AN INVESTIGATION OF TOOL CONDITION MONITORING

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ABSTRACT

In any manufacturing industry, machine tools play an important role in the production of parts. The dimensional accuracy and surface finish of the work piece depends mainly on the condition of the machine. The vibration signatures for different arrangement are recorded to determine the dynamic characteristics of the system, which include work piece, tool and lathe components. These vibration signatures are analyzed to determine causes of inaccuracy in the manufacturing process and faulty components. Many condition monitoring techniques are available to monitor the machine tool experimentally. Among these techniques vibration monitoring is the most widely used technique because most of the failures in the machine tool could be due to increased vibration level. Experimental vibration analyses are conducted for a lathe system to detect the possibility of faults and to develop accurate cutting process. Experiments are carried out using the condition monitoring instrument VIBROMETER to measure vibration severity for different cutting speed, depth of cut, feed rate. The value of vibration (rms and peak) at tool post and at bearing is determined from the experimental analyses, it is found that the vibration velocity increases at the cutting speed, depth of cut and feed rate increases.

Key words: vibrometer, cutting tool vibration, rms value, peak value.

INTRODUCTION -

The modern trend of machine tool development is required to produce precise, accurate and reliable product which are gradually becoming more prominent features. In a machining operation, vibration is frequent problem, which affects the machining performance and in particular, the surface finish and tool life. Severe vibration occurs in the machining environment due to a dynamic motion between the cutting tool and the work piece. The monitoring of manufacturing processes and equipment conditions are the essential part of a critical strategy that drives manufacturing industries towards being leaner and more competitive. Many sensors were used for tool condition monitoring system namely; touch sensors, power sensors, vibration sensors, temperature sensors, force sensors, vision sensors, flow sensors, acoustic emission sensors and so on. All operating machines, having rotary and/or reciprocating parts give rise to vibration. Machine tools are liable to deterioration in their performance level with respect to time due to various causes such as wear and tear, ageing, unbalance, looseness of parts etc., and produce a corresponding increase of the vibration level. Machine tool vibration, if uncontrolled, can adversely affect the surface finish, dimensional accuracy and tool life. About 70% of the failures in the machine tool could be due to increased vibration level of the machine. Lathe is one of the most important machine tool in manufacturing industries. A bearing is the most common critical component in a Lathe. Proper performance and functioning of bearings has always been a major concern in rotating machinery, since all the forces are transmitted to the bearings. It has been well established that 80% of the bearings failed to attain their expected life. A defect in the spindle bearing and unbalance forces in a lathe will induce more vibration, which result in deterioration of the dimensional accuracy and surface finish of the work piece. The extraction of vibratory signatures can be a valuable diagnostic tool to predict impending failures of the bearing and tool post. In all the cutting operations like turning, boring and milling, vibrations are induced due to the deformation of the work piece, machine structure and cutting tool. Today, the standard procedure adopted to avoid vibration during machining is by careful planning of the cutting parameters and damping of cutting tool.

LITERATURE REVIEW

The literature review has been carried-out in the areas of vibration monitoring of turning machiner.Techniques of faults diagnosis and analysis of resulting vibration signatures have been reviewed. Vibration signal analysis has become an established method for monitoring the condition of turning machines.

S.S Abuthakeer et al., 2011 have done comprehensive experimental study for the behavior of the system under any cutting condition within the operating range. The online tests show that the proposed system reduces the vibration of cutting tool to a greater extend.

Julie and Joseph, 2008 have been trying to demonstrate tool condition monitoring approach in an end-milling operation based on the vibration signal collected through a low-cost, microcontroller-based data acquisition system.

Marlon C. Batery and Hamid R. Hamidzadeh, 2007 Has done analytical and experimental vibration analyses for a lathe system to detect the possibility of faults and to develop an accurate cutting1process.the vibration signatures were analyzed to determine cause of inaccuracy in the manufacturing process and faulty components. Problem causing components for several case studiers (different speeds feed rate and tool lengths) were identified.

Kirby and Chen, 2007 The researchers determine mean amplitude of vibration using accelerations in both directions along the axes.

