Effect of tool Overhang length on turning operation using finite element model

B.Tulasiramarao, P. Ramreddy, K. Srinivas, A.Raveendra

Abstract— Turning accuracy and productivity rates become key determinants and both the accuracy and surface quality plays vital role. In this paper the cutting tool modeled with finet element model and for different tool overhanging lengths analytical modal has prepared. The modal and stiffness data of the tool are extracted from ANSYS software also the mode shapes were drawn. Tool overhang was selected as input and the influences of tool overhang on the stability of turning using finite element was obtained. The stability lobe diagrams corresponding to different tool overhangs different stiffness, tool frequencies and damping ratios were presented.

Keywords- ansys software, finite element model , tool over hang length and SLD.

I. INTRODUCTION

Turning is one of the most common machining operation in industry. In a turning process, work-piece rotates about its longitudinal axis on a machine tool called a lathe. The work-piece is supported by a chuck at one end and by a tailstock at the other end. A cutting tool mounted on the lathe is fed along the work-piece axis to remove material and produce the required shape. In a turning process, there are several parameters that define the cutting conditions. They are cutting speed, feed rate, and cutting depth. Cutting speed is the rate at which the uncut surface of the work-piece passes the cutting edge of the tool. Feed rate is the distance moved by the cutting tool in the longitudinal direction in each revolution. Cutting depth is the thickness of the metal removed in the radial direction by the cutting tool in the longitudinal direction in each revolution. Cutting depth is the thickness of the metal removed in the radial direction. The principal surface machined is concentric with the axis of the work-piece as shown in Fig 1.1.

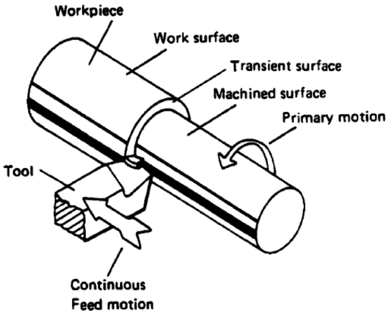

Figure 1.1: Cylindrical turning on a lathe

Turning operations are most widely used to produce accurate size and shapes in the manufacturing industry. Applications can be found in the turning of dies and molds, jet engine parts made of heat resistant alloys, aircraft fuselage and wing panels, and biomedical parts.

1.1 stability lobe diagram

The stability lobe diagram depends on many parameters including tool stiffness, frequency, damping ratio, tool material and geometry, work piece material and its dynamics along with the cutting parameters. The cutting parameters such as speed, feed rate, depth of cut, tool length etc. has a considerable influence on the chatter behavior. Higher cutting speeds leads to less production time and reduction of tool life. Compared to the feed rate, depth of cut influence more on the stability behavior. Tool overhang is defined as the length by which the tool extends from the tool holder.

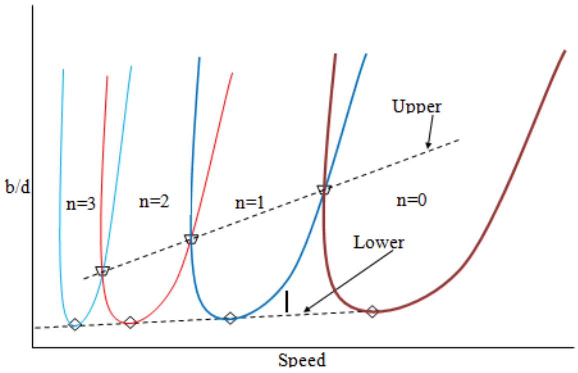

Fig.1.2 Stability lobe diagram

Length is a variable that can be used to tune the machining process. It acts as an absorber for the vibrations produced during machining. The stability lobe diagram has upper and lower boundaries which are also influenced by the tool wear during cutting operation.

II. EFFECTS OF TOOL OVERHANG LENGTH

Classical models available in literature, employed either the elastic tool or a rigid work-piece. These models may not express exactly the dynamic behavior of the system. The dynamic operation of the cutting depends on the geometrical and mechanical characteristics of the tool and work-piece. This section describes the results of tool overhang effect on the output features such as cutting forces and surface roughness. Experiments are carried out on engine lathe to study the effect of tool overhang on stability. Results of finite element model of the system are also shown.

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III. ANALYTICAL RESULTS

The modal and stiffness data of the tool are extracted separately from ANSYS software. Initially the solid model of the tool is developed without loosing all details of the geometry, and it is meshed with solid elements. Natural frequencies, damping ratios and stiffness values are obtained first. The solid model of the tool (employed in the experiments) is generated in Autodesk-Inventor. Figure 3.1 shows the dimensions of the tools employed in the present task.

