# Impact of Chatter Amplitude on Surface Roughness of Carbide Insert Tool Using Laminates among Tool and Tool Holder

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***Abstract-***Chatter seems throughout the metallic reducing method as a result of resonance resulting from the interaction of the prominent natural frequencies of the gadget with the frequency of chip serration. Chatter leaves a lousy floor finish on the part and negatively affects dimensional tolerances, decreased productiveness, immoderate device wear and damaged device-device components. This paper provides an progressive approach to chatter suppression throughout turning manner by way of offering extremely-thin steel rubber laminates between carbide insert device and tool holder via growing the stiffness of the device. The dynamic behavior of the workpiece and device with laminates are simulated the usage of ANSYS and investigated experimentally. it's miles obvious that with the introduction of rubber brass laminates among tool and device holder the amplitude of vibration of tool decreased and thereby floor finish of workpiece advanced.

***Keyword:*** *-Vibration; Laminates; Amplitude; Surface roughness; Carbide insert tool; Rubber brass laminates*

**Introduction**

In today's competitive industry, it is imperative to achieve a high quality product. Surface finish is one of the most important measures for determining the quality of products in machining. When it comes to the machining of automotive parts, surface roughness and integrity become prime importance because it defines the aesthetics, tribological properties, corrosion resistance, level of fatigue life improvement, and fit of critical mating surfaces. As a result, the desired surface finish usually specified for a particular application, and specific machining parameters selected in order to achieve that desired level of finish. Senthil kumar et al.[1] demonstrated improvement of damping capability of boring bar using particle damping (lead and copper particles of various sizes). Ummu Atiqah et al.[2] performed an experiment under the application of magnetic field from permanent magnet located side direction of the tool holder and monitoring the vibration signals using a vibration data acquisition system during turning operation. It is apparent that a reduction of chatter when a magnetic field applied and result in improving surface finish. Kohle et al.[3] observed that in CNC lathe cutting tool vibrations are controlled using passive damping support with tool holder.

Dayanand Wadhwankar et al.[4] used passive damper of different orientation reduces vibration level in Boring tool & tool holder &work piece to be enlarging hole improving surface finish. Yasir et al.[5] performed end milling operation using AISI 316L stainless steel with tungsten carbide tool. The Response Surface Methodolgy (RSM) was used for optimization and investigated effect of cutting parameters on the surface topography. Their study revealed that feed rate is most affecting parameters while milling AISI 316L steel. Ufuk Yigit[6] analyzed the effect of piezoelectric shunt damping on chatter vibration in a boring operation. Electrical impedance of the circuit consisting of piezoceramic transducer and passive shunt is turned to the desired natural frequency of the cutting tool in order to maximize damping. The experiment showed that application of piezoelectric shunt damping results in a significant increase in the absolute stability limit in boring operations. Thanh Trung do[7] developed a damping system with an object mass and two springs and it assembled the tool holder using two damping design, the results reveal that the damping system reduced tool holder vibration and improving the surface quality of the parts being machined in the turning process.

Girinath[8] developed the magnetorheological damper for suppressing the tool vibration and promoting better surface finish. Sachin Chauhan et al.[9] researches have used Taguchi and RSM approaches to design and for the optimisation of the parameters. Sobron Yamin Lubis et al.[10] research was carried out using the experimental method of AISI 4340 steel metal workpiece turning using cutting tool coated and effect of cutting parameters using carbide tools on the surface roughness of metal steel workpieces determined. Aditya et al.[11] achieved an increased stability by using viscoelastic material dampers. From the investigation it was observed that the overall vibration decreases and improvement in surface finish. Chen and Liu[12] applied an actuator with four electromagnetic units which was responsible for delivering the active damping for the tool in a turning process. The experimental result shows that the tool vibration was successfully damped by the actuator. Paul et al.[13] used a mass impact damper and installed it on the bottom of the tool holder, aiming to reduce the tool vibration. Yip[14] experimented the titanium alloys were rotated in between of two permanents and suffered from an eddy current damping effect. The experimental results showed that tool marks caused by the small tool movements in the tool tip vibration were highly reduced, resulting in improvements of surface roughness and surface profile.