Taskesen, 2005 have proposed the On-line vibration control system for turning operation uses a closed loop feedback circuit which measures the relative vibration between the cutting tool and the work piece. There have been many investigations on vibration prediction and controlling based on periodic measurements of various machining conditions using accelerometer and active vibration controller.

Choudhury et al., 1996 has developed a computer program using Visual Basic programming language in order to analyze one and two degree of freedom of machine tool chatter vibrations.

Jagadish. M. S. and H. V. Ravindra were carried out the experiment on a lathe using the Condition Monitoring instrument to measure vibration severity for different spindle speed. From the experimental and numerical analysis, it was found that the vibration velocity increases as the spindle speed and depth of the defect increases. Also the value of vibration velocity at front bearing due to unbalance forces was determined and it was compared with the experimental value.

METHODOLOGY:

The experiment was carried out on Centre Lathe machine by selecting two measuring points, one at tool post and other at bearing in axial direction and in tangential direction. The experimental setup is shown in Figure 1. It include a tool made up of carbon steel,workpiece made up of mild steel (length 75mm,diam. 25mm and weight 285gm) without any cutting fluid. The vibration was measured by placing the vibrometer at two different points i.e. tool post and bearing. The experiments were repeated for different speed, different depth of cut and different feed rate. Readings were noted down in four different level i.e. four different depth cutting speed and feed rate .RMS value {It is a set of values (or a continuous time waveform) is the square root of the arithmetic mean of the squares of the original values (or the square of the function that defines the continuous