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Study on A Damping System for the Toolholder in a Turning Process

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ABSTRACT: *In the turning process, vibration of the toolholder significantly affects the surface roughness. This study introduces an application of a damping system for reducing toolholder vibration and improving the surface quality of the part being machined in the turning process. The damping system is designed with an object mass and two springs, and it assembles the toolholder using two damping designs. After assembly, the toolholder is used for machining the workpiece with a cutting length of 60 mm, cutting depth of 0.5 mm, velocity of 0.05 mm/rev, and spindle speed of 1000 rev/min. For Design 1, the result shows that when the object mass B (11.83 g)is used and the spring constant is increased from 400 to 2800 N/m, the vibration angle dR decreases from 0.22331° to 0.04632°; however, when the spring constant continually rises to 3733 N/m, the vibration angle increases to 0.10273°. When using Design 2, when the spring constant increases from 400 to 500 N/m, dR reduces to 0.122°. Moreover, Design1 shows better stability than Design 2 with different object masses and spring constants. Object mass B is selected for evaluating the effect of the damping system on the surface roughness. The results show that the surface roughness varies from 0.925 to 1.169 μm and from 1.22225 to 0.84225 μm with Design 1 and 2, respectively.*

Keywords: *turning process, toolholder, vibration, damping system, surface roughness*

I. INTRODUCTION

In recent years, the turning process involving hard metals has gained significant interest owing to its efficiency. Precision turning, one of the most important metal-manufacturing methods, is commonly used in high-technology industrial applications. In terms of the quality characteristics of the product being turned, the vibrations in the cutting tool, chuck, and workpiece play an important role in the machining performance [1-2]. In particular, vibration of the toolholder is the main reason for the instability of cutting inserts [3-5] because it reduces the quality of machined-surface roughness [6] and the dimensional accuracy of the product [7].Many researchers have demonstrated that one of the main factors that have the highest influence on surface roughness and can degrade surface quality is toolholder vibration during the turning process [8, 9].

In general, toolholder vibration is a dynamic instability in the cutting process. It is a result of an interaction between the workpiece and the dynamics of the cutting tool. This type of vibration leads to a poor surface finish, cutting-tool damage, and irritating, unacceptable noise [10]. Excessive tool vibration during machining increases tool wear and leads to a poor surface finish [11]. In the field of vibrations in metal cutting, the amplitude and natural frequency of cutting-tool vibrations under resonance during the cutting process are related to the dynamic cutting force acting on the cutting tool and variations in the chip thickness. The variations in cutting-tool vibration during the cutting process were observed by detecting the surface roughness of the machined surface [12]. The approaches for controlling cutting-tool vibration include a proper setup of cutting parameters [13], which is highly effective, or reducing the length of the toolholder [14]. Another research direction is the application of a damping system on the toolholder. Tewani et al. [15] introduced an active dynamic absorber to suppress the vibration of a boring bar.

The aim of this paper is to observe the vibration amplitude of a toolholder and the surface quality of the workpiece using different types of damping systems. To this end, the structure of a turning toolholder was designed; it combined the object mass and two springs for testing the effect of damping on vibration reduction. The selected object mass and spring constant were changed with 4 and 7 types, respectively. A cutting test was conducted to visualize the effect of toolholder vibration on surface roughness.

II. EXPERIMENTAL METHOD

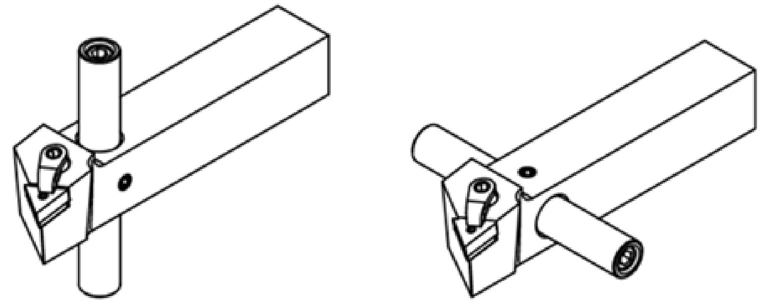
In this paper, for observing the effect of the damping system on toolholder vibration and workpiece quality, an experiment was conducted using a CNC turning center machine with the machine specifications listed in Table 1. The cutting process was performed using a toolholder assisted by the damping system. The toolholder and the damping system were designed and assembled according to two damping designs, as shown in Fig. 1, and manufactured as shown in Fig. 2. The damping system comprised the object mass and two springs mounted onto a pipe with two closed caps. Its assembly is shown in Fig. 3. It was operated with the object mass varied from 9.07 to 12.62 g, and the spring constant increased from 400 to 3733 N/m. The damping parameters are shown in Table 2. The positions of the workpiece and toolholder for the turning operation are shown in Fig. 4. For observing toolholder vibration, a sensor was designed and assembled on the toolholder. The sensor position is shown in Fig. 4. This sensor presents the history of vibration magnitude at angles of dP and dR. The origin of the coordinates is shown in Fig. 5.

