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INVESTIGATION OF CHATTER STABILITY IN BORING OPERATIONS USING POLYMERS AS IMPACT DAMPERS

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ABSTRACT

Chatter is a problem of instability in the metal cutting process. The phenomenon is characterized by violent vibration, poor surface finish and causes reduction of the life of the tool. In all cutting operations vibrations are induced due to the deformation of the work piece. The main objective of this proposed work is to introduce the impact dampers in between the tool insert and tool and reduce the chatter. In this investigation, improvement of damping capability of boring tool and reduction of chatter vibration using dampers are analyzed. The polymers selected for the dampers are acrylate, epoxy and polyamides. The main contributions of the current study are observed that the natural frequency of the boring tool has been enhanced with dampers. From harmonic and transient analysis it is observed that there is a reduction in amplitude of vibration with respect to frequency and time taken to decay the amplitude of boring tool with dampers.

Key words: chatter, boring, polymer impact dampers.

1. Introduction

In the boring operation the tool holder shank are subjected to a dynamic excitation due to the deformation of the work material during the cutting operations. The chip formation process usually induces vibration in the machine-tool system. Energy from chip formation process excites the machine tool system. Modes of the work piece may also influence the vibration. The relative dynamic motion between cutting tool and work piece will affect the result of machining, in particular the surface finish. Further more, the tool life is correlated with the amount of vibration, with the modern trend of machine tool development: accuracy and reliability are gradually becoming more prominent features.

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The main objective of the proposed work is to introduce the impact damper in between the tool insert and tool holder. In this investigation, improvement of the damping capability of boring tool and reduce the chatter vibration using three types of polymers which are polyamides, acrylate, and epoxy. These materials having high density and so that inertia mass of boring tool is increased to reduce the chatter vibration in boring operation. From the result suggesting which damping materials will be suitable for reduce the chatter vibration of boring operations comparing with each other

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2. Properties of tool and polymers

Tool property

Material : EN31

Density :7.84 x 10^{-6} kg/mm^3

Young's modulus : 2.84 x 10^5 N/mm^2

Poisons ratio :0.3

Insert property

Material : cemented carbide

Density :14.95x10^{-6} kg/mm^3

Young's modulus : 6.25 x 10^5 N/mm^2

Poisons ratio :0.22

Acrylate property

Density :1.4x10^{-6} kg/mm^3

Young's modulus : 7.5 Gpa

Poisons ratio :0.35

Epoxy property

Density :2.2x10^{-6} kg/mm^3

Young's modulus : 6.9 Gpa

Poisons ratio :0.4

Polyamide property

Density :$1.1x10^{-6}$ kg/mm^3

Young's modulus : 2.8 Gpa

Poisons ratio :0.41

3. Investigation of dynamic behavior of boring tool using ansys

3.1 Modal analysis

Modal analysis is used to determine the natural frequencies and mode shapes of the structure. The natural frequencies and mode shapes are very important parameters in the design of a structure for dynamic loading conditions. They are also required for to do a spectrum analysis or a mode superposition harmonic or transient analysis. Modal analysis in the ansys program is a linear analysis any nonlinear ties such as plasticity and contact element, will be ignored even if are defined. We can choose from three mode extraction methods-reduced, full and damped. The damped method allows you to include damping structure.

3.2 Results of modal analysis

Figure 1 first mode shape of boring tool without dampers

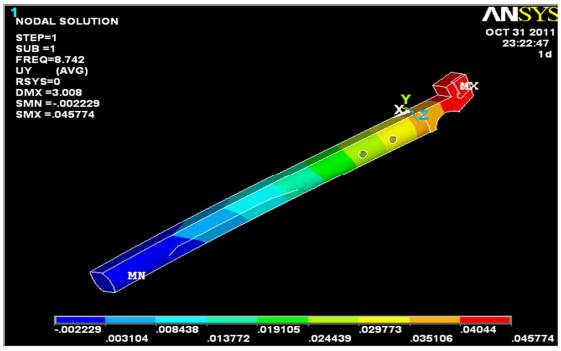

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Figure 2 first mode shape of boring tool with acrylate impact damper