waveform)} value and PEAK value (The maximum instantaneous value of varying current, voltage or power during the time interval under consideration.) were measured .After taking all the readings in four different level, graph has been plotted and made the comparison for different cutting speed ,feed rate and depth of cut that how these parameters affect the vibration level.

Fig 1 Centre Lathe Machine

DATA COLLECTION

Experiment has been performed in the workshop of Mits College Gwalior on centre lathe machine. Data has been collected in two directions in tangential direction and in axial direction. Vibrations were measured at two points at tool post and at bearing with the help of vibrometer as shown in table 1

Table 1. Input parameters and dynamic response of accelerometers

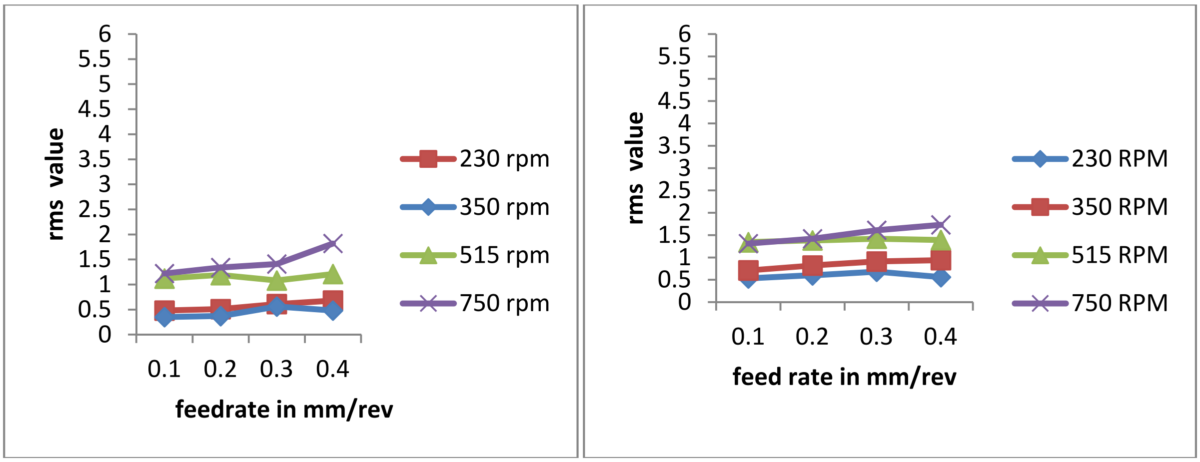
EXP NO.	**CS RPM**	**DOC mm**	**FR mm/ rev**	**Amplitude of acceleration level of cutting tool**							
				Tool post				**Bearing**			
				Axial		**Tangential**		**Axial**		**Tangential**	
				RMS	**PEAK**	**RMS**	**PEAK**	**RMS**	**PEAK**	**RMS**	**PEAK**
1	**230**	0.5	0.1	0.48	1.89	0.52	2.04	0.24	2.88	0.37	2.81
2	**230**	0.5	0.2	0.51	1.92	0.58	1.89	0.31	3.89	0.41	3.31
3	**230**	0.5	0.3	0.61	2.04	0.69	2.08	0.34	3.12	0.48	4.21
4	**230**	0.5	0.4	0.68	2.08	0.66	1.93	0.39	4.91	0.53	5.25
5	**230**	1	0.1	0.53	1.95	0.62	2.34	0.43	3.59	0.45	3.92
6	**230**	1	0.2	0.60	2.04	0.68	2.89	0.51	4.13	0.48	4.42
7	**230**	1	0.3	0.68	2.11	0.74	5.49	0.49	4.89	0.53	5.12
8	**230**	1	0.4	0.56	1.94	0.59	6.73	0.63	6.34	0.64	6.79
9	**230**	1.5	0.1	0.58	2.22	0.63	3.22	0.71	5.02	0.62	7.48
10	**230**	1.5	0.2	0.77	3.02	0.71	5.02	0.58	4.08	0.85	8.19
11	**230**	1.5	0.3	0.79	3.84	0.79	5.84	0.84	5.34	0.89	9.93
12	**230**	1.5	0.4	0.92	4.44	0.92	6.83	0.91	6.72	0.94	10.41
13	**230**	2	0.1	0.62	6.14	1.09	5.14	0.72	5.43	0.69	8.99
14	**230**	2	0.2	0.68	6.82	1.21	5.82	0.84	6.53	0.86	9.23
15	**230**	2	0.3	0.83	7.64	1.29	6.71	0.81	5.89	0.91	12.24

