Harmonic Analysis of Damped Single Point Cutting Tool For various metal Shim

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Abstract- *With increasing demand of high rate of production have led to develop high speed cutting machine toolwhich ultimately inducing higher vibration in cutting operation.Finishing processes are very important for engineering components. Grinding process is conventionally used for finishing of harder material components but due to set-up complexity and cost involved, hard turning process is often considered along with grinding. Chatter is major obstacle in hard turning and it often leads to excessive vibration. Tool life and machine structures are adversely affected by tool wear produced due to regenerative chatter. For better productivity and safe machining, chatter in machining is major phenomenon to be investigated and objective is to reduce chatter occurrence. Many methods have been suggested by researchers to limit chatter in machining operations. In present work, Single point cutting tool having cutting clamp insert is used with hard turning operation. Damping of cutting tool system is proposed using various shim materials which is to be placed below carbide clamp insert. Various shim materials are proposed with high damping properties. Damping ratio of cutting tool system with various shim material is to be determined using half bandwidth method. Analytical model and stability analysis are proposed using simulation in this work.*

Keywords- chatter, damper tool, vibration model, shim, hard turning

I. INTRODUCTION

During operations, machine tools are subjected to static or dynamic loads. Vibrations are caused absolutely by the load acting during the action of the load (forced vibrations), initiated by a load but persisting after load has ceased to act (free vibrations), through an interaction between the structure and cutting process (Self-excited vibrations). Self-excited vibrations extract energy to start and grow from the interaction between the cutting tool and the workpiece during the machining process.Inferior surface finish, Excess amount ofnoise, Reduction in tool life are the some of the adverse effects produces by chatter. Machining chatter has been studied by scholars over the past decades, since chatter has a significant impact on surface quality and productivity. Researchers have carried out extensive research on offline chatter prediction, online chatter detection, and chatter suppression.

II. HARD TURNINGSYSTEM

Hard turning has evolved as an economical process for machining of hardened parts compared to cylindrical grinding process. The surface roughness, dimensional and geometrical accuracies achieved by hard-turning process are similar to those achieved by grinding process. Cubic boron nitride (CBN) is generally used as cutting tool in hard turning. Carbide tools are also most widely used for hard machining. Bearing bush is used on feed rollers end shafts upon which bearings which are used in super finishing machines in bearing industries. These bearing bushes are manufactured using very hard material of hardness 60 HRC which requires very high surface finish and accuracy.

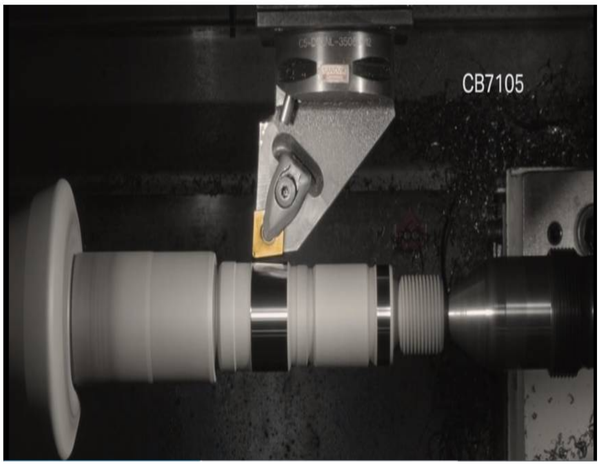

Figure 2.1: Hard turning [19]

2.1 Effect of Speed and Damping on System Stability

The variation of stability as function of speed for different stiffness of cutting tool is clearly shown in the Figure8. The stability plot is based on the approximated values of mass and damping, the plot shows the effect of the variation of stability with the change in speed by keeping the damping ratio and mass of the system constant with different values of stiffness. When stiffness increases, the natural frequency is also increased. If the natural frequency increases then the boundary curve moves right. Moreover, if it decreases on the contrary then the curve moves left.