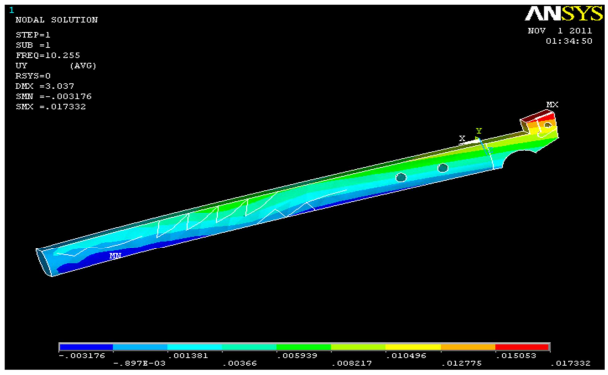

Figure 3 first mode shape of boring tool with Epoxy impact damper

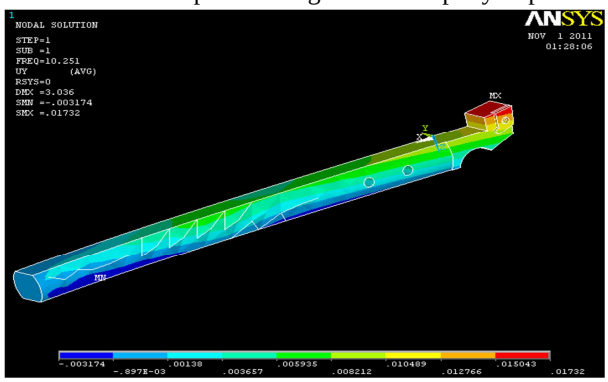

Figure 4 first mode shape of boring tool with polyamide impact damper

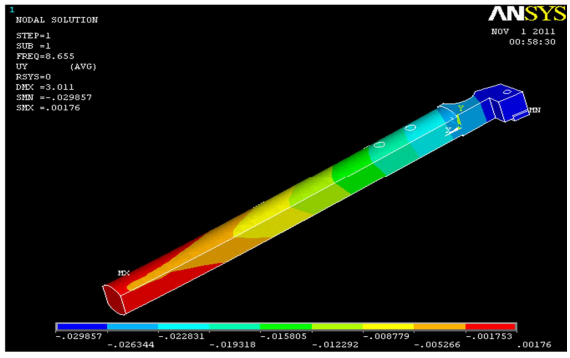

Figure 5 second mode shape of boring tool without dampers

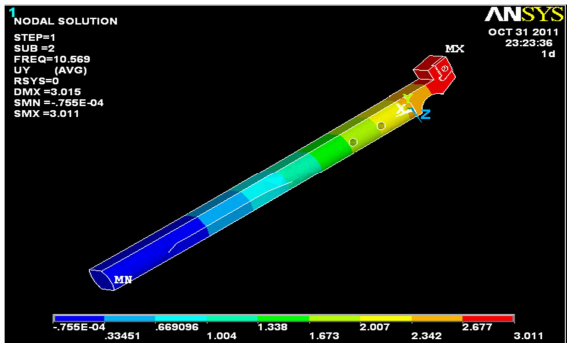

Figure 6 second mode shape of boring tool with acrylate impact damper

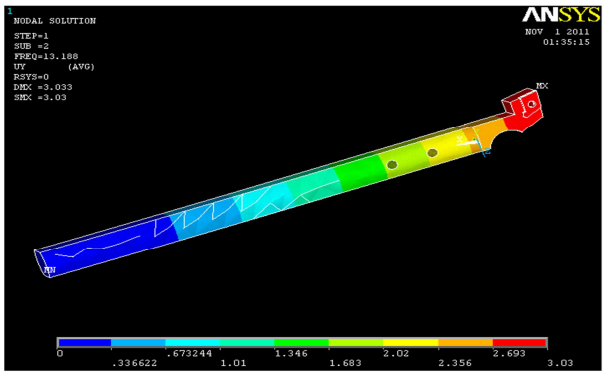

Figure 7 second mode shape of boring tool with epoxy impact damper

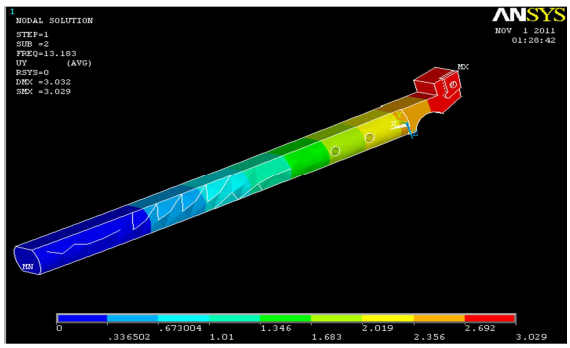

Figure 8 second mode shape of boring tool with polyamide impact damper

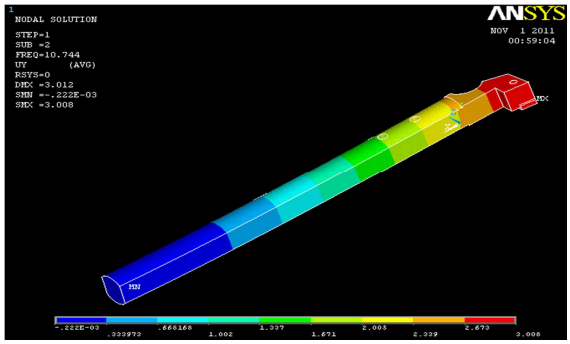

Figure 9 third mode shape of boring tool without damper

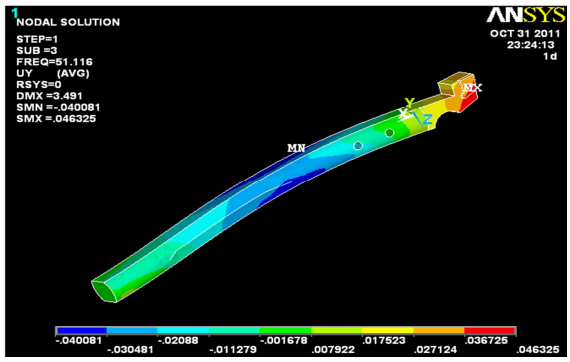

Figure 10 third mode shape of boring tool with acrylate impact damper

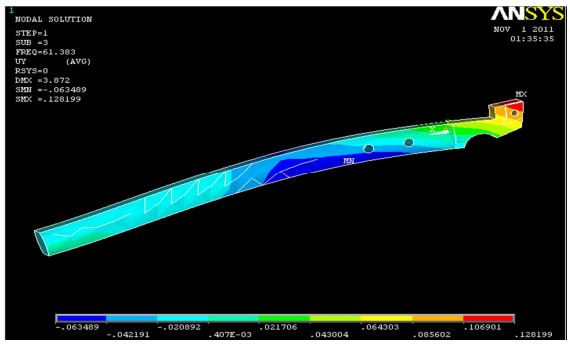

