ORIGINAL RESEARCH PAPER

Engineering

LOW FREQUENCY VIBRATION TURNING AND ITS DEVELOPMENT: A REVIEW

KEY WORDS: Vibration Assisted Machining, Servo Axes, Built-up Edges.

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ABSTRACT

Low frequency vibration Turning is a peripheral energy assisted machining method to improve the material removal process by superimposing high frequency and small amplitude vibration on either tool or work piece motion. The servo axes vibrated in the axial direction and cutting is achieved while synchronizing this vibration with the rotation of the spindle. Because "air-cutting" time is provided along with cutting, it is characterized by intermittent removal of chips. It is ideal for cutting difficult-to-cut materials like Inconel, stainless steel and copper. It is state-of-the-art and overwhelms various risks associated with these materials, such as entanglement of chips and built-up edges. Three main problems, lack of awareness of mechanism, establishment of a standard for the choice of certain parameters, application level, still in expertise for low-frequency vibration cutting were explored and the development tendency as well as the prospect of low-frequency vibration turning in future was foreseen.

INTRODUCTION

The growing demand for high precision micro components in various industries has emphasized the importance of machining methods for hard and brittle materials to achieve tight tolerance and high-quality surface finish.

Continuous efforts to improve machining performance have been performed, and lots of developments have been achieved. One important development is of vibration-assisted machining (VAM). Vibration-assisted machining (VAM) is an external energy assisted machining method to improve the material removal process by application of high frequency and small amplitude vibration onto tool or workpiece motion. VAM has been applied to various machining processes, including turning, drilling, grinding, and more recently milling, for the processing of hard-to-machine materials [1],[2]

LITERATURE SURVEY

Naresh Kumar Maroju, Krishna P. Vamsi & Jin Xiaoliang, 2017[3] has studied the mechanics of orthogonal turning with low-frequency (less than 1000 Hz) vibration assistance. Finite element simulations are conducted to predict and compare the stresses, forces, and temperature between conventional turning (CT) and low frequency vibration-assisted turning (LVAT).

Martin Fuchs, Christoph Habersohn, Yakup Kalkan, Christoph Lechner, Friedrich Bleicher, 2015[4] has done Metrological Investigation of an Actuator Device for Vibration Assisted Turning. They developed a hydraulic based tool post actuator system making it possible to investigate the influence of superimposed frequencies on surface roughness and chip breaking. Frequencies of 0 to 30 Hz were applied while measuring the stroke of the tool post using laser interferometry. The results show that there is a significant dependency between the frequency of the tool post actuator system and the stroke value.

Riaz Muhammad,, Naseer Ahmed, Anish Roy, Vadim V. Silberschmidt, 2015[5] has conducted the Numerical Modelling of Vibration-Assisted Turning of Ti-15333. They have developed three-dimensional finite element models for both conventional and ultrasonically assisted turning techniques in a commercial code MSC Marc/Mentat. The models were used to investigate the effect of vibration on cutting forces and temperature levels in a cutting region for various cutting conditions.

LOW FREQUENCY VIBRATION TURNING

Previously, non-conventional machining methods, such as EDM, ECM, laser machining, ion-beam machining, electro beam machining, etc., were adopted to realize the processing of hard and brittle materials. However, those methods have significant drawbacks on the machining of hard and brittle materials, including the long preparation time, low processing efficiency, high setup cost, and high environ mental requirements.