The objective of this work is to suppress the chatter vibration by bringing better stability during the cutting process by providing ultra-thin metal rubber laminates and increasing the stiffness of the tool. The dynamic behaviour of the workpiece cemented carbide insert tool with laminates is simulated using ANSYS and investigated the vibration of the tool and surface roughness of the workpiece experimentally. The surface finish of the workpiece improved using laminates between tool and tool holder.

## Finite element analysis of tools

Solid 45 elements available in ANSYS are used in modelling the cemented carbide insert tool. It is an eight noded element with three degrees-of-freedom per node. It is preferred over other elements as it has good plasticity, creep, swelling, stress stiffening, large deflection and large strain capabilities. Solid layered 46 elements are chosen for composite tool holder. This is an eight-nodded element with three degrees of freedom at each node.

Solid 3D Tetrahedral 92 element chosen for cemented carbide insert tool. Free meshing capability of this element allows the meshing of highly intricate shapes like that of the tool. The modelled cemented carbide insert tool and tool with brass rubber laminates are referred as R_CBI and R_CBRL henceforth.

FEA is essential as the computation time and cost relates to the number of elements chosen. Several elements to be chosen for idealization is related to the accuracy desired, size of elements and the number of degree of freedom involved. Although an increase in the number of elements generally means more accurate results, there will be a certain number of elements beyond which the accuracy cannot be improved by any significant amount, since the use of large number of elements involves large number of degrees of freedom. It may not be possible to store the resulting matrices in the available computer memory.

For convenience, only one parameter (deflection) in the Z direction of Tool elected for study of convergence. The results plotted in Figure 1, with varying number of elements against deflection in the Z direction.

It inferred from the graph that when the number of elements is more significant than 7600, there is no further improvement in deflection. So, a mesh density corresponding to this chosen for analysis. The cemented carbide tool properties of Young's Modulus $625X10^6$ psi, Density 14950 $Kg/m^3$ & Poisson's Ratio 0.22**.** The portion of the tool clamped at the tool post-fixed and the remaining portion is let free of any boundary conditions.

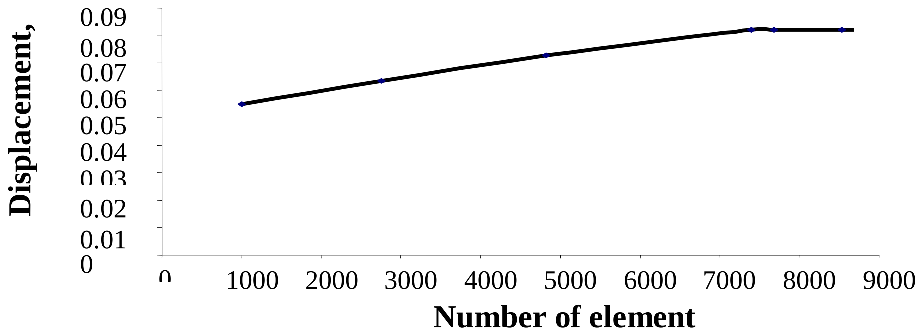


**Figure 1. Element convergence of solid tool**

The workpiece turned in a lathe at a feed rate of 0.3mm/rev and depth of cut is 0.1 mm. At equilibrium condition load acting on the tool is Radial load along X-axis = 0.45393 N, Axial load along Y-axis = 6.12528 N, Tangential load along Z-axis = -6.1137N. These values used in analysis and solid models of R_CBI and R_CBRL tool models.

### Modal analysis of tool

A modal analysis determines the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component. It can also serve as a starting point for another analysis like harmonic analysis or a spectrum analysis. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. Modal analysis is done and frequency values for five modes of vibration obtained. The mode shapes corresponding to the natural frequencies are animated.

### Harmonic analysis

Any sustained cyclic load will produce a sustained cyclic response (a harmonic response) in a structural system. Harmonic response analysis gives the ability to predict the sustained dynamic behaviour of the structure, thus enabling to verify the design successfully and to overcome the resonance and other harmful effects of forced vibrations. From the post-processing "Frequency Response" value of the tool is obtained. The natural frequencies at which the tool will get vibration and highest peaks of the natural frequency of the tool with corresponding maximum amplitude of vibration shown in Table 1.