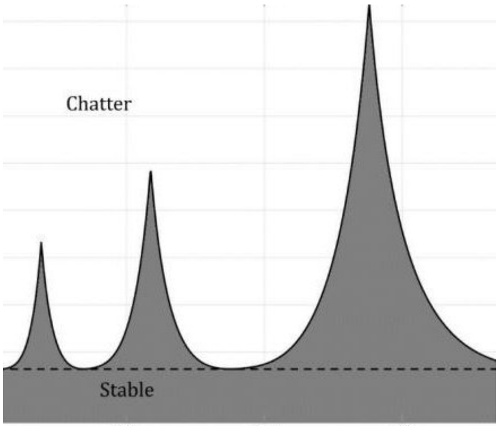

Figure 2.2: Stability lobe behaviour [6]

2.2 Damping Capacity and Materials

Damping capacity is a measure of a material's ability to dissipate elastic strain energy during mechanical vibration or wave propagation. When ranked according to damping capacity, materials may be roughly categorized as either high- or low-damping. Lowdamping materials may be utilized in musical instruments where sustained mechanical vibration and acoustic wave propagation is desired. Conversely, high-damping materials are valuable in suppressing vibration for the control of noise and for the stability of sensitive systems and instruments. For determining damping capacity of materials, various parameters are expressed. The inverse quality factor, Q^{-1}, iswidely used to characterize material damping through:

$$Q^{-1}=(f_2-f_l) / f_r$$

where f_l and f_2 refer to half-power bandwidth frequencies andf_r is the resonant frequency in the spectrum of square amplitude versus frequency for a specimen under forced vibration. The broadness of the resonant peak characterizes the magnitude of material damping. For small damping cases (tan $\phi< 0.1$), all of the aforementioned damping quantities, Ψ, tan ϕ, ϕ, δ and Q^{-1}, are related by:

$\Psi = 2\pi\dot{\eta}$
$= 2\pi\tan\phi$
$= 2\pi Q^{-1}$
$= 2\delta$

Where, δ is logarithmic decrement, ἠ is loss factor, tan ϕ is loss tangent, Q^{-1} is inverse quality factor.

III. 3D MODELLING AND MATERIAL PROPERTIES

3D modelling of shim and insert are done in SolidWorks software. Tool holder is used with carbide cutting insert and various metal shim. Thickness of insert is taken as 4.76 mm and shim thickness 3.18 mm. Tool holder selected is PCLNR 2020 K12 which is having length of 125 mm and insert of rhomboid shape 80^0. Assembly of single point cutting tool IGES fileis to be called in ANSYS APDL 15.0.

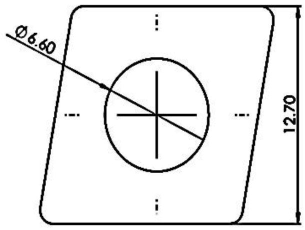

Figure 3.1: Cutting insert model [21]

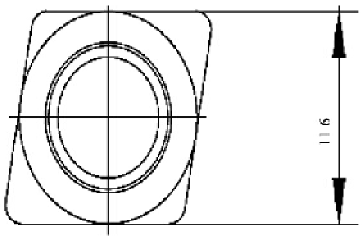

Figure 3.2: Cutting insert model[21]

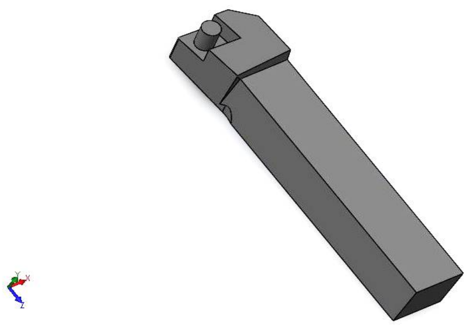

Figure 3.3: Tool holder model[21]

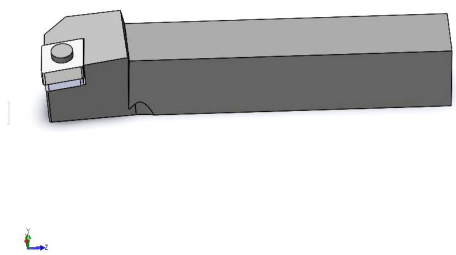

Figure 3.4: Cutting tool assembly[21]

Tool holder is made of tool steel EN31 and various shims are to be chosen as mentioned in table and properties are given which are used in material assignment.

