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Vibration Analysis of Single Point Cutting Tool on Lathe Machine by Using FFT Analyzer

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Abstract: The current research focuses on investigating various adjustable factors that impact the outcomes, such as the magnitude of vibrations. The ability to predict vibrations between the tool and workpiece is crucial for machine tool users to select optimal cutting parameters, such as depth of cut and spindle rotation, in order to minimize vibrations. Machining is a complex process where several parameters can negatively affect the desired outcome. Among them, cutting tool vibrations play a significant role in influencing dimensional precision of machined components and the lifespan of cutting tools. Cutting tool vibrations primarily occur due to cutting parameters such as cutting speed, depth of cut, and tool feed rate. In this study, cutting tool vibrations are managed in a lathe machine by utilizing a tool holder supported with and without a damping pad. The vibration signals of the cutting tool are controlled and analyzed using FFT (Fast Fourier Transform) analysis. To predict and validate the results, the Taguchi method, experimental studies, and data analysis are conducted to confirm the effectiveness of the proposed damping system. Additionally, a regression analysis is employed to develop the most suitable equation for predicting the expected response value based on given predictor values.

Index Terms –cutting tool, Four Channel B & K's FFT Analyzer & cutting speed, Piezoelectric Sensor, tool feed rate, FFT Analyzer.

I. INTRODUCTION

Metal cutting, also known as machining, is a long-established process used in the manufacturing industry to shape components. In order to remain competitive, manufacturing companies must machine components with the necessary quality while minimizing costs, making tool life a crucial concern for both engineers and researchers. The primary challenge faced by modern machining industries is to achieve high-quality results, including dimensional accuracy of the workpiece, surface finish, increased production rates, reduced tool wear, cost-effectiveness, and improved product performance with minimal environmental impact. Tool wear negatively affects cutting tools by weakening them, increasing cutting forces, and causing inconsistencies in material removal. Machine and machine tools are prone to vibrations, which can be caused by various factors such as material inconsistencies in the workpiece, variations in chip cross-section, disturbances in workpiece or tool drives, dynamic loads resulting from acceleration or deceleration of heavy moving components, vibrations transmitted from the environment, and self-excited vibrations generated by the cutting process or friction (referred to as machine tool chatter). The acceptable level of relative vibration between the tool and workpiece is determined by the required surface finish, machining accuracy, and the detrimental effects of vibration on tool life.

II LITERATURE REVIE

The various works are carried out in static analysis, Modal analysis of Structural machine. Among which few are categorized and discussed below.

Rogério Fernandes Brito, Solidônio Rodrigues de Carvalho, Sandro Metrevelle Marcondes de Lima e Silva, studies the heat influence in cutting tools considering the variation of the coating thickness and the heat flux. K10 and diamond tools substrate with TiN and Al2O3 coatings were used. The numerical methodology utilizes the ANSYS CFX software. Boundary conditions and constant thermo physical properties of the solids involved in the numerical analysis are known. To validate the proposed methodology an experiment is used. **[1]**

L.B.Abhang and M. Hameedullah developed first and second order mathematical models in terms of machining parameters by using the response surface methodology on the basis of the experimental results. The experiment was turning EN-31 steel alloy with tungsten carbide inserts using a tool-work thermocouple technique. The results are analysed statistically and graphically. The metal cutting parameters considered are cutting speed, feed rate, depth of cut and tool nose radius.**[2]**

Yash R. Bhoyar, P. D. Kamble conducted a study on the modeling of the turning process specifically for EN-24 steel. The effects of cutting speed, feed rate, and the type of alloy steel on temperature behavior were investigated using the Finite Element Analysis Software Deform 3D. The workpiece was modeled as an elastic-plastic material to account for thermal, elastic, and plastic effects. A linear model with varying lengths was employed to represent the workpiece under different conditions. To measure the temperature, an Optical Infrared Pyrometer was utilized. This thermal device detects the temperature of an object by analyzing the emitted, reflected, and transmitted energy using optical sensors and detectors, providing temperature readings on a display panel.**[3]**

Maheshwari N Patil, Shreepad Sarange presented a methodology in order to determine tool forces and temperatures for use in finite element simulations of metal cutting processes. From the experimental set up, it is clearly observed that as depth of cut increases, the temperature generated in the tool at the tool tip also increases. It is also observed that, as the depth of cut increases, tool forces also increase. It is main reason of tool failure. It is also observed that tool start vibrating at the depth of cut 2.5 mm. At this condition more heat is dissipated at the tool, due to which tool blunt. Experimental set up is made for force measurement during cutting using dynamometer and analyses the effect on the tool.**[4]**

