	0.1029	0.0998	0.0998	0.0994
9	0.0249	0.0123	0.0073	0.0065	0.0077
10	0.2623	0.2513	0.0353	0.0279	0.022
11	0.342	0.1359	0.1056	0.1031	0.1024
12	0.1698	0.0168	0.0112	0.0091	0.0102
13	0.2633	0.077	0.0243	0.0213	0.0197
14	0.287	0.1092	0.1036	0.1028	0.1004
15	0.1488	0.0115	0.0091	0.0079	0.0085
16	0.1072	0.0407	0.0193	0.0196	0.018
17	0.1234	0.1025	0.1006	0.0999	0.0998
18	0.0307	0.0103	0.0089	0.0065	0.0083
19	0.2853	0.1353	0.0369	0.0337	0.0226
20	0.361	0.1209	0.1093	0.1064	0.1037
21	0.1748	0.0075	0.0143	0.0095	0.0109
22	0.2473	0.0551	0.0302	0.0268	0.0204
23	0.244	0.1033	0.109	0.1054	0.1011
24	0.1368	0.0097	0.012	0.0103	0.0092
25	0.2063	0.031	0.027	0.0207	0.0192
26	0.23	0.1219	0.1059	0.1003	0.1002
27	0.0659	0.0102	0.0139	0.0068	0.0086

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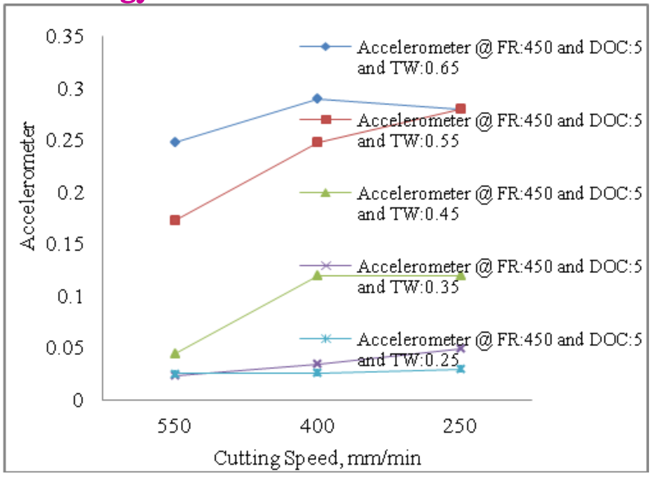

Figure 5: Influence of flank wear under the longitudinal cutting dirction at constant feed rate and depth of cut.

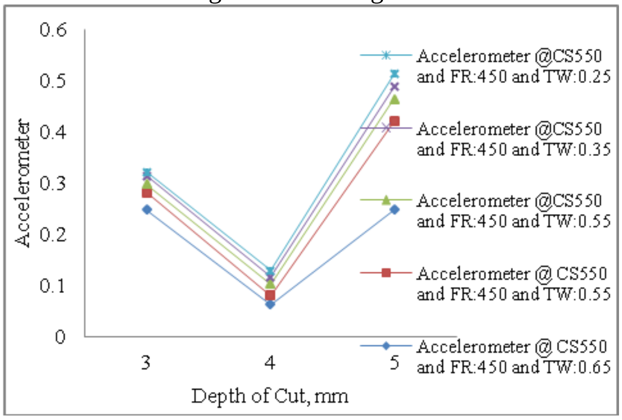

Figure 6: Influence of flank wear under the longitudinal cutting dirction at constant cutting speed and feed rate.

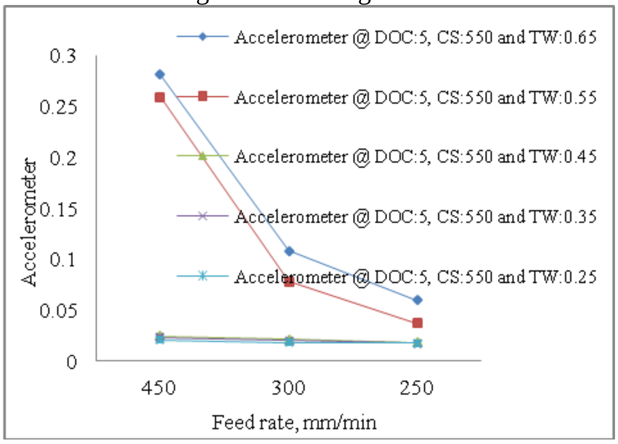

Figure 7: Influence of flank wear under the transverse cutting dirction at constant Cutting speed and depth of cut.

