Vibration Analysis of OHNS Turning Using FEA

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***Abstract*—Hard material machining is the essential feature for the parts that are involved in the matting areas. While hard turning, so many parameters influence the accuracy of the work piece and the tool life. Cutting tool vibration is one of the remarkable parameter that margins the level of work accuracy and tool life period. The vibration analysis for the turning tool is necessary to predict the proper cutting parameters for the specific operation. The cutting tool model is created by using the Pro- E software and then it is imported in to the finite element analysis. The modal and harmonic analysis are performed in finite element analysis, also that the boundary amplitude of the cutting tool is obtained since the vibration at natural frequency level. It is concluded that the range of the frequency level depends upon the feed rate, depth of cut and cutting force. Selecting proper cutting parameters and provision of the isolation to the cutting tool may reduce the amount of vibration induced in the cutting tool. Vibration analysis helps to select the optimal cutting parameters for the hard turning operation of work materials with 45 HRC-65HRC.**

Index Terms— **Hard Turning, Vibration, Feed, Depth of cut, Cutting Speed, FEA.**

I. INTRODUCTION

Hard turning (HT) is the machining operation to obtain new dimensions on cylindrical parts in a short period of operation with the required parameters. Hard turning process has been performing with hardness of 40-62 HRC ferrous metal components. The surface finish, tool wear and dimensional accuracy are considered as important quality parameters in hard turning operation. It is the accepted machining technique to produce the engineering components with high wear resistance. The ceramics and CBN cutting tools are mostly preferable cutting tools for dry state HT because of its hardness.

The machining quality is determined by several factors in hard turning; however, cutting tool vibration implies an important role on cutting tool life, surface finish of products and heat generation at the contacting surface of cutting tool and work piece [1]. Improper selection of cutting parameters is valuable phenomenon to increase the vibration during hard turning operation. [2].The increasing of feed rate and cutting speed increases the amplitude of vibration, however, increasing depth of cut with the same cutting speed minimize the vibration of multilayer coated carbide insert cutting tool in mild steel turning process with depth of cut at the same cutting speed [3].The AISI 4140 steel hardness and machining parameter of cutting speed influences the vibration and tool wear in dry turning process. The experimental results better agreement with the 3D finite element analysis, its help to predict the good cutting parameters for the machining operation [4].The machining of AISI 4340 (34CrNiMo6) tempered tool steel with the hardness 46- 53 HRC is difficult due to its hardness. By selecting proper cutting parameters for the turning operation, the surface roughness value of the work material and tool wear. The improvement of the surface finish maintains direct proportionality with the cutting speed with the optimal level of other cutting parameters. The tendency of variation of cutting speed influences the surface quality of the work material and wear rate on cutting tool [5].

The cutting tool nose radius mostly reference value for the depth of cut assigning in hard turning operation ,such that spindle speed and cutting speed are the insignificant factors in machining of AISI 1045 steel with SNGN 120408 cutting inserts in hard turning operation [6]. The grinding process on hard materials has been replaced by hard turning operation help to achieve better quality and quantity on production line process. The cutting tool vibration reveals the surface quality and tool life of the components [7]. The machining quality characters are mostly affected by the regenerative chatter in the turning operation. The self-excited vibration between the cutting tool and workpiece causes chatter and minimize the surface finish and increase the tool wear during machining operation [8]. The cutting speed pronominally influences the axial cutting force and depth of cut influences the radial cutting force however, the effect of feed rate on cutting tool vibration is minimum comparing to other machining parameters which generates remarkable vibration in the cutting tool. The ANOVA regression mathematical model produces accuracy results which deviate with the confirmation observation in permissible level [9]. At the lowest level of feed rate and depth cut, the variation of cutting speed influences the vibration magnitude.[10].