Table 3.1: Material properties

Material	Young Modulus (N/mm^2)	Density (kg/mm^3)	Poisson's Ratio
Tool steel EN31 (Holder)	$215*10^3$	$7.85*10^{-6}$	0.30
Carbide	$534*10^3$	$1.59*10^{-5}$	0.22
Magnesium(AZ91)	$45*10^3$	$1.81*10^{-6}$	0.31

IV. HARMONIC ANALYSIS ANSYS 15.0 APDL

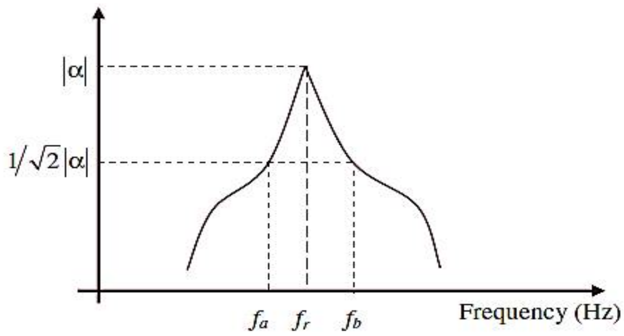

Figure 4.1: Half bandwidth method

Damping ratio is predicted using the half power bandwidth method. The bandwidth is the frequency difference between upper and lower frequencies for which the power is dropped to half of its maximum value. From the Figure 4.2, it is shown as the amplitude peak is 0.0184 mm and the corresponding frequency is 178 Hz.

Peak response f_r = 178 Hz
Half power point = 0.707 × 0.0184
Half power band width (f_b - f_a) = 182-176 Hz
Damping Ratio ξ = 6 /2(178) = 0.01162

From the Figure 4.3, it is shown as the amplitude peak is 0.56 mm and the corresponding frequency is 228 Hz. Using the half bandwidth method, the damping ratio for magnesium shim tool holder is calculated as follows,

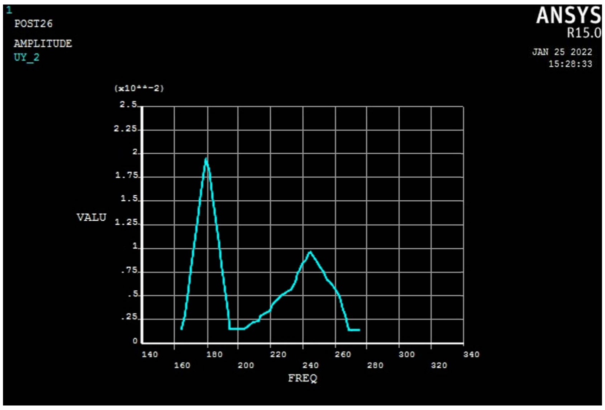

Figure 4.2:Freq. Vs. Amplitude: Carbide shim

Peak response f_r = 228 Hz
Half power point = 0.707 × 0.56
Half power band width (f_b - f_a) = 237-219 Hz
Damping Ratio ξ = 18 /2(228) = 0.0394

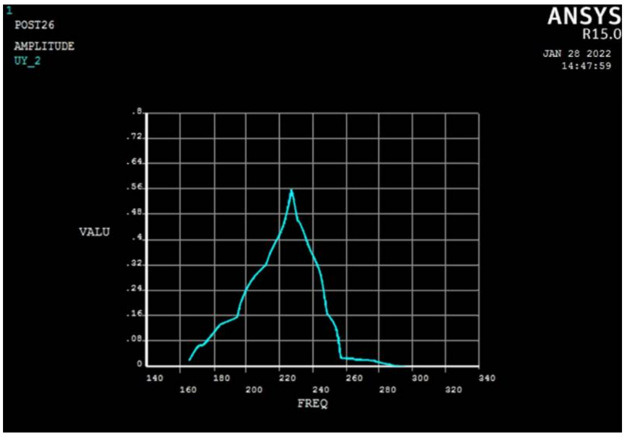

Figure 4.3:Freq. Vs. Amplitude: Magnesium shim

V. CONCLUSION

Damped single point cutting tool is designed with shim material. Various shim material incorporated tool is simulated in ANSYS harmonic analysis. ANSYS 15.0 APDL module is used for harmonic analysis. From the frequency amplitude graph, half power points are identified and damping ratio is predicted by half power bandwidth method. Damping ratio is obtained as0.01162for normally used carbide shim. Improved damping ratio for magnesiummaterial shim is 0.0394. It shows improved damping characteristics of tool. DOE is to be done to validate results with experimental tests.

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