16	**230**	2	0.4	0.90	7.93	1.31	7.93	0.86	7.41	0.88	9.99
17	**350**	0.5	0.1	0.35	3.28	0.76	3.31	0.78	6.68	0.99	8.41
18	**350**	0.5	0.2	0.37	3.69	0.81	4.89	0.81	10.96	1.01	10.11
19	**350**	0.5	0.3	0.56	4.53	0.89	5.13	0.84	9.93	1.11	11.68
20	**350**	0.5	0.4	0.48	5.52	1.10	7.53	0.89	8.89	1.34	11.93
21	**350**	1	0.1	0.71	4.18	0.79	5.87	0.93	7.14	0.99	8.68
22	**350**	1	0.2	0.82	5.23	0.83	6.12	0.98	8.23	1.04	9.93
23	**350**	1	0.3	0.91	6.48	0.91	7.78	1.04	11.11	1.81	11.53
24	**350**	1	0.4	0.94	7.83	0.98	8.93	1.06	12.58	1.92	13.44
25	**350**	1.5	0.1	0.76	3.28	0.82	7.37	1.08	8.19	1.73	12.27
26	**350**	1.5	0.2	0.84	4.42	0.84	7.93	1.04	11.62	1.88	14.45
27	**350**	1.5	0.3	0.92	7.79	0.89	8.19	0.98	12.31	1.68	13.34
28	**350**	1.5	0.4	0.96	8.68	0.93	10.01	1.14	13.82	1.43	16.64
29	**350**	2	0.1	1.31	6.26	1.38	7.89	1.04	14.23	1.49	12.23
30	**350**	2	0.2	1.61	11.21	1.89	8.66	1.10	11.83	1.71	14.45
31	**350**	2	0.3	1.42	9.11	2.43	9.12	1.21	13.44	2.01	15.63
32	**350**	2	0.4	1.70	12.40	3.12	11.54	1.34	14.26	2.44	16.41
33	**515**	0.5	0.1	1.12	6.09	1.30	*8.75*	0.91	8.81	1.16	9.11
34	**515**	0.5	0.2	1.19	7.43	1.34	*9.84*	0.92	10.01	1.72	10.23
35	**515**	0.5	0.3	1.08	5.84	1.38	*11.96*	0.94	11.12	1.81	12.21
36	**515**	0.5	0.4	1.21	8.89	1.46	*12.44*	0.96	12.43	1.69	10.39
37	**515**	1	0.1	1.34	9.46	1.78	*9.96*	0.97	11.31	2.62	12.90
38	**515**	1	0.2	1.38	10.41	2.41	*11.23*	1.01	11.38	3.12	13.41
39	**515**	1	0.3	1.42	11.23	2.82	*12.34*	1.03	12.51	3.03	13.01
40	**515**	1	0.4	1.39	10.64	3.02	*14.02*	1.31	13.43	3.42	14.41
41	**515**	1.5	0.1	1.39	6.64	3.08	*12.20*	1.48	12.75	4.28	16.32
42	**515**	1.5	0.2	1.41	7.78	3.12	*13.23*	1.72	14.48	4.31	16.69
43	**515**	1.5	0.3	1.61	9.56	3.19	*14.21*	1.61	13.43	4.46	18.81
44	**515**	1.5	0.4	1.7	12.89	4.24	*14.28*	1.81	15.53	5.23	21.23
45	**515**	2	0.1	1.90	11.08	3.78	*13.09*	1.36	11.12	4.01	16.20
46	**515**	2	0.2	2.02	14.56	3.95	*13.93*	1.42	10.43	5.02	17.34
47	**515**	2	0.3	1.98	13.34	4.12	*14.44*	1.53	12.34	5.08	16.56
48	**515**	2	0.4	2.41	15.52	5.19	*15.53*	1.64	13.54	6.04	18.34
49	**750**	0.5	0.1	1.22	7.78	4.72	12.86	2.02	10.79	2.02	12.34
50	**750**	0.5	0.2	1.34	9.46	5.29	13.44	2.06	12.36	2.08	13.05
51	**750**	0.5	0.3	1.41	10.41	5.94	14.56	2.23	13.41	2.29	13.56
52	**750**	0.5	0.4	1.82	12.23	6.24	16.64	2.41	13.81	3.13	14.23
53	**750**	1	0.1	1.31	8.53	6.12	12.53	2.02	15.43	4.86	14.64
54	**750**	1	0.2	1.42	11.23	7.12	13.48	2.05	16.41	5.03	22.05
55	**750**	1	0.3	1.61	12.56	7.9	14.49	2.27	17.23	5.54	31.06
56	**750**	1	0.4	1.73	12.89	8.2	15.63	2..21	17.75	6.69	33.45
57	**750**	1.5	0.1	2.09	8.58	6.32	16.64	1.82	12.24	7.14	28.22
58	**750**	1.5	0.2	2.41	10.48	7.34	19.23	2.10	14.58	7.89	32.49
59	**750**	1.5	0.3	3.21	14.19	5.94	15.98	2.23	18.83	8.43	36.83
60	**750**	1.5	0.4	2.86	13.82	6.22	20.22	3.11	22.45	8.91	40.40
61	**750**	2	0.1	3.02	9.50	6.23	22.26	2.13	23.38	7.16	34.75
62	**750**	2	0.2	3.24	11.10	7.14	23.39	2.48	26.63	8.36	41.23
63	**750**	2	0.3	4.12	13.29	8.49	24.48	3.32	29.98	8.98	43.34
64	**750**	2	0.4	5.11	15.56	8.98	26.83	4.46	31.34	9.14	46.89