The vibration analysis revealed with the mathematical approaches of Short-Time Fourier Transform and Fast Fourier Transform enhanced better results[11].The cutting parameters and cutting tool nose radius are influencing variables in S-20 turning, where as spindle speed and depth of cut influenced the magnitude of transverse vibration of cutting tool. Based on ANOVA analysis, the spindle speed contributes most effect on vibration of machine tool[12]. The application of composite materials unique because of their physical and mechanical properties. The machining of composites is difficult one due to the improper machining parameters used. The squeeze cast LM2+ Al2O3 composite machined by using TNMG 160408 MT insert. By using optimal cutting variables the surface finish of the composite improved considerably [13]. The high amplitude vibration induced in hard turning operation causes the poor surface finish, cutting tool life reduction, and increasing of rejection rate. To overcome these defects, proper cutting parameter utilization in turning process is essential. The optimization techniques assign better results to identify the machining parameters and ANSIS software enhance guidance results on vibration growth during operation. In the pre-posting analyzing process of ANSIS software, the failure mode can be easily predicted and remarkable solutions can be followed [14-15].

The preceding researchers established the less hardness ferrous component quality affecting parameters; however, the hardness above 50 HRC materials is not studied in enough. The effect of turning tool vibration on quality of the OHNS (oil hardened non-shrinkage steel) of hardness 50HRC machined part has been predicted using FEA. The machining parameters are selected from the design data book. The following sequence of procedure has been carried out to obtain the result of the same. FEA model of the turning tool assembly constructed in Pro-E software. The modal analysis to obtain the natural frequency of the turning tool and harmonic analysis are performed by using ANSYS software.

II. WORK MATERIAL, CUTTING TOOL AND CUTTING VARIABLES

The OHNS material cylindrical bar of 130 mm length and 35 mm diameter is used for the hard turning operation. The initial hardness 22 HRC of the work piece was increased to 45-48 HRC through heat treatment process. The different element composition of the work material is given in table 1.

Table1.Chemical Composition of AISI/SAE-01 Steel

Element	Composition %
C	0.75
Si	0.25
Mn	1.7
Cr	0.54
Ni	0.311
Cu	0.12
W	0.426
P	0.04
Ferrous	95.6

The cutting tool inserts are tungsten based MITSUBISHI - CNMG 120408 MJ. VP (MIRACLE) coated carbide as shown in figure.1. The PCLNR 2020 K12 WIDAX right-hand style tool holder with a rake angle of -50°is used. The rigid clamping system followed to mount the inserts on the tool holder

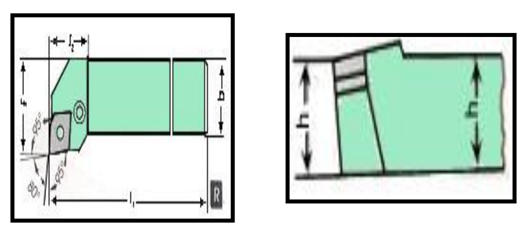


Fig.1. WIDAX Turning Tool Assembly

The two level of machining are taken from the design data book corresponding to the work material and tool material and kind of operation. The details of the assigned cutting variables with its level are given in the Table.2.

Table 2. Cutting Parameters and Cutting Forces

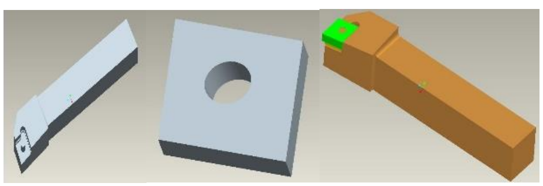
Acadamician Granovsky empirical method is used to calculate cutting forces and energy consumption Table 2 shows the calculated values of cutting force (Fz) and Feed force (Fx) for the corresponding input cutting variables.

V (m/sec)	F (mm/rev)	d (mm)	Fz (N)	Fx (N)
69.82	0.32	1.0	12.70	3.95
69.82	0.32	0.5	6.50	1.98
69.82	0.23	1.0	9.92	3.19
69.82	0.23	0.5	4.955	1.59

IV. FINITE ELEMENT MODELING AND ANALYSING

A. Finite Element Modelling

Pro/ENGINEER is efficient geometric tools create complex designs with a great precision. Figure. 2 shows the pro- E model of the cutting tool with the following basic dimensions.



Shank Insert Cutting Tool Assembly

Fig 2. Pro/E Cutting Tool Model

B. Finite Element Analysis (FEA)

FEA is the simulation analysis system by a mathematical approximation of the real system. The trouble-free interrelated building blocks named elements. The coordinate location in space is called node where degrees of freedom and actions of the physical system exists.ANSYS11.0 analyzing software was used to predict the level of vibration during hard turning process. It is also used to perform the modal analysis and harmonic analysis of the cutting tool.

