A Review - Experimental Investigation of Chatter with Shim Materials

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Abstract— Chatter is a self-excited vibration that is fre-quently observed during milling operations and can affect productivity and part quality. For this reason, the manufacturing sector has been the focus of industrial and academic interest for a number of years. Since the late 1950s, a signifi-cant amount of research has been done to ad-dress the chatter problem. Scholars have exam-ined methods for identifying, avoiding, pre-venting, controlling, or suppressing chatter. The modern metal processing industry is defined by high frequency vibrations produced by spindle speed equipment. This greatly raises the de-mands on the cutting tool's rigidity and damp-ing. This study aims to increase the hard turn-ing efficiency and the quality of the machined surface by employing shims with strong damp-ing capabilities in the insert clamp set. In order to analyze the status of stress-strain in the clamp set construction of insert, computer sim-ulation and experimental inquiry are offered. Study is done on the static and dynamic proper-ties of a cutting tool with a shim composed of various materials.

Key words: Chatter, Shim Materials

I. INTRODUCTION

The properties of a machining system operating continuously under a periodic external stimulating impulse give rise to chatter, a type of vibration in the cutting process. In a metal cutting operation, it typically demonstrates the strong relative vibration between a tool and a workpiece. As Lida zhu and changfu lia reviewed paper provides a comprehensive review of studies on offline chatter prediction, online chatter identification, and chatter suppression. It focuses on regenerative and mode coupling chatter, critically analyzes relevant literature, identifies current research problems, and proposes future directions, including integrating smart tools, high-speed wireless data transmission, advanced real-time data processing, and specialized chatter monitoring for complex surfaces.[1].

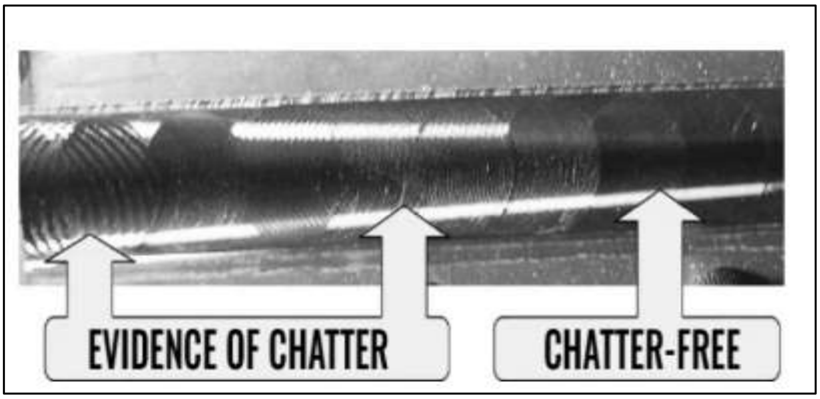

Fig. 1: chatter marks

Besmir Cuka, Minho Cho and Dong-Won Kim's paper introduces a novel method for online chatter onset detection in machining, leveraging a Gabor filter bank and the Teager-Kaiser Energy Operator (TEO) to identify dynamic transitions. By eliminating the need for Fourier transforms, it reduces time lag and offers promising prospects for tool wear and breakage detection in diverse cutting scenarios.[2]. And jonathan steven shepard research enhances end milling simulation for better chatter prediction and introduces a force-based chatter detection algorithm. Experimental data validates simulation for stable milling and highlights differences in unstable cases. The study also reveals the sensitivity of chatter to CNC machine dynamic parameters.[3].Caixu YUE addresses machining vibration types and focuses on self-excited vibration, particularly regenerative chatter. It reviews state-of-the-art research on chatter prediction, detection, and control in milling processes, emphasizing factors like stability, tool runout, and gyroscopic effects. It also highlights passive and active control technologies and intelligent algorithms for analysis.[4].Jaimin patel analyzes tool harmonic response using different shims (carbide, brass, aluminum, stainless steel, and none). Stainless steel shim offers the best damping (damping ratio = 0.00199) and minimal vibration (3.3⊗10-4 mm/s2). Suggests stainless steel shim as an effective damping material for the manufacturing industry.[5].