**Table 1. Natural frequency of tool with maximum amplitude of vibration**

| **Sl.no.** | **Natural Frequency** | | **Harmonic analysis** | | |
|---|---|---|---|---|---|
| | Cemented carbide insert tool, Hz | Cemented carbide insert tool with ultra-thin brass rubber laminates, Hz | Frequency range, Hz | Highest peak of the natural frequency, Hz | Maximum amplitude of vibration, mm |
| 1 | 4816 | 4808 | 0-10000 (Solid tool)<br>0-15000 (tool with laminates) | 8000 (Solid tool)<br>8500 (tool with laminates) | 2.8 (Solid tool)<br>1.25 (tool with laminates) |
| 2 | 5416 | 5417 | | | |
| 3 | 6157 | 6159 | | | |
| 4 | 7641 | 7638 | | | |
| 5 | 7779 | 7776 | | | |

**Transient analysis**

Transient vibration caused by shock (impulsive force) loading of the machine tool, when the tool strikes a hard grain in the workpiece, suddenly. In such cases, a relatively large

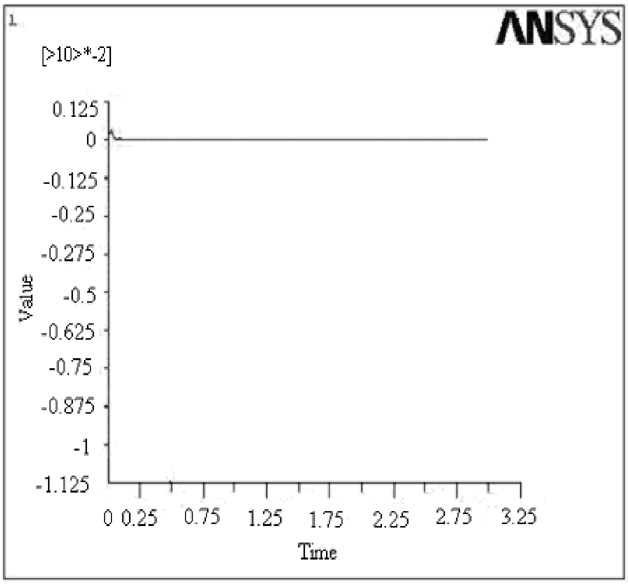


**Figure. 2 Acceleration amplitude of cemented carbide insert tool for 3 sec**

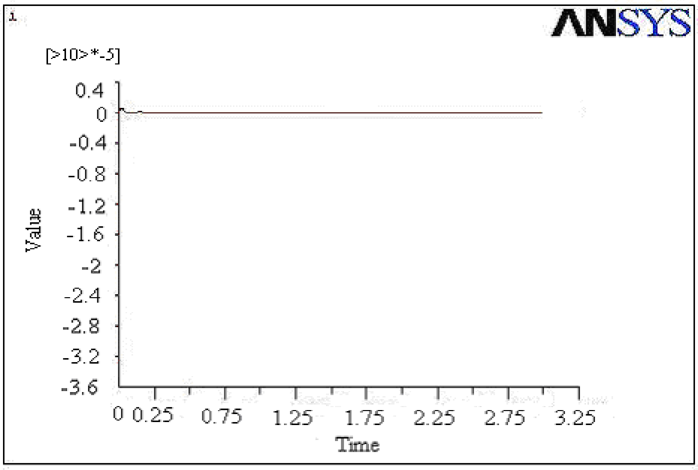


**Figure. 3 Acceleration amplitude of cemented carbide insert tool with ultra-thin brass rubber laminates for 3 sec**

force acts for a relatively short time on the elastic structure of the machine tool. The acceleration amplitude-time response of tools has shown in Figure 2 & 3. As a consequence, it starts vibrating. On account of the damping invariably present in the system, these vibrations, however, decay fairly rapidly with time.

**Vibration analysis of carbide insert tool with and without laminates**

**Design of Experiments**

This analysis focused on investigating the vibration of the tool insert and surface roughness of the workpiece by using the brass laminates between the tool holder and insert. The Design of Experiments (DOE) technique has analysed for planning total number of experiments. In this study, two-level factorial design for three factors

(Montgomery 2003) has adopted which consists of eight treatment combinations ($2^3$) like cutting speed, feed rate, and depth of cut.