The analysis is based on the estimated cutting force, mechanical properties of the cutting tool and cutting speed. The preferred mechanical properties of the cutting tool materials are listed in Table 3.

Table 3. Cutting Tool Material Properties

Materials properties	Insert and shim seat	Tool holder
Material	VP coated carbide	AISI 1045
Young's modulus, E (10^3 N/mm^2)	534	207
Poisson's ratio (ν)	0.22	0.3
Density ρ (10^{-9} Kg/mm^3)	11900	7844

C. FEA Meshed Model

The SOLID 70 element is used to construct a FEA model of turning tool. The eight nodes of the element having three degrees of freedom at each node. The tool surface has been dissertated parts as finite elements. By generating finer mesh, the accuracy of the results can be revealed from analysis.

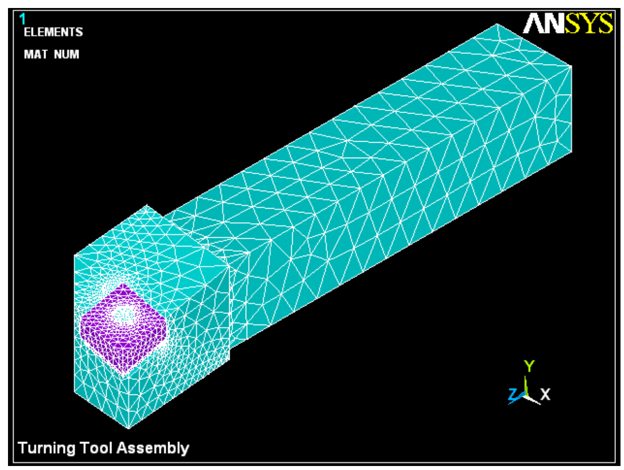


Fig.3. Meshed model of tool geometry

The figure 3 shows the cutting tool with 5763 elements and 24327 nodes. At the insert portion, the mesh is refined to obtain better results in analysis. The following boundary conditions are used for the FEA.

- The insert and tool holder are having perfect contact due to the smooth surface contact and rigid fit.
- The bottom surface area of the tool shank is completely arrested at all degree of freedom.
- The top surface area of the tool is clamped in three positions at equal distance to arrest the X & Y directions at corresponding node.
- The flank area is over-hanged from the tool post. The load is applied at the node near to the insert.

V. RESULT AND DISCUSSION

Simulation results for the modal analysis and harmonic analyzing details are shown below. At the constant feed rate the amplitude of vibration of the cutting tool is obtained. Also, that the harmonic analysis for the each set of parameters is analyzed.