Variable or parameter	Parameter designation	Level 1	Level 2	Level 3	LEVEL 5
CUTTING SPEED (RPM)	A	230	350	515	750
DEPTH OF CUT (MM)	B	0.5	1	1.5	2
FEED RATE (MM/REV)	C	0.1	0.2	0.3	0.4

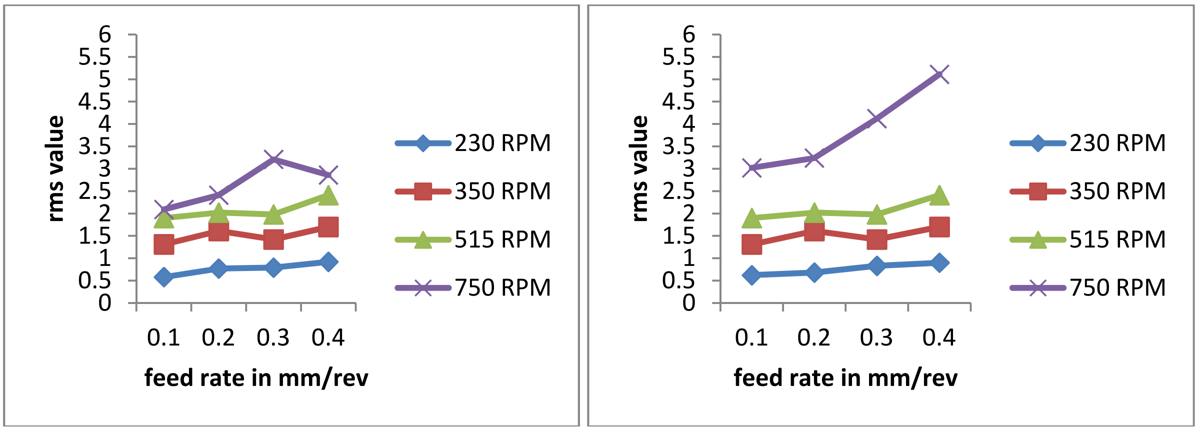
RESULT AND DISCUSSION

The vibration phenomenon for various cutting condition has been analyzed by plotting the graph for different cutting speed and depth of cut. The plan of the experiment was developed to assess the effect of cutting speed, feed rate and depth of cut on the cutting tool vibration. Table 1 illustrates the experimental result of vibration in both tangential and axial cutting direction. Fig 2 Shows the comparison of vibration level in axial direction at tool post for different depth of cut that how the cutting parameters affect the vibration level similarly fig.3 shows the comparison of vibration level in tangential direction at tool post, fig 4 shows the comparison of vibration in axial direction at bearing and fig 5 shows the comparison of vibration in tangential direction at bearing



FOR O.5MM DOC (a)

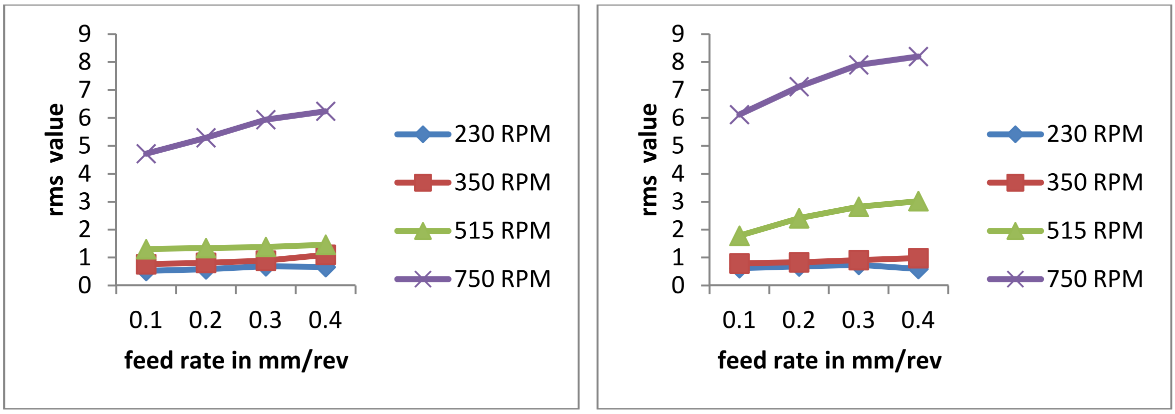
FOR 1 MM DOC (b)



FOR 1.5MM DOC (c)

FOR 2MM DOC (d)

Fig 2a.2b.2c, 2d variation of vibration in axial direction (At tool post) RMS value