The "1" and "0" notations are used to represent the low and high levels of each factor level. There are seven degrees of freedom between the eight treatment combinations in the $2^3$ factorial designs. Three degrees of freedom are associated with the main effects of speed, feed rate and depth of cut, four degrees of freedom are associated with interactions, one with speed and feed rate, speed and depth of cut, feed and depth of cut and another with speed, feed and depth of cut.

**Experimental procedure**

The workpiece has been held in a three-jaw chuck of a CNC lathe, and a non-contact sensor (vibration pickup) has fitted to the magnetic base stand. The sensor has been placed so that it is 2 mm away from the tool during the course of the test; the sensor output has been connected to the vibration meter to measure the amplitude of vibration of the tool. Figure 4 illustrates the experimental set-up with a carbide tool and laminate used to perform the experiments. The cutting tests are performed with two levels cutting and tool parameters and these are specified in Table 2. The experiments have conducted for solid tool and amplitude of vibrations also measured from the vibration meter. The above procedure has been repeated for machining with laminate in the tool. The laminate (brass metal with nitrile rubber) consists of n =7 layer of nitrile rubber with thickness of 0.20 mm each and n+1 = 8 layers of metal with thickness of each 0.08 mm each with a length of 80 mm. The effect of various parameters on acceleration response amplitude of solid tool and tool with laminates is described in Table 3.

**Table 2. Experimental conditions for turning carbide tool with mild steel workpiece**

| | |
|---|---|
| Machine Tool | PILATUS 20T CNC |
| Driving motor | 3 H.p 400/440v, 3 ph, 50 cy A.C |
| Tool Insert type | CNMG 1204 08.49 tungsten carbide,<br>Rhombic shape insert, nose angle 80· |
| Workpiece size | Length: 500 mm and diameter: 25mm |
| Work material | Mild steel (IS-226, (475 BHN) |
| Cutting Condition | Cutting speed : 90 & 120 m/min<br>Feed rate : 0.10 & 0.15 mm/rev<br>Depth of cut : 0.25 & 0.50 mm |
| Cutting condition | Dry |


(a) Machining setup

(b) EN2-BS970/Mild steel workpieces

Figure 4. Experimental set up for measuring vibration amplitude of tool

**Table 3. Amplitude of vibration of tool with laminates**

| Test no | Coded levels | | | Factor levels | | | Amplitude of vibration (microns) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Distance from a free end of workpiece in mm | | | | | |
| | | | | | | | 40 | 70 | 100 | 40 | 70 | 100 |
| | Speed | Feed rate | Depth of cut | Speed (m/min) | Feed rate (mm/rev) | Depth of cut (mm) | Solid tool | | | Tool with laminates | | |
| 1 | 0 | 0 | 0 | 90 | 0.1 | 0.25 | 2.4 | 2.2 | 3.1 | 1.4 | 1.7 | 2.6 |
| 2 | 1 | 0 | 0 | 120 | 0.1 | 0.25 | 2.7 | 2.9 | 3.4 | 2.1 | 2.4 | 2.8 |
| 3 | 0 | 1 | 0 | 90 | 0.15 | 0.25 | 3.4 | 3.7 | 3.9 | 2.9 | 3.1 | 3.6 |
| 4 | 1 | 1 | 0 | 120 | 0.15 | 0.25 | 3.9 | 4.4 | 4.7 | 3.1 | 3.4 | 3.9 |
| 5 | 0 | 0 | 1 | 90 | 0.1 | 0.5 | 3.3 | 3.7 | 4.2 | 2.9 | 3.1 | 3.5 |
| 6 | 1 | 0 | 1 | 120 | 0.1 | 0.5 | 3.5 | 3.9 | 4.6 | 3.2 | 3.6 | 4.2 |
| 7 | 0 | 1 | 1 | 90 | 0.15 | 0.5 | 3.2 | 3.5 | 4.7 | 2.8 | 2.4 | 2.9 |
| 8 | 1 | 1 | 1 | 120 | 0.15 | 0.5 | 4.1 | 4.5 | 4.8 | 3.3 | 3.8 | 4.3 |

It observed from Table 3 that amplitude of vibration had reduced in machining the component with rubber brass laminates. The amplitude of vibration reduced more at turning minimum distance from the free end of the workpiece for rubber layered brass laminates.

