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EXPERIMENTAL INVESTIGATION OF CHATTER IN HARD TURNING MACHINING WITH VIBRATION ANALYSIS

KEYWORDS: Chatter, finite element method, ANSYS, CNC turning

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ABSTRACT Chatter is a topic of immense engineering importance because its occurrence in machining results in poor surface finish promotes tool wear and hampers productivity. In this paper, chatter is reducing by change damping value of tool holder by changing shim material. Finite element method is use for find damping ratio of different shim material. Model analysis is done by ANSYS. Experiment work is done on CNC turning 45 HRC mild steel work material for collect acceleration data and compares the accelerations value for different shim material. Find out the best shim material for turning operation.

Introduction:

The turning operation is the very basic machining operation in the manufacturing industry. Turning is a manufacturing process which carried out through relative rotation of part and cutting tool. Turning is the most basic and common machining method which plays an important role in production in many shops. The machining of metals often accompanied by a violent relative vibration between work piece and tool is called chatter. In a turning process, three different types of mechanical vibrations are present are present due to a lack of dynamic stiffness/rigidity of the machine tool system comprising tool, tool holder, work- piece and machine tool itself. Successful machining operations depend upon the dynamic relationship between the work piece and cutting tool. Under certain circumstances, the motion of the tool against the work piece can produce a self-exciting system, resulting in large amplitude of vibrations. This vibration or chatter adversely affects the life of the tool, the quality of the cut, and the speed at which operations may be performed. Understanding and properly controlling the interaction of tool/work piece dynamics to control chatter can yield reduced costs and higher overall productivity.

Literature survey:

N.K. Chandiramani and T. Pothala (2005) used two-degree-of-freedom (2-dof) model comprising nonlinear delay differential equations (DDEs) are analyzed for self-excited oscillations during orthogonal turning. The model includes multiple time delays, possibility of tool leaving cut, additional process damping, ploughing force, and variations in shear angle and friction angle. The frequency of tool disengagement increases with cutting velocity, despite cutting force in the shank direction remaining constant over a certain velocity range. Bason E. Clancy and Yung C. Shin (2002) used three-dimensional mechanistic frequency domain chatter model for face turning processes, which can account for the effects of tool wear including process damping. This model can be used with complex geometry tools to accurately predict the magnitude and direction of the process damping force.

Mayur S Ghormade and D.H.Pandya (2015) was study characteristic of the damped tool using finite element analysis (FEA). Damping ratio is one of the dynamic characteristic of system. Damping ratio of cutting tool with three different shims is predicted by using frequency response function and half band width method. An analytical model is simulated using MATLAB.

Ramezanali Mahdavinejad (2005) was worked on instability analysis of machining process is presented by dynamic model of turning machine. This model, which consists of machine tool's structure, is provided by finite element method and ANSYS software, so that, the flexibility of machine's structure, work piece and tool have been considered. Kambiz Haji Hajikolaei, Hamed Moradi and Gholamreza Vossoughi (2010) suppress regenerative chatter in turning process by spindle speed variation and adaptive force regulation. In this paper, two control strategies are developed to suppress chatter vibration in the turning process including a worn tool. Naren Deshpande and M.S. Fofana (2001) studies a single DOF model for turning involving regenerative chatter. Linear stability charts are derived which can aid in the design of cutting edge technology. The relevant nonlinearity is considered only on the cutting force variation in chip thickness. I.N. Tansela, X. Wanga, P. Chena, and A. Yenilmezb (2005) used S-transformation for detect the chatter. S-transformation was proposed in order to prepare 3D plots to display the variation of the amplitude of the sensory signals of the turning operation in the time and frequency domain, simultaneously. A frequency–time–damping index plot was obtained from the s-transformation result. Y.S. Tarnga, J.Y. Kaob and E.C. Leea (2000) used piezoelectric inertia actuator mounted on a cutting tool and acting as a tuned vibration absorber for the suppression of chatter in turning operations has been explored. The piezoelectric inertia actuator must satisfy the following criteria to suppress chatter in turning effectively. Erol Turkes a, Sezan Orak b and Suleyman Neseli (2011) chatter prediction was investigated for orthogonal cutting in turning operations. Therefore, the linear analysis of the single degree of freedom (SDOF) model was performed by applying oriented transfer function (OTF) and decomposition form to Nyquist criteria. Zhehe Yao, Deqing Mei and Zichen Chen (2010) in this study, intelligent chatter recognition systems based on wavelet transform and SVM was investigated via boring process. Wavelet transform has an integrated description in both time domain and frequency domain. Adam A. Cardi and Hiram A. Firpia (2007) method was differing from other chatter detection investigations because with the direct displacement measurement of the tool holder and the output from the Neural Network observer, there is information about both bodies' motions.

The main Objective of this paper is to reduce the chatter by changing the damping capacity of tool holder by change shim material. Damping is finding using finite element method. Experiment work is done for collect acceleration. And the result is validating with surface roughness value of work piece.

Computation Work and result discussion:

In order to make Finite element model ANSYS software is use. A geometric model of cutting tool holder is shown in Figure (1).

Modal analysis is done for find out Natural frequencies and vibration modes of cutting tool holder. Meshing and Boundry condition is shown in Figure (1).