S. H. Rathod, Mohd. Razik conducted Three analyses were conducted using High-Speed Steel and Carbide Tip Tool at different cutting speeds to compare the experimental results. The study found that the primary factors contributing to increased cutting temperature are cutting speed, feed rate, and depth of cut. Temperature at the tool-tip interface was measured using a Fluke 62 max IR thermometer. The single point cutting tool was solid modeled using CAD Modeller Pro/E, and FEA was performed using ANSYS Workbench 14.5. Various parameters were varied to assess their impact on temperature, and the results were compared with both the experimental and FEA results. The comparison revealed a nearly 4% variation between the results. **[5]**

III.METHODOLOGY

The controllable parameters in cutting operations, such as cutting speed, depth of cut, and feed rate, are crucial considerations when dealing with the vibrations generated during machining. This study aims to establish a relationship between surface roughness and the vibration level of the machine tool. Vibration amplitude in the machine tool can be measured using displacement, velocity, or acceleration. To achieve this, an accelerometer can be positioned near or at the tip of the cutting tool to capture extensive information regarding vibration levels. If the collected signals are in phase and have the same amplitude, it indicates rigid body motion with no relative motion occurring between the cutting tool and workpiece. Therefore, as an initial approximation, this condition is necessary to address the issue in the machine tool. On the other hand, significant differences in vibration phase and amplitude imply larger errors in the cutting operation. For this study, the machining operation of straight turning is chosen. In straight turning, a single-point cutting tool removes material in the form of chips from the outer surface of a rotating cylindrical bar.

Fig. No.1 Methodology Flow Chart

IV OBJECTIVE AND PROBLEM DEFINITION

- To measure the vibrations of HSS single point cutting tool.
- To measure the vibrations of Carbide tipped single point cutting tool.
- To find the better tool with cutting parameters for maintaining good surface finish. Vibration Analysis of Single Point Cutting Tool on Lathe Machine by Using FFT Analyzer.
- The vibrations produced by the cutting tool have a direct impact on the surface finish quality of the machined component.
- Excessive vibrations beyond acceptable limits can lead to the development of chattering. The magnitude of cutting tool vibrations is influenced by the cutting speed and depth of cut. In conclusion, it can be stated that controlling the vibrations of the cutting tool is crucial to achieve the desired surface finish quality.
- By optimizing the cutting speed and depth of cut, the detrimental effects of vibrations can be minimized, leading to improved machining results.

V.DETAILS OF EXPERIMENTSETUP

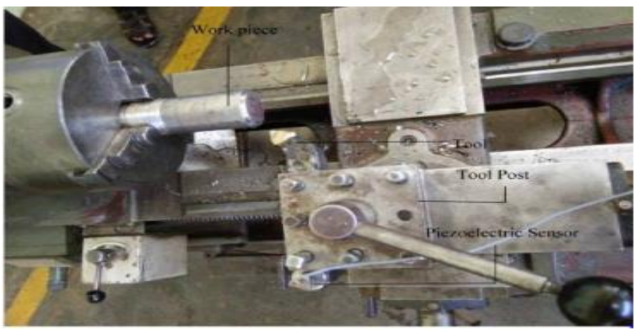

Fig.No.2. Experimental Setup Fig.No.3 Piezoelectric Sensor on the tool post on Lathe

Table No. 3. Process Parameters

Process Parameters	Levels I	II	III
Cutting Speed (rpm)	680	395	225
Feed(mm/rev)	0.046	0.046	0.046
Depth Of Cut(mm)	0.5	1	1.5

The above table shows with respect to the cutting speed we taken the Fees (mm/rev) and Depth of Cut(mm) at the 3 levels.