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Figure 11 third mode shape of boring tool with epoxy impact damper

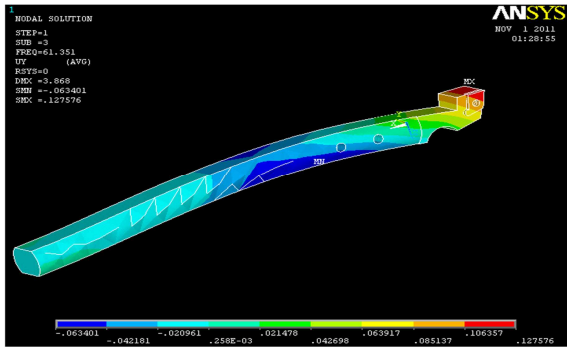

Figure 12 third mode shape of boring tool with polyamide impact damper

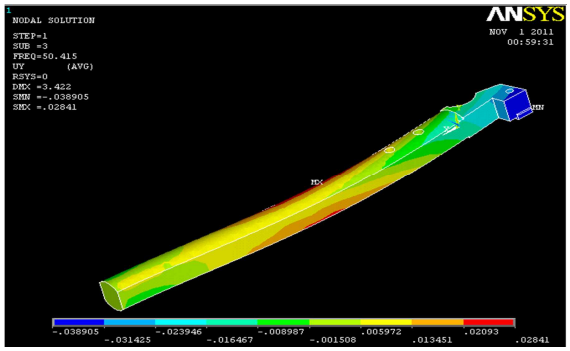

Table 1 Natural frequencies of the boring tool

Mode	thout damp (Hz)	Acrylate dar (Hz)	Epoxy dar (Hz)	polyamide dar (Hz)
1	8.7422	10.255	10.251	8.6554
2	10.569	13.188	13.183	10.744
3	51.116	61.383	61.351	50.415

From these results on the modal analysis, three modes of extraction have been carried out such mode shapes are vertical bending, horizontal bending, and twisting. The frequencies of modal analysis of boring tools with and without dampers are not coinciding with each other in different mode shapes of the boring tool because the impact dampers with high stiffness is introduced between the tool and the tool insert.