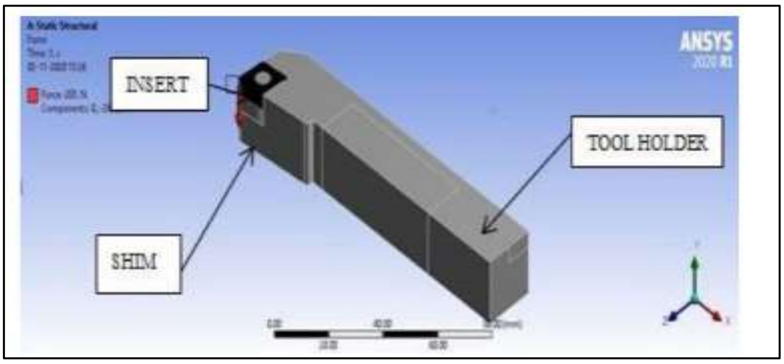

Fig. 2: tool arrangement

Experiments and optimization with Design Expert software to examine the use of shims in face milling on VMC. SS shims reduce vibration by 20-40% at medium and low cutting speeds, while carbide shims reduce it by 20-50% at high cutting speeds. ANOVA and graphical optimization recommend carbide shims for high cutting speeds and SS shims for lower and medium speeds, supported by experimental analysis. The research contributes to a valuable machining database for engineers. Design Expert was chosen for its structured optimization capabilities and user-friendliness. It's particularly suitable for continuous processes and mass production but less so for job or batch production [13]. Sintegran shims give the lowest surface roughness ,Acoustic measurements (RMS values) confirm this. Chlorites and sandstones have low acoustic activity. Sandstone shims reduce high-frequency vibrations, while chlorites shims are better at low frequencies. Mineral and composite shims improve machining and vibration absorption. Properly securing cutting inserts enhances surface quality[6]. Used Taguchi method to minimize surface roughness. Found the best parameters: speed (4000 rpm), feed (0.2 m/min), depth of cut (0.4 mm), tool nose radius (1.2 mm), and shim material (Aluminum). ANOVA analysis shows spindle speed, feed, and depth of cut significantly affect surface roughness, while tool nose radius and shim material have less impact.[7]. Simplified models predict chatter stability well. Suppress chatter with machine modifications or active control. Most research focuses on tool wear's impact on chatter, not the other way around. Tool condition is estimated from forces and vibrations; wear is measured directly. Tool life often uses a 0.2 mm flank wear criterion. Future work aims to link chatter and tool wear theoretically, integrating wear into the turning process model, ongoing at the University of Western Australia.[8]. Machining vibrations, categorized as free, forced, and self-excited, must be controlled to prevent damage. Self-excited vibrations, like regenerative chatter, are a common concern. Chatter research, dating back to the 1950s, has led to significant advancements aided by computers, sensors, and actuators. Methods to ensure stable cutting fall into four categories: out-of-process, in-process, passive, and active. Detecting and controlling chatter is crucial to avoid poor quality, inaccuracy, noise, wear, and increased costs.[9]. This paper constructs a dynamic milling model for stability lobes based on experiments. It's a two-dimensional linear delay-differential equation with features like feed dependency and spindle speed variations. The method of D-partitioning is used for stability lobe generation. This method differs from Altintas' approach by allowing critical depth-of-cut determination at a specific spindle speed, not an unknown chatter frequency. The model predicts stability limits and chatter frequencies with good agreement to experiments. Future improvements may involve accounting for cutter helix angles, higher-order matrix approximations, and considering time-dependent delay parameters, which would require a different analysis method due to non-autonomous equations.[10].

The paper introduces a 2 DOF mechatronic simulator for studying chatter in milling. The simulator realistically replicates regenerative chatter and implements active damping to stabilize milling operations. Active damping proves effective, especially in low-stability regions, making it a promising solution for chatter control. While the simulator has some speed limitations, it offers valuable insights into chatter mechanisms and the potential of active damping for practical machining applications, serving as a bridge between theory and implementation in the SMARTOOL project [16]. Y.S.Tarnga research that explores using a piezoelectric inertia actuator as a tuned vibration absorber on a cutting tool to suppress chatter in turning operations. For effective chatter suppression, the absorber's natural frequency should match the cutting tool's natural frequency, and it should have a higher damping ratio. Experiments demonstrate a sixfold increase in cutting stability and significant chatter reduction using this technique[11]. In 35 experiments with optimization, the study finds that SS shims effectively reduce vibration amplitude by 20-40% at medium and low cutting speeds compared to no shim and carbide shim in face milling on VMC. On the other hand, carbide shims significantly reduce vibration by 20-50% at higher cutting speeds. The ANOVA and graphical optimization suggest carbide shims for high cutting speeds and SS shims for lower and medium speeds, a conclusion supported by experimental analysis. These shim designs offer versatile solutions and are proven through optimization.[12].

