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A step forward to chatter analysis in turning machines

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Abstract: Chattering is a well-known and self-exited vibration. The stock removal rate is highly affected by this phenomenon. In this paper 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 structure, workpiece and tool have been considered. The model is evaluated and corrected with experimental results by modal testing on TN40A turning machine in which the natural frequencies analyzed.

Keywords: Vibration, Chatter, Modal test, Stability lobes

1.INTRODUCTION

Chatter is a kind of self-exited vibration and an undesirable phenomenon, which is occurred during machining in machine tools [1]. When chatter takes place the surface of the workpiece material is not only damaged, but the tool breakage and the amortizations of other machine parts are the results of this phenomenon. In this case, the cutting width and machining rate must be under limitation of chatter creation. The conventional method to prevent from this phenomenon in machining process is to reduce machining rate or dept of cut which will reduce the stock removal rate itself [2].

Most investigations in this subject are about theoretical analysis of the recognition of stability boarding in machining processes and also the detection, control and protection of chattering phenomena [3]. The effect of tool wear is also considered in chattering by some researchers [4-7]. The control method of chatter with the self-setup of spindle speed is proposed [8].

2.CHATTER IN MACHINING PROCESS

Chatter in machine tools is caused by one of two mechanisms named mode coupling and regeneration of waving surfaces.

The critical cutting width based on regeneration mechanism in machining process is calculated from following equations:

$$a_{\lim} = \frac{-1}{2k_f G(\omega_c)} \tag{1}$$

Where k_f and $G(\omega)$ are shearing strength and the real part of vibration conversion function of the system. According to the chattering theories, chatter vibrations occur at high frequencies, which, are closed, to one of vibration modes of system. Therefore from response frequency of the system, the stability lobes of machining process at frequencies close to the major modes of the system can be plotted.

3.MODELING PROCEDURES

In order to make a finite element model, a three dimensional model of machine's structure with ANSYS software has been under consideration. The model is applied on TN40A turning machine from Tbriz Co.(figure1).

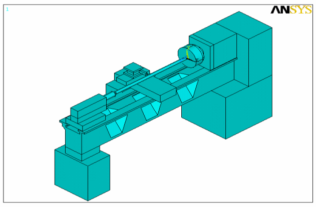

Figure1: ANSYS Geometrical model of TN40A machine

After modeling, the necessary input data as material properties are applied and making elements of the model is carried out with solid 45. The element distribution is uniform to exceed boundary and it is so that in the parts with relatively small dimensions like tool, tool holder, workpiece and tailstock the element dimensions are finer and controlled. This provided model has 80721 elements and 19214 nodes. Afterwards, boundary conditions on supporting are applied on the earth connection of machine tool and finally modal analysis has been done to obtain natural frequencies. In continuation, the correction of finite element model with its detail addition to coincide the software analyzing and modal testing results is accomplished.

4.MODAL ANALYSIS

Modal analysis has been done on the five types of finite element model to determine the natural frequency of machine tool structure elements and workpiece and to discrete them from each other. These models are as follows:

No1; complete model of machine tool's structure and workpiece, in chuck-tailstock case.

No.2; the model of spindle, chuck, center and workpiece with tailstock.

No.3; Workpiece model.

No.4; tool model.

No.5; the complete model of machine structure without workpiece.

The modal analyzed natural frequencies of these models via ANSYS software by subspace method are shown in table 1.