3.3 Harmonic response analysis

Harmonic response analysis is a technique used to determine the steady-state response of a linear structures response at several load that vary sinusoidal with time. The idea is to calculate the structure response at several frequencies and obtain graph of some response quality verse frequency. Peak response are then identified on the graph and stressed reviewed at those peak frequencies.

3.4 Results of harmonic analysis

Figure 13 harmonic analysis of boring tool without damper

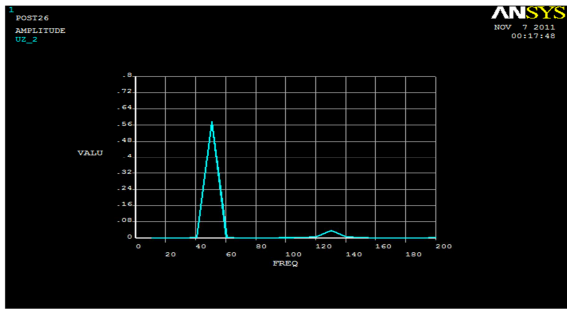

Figure 14 harmonic analysis of boring tool with acrylate damper

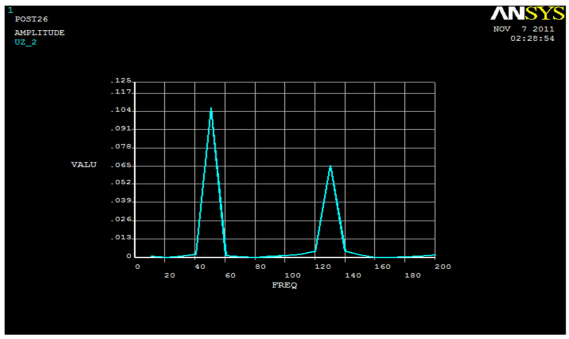

Figure 15 harmonic analysis of boring tool with epoxy damper

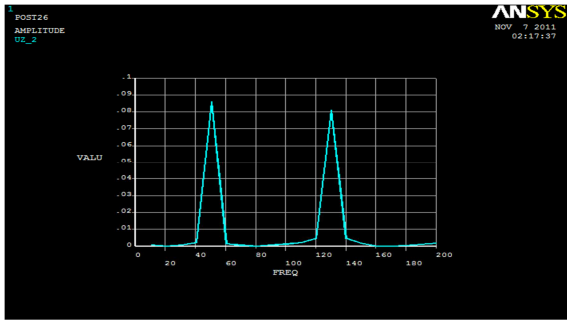

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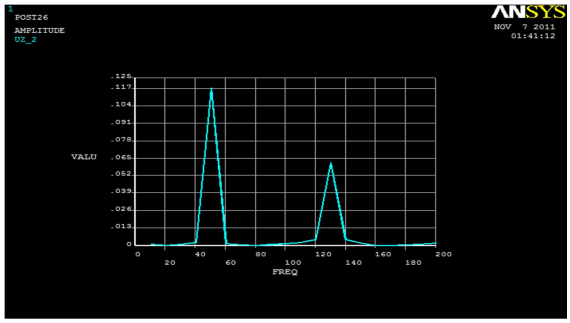
Figure 16 harmonic analysis of boring tool with polyamide damper



The results obtained from the harmonic analysis of boring tool with and with out damper plotted as below. The peak vale of the amplitude has been reduced with respect to the frequencies in this analysis. The results are shown from figure 13 To 16

Table 2 Comparison of peak value

Damping materials	Peak value(mm)
Without damper	0.60
ith Acrylate impact dampe	0.107
With Epoxy impact damper	0.088
ith polyamide impact dampe	0.117

3.5 Transient dynamic analysis

Transient dynamic analysis is a technique used to determine the dynamic response of structure under the action of any general time-dependent loads. You can use these types analysis to determine the time-varying displacement, strain, stress and forces in a structure as it response to any combination of static, transient, harmonic load. The time scale of the loading is such that the inertia or damping effect are consider important.