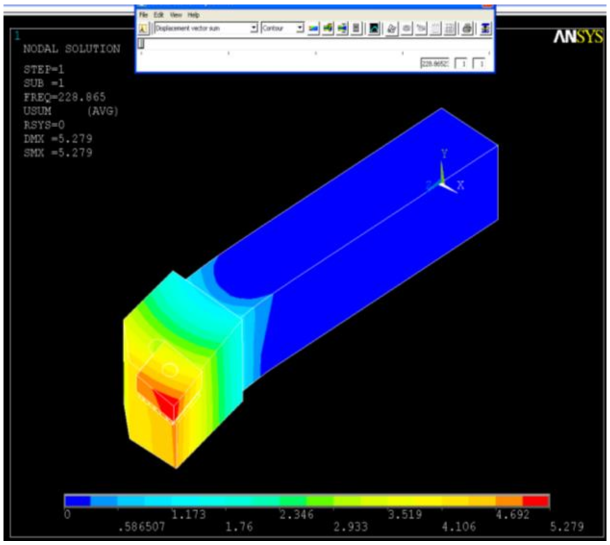


Fig 4a. Modal Analysis: First set parameters

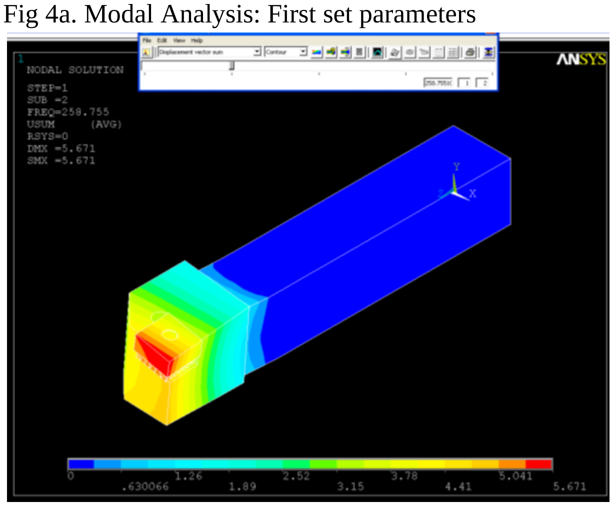


Fig 4b. Modal Analysis: Second set parameters

The modal analysis for the four reading settings was carried out in FEA. For the cutting speed 69.82 m/sec, feed rate 0.32 mm/rev and depth of cut 1 mm, the average frequency of the vibration is 228.865Hz with the displacement of 5.279 mm. The frequency rate imposed for the second setting cutting parameters is 258.755 Hz such that the frequencies are 553.874 HZ and 854.19 Hz for third and fourth setting cutting parameters respectively. The increasing depth of cut will lead the vibration on cutting tool it is clear from the third cutting parameters setting FEA.