VI.EXPERIMENTAL ANALYSIS

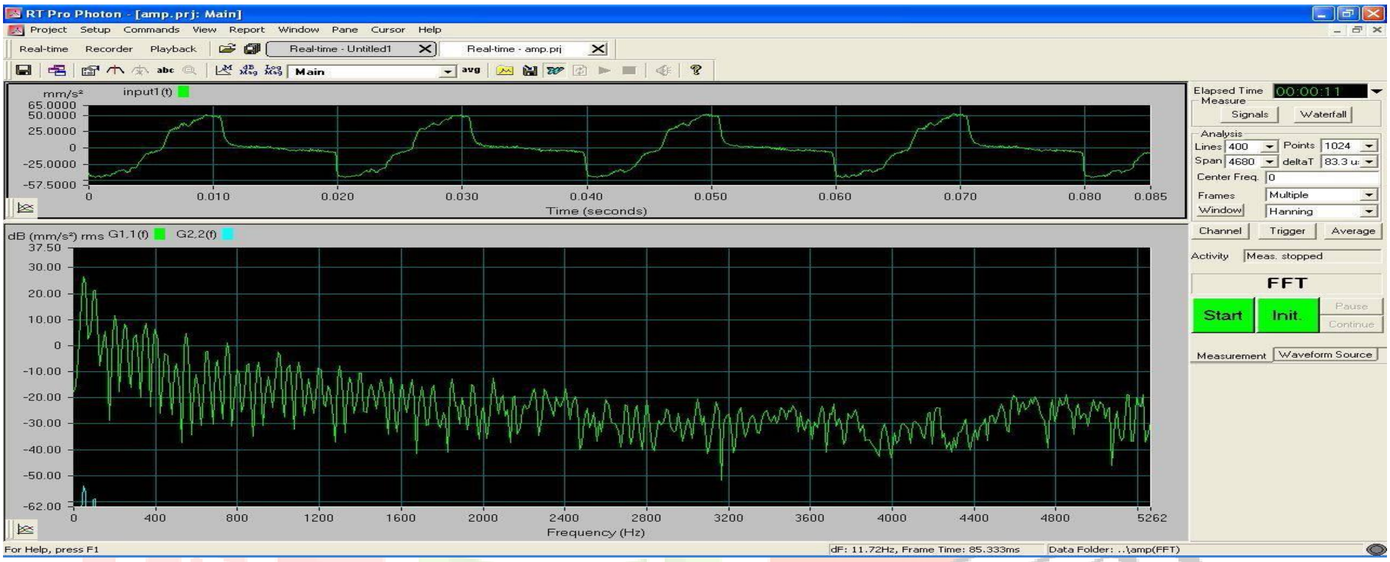

Fig. No. 4. Frequency Vs Amplitude graph on FFT Analyzer.

For experimental analysis we change 3 depths of cut for single spindle speed of lathe machine. We selected minimum auto feed configuration for longitudinal propagation of 0.046 (mm/rev). Selected Speeds are of high-level speed of lathe machine which got by changing belt position on stepped cone pulley drive.

Project File Name: Carbide tip single point cutting tool

Speed = 225 rpm

Depth of cut = 0.5mm

VII.RESULT AND DISCUSSION

When choosing cutting tools for specific manufacturing processes, it is crucial to consider various performance parameters that can be assessed based on material properties. Among these parameters, high-heat tolerance stands out as a critical factor when selecting cutting tools, particularly due to the issue of tool overheating during production. It is widely recognized that carbide cutting tools exhibit superior thermal resistance compared to HSS cutting tools. Steel tools are prone to deformation under extreme temperatures, whereas carbide tools, with their carbon-tungsten or carbon-titanium composition, possess the necessary strength to withstand high-temperature applications.In terms of cutting performance, carbide tools are known for delivering cleaner cuts and finishes compared to HSS tools. This is primarily due to steel's tendency to wear more rapidly than carbide, which results in less grain damage and reduced kickback incidents with carbide tools. Additionally, carbide tools retain their sharpness for longer periods, reducing the need for frequent sharpening. They are particularly suitable for high-speed cutting applications that alleviate strain on the machinery. However, it is worth noting that when using carbide tools, surface roughness tends to be higher compared to HSS tools.

Table. No. 4. Comparison between Carbide tip tool and HSS tool

Speed (rpm)	Depth Of Cut(mm)	Max. Amplitude(mm/sec²) For Carbide tool	Max. Amplitude(mm/sec²) For HSS tool
225	0.5	188.4	53.75
	1	190.4	57.5
	1.5	191.5	62.5
395	0.5	190	53.5
	1	186	57.5
	1.5	184	66.25
680	0.5	187.5	50
	1	195.83	50.662
	1.5	200.10	58.75

While carbide tools offer greater tool life, it is important to note that HSS tools are more resilient and less brittle. HSS tools are not Fig. No. 5. Max Amplitude of tool vs Depth of Cut. designed for extended durability like carbide tools, so wear resistance is not a critical factor.