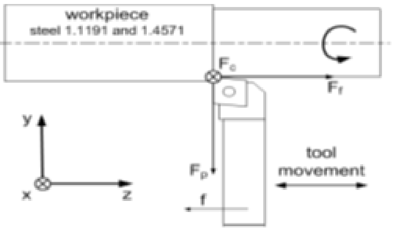

Figure 1: Tool movement and forces during vibration [4]

SOURCE: www.googleimages.com/Lowfrequencyvibrationturningforces

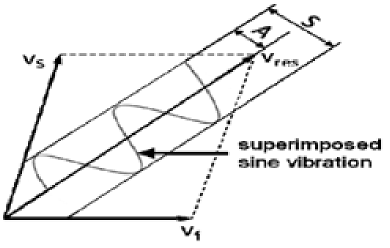

Figure 2: Velocities (v), amplitude (A), peak-to-peak value (S) and superimposed vibration. [4]

SOURCE: www.googleimages.com/Lowfrequencyvibrationturningforces

Vibration assisted turning, like all other vibration assisted manufacturing methods, bases on the principle of superimposing vibration on the actual manufacturing process. In this particular case a sine shaped vibration was superimposed along the z-axis causing a variation of the feed f at the tool center point (Figure no. 1). Therefore the cutting force F_c as well as the passive force F_p and the feed force F_f cannot be considered constant during the operation.

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CUTTING MECHANISM

Figure no. 2 shows that the feed velocity of the turning process and the stroke velocity S induced by the actuator device leads to a resulting velocity V_{res} with a certain amplitude A and an overall peak-to-peak value S (stroke) on which the sine vibration is superimposed. Due to the superimposed vibration on the helical movement, it is possible to achieve active chip breaking. Therefore frequency is adjusted in such a matter that the peak in the current workpiece revolution aligns with a low from the previous workpiece revolution causing a chip cross section small enough to break immediately.

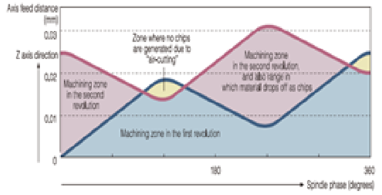

Fig. 3 Feed distance per spindle revolution.

Source: Citizen Machinery Co. Ltd., Japan

ACTUATORS DEVICE

The actuator device used for vibration assisted turning based on a hydraulic cylinder. Additionally to a normal hydraulic cylinder the actuator was modified in terms of adding linear guides and the ability to be fitted into almost any machine tool via its HSK tool holder (see Figure no. 4). Hydraulics was used to cope with the expected high feed force F_f which acts directly against the linear movement of the actuator. The servo valve alternately put pressure on the front side and the back side of the piston inside the actuator causing the slide, and therefore the tool, to vibrate in the predefined frequency.

The servo axes are vibrated in the axial direction and cutting is performed while synchronizing this vibration with the rotation of the spindle. Because "air-cutting" times are provided during cutting, it is characterized by intermittent expulsion of chips.

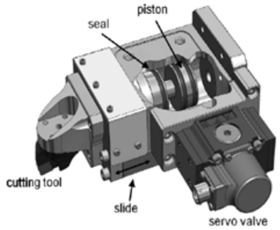

Figure 4: Actuator device (HSK tool holder not shown).[4]

SOURCE: www. google images. com/LFV Tactuation devices

CHIP SHAPE

In low frequency vibration turning, "air cutting" time provided during cutting serves to break chips up finely and expel them. This "air cutting" time also prevents the machining temperature rising, which both prolongs tool lives and gives relief from various problems caused by chips.

Figure no. 5: Chips generated by low frequency Vibration turning[6]

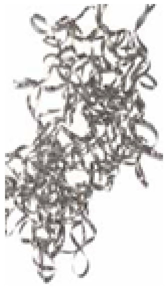

Figure no. 6 : Chips generated by conventional turning[6]turning[6]

Source: Citizen Machinery Co. Ltd., Japan

ADVANTAGES OF LOW FREQUENCY VIBRATION TURNING

Due to its unique technological effects, advantages of low-frequency vibration turning can be summarized as follows:

1. High accuracy and high surface quality:

In low-frequency vibration turning chip deformation and cutting force are not large, cutting temperature is low, no built-up edge, no cutting edge inclination with no micro-crack on machining surface, high accuracy and high surface quality workpiece can be prone to be machined.