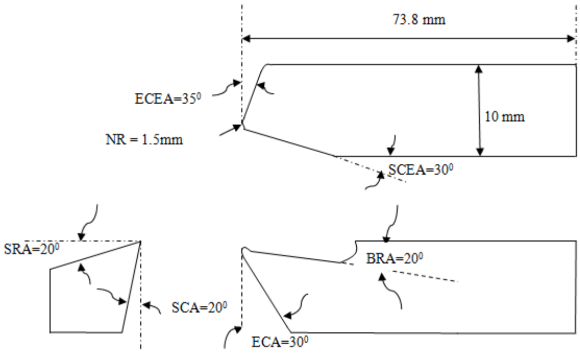

Fig. 3.1 Signature of the present cutting tool employed in solid modeling

(ECEA: End cutting edge angle, SRA: Side rake angle, BRA: Back rake angle, ECA: End clearance angle, SCA: Side clearance angle, SCEA: Side cutting edge angle, NR: Nose radius)

This is imported into ANSYS(version:8) and solid tetrahedral elements with 10 nodes (SOLID 92) and three degrees of freedom (Ux, Uy, Uz) are used to mesh the solid geometry with the following material properties: Young's modulus E=200 GPa,

Poisson's ratio: 0.28,

Density: 8150 kg/m3.

Figure 3.2 shows the meshed geometry of the cutting tool.

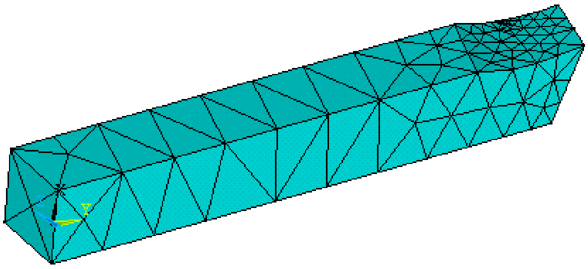

Fig.3.2 Finite element model of the present cutting tool

The amount of tool overhang is specified as the distance from tool tip to the nodal area over which the tool holder is mounted. The tool holder boundary is simulated with fixed conditions in all the directions. Thus in order to vary the overhang length, the positions of the nodes under arrest are to be changed. The stiffness of the tool is obtained from static analysis; natural frequencies are obtained from modal analysis while the damping ratios are predicted from harmonic response curves. With several values of tool overhang the modal and stiffness data of the cutting tool obtained is shown in table 3.1.

Table 3.1 Modal and stiffness data of tool

Tool Over hang (mm)	Stiffness(N/m)			Natural Frequency(Hz)	Damping ratio		
	K_x	K_y	K_z	ω_y	ζ_x	ζ_y	ζ_z
70	930	3301	717	112	0.0295	0.027	0.033
63	1103	3412	779	122	0.0416	0.052	0.045
55	1434	4424	1077	138	0.0425	0.043	0.05
47	2439	7310	1751	165	0.0158	0.008	0.016
39	5128	13390	3156	199	0.0428	0.042	0.026
30	5426	15680	3620	204	0.0222	0.019	0.022

The work-piece is modeled as a finite element beam with 4 elements and total 5 nodes. The following dimensions of the work-piece are considered:

Length=480mm,

Diameter=50mm,

Young's modulus: 210 GPa,

Density=7860kg/m^3,

Damping ratio ζw=0.25,

Rotational stiffness of the chuck Kt =104 Nm/rad.

The tool interaction dynamic forces Fx act at a specified node where the tool is in contact with the work-piece. The assembled mass and stiffness matrices are obtained from the element matrices described below.

$$k = \frac{EI}{\lambda^3}\begin{bmatrix} 12 & 6\lambda & -12 & 6\lambda \\ 6\lambda & 4\lambda^2 & -6\lambda & 2\lambda^2 \\ -12 & -6\lambda & 12 & -6\lambda \\ 6\lambda & 2\lambda^2 & -6\lambda & 4\lambda^2 \end{bmatrix}, \quad m = \frac{\rho A\lambda}{420}\begin{bmatrix} 156 & 22\lambda & 54 & -13\lambda \\ 22\lambda & 4\lambda^2 & 13\lambda & -3\lambda^2 \\ 54 & 13\lambda & 156 & -22\lambda \\ -13\lambda & -3\lambda^2 & -22\lambda & 4\lambda^2 \end{bmatrix}$$

The first three mode shapes of tailstock supported work-piece are shown in Figure 2.3. The fundamental frequency of work-piece can be seen as 2588 rad/sec which is much higher than the equivalent work-piece without tailstock support.