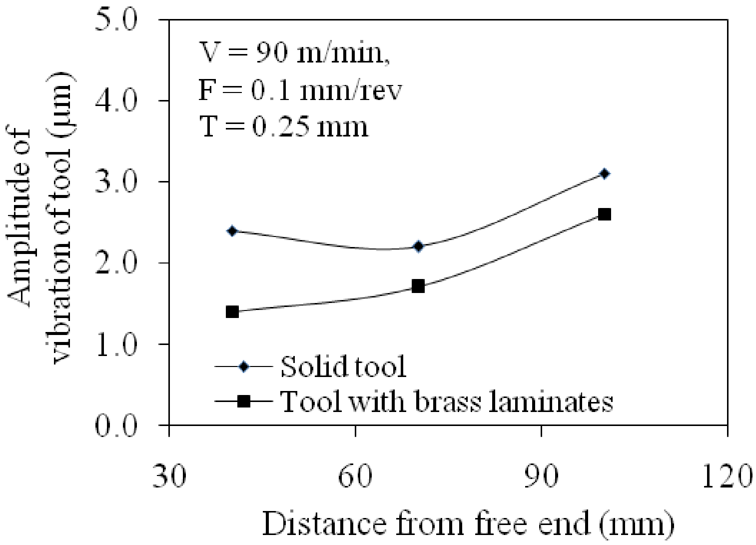


**Figure 5**

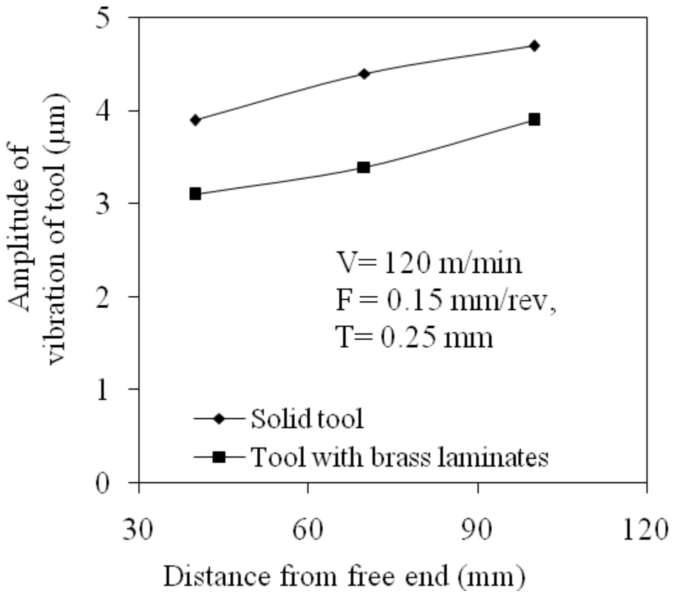


**Figure 6**

**Figure 5 & 6. Difference in amplitude of vibration of solid tool and tool with laminates**

From Figure 5 & 6, it is observed that the amplitude of vibration reduced more at turning minimum distance from the free end of the workpiece for rubber layered brass laminates.

**Surface roughness measurement**

Vibrations produced by cyclic variation in the dynamic components of the cutting forces. Usually these vibrational motions start as small amplitude vibration that is responsible

**Table 4 Surface roughness of the workpiece turning with a carbide tool**

| Test | V | F | T | Solid tool | | Laminates | | % decrease in Ra using laminates |
|---|---|---|---|---|---|---|---|---|
| | | | | Amplitudes(µm) | Ra (µm) | Amplitudes (µm) | Ra (µm) | |
| 1 | 90 | 0.10 | 0.25 | 3.1 | 5.37 | 2.6 | 5.01 | 36 |
| 2 | 120 | 0.10 | 0.25 | 3.4 | 5.84 | 2.8 | 5.59 | 25 |
| 3 | 90 | 0.15 | 0.25 | 3.9 | 7.04 | 2.3 | 6.91 | 13 |
| 4 | 120 | 0.15 | 0.25 | 4.7 | 5.84 | 2.2 | 5.52 | 32 |
| 5 | 90 | 0.10 | 0.50 | 4.2 | 3.21 | 2.1 | 3.10 | 11 |
| 6 | 120 | 0.10 | 0.50 | 4.6 | 6.57 | 2.4 | 6.21 | 36 |
| 7 | 90 | 0.15 | 0.50 | 4.7 | 5.60 | 2.3 | 5.41 | 19 |
| 8 | 120 | 0.15 | 0.50 | 4.8 | 6.89 | 2.9 | 6.58 | 31 |