2. Realization of machining for difficult-to-cutting components:

Complex structure, thin-walled, overall structure, three-dimensional cavity, profiled hole, group holes, narrow slit etc. difficult-to-cutting parts can get high surface quality by Low-frequency vibration

(3) Ease in chip breakage:

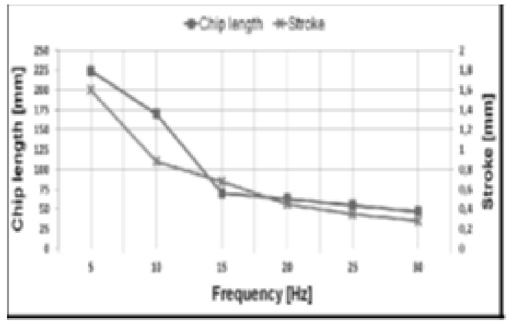

Figure no. 7: Chip length in dependency on applied frequency [4]

Source: www.googleimages.com/Lowfrequencyvibrationturningforces

The existence of vibration caused eye shaped chips with comparably shorter length. Thus, it could be shown that a distinct chip breaking was caused by the in feed direction forced vibration, which shows that the active influence on the chip cross section works properly (see Figure no. 7).

FUTURE SCOPE

Existing problems in VAT

Low-frequency vibration turning, still has some problems to be solved. The following are some of the most urgent and primary problems:

i. The mechanism of low-frequency vibration turning is still lack of unified awareness.
ii. A unified standard for the choice of certain parameters in low-frequency vibration turning has not yet been established.
iii. Practical level of low-frequency vibration turning technology needs further improving.

DEVELOPMENT TENDENCY OF VAT

Development Tendency In order to further understand and make full use of low-frequency vibratory machining technology, attention may be paid to and effort may be shared on the following aspects,

(1) Deep study on the mechanism of low-frequency vibration turning.

The mechanical analysis of interaction between the workpiece and the cutting tool in low-frequency vibration turning; micro research and mathematical description of the mechanism of low-frequency vibration turning are being studied.

(2) Standardization and serialization of parameter selection for low-frequency vibration turning.

Standardization and serialization of parameter selection is an important condition that the low-frequency vibration turning technology can go out of the laboratory and step into the market.

(3) Development of intelligent selection system of cutting parameters.

Intelligent selection system of low-frequency vibration machining parameters is strongly needed to develop. User-friendly CAD / CAM software interface, be able to respond to various input parameters, run the simulation program, show the results of operations (cutting force, cutting temperature, surface finish, shape error, flatness, etc.) must be developed.

(4) Development and adoption of new materials of cutting tools

In the low-frequency vibration turning, in addition to select appropriate parameters of cutting tools, it should pay more attention to the development and use of tool materials. Among them diamond, artificial diamond, ultra-fine grain cemented carbides, CBN, and other new and premium materials.

(5) Wideness and expansion to other areas

Low-frequency vibratory machining has been available in turning, drilling and tapping and has advanced to a proper stage. Meanwhile low-frequency vibration lapping, polishing, grinding, broaching and other machining processes are being developed and have made progress.

CONCLUSION

Recently, vibration-assisted turning has been attracting more attention from both academia and industry. This paper reviewed the latest developments and applications in vibration-assisted turning. Since cutting velocity and uncut chip thickness change continuously in the turning process, the trajectory of tool tip in vibration-assisted turning becomes more complex than other vibration-assisted machining operations.

Using the developed actuator system the formation of continuous chips could be completely avoided for machining the steel material. Therefore one can assume that applying frequencies above 30 Hz combined with actuator amplitudes in the order of the 2 x the feed. This order will improve the surface quality and also provide sufficient active chip breaking during the machining.

To be sure, under the joint efforts of scientific and technological workers all over the world, low-frequency vibration machining technology will make breakthrough progress and play a greater role in the field of advanced manufacturing processes.

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