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3.6 Results of transient dynamic analysys using adams

Figure 17 transient analysis of boring tool without damper

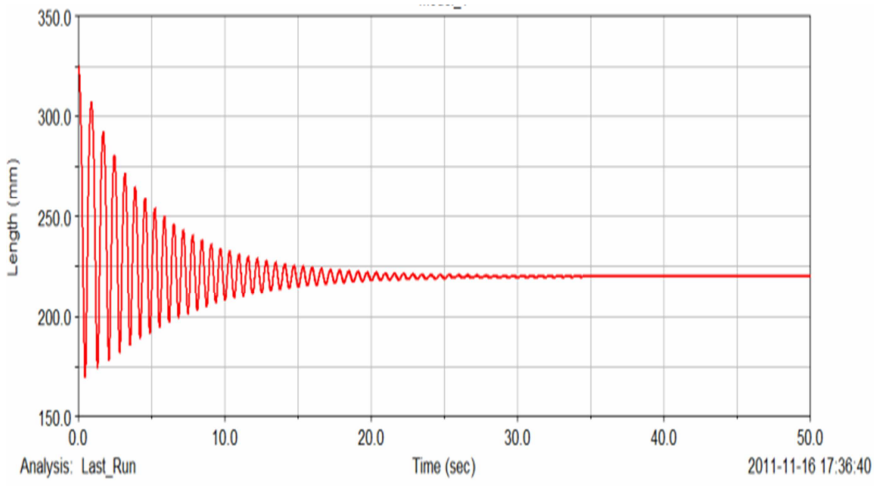

Figure 18 transient analysis of boring tool with acrylate impact damper

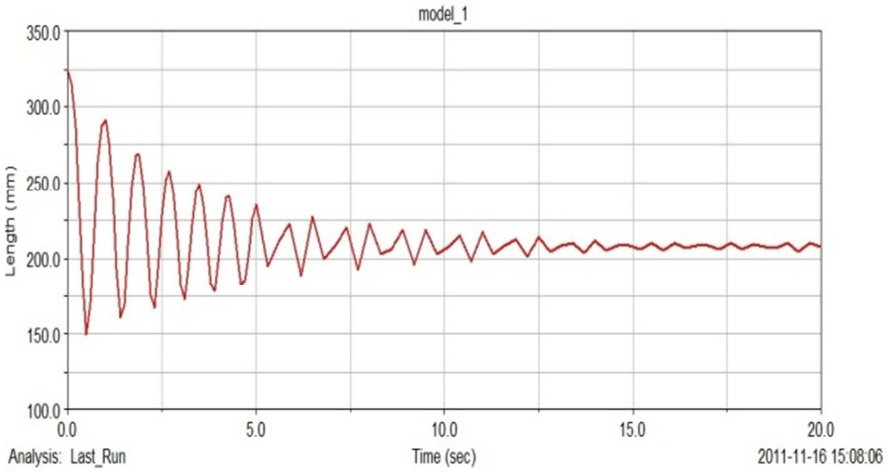

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Figure 19 transient analysis of boring tool with epoxy impact damper