Fig.3.3 First three modes of propped cantilever work-piece

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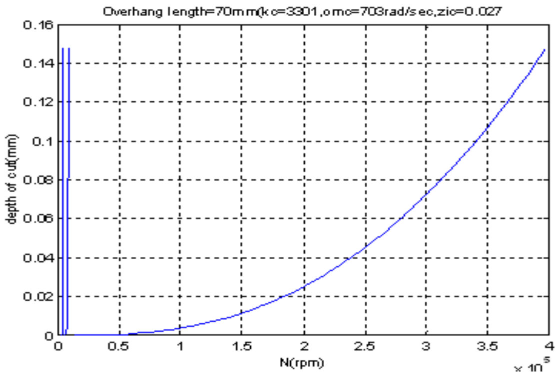
23YJThe first normalized modal vector is

$$\{\phi^{(1)}\} = [0 \quad -3.3654 \quad -0.3665 \quad -2.416 \quad -0.5205 \quad -0.0132 \quad -0.3688 \quad 2.4098 \quad 0 \quad 3.4162]^T$$

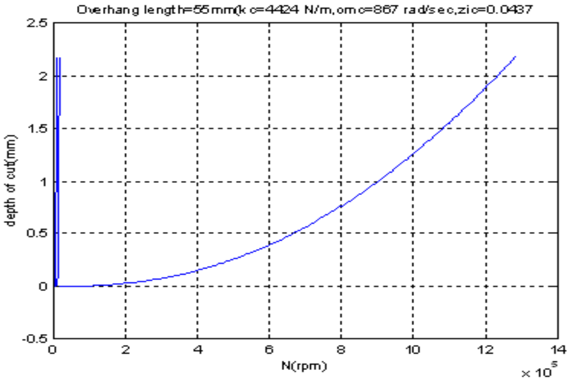
This is used to un-couple the differential equations and permits all the 10 equations to express as a single second order differential equation in terms of one modal co-ordinate p1.

The equation so obtained when the cutting tool is in contact with the work-piece at the node-4 can be written as

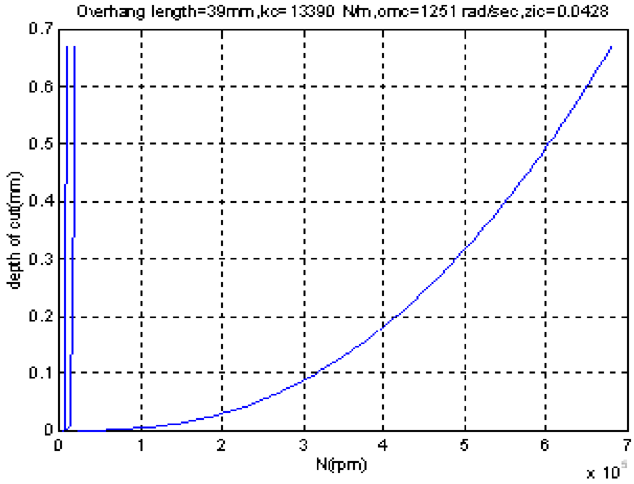
The stability lobe diagrams corresponding to different tool overhangs (different stiffness, tool frequencies and damping ratios) are presented in Figure 4.20 (a)-(c). It is seen that tool overhang has much influence on stability of cutting.



(a)



(b)



(c)

Fig. 3.4 Stability lobe diagrams at different overhang lengths.

In the diagrams, the rightmost lobe (n=0) at higher speeds occupies wide area and dominates the rest. It is observed that the increase in tool overhang first improves the stable depths of cut, then with further increase, again the critical depths reduces. Thus there is an optimum overhang between the extreme cases under consideration.

4. CONCLUSION

In this experimental work, stability analysis in turning process has been presented. An attempt also made to establish the influences of tool overhang on the stability of turning using finite element modeling. Single degree of freedom model of cutting tool was prepared from the first mode dynamics of a three dimensional finite element model of orthogonal cutting tool. Likewise, the work piece dynamics is arrived with finite element beam model. The tool-work interaction forces were expressed in terms of current and previous deformations of tool and work. The stability lobe diagrams with different tool overhang lengths (stiffness) were plotted.

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