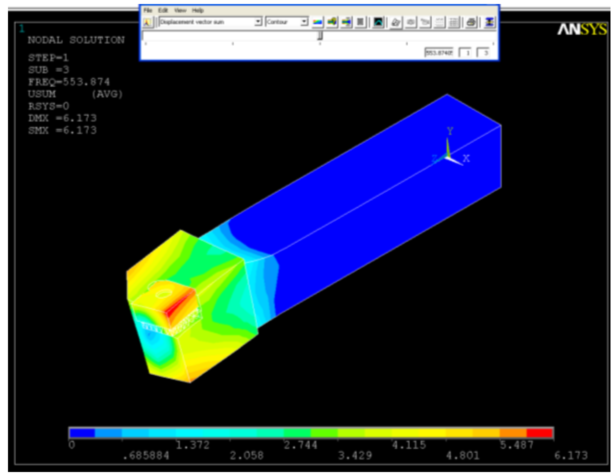


Fig 4c. Modal Analysis: Third set parameters

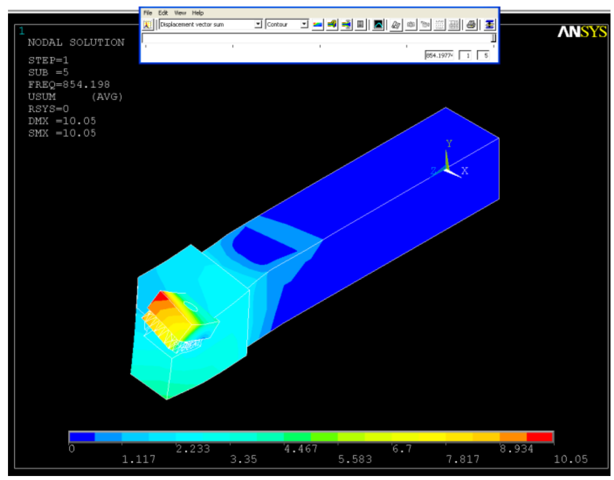


Fig 4d. Modal Analysis: Fourth set parameters

Fig.4 Modal Analysis

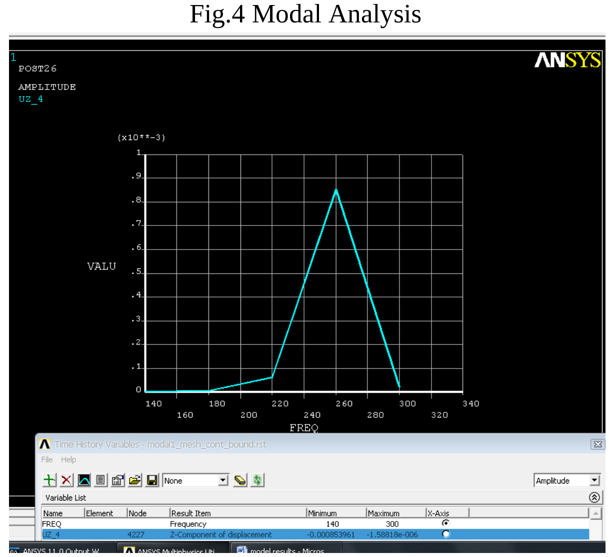


Fig 5a. Harmonic analysis – first set cutting parameters

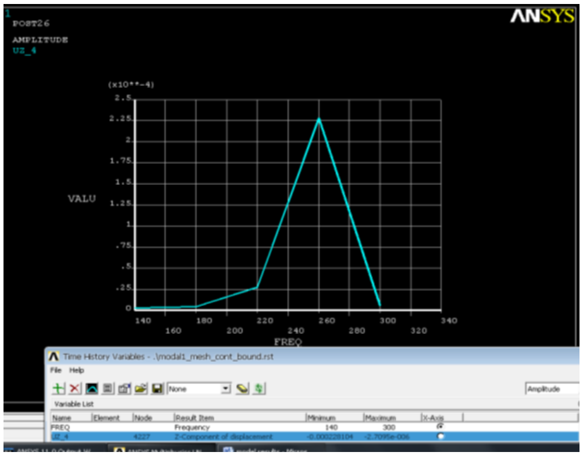


Fig 5b. Harmonic analysis – Second set cutting parameters

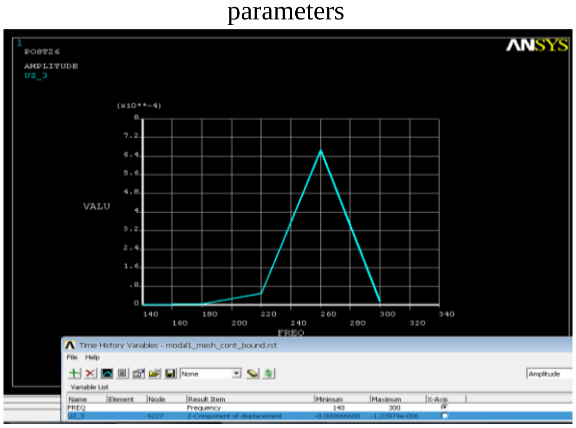


Fig 5c. Harmonic analysis – Third set cutting parameters

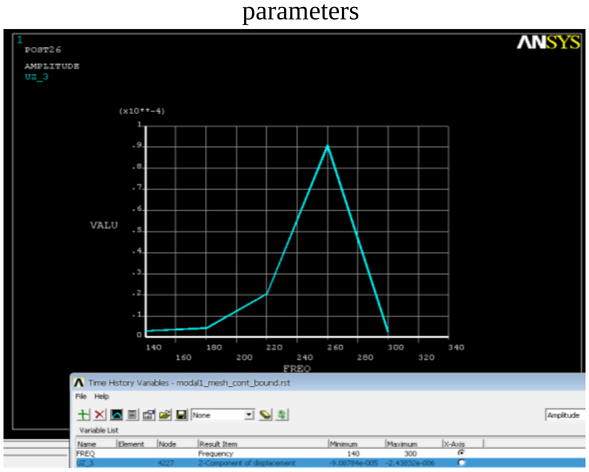


Fig 5d. Harmonic analysis – Fourth set cutting parameters

Fig 5. Harmonic Analysis

The harmonic analysis for the different cutting conditions is given in the figure 5. The depth of cut 0.5 mm and feed rate 0.32 mm/rev implies the higher rate of displacement at 260Hz amplitude of vibration. it is observed that the magnitude of vibration on cutting tool significantly increased with the variation of depth of cut, the moderate depth of cut produces minimal rang of vibration on the cutting tool.

V. CONCLUSION

The parameters for hard machining such as cutting speed, feed rate, and depth of cut for maximum vibration has been found out. The conclusions drawn from this work are summarized as follows:

- The amplitude of the vibration in a cutting tool increased with the increasing in the depth of cut.
- The magnitude of vibration increased with the assigning of both feed rate and depth of cut, however, the increasing of depth of cut increases the value of the vibration frequency level
- FEA results show that the maximum vibration is induced in the insert as well as in the shank.
- Vibration in the tool increases mainly due to increase in cutting speed and depth of cut.
- The cutting vibration during turning operation with the different work materials can be easily predicted in the finite element analysis.
- FEA is an effective analyzing tool to pre-select the optimal machining parameters for the metal cutting operations.

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