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COMPUTATION ANALYSIS OF SINGLE POINT CUTTING TOOL WITH DIFFERENT SHIM MATERIALS

RAČUNSKA ANALIZA REZNOG ALATA SA JEDNOM OSLONOM TAČKOM SA RAZLIČITIM MATERIJALIMA PODLOŠKE

Originalni naučni rad / Original scientific paper
UDK /UDC:

Rad primljen / Paper received: 6.4.2021

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Keywords
- vibration
- shim materials
- harmonic response analysis

Abstract

In this paper, a passive damping control system has been developed by computational investigation to decrease vibration in a machining process by inserting different shim materials beneath the insert. The different shim materials of carbide, aluminium, brass, and stainless steel are compared through computational analysis. In this computation analysis of different shim materials, the harmonic response and damping ratio are evaluated. The damping ratio is derived by half power bandwidth theory. This research work is led to conclude that harmonic response analysis and damping ratio accomplish that single point cutting tool with stainless steel shim is useful to reduce chatter.

Ključne reči
- vibracija
- materijali za podloške
- analiza harmonijskog odziva

Izvod

U radu je predstavljen razvijeni pasivni sistem upravljanja prigušenjem, koji je istražen računskom metodom, radi smanjenja vibracija u procesu rezanja ubacivanjem različitih materijala podloški. Proračunskom analizom su upoređeni različiti materijali tipa karbida, aluminijuma, mesinga, nerđajućeg čelika. Računskom analizom različitih materijala podloški, dobijeni su rezultati za harmonijski odziv i koeficijent prigušenja. Koeficijent prigušenja je dobijen primenom metode propusnog opsega polovine snage. Na osnovu ovih istraživanja analizom harmonijskog odziva i na osnovu koeficijenta prigušenja, zaključuju se prednosti reznog alata sa jednom oslonom tačkom i materijalom podloške od nerđajućeg čelika, u smanjenju podrhtavanja.

INTRODUCTION

Chatter is one of the most significant factors affecting the performance of the machine tool. Chatter on the work piece influences the surface roughness of the workpiece, dimensional accuracy, increases the rate of tool wear, and reduces the life of the tool. For the improved surface finish of a component, chatter is an important element that needs to be reduced, /1/.

Chatter is a self-excited machining vibration that occurs during machining processes such as turning, milling, drilling, boring, etc. The chatter in turning occurs due to relative movement between workpiece and cutting tool /1, 2/. The different types of chatter are categorized into primary and secondary chatter. Primary chatter induces due to: (a) friction; (b) mode coupling effect; and (c) thermomechanical effect /1, 2/. The main cause of chatter is the regenerative effect, also known as regenerative chatter; it comes in the category of secondary chatter. The regenerative chatter occurs in turning because of overlapping cuts involved during machining that leads to phase angle variation of chip thickness between the inner and outer modulation of a chip. This is known as the regenerative effect, which is the main reason for vibration amplification. Most of the time researchers use the word chatter in the phrase of the regenerative chatter, /3/.

Almost all chatter reduction techniques are classified into two types: active control of chatter and passive control of chatter /1/. Ma et al. /4/ presented a method for regenerative chatter suppression in CNC turning using displacement measurement only. The author used a piezoelectric actuator based fast tool servo for active control of chatter. Yang et al. /5/ designed and optimized tuning of multiple mass dampers for increasing resistance to chatter. This method provides better results as compared to the single tuned mass damper. Tang et al. /6/ experimented with a piezoelectric actuator as a vibration absorber with tuning for improving cutting stability. Altintas et al. /7/ identified coefficients of cutting force and provided the stability region using process damping. Similarly, Tyler et al. /8/ worked on process damping for predicting stability conditions through time-domain simulation. Kishore et al. /9/ used a well-known half-power bandwidth method which provides a damping ratio. Rogov et al. /10/ improved the performance of cutting tools by using shim of composite materials. It has also been concluded that epoxy granite and sandstone provide better damping for machining of hardened steel. Irvine et al. /11/ gives different damping values for various materials and systems. Mevada et al. /12/ performed harmonic analysis in Ansys® and concluded that harmonic response analysis is an effective technique for estimating of damping characteristics of the system. Chatter reduction using different shim is a passive control technique and it is easy to implement.