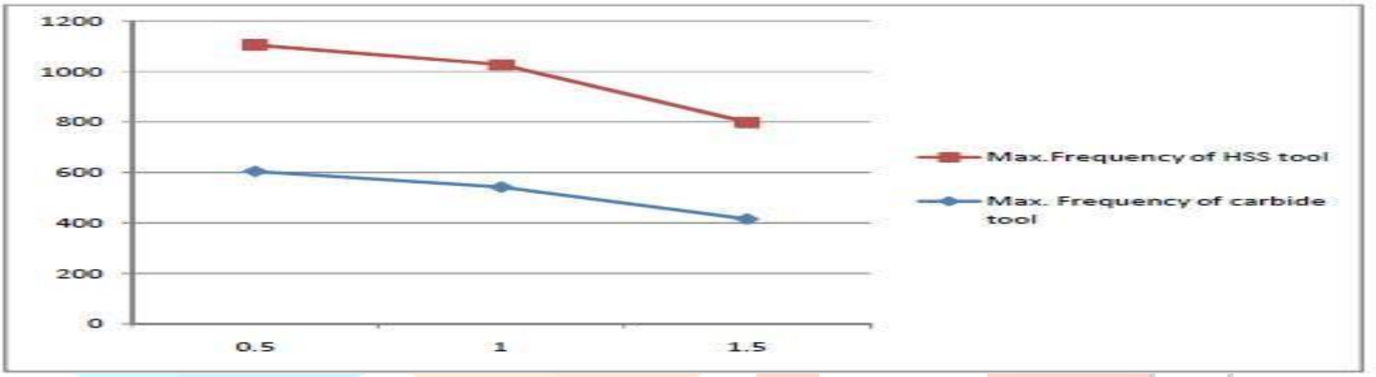

Fig. No. 5. Max Amplitude of tool vs Depth of Cut.

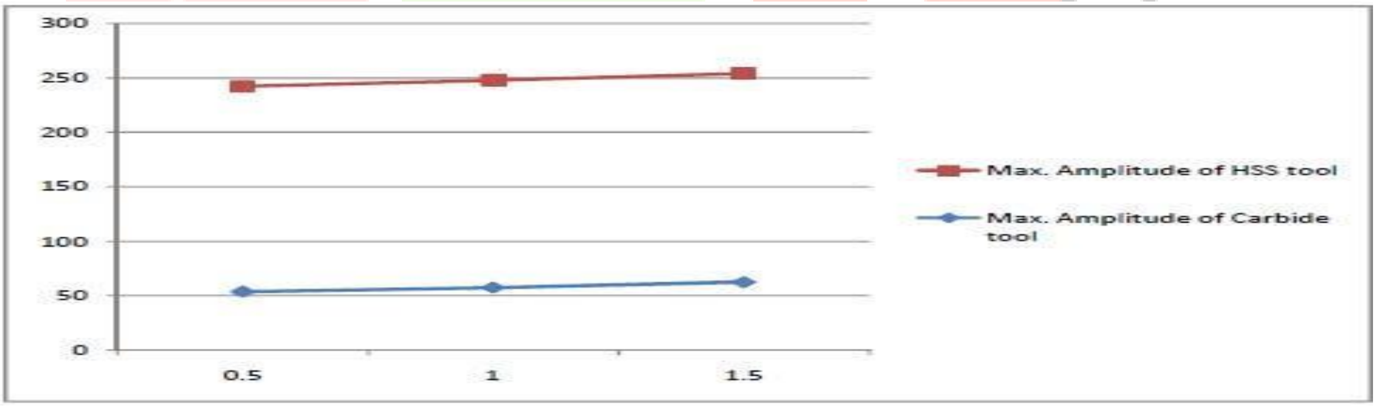

Fig.No.6. Max Frequency of tool vs Depth of Cut

VIII.CONCLUSION

From the result table the graph (depth of cut vs max. amplitude) and (depth of cut vs frequency) is plotted as shown in figure. From this graph following conclusion can be drawn

- As depth of cut goes on increasing the amplitude of vibration for both HSS and Carbide Single Point Cutting Tool goes on increasing that is amplitude is proportional to depth of cut
- As depth of cut goes on increasing frequency goes on decreasing for both HSS and Carbide Tool that is frequency is inversely proportional to depth of cut.
- For Carbide tools have vibrations with low amplitude as compare to HSS tool.
- Carbide tipped Single point Cutting tool gives better surface finish as compared with High-Speed Cutting Tool

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