for the serrations on the finished surface and chip thickness irregularities. Under some conditions, the cutting process may be unstable, and the small amplitude vibration can progress to the significant amplitude motion and as termed ‘chatter’. Mechanical vibrations generally result from periodic wave motions. The nature of vibration signal arising from the metal cutting process like facets of free, forced, periodic and random types of vibration. The surface roughness was evaluated with Surftest SJ-400, while measuring instrument and the measurements are repeated three times along the shaft axis for each sample and each measurement was about 120º apart and their averages were presented in Table 4. It is observed that the surface roughness values decreases upto 36% due to installation of laminates between tool and tool holder.

**Effect of tool overhang length on acceleration amplitude**

It is known that, the long overhang increases vibration. Increasing the vibration of cutting tool through increasing the tool overhang will cause the increase in irregularity of surface texture

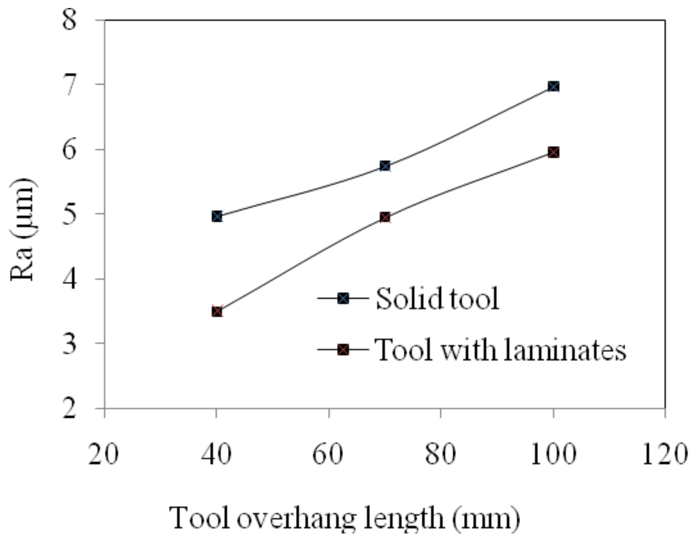


**Figure 7. Effect of tool overhang length on acceleration amplitude with and without laminates**

of workpiece and decrease tool life. The surface roughness of workpiece is proportional to cutting tool acceleration. The effect of selected 40, 70 and 100 mm overhangs length on the acceleration amplitude with and without laminates is presented in Figure 7. It is observed that acceleration amplitude of the tool is directly proportional to the tool overhang length. The surface roughness value decreased for the installation of laminates between tool and tool holder for the same tool over hang length.

**Conclusions**

The following conclusions can be drawn, primarily based at the experimental and results supplied in this paper:

1. In this experimental have a look at, an modern method to chatter suppression in the course of the turning procedure via presenting ultra-thin metal rubber laminates between carbide insert device and device holder has performed. further the dynamic behaviour of the workpiece and tool with laminates are simulated the use of ANSYS and investigated.

2. An vibration control device for the duration of turning is advanced and examined for controlling system device vibration, ensuing in extended productiveness and improved machining accuracy.

3. A 3 issue stage factorial layout matrix become hired for fast statistics collection and choice making because the variety of observations had to make a choice minimized.

4. The amplitude of vibration of tool has been decreased the use of thin rubber layered steel laminates among tool holder and insert.

5. The proposed rubber layered laminates is able to drastically growing the nice of the machined floor. The floor roughness fee reduced upto 36% because of installation of laminates among tool and tool holder.

6. From the experiments completed at the machining parameters, we observed that the same overhang period of the device, installation of laminates among device and tool holder, the floor roughness values reduced substantially. consequently it is concluded that installation of laminates offers suitable results as a vibration damper.

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