In the present work, shim materials like carbide, aluminium, brass, and stainless steel are used to reduce vibration in CNC turning operations.

FEA ANALYSIS OF DIFFERENT SHIMS

This chapter introduces the design for DCNL single point cutting turning tool holder assembly with shim materials.

The computational 3D model of the Kyocera made DCNL 2020K12 tool is established as shown in Fig. 1. Different shim materials have been put below the insert of the cutting tool. As shown in Fig. 1, maximal tangential cutting force of 283 N is applied in the negative *y*-direction. Machine tool geometry is studied with five different types of shim slot: carbide, aluminium, brass, and stainless steel shim. Densities of shim materials are carbide 1.59×10^{-5} kg/mm^3; aluminium 2.7×10^{-6} kg/mm^3; brass 8.5×10^{-6} kg/mm^3; and stainless steel shim 7.9×10^{-6} kg/mm^3. The tool material is structural steel, and the insert material is tungsten carbide. The frequency response and damping of dissimilar shim materials are determined by harmonic analysis.

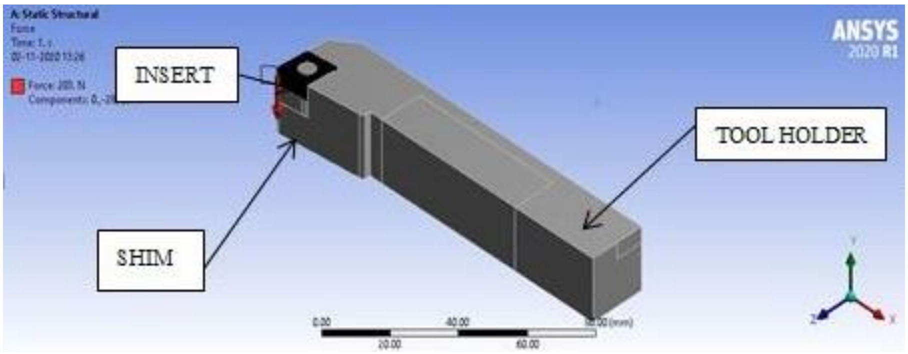

Figure 1. Assembly model and boundary conditions of a DCNL single point cutting tool.