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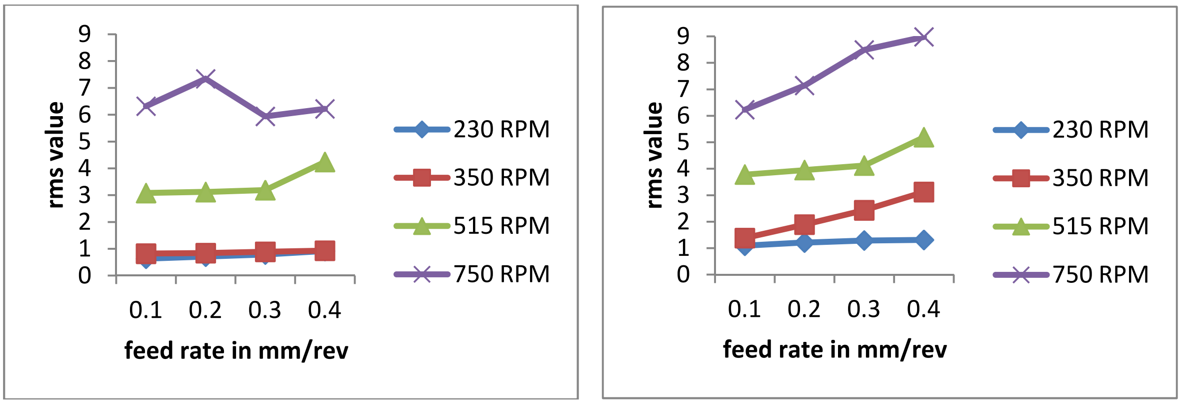
FOR 1MM DOC (b)



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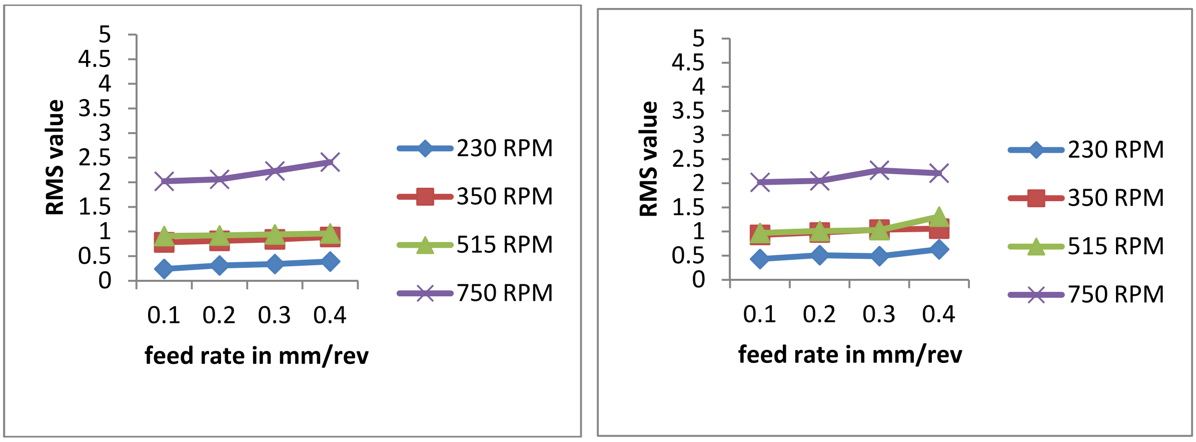
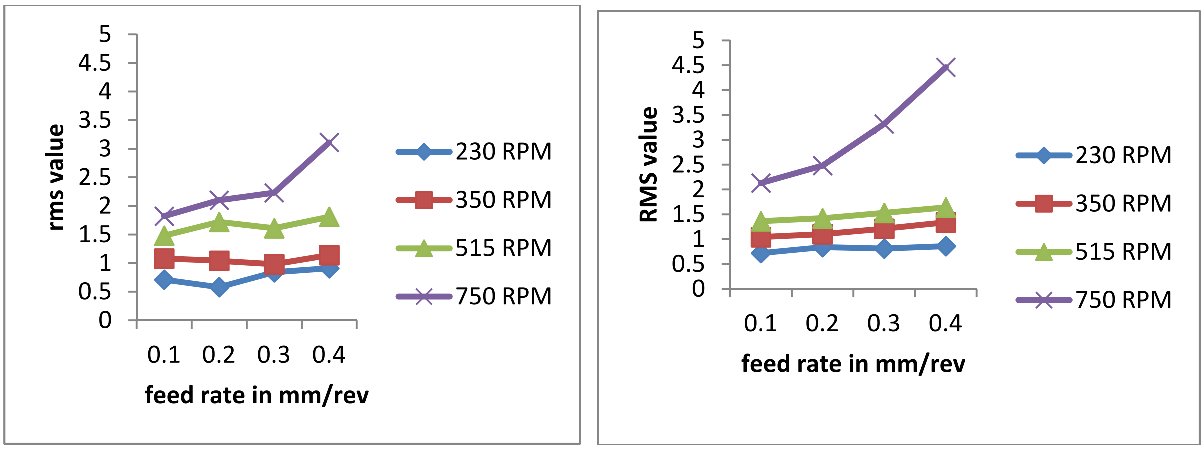
FOR 2MM DOC (d)