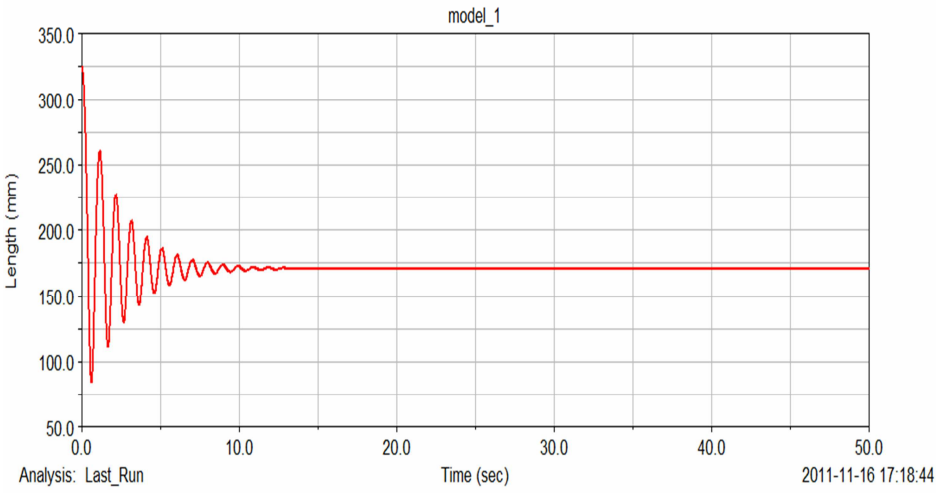

Figure 20 transient analysis of boring tool with polyamide impact damper

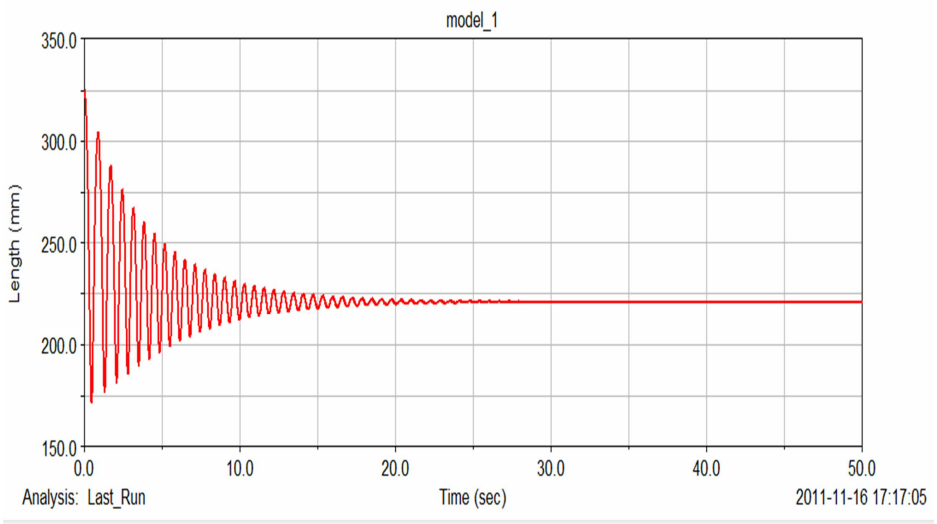

Table 3 Time to decay the amplitude of boring tool

Damping materials	Time taken to decay (sec)
Without damper	35
Vith acrylate impact damper	20
With Epoxy impact damper	12
ith polyamide impact dampe	25

The amplitude of the boring tool for without damping materials is reduced with epoxy damper which is very less reduction but the time taken to decay the amplitude is reduced considerable amount. Time taken to decay the amplitude of boring tool without damping materials starts from 35 seconds is reduced to 12 seconds for with epoxy.

3.7 Comparison of damping ratio

The amplitude values are taken from adams transient analysis results for calculations of damping ratio. From the transient analysis, we know the amplitude decay with respect to the time has been reduced with damped boring tools when compared with undamped boring tool.So the damping ratio can be calculated from the transient analysis by using logarithmic decrement which is ratio between the successive amplitudes(x1,x2).

Logarithmic decrement $\delta = \ln (x1/x2)$

Damping ratio $\xi = \delta/2\pi$

For boring tool without damper, the damping ratio is 0.0075. from the comparisons the damping ratio has been increased with damped boring tool when compared without damper. Epoxy damper only gives the significant improvement in damping ratio.

4. Conclusion

The conclusions drawn from the investigations are the results were obtained from modal analysis of boring tool with and without dampers. It is observed that the natural frequency of boring tool has been enhanced with damper.

From the harmonic analysis, it is observed that amplitude of the vibration has been reduced with damper. In that analysis with Epoxy damper the amplitude of vibration of boring tool has been reduced by 82.6% when compared with the boring tool without damper.

From the transient analysis it is observed that there is reduction in time taken to decay the amplitude of boring tool with dampers.

From the comparison of damping ratio of different damper the damper gives the increased damping ratio by 96.7% when compared with boring tool without damper..

Table 4 Comparison of damping ratio

Damping material	Without damper	With acrylate impact damper	With Epoxy impact damper	With poly-amide impact damper
Damping ratio	0.0075	0.1243	0.2308	0.0116

Hence the results of the finite element analysis of boring tool with epoxy impact damper shows that there is significant improvement in the dynamic behavior of structural analysis, when compared with other dampers.

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