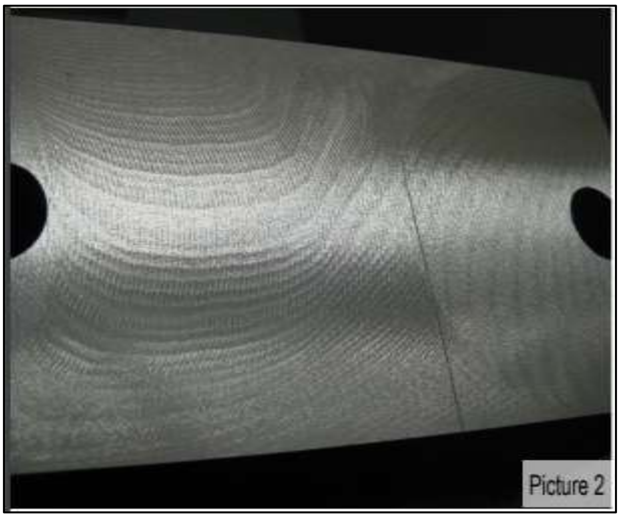

Fig. 3: chatter marks on workpiece

Mohit Shrivastava uses the brass shim and This study uses a computational model to analyze milling chatter and validate it with experiments. Brass shim significantly improves surface finish (0.6 µm and 1.0 µm) at certain conditions, while aluminum and conventionally used carbide shims result in poor roughness. Brass also exhibits reduced chatter, with less cutting and thrust frequencies. Brass motion behavior is quasi-periodic, further supporting improved surface finish[14]. the Quick Chatter Prediction Method (QCPM) is a fast and efficient way to predict chatter in milling. The Robust Chatter Prediction Method (RCPM) helps select cutting parameters and assess system stability. Various strategies like damping devices, variable pitch cutters, and spindle speed modulation can be used for chatter suppression. Two main approaches involve simulation models for design and process planning or recording and analyzing data during machining, with the potential for integration of prediction, detection, and suppression systems in the future to enhance manufacturing productivity and competitiveness.[15]. This paper aims to enhance cutting tool performance by using high-damping shims in the insert clamp set. The study introduces a dynamic model for the cutting tool, incorporating various elements' effects on static and dynamic characteristics. Findings and conclusions include: Shims made of epoxy granite and silty micaceous sandstone exhibit high damping and effectively support the cutting insert, improving roughness quality by 20-40%. Optical polarization modeling predicts dynamic properties of the insert-clamp set. Relative displacements and logarithmic decrements in the clamp set are determined through static analysis. Monitoring high-frequency vibro-acoustic signals aids in hard turning tool tip positioning.A dynamic cutting tool model helps assess relative displacements of tool components.Epoxy granite shims show superior damping based on FRF values.Shims of epoxy granite and sandstone reduce vibro-acoustic signal levels.The study analyzes the impact of cutting parameters and shim materials on surface roughness in hard turning, establishing relationships between cutting conditions and roughness based on shim material[18].Vibrations in machining, including regenerative chatter, result from machine and tool system imbalances. Controlling vibration is crucial to prevent damage. Extensive research has been conducted on chatter since the late 1950s, leading to various methods and solutions. Advances in technology have improved our understanding and strategies for stable cutting. This paper reviews the literature and discusses methods to ensure stable machining[17].

II. CONCLUSIONS

This study examines how utilizing shims with large damping capacities in the clamp set insert can enhance the cutting tool's performance. Additionally, it is evident from the avoided negative effects—poor surface quality, unacceptable accuracy, excessive noise and tool wear, machine tool damage, decreased material removal rate (MRR), increased time, material, and energy costs—that chatter needs to be detected, identified, avoided, prevented, reduced, controlled, or suppressed. Many studies have been conducted to prevent chatter, and in order to achieve better results, they have used shims made of various materials, such as carbon, stainless steel, aluminum, etc. Currently, we are attempting to make shims out of non-metallic materials. After that, we will conduct experiments, compare the outcomes, and refine our findings.

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