Fig3a, 3b, 3c, 3d variation of vibration in tangential direction (At tool post) RMS value



FOR 0.5 MM DOC (a)

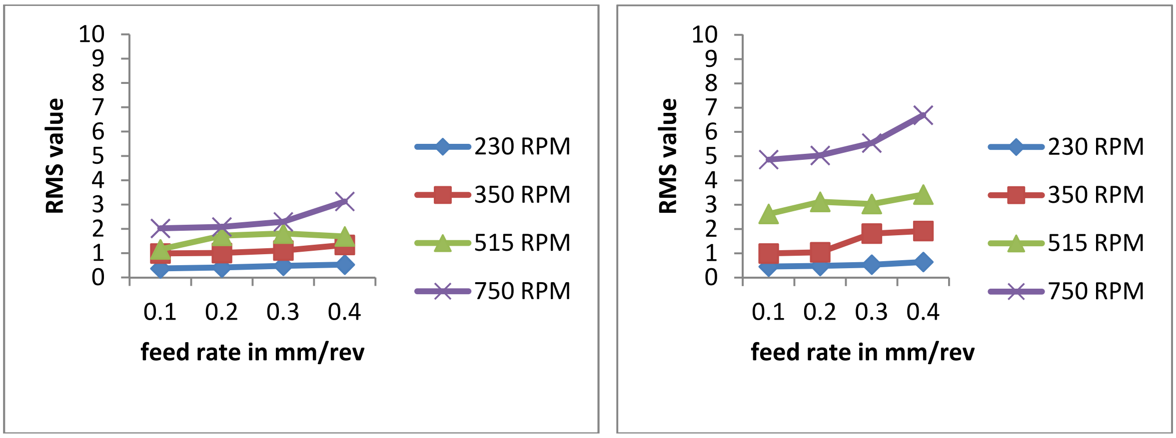
FOR 1MM DOC (b)



FOR 1.5MM DOC (c)

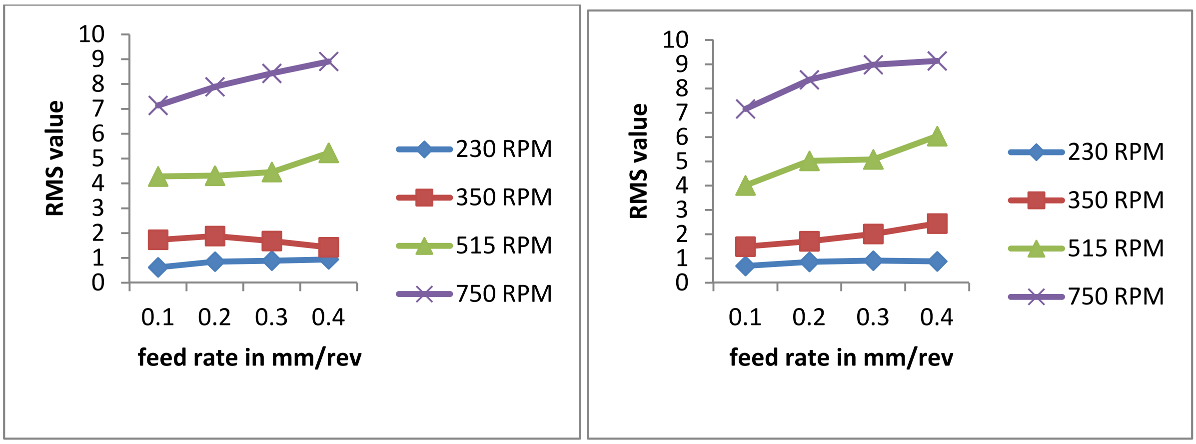
FOR 2MM DOC (d)