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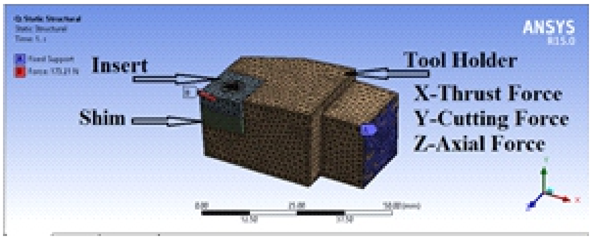

Figure (1): Meshing and boundary condition of tool holder

Than harmonic analysis is done using mode frequency for find Frequency response curve. In present work analysis is done for all shim material and find out damping ratio. Damping ratio is predicted by using the half power bandwidth method. The bandwidth is the frequency difference between upper and lower frequencies for which the power has dropped to the half of its maximum value. Frequency response graph was found using Harmonic analysis which is shown in Figure (2)

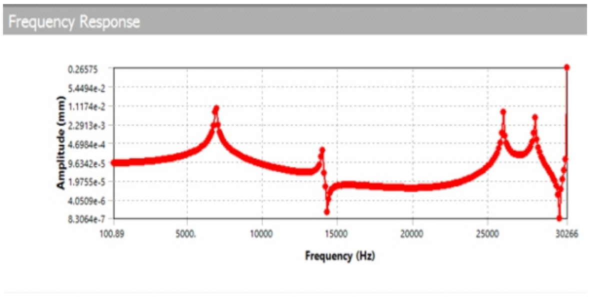

Figure (2): Frequency Response Graph.

Analysis is done taking only shim. And find damping ratio which is shown in Table (1).

Computational works show that the damping ratio is high in aluminum shim and low in carbide shim. But damping ratio is low in tool holder with brass shim and high in tool holder with aluminum shim. As per computational work conclude that the damping is change by changing shim material.

Table (1): Damping Ratio of Shim material

Shim	Natural Frequency f_r	Damping Ratio
Aluminum	1.36E+05	0.0033
Brass	92927	0.0022
Carbide	1.59E+05	0.0017

Experimental Setup and result discussion:

The experiments were carried out on the CNC lath machine on En 31 mild steel bar with 45 HRC work material. The bars of 48mm diameter and length of 40mm were used for the experiments. The bar was cut using CBN650 insert. The turning experiments were conducted at constant feed rate for a particular diameter work piece. Three different cutting speed 150m/min, 175m/min, 200m/min are take, three different depth of cut 0.3mm, 0.4mm, 0.5mm, and three shim Carbide, Brass and Aluminum are taken for experiments. The CO-CO80 Dynamic Analyzer and acceleration sensors are used for the vibration measurement. The vibration was measured in both X-direction (Thrust force direction) and Y-direction (Cutting force direction). Data are analyzed with sampling frequency of 5.12 KHz. Surface roughness is measured with SJ 210 surface roughness tester (-200 µm to 150µm). The experiment setup is shown in Figure (3).

Figure (3): CNC Machine and Dynamic Analyzer

Combination of Shim material, Cutting speed and Depth of cut total 27 experiments are done. The lists of experiments are shown in Table (3). During cutting process the acceleration data is collected, using this data and note the accelerations value of all cutting process.

Table (2): List of Experiments with acceleration and surface roughness value.

Sr. No	Shim	Cutting speed (m/min)	Depth of cut (mm)	Acceleration Value (mm/s^2)		Surface Roughness (µm)
				X-Direction	Y-Direction	
1		150	0.3	600	1000	0.420
2		150	0.4	15000	40000	2.750
3		150	0.5	2000	3000	0.411
4		175	0.3	7000	10000	1.001
5	Carbide	175	0.4	15500	40000	2.627
6		175	0.5	16000	50000	2.225
7		200	0.3	6000	11000	1.581
8		200	0.4	15000	30000	2.746
9		200	0.5	11000	20000	2.701
10		150	0.3	4000	10000	1.514
11		150	0.4	15000	40000	3.201
12		150	0.5	17000	60000	3.811
13		175	0.3	1000	2000	0.673
14	Aluminum	175	0.4	2000	4000	0.399
15		175	0.5	12000	50000	2.068
16		200	0.3	4000	10000	1.121
17		200	0.4	15000	40000	3.767
18		200	0.5	14000	40000	2.260
19		150	0.3	600	1300	0.415
20		150	0.4	400	600	0.416
21		150	0.5	650	2500	0.385
22		175	0.3	5000	10000	1.100
23	Brass	175	0.4	17000	35000	3.204
24		175	0.5	15000	30000	2.038
25		200	0.3	1000	4000	0.611
26		200	0.4	550	1500	0.458
27		200	0.5	1400	2500	0.640

The maximum value of acceleration in X-Direction (Cutting Force Direction) and Y-Direction (Thrust force Direction) shown in Table (2).

Experiment show that the range of acceleration value in X-Direction is 600 to 1500 has low surface roughness value 0.4 and range of acceleration value is 6000 to 15000 has high surface roughness value 1 to 2.76 in carbide shim is used. The range of acceleration value in X-

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Direction is 1000 to 4000 has low surface roughness value 0.39 to 1.1 and range of acceleration value is 12000 to 17000 has high surface roughness value 1.5 to 3.8 in Aluminum shim is used. The range of acceleration value in X-Direction is 400 to 1000 has low surface roughness value 0.35 to 0.64 and range of acceleration value is 5000 to 17000 has high surface roughness value 1.1 to 3.2 in Brass shim is used.

Conclusion:

In this work conclude that the carbide shim is good for 150 m/min cutting speed. Brass shim is good in 150 and 200 m/min cutting speed and any depth of cut. Aluminum is not justified for use in turning operation. Also conclude that the acceleration value is low in brass shim so brass shim is better for turning operation compare carbide and aluminum. Also the surface roughness value show the good result in brass shim.

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