4.1 Modal Analysis of Finite Element Models and Its Natural Frequencies Analyzing

Analysis of natural frequencies and mode shapes of FEM from table 1 are as follows:

Table1.
Natural frequencies from modal analysis of finite element models in ANSYS (Hz)

Model No. 5	Model No. 4	Model No. 3	Model No. 2	Model No.1	No.
74.86	2780.2	23.605	153.14	74.072	1
101.11	3406.5	23.642	153.35	101.35	2
111.70	9024.8	147.06	440.98	112.44	3
142.24	9078.8	147.33	441.51	142.07	4
172.11	11664	408.23	604.71	150.85	5
203.28	15667	409.18	606.21	152.37	6
302.18	16470	674.17	877.85	174.00	7
314.22	17595	790.26	932.47	205.04	8
340.25	33661	791.93	933.98	300.29	9
355.14	34707	960.62	1259.6	311.66	10
380.11		1286.4	1447.1	341.14	11
404.15		1288.1	1450.7	366.46	12
426.94		1888.2	1648.9	377.83	13
474.20		1892.5	1914.6	390.33	14
487.91		2030.0	1917.3	418.52	15
				439.46	16
				445.32	17
				478.75	18
				498.07	19
				511.16	20

The fifth and sixth natural frequency modes of model No.1 are similar to the first and the second vibration modes of the model No.2 respectively. Therefore these modes in model No.1 are related to the vibrations of spindle, workpiece and tailstock, so that, the vibrations of machine tool structure is not interfering on them.

The vibration frequency region of tool's model (model No.4) is much higher than the vibration frequencies of machine's structure.

5. MODAL TESTING

In order to analysis chatter phenomena and stability lobes plotting, a turning TN40A machine and B&K 2-channels Fourier analyzer with a piezoelectric B&K 8200 accelerator and plastic hammer (8202) are used. The stability lobe is plotted via transmission functions obtained from modal testing (Figure2).

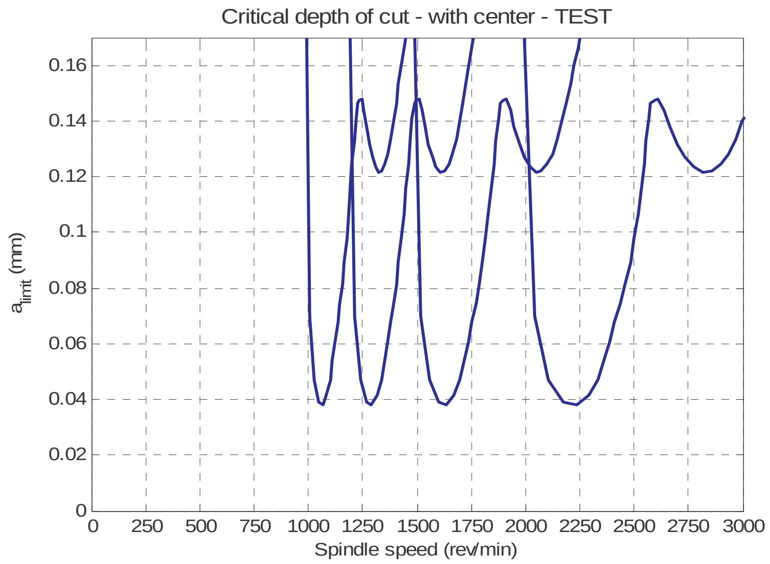

Figure2: Modal testing's stability lobe in chuck-tailstock case

Due to the effectiveness of 122.52Hz frequency mode and its vicinity with 94.74Hz mode, two minimum points are shown in each branch of the stability lobe. The first one is related to 94.74Hz vibration mode, which is more flexible, and the second one is related to 122.32Hz vibration mode.

6. CONCLUSION AND RESULTS

According to the model analysis, the natural frequencies and vibration modes shape of the model in chuck-center with and without tailstock cases, are determined. In order to evaluate FEM usage in this research, the natural frequencies and vibration modes shape of finite element modeling and modal testing are compared. The comparison between natural frequencies of finite element modeling and model testing shows the closeness of the results, so that, in frequency calculation of vibration mode with the most flexibility that is used in stability lobe plotting, the amount of error in chuck-center with and without tailstock are 13% and 6% respectively. The comparison between stability lobes obtained from modal analysis results in chuck-center with and without tailstock shows that in this case the frequency of chatter starting and the limiting width of chips are increased. In the other words, the machining stability process in chuck-center with tailstock is more than tailstock free case.

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