Fig4a, 4b, 4c, 4d Variation of vibration in axial direction (At bearing) RMS value



FOR 0.5MM DOC (a)

FOR 1MMDOC (b)



FOR 1.5MM (a)

FOR 2 MM DOC (b)

Fig5a, 5b, 5c, 5d Variation of vibration in tangential direction (At bearing) RMS value

CONCLUSION

In this course of study, Experiments were conducted on centre lathe machine, machining variables such as cutting tool vibration in tangential and axial direction were measured based on the vibration signal collected through a vibrometer data acquisition system. The effect of cutting parameters such as cutting speed, depth of cut and feed rate on machining variables is evaluated. Based on the current study, the following conclusions can be drawn. Transient dynamic analysis showed that the vibration velocity level increases as the cutting speed, depth of cut and feed rate increases. It was also found that the vibration velocity level depends upon the location of the defect. From the graph it is concluded that at cutting sped 230 rpm and 350 rpm there is a little differences in the variation of vibration but as the cutting speed increased up to 515 rpm and 750 rpm there is a greater influenced on vibration level .vibration is highly raised, hence cutting speed highly influenced the vibration, same thing we are observing in case of depth of cut and feed rate as these parameter increased vibration level increased. Hence from the above experiment it is concluded that the parameter which is highly affect the vibration is cutting speed then depth of cut and then feed rate. The optimal condition for working on centre lathe machine is cutting speed of 230-350 rpm, feed rate of 0.1-0.2 mm/rev and depth of cut up to 1 mm so it is not advisable to wok on high cutting speed, feed rate and more depth of cut because it directly affect the tool life it also shows that vibrations at bearing and in tangential direction are highly occurred comparatively at tool post and in axial direction.

REFERENCES

[1] Jemielniak K. Commercial tool condition monitoring systems. International Journal of Advanced Manufacturing Technology, 1999, 15 (4): 711–721.

[2] Kurada S. and Bradley C. A review of machine vision sensors for tool condition monitoring. Computers in Industry, 1997; 34: 55–72.

[3] Ian Kinghom, smart sensor technology-the next generation paper technology, vol.35, no.2, pp.39-41, 1994.

[4] Dimla D.E. Sensors signals for tool-wear monitoring in metal cutting operations - A Review of methods. International Journal of Machine tools and Manufacture, 2000; 40: 1073–1098.

[5] Julie Z.Z. and Joseph C.C. Tool condition monitoring in an end-milling operation based on the vibration signal collected through a microcontroller-based data acquisition system. International Journal of AdvancJoed Manufacturing Technology, 2008; 39: 118-128.

[6] Indian Standard, .Mechanical Vibration-Balance Quality Requirements of Rigid Rotors., BIS 11723 (Part 1): pp.7, 1992.

[7] S.A. Spiewak, R. Duggirala, K. Barnett, Predictive monitoring and control of the cold extrusion process, Annals of CIRP 49 (1) (2000) 383–386.

[8] D. Lin, M. Wiseman, D Banjevic, A.K.S. Jardine, An approach to signal processing and condition-based maintenance for gearboxes subject to tooth failure, Mechanical Systems and Signal Processing 18 (2004) 993–1007.

[9] D.E. Dimla Sr., P.M. Lister, On-line metal cutting tool condition monitoring: I: force and vibration analyses, International Journal of Machine Tools and Manufacture 40 (5) (2000) 739–768.

[10] Liu, C.H., Andrian, C., Chen, C.A.,Wang, Y.T. Grinding Force Control in Automatic Surface Finish System, Journal of Materials Processing Technology (2005) 170: 367–373.

[11] J.kopac**, i**nfluence of cutting material and coating on tool quality and tool life, journal of material processing technology,vol78,pp.95-103,1998.

[12] G.Byme, D.Dornfield, I.Inasaki, G.Ketteler, W.koing and R.Teti, Tool condition monitoring- The status of research and industrial application, Annals of the CRIP, vol .44, no.2, pp.541-567, 1995.

[13] S.B. Rao,Tool wear monitoring through the dynamics of stable turning, journal of engineering for industry,vol.108,pp. 184-189, 1986..