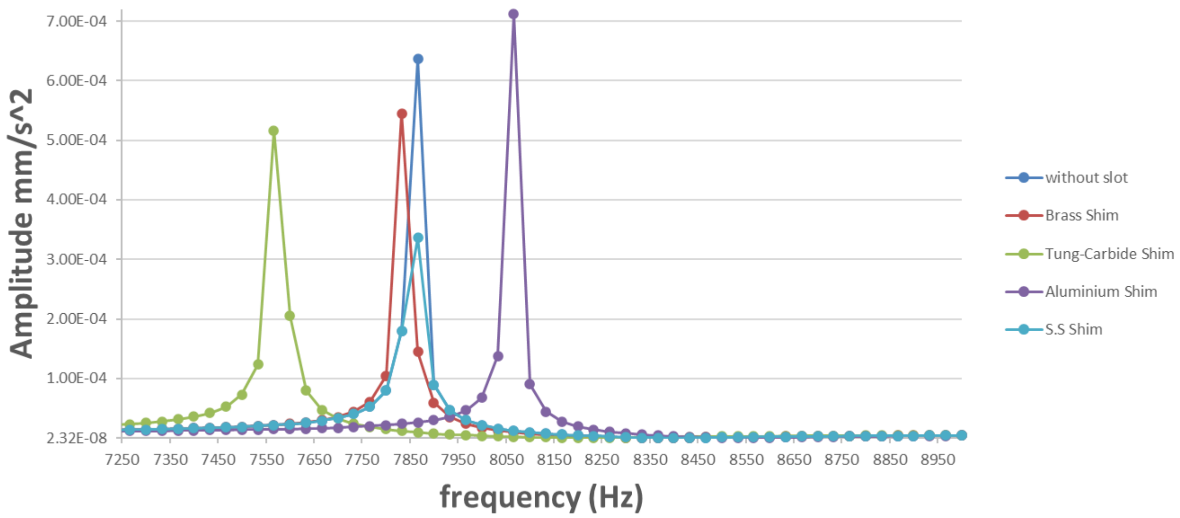

Figure 2. Amplitude (mm/s^2) vs. frequency (Hz) of shim materials.

HARMONIC RESPONSE ANALYSIS OF SHIMS

By using ANSYS® Workbench 20.1 the harmonic response is found for the tool with 4 types of shims. The damping ratio is evaluated by using the half-power bandwidth method. In Fig. 1, the *x*-axis is the frequency in Hz, and the *y*-axis is the amplitude in mm/s^2.

As shown in Fig. 2, the outcomes have a specified amplitude vs. frequency response curve through which we can find the damping ratio by using the half-power bandwidth method. All the results are in shown in Table 1.

Table 1. Damping ratio of the different shim materials.

Shim material	Without cut shim	Carbide shim	Brass shim	Aluminium shim	Stainless steel shim
Natural frequency f_r (Hz)	7866.7	7566.7	7833.3	8066.7	7866.7
Maximum amplitude $\times10^{-4}$ (mm/s^2)	6.3	5.1	5.4	7.7	3.3
Damping ratio	0.00144	0.00152	0.00132	0.00073	0.00199

RESULTS AND DISCUSSION

In this research work the harmonic response and damping ratio are determined by computation analysis with passive damping techniques. It is evident that the maximal damping ratio is produced with the stainless steel shim, and the minimal damping ratio is produced with aluminium shim.

As shown in Table 1, we find the harmonic response of the different discussed shim materials and damping ratio by half-power bandwidth method. By comparing all damping ratios of different shim materials in the above Table 1, it is clear that a single-point cutting tool with stainless steel shim has a maximal damping ratio ($\zeta = 0.00199$) compared to the other shim materials.

Harmonic analysis is performed with Young's modulus, Poisson's ratio, as an essential input. For the without shim material tool geometry, the applied tangential load of 283 N magnitude is at the tip of cutting insert, and the maximal frequency is 7866.7 Hz. Similarly, for the single point cutting tool with carbide, brass, aluminium, and stainless steel shim, the applied load as shown in Fig. 1, with the amount of maximal frequencies of 7566.7, 7833.3, 8066.7, and 7866.7 Hz, respectively. The harmonic response of the single point cutting tool with stainless steel shim is comparatively lower in amplitude in contrast to the carbide, brass, and aluminium shim, and to the single point cutting tool without shim geometry. But we have found that the single point cutting tool with aluminium shim has a higher peak of response and it is not appropriate. So, it must be evaded in engineering because of the unsafe response. Having a maximum damping ratio is significantly more stable. For reducing the vibration, the maximal damping ratio is more appropriate for better stability of machine tools.

CONCLUSION

In this paper, the harmonic response of the tool with different shim materials is performed by computational analysis. The damping ratio is determined with half-power bandwidth method by performing FEA analysis for different shim materials as carbide, brass, aluminium, and stainless steel shim, and with conventional cutting tool without shim material. Single point cutting tool with stainless steel shim is noted with maximal damping ratio $\zeta = 0.00199$ and with minimal amplitude of vibration in acceleration mode of 3.3×10^{-4} mm/s^2. This work has shown that the single point cutting tool with stainless steel shim has damped out vibrations more efficiently as matched to shim materials of carbide, brass, and aluminium, and the cutting tool configuration without shim. Present work leads to conclude that stainless steel shim material is justified as an effective passive damping material which could be more beneficial in the manufacturing industry.

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