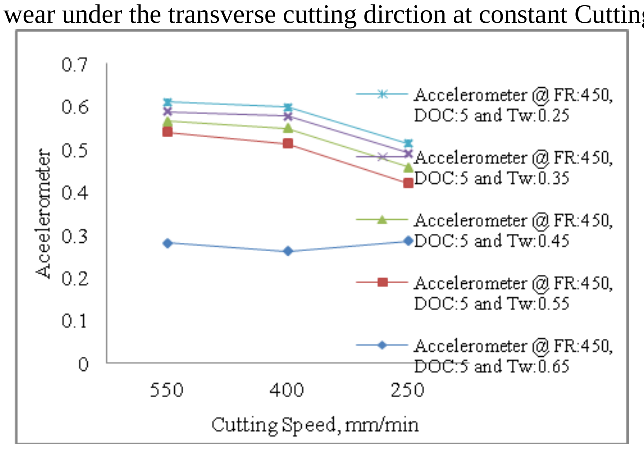

Figure 8: Influence of flank wear under the transverse cutting dirction at constant feed rate and depth of cut

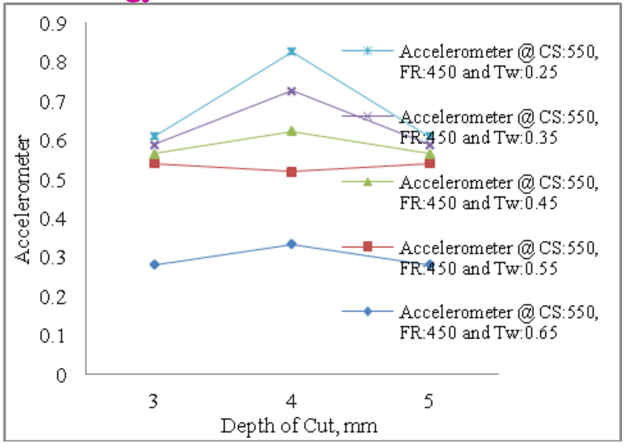

Figure 9: Influence of flank wear under the transverse cutting dirction at constant cutting speed and feed rate.

4. Results and Discussions:

In this analysis, experimental tests on three different models have been proposed using accelerometers in the cutting direction of longitudinal cutting and transverse cutting. Vibration monitoring during turning operation can be useful for predicting flank wear. For this purpose, frequency domain analyses have been carried out. It is observed that, vibration peaks exhibit response in a particular dynamic frequency range (3.6 kHz to 4.4 kHz) with respect to various machining conditions. The damping characteristics of the turning tool have been studied under dynamic conditions in the above said frequency range. The effects of three cutting parameters on the three response parameters are discussed below. The relation between accelerometer values, and depth of cut for various flank wear levels are as shown in Figs. 6 and 9. The tool vibration increases with increase in depth of cut as well as increase in flank wear. This is due to an increase in cutting force which reduces stiffness of the cutting tool. It is observed that, in all cases the amplitude of vibration in terms of acceleration, is small up to 0.4 mm flank wear level due to small variation in cutting force. The relationships between machining parameter feed rate and acceleration, for various flank wear levels are shown in Figs. 4 and 7. The amplitude of tool vibration, increases with increase in feed rate which results in increased dynamic cutting force. The increase in dynamic cutting force is associated with reduction in the stiffness of the cutting tool. In the same manner, the effects of cutting speed for various flank wear levels are shown in Figs. 5 and 8. Increase in cutting speed reduces the cutting force, and hence it will reduce the vibration.

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