Table 1: Specifications of the CNC Turning machine

Powerful standard equipment –Main spindle	7.5 kW
Spindle speed	6000 rpm
Machine dimension	1690 mm × 1290 mm × 1800 mm
Max work piece	Ø300 mm
Controller	Mazatrol T32-2
Turret	8 tools

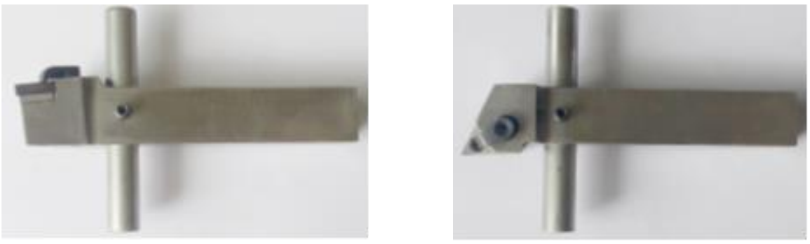
Table 2: Damping parameters

Toolholder Design	Object Mass	Spring Constant (N/m)
I, II	A(m_A = 12,62 g) B(m_B = 11,83 g) C(m_C = 11,04 g) D(m_D = 9,07 g)	K1 = 400
		K2 = 500
		K3 = 1647
		K4 = 1806
		K5 = 2800
		K6 = 2947
		K7 = 3733



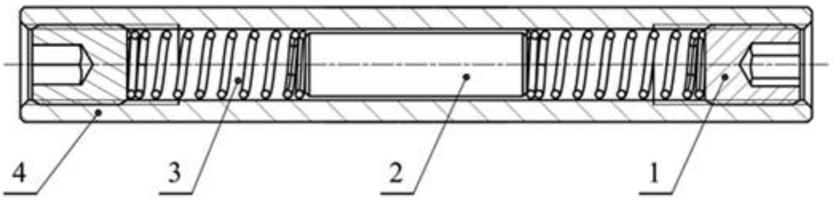
(a) Design 1 (b) Design 2

Figure 1: Toolholder designs



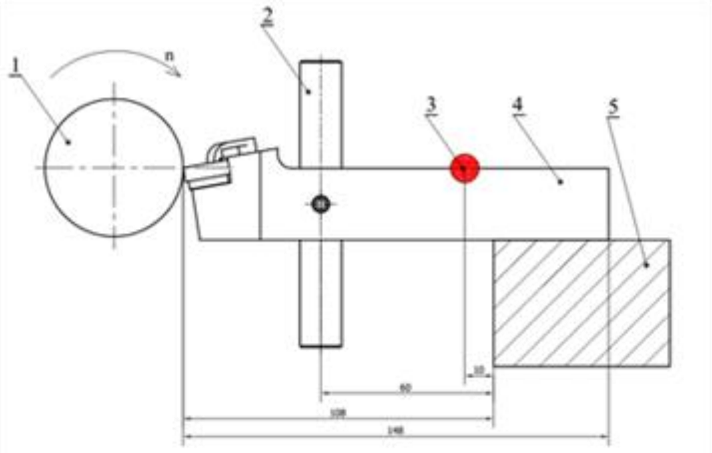
(a) Design 1 (b) Design 2

Figure 2: Toolholder after manufacturing



1/ Closed cap 2/ Object mass
3/ Spring 4/ Pipe cover

Figure 3: Damping system



1/ Work piece
2/ Damping system
3/ Sensor location
4/ Tool holder
5/ Turret

Figure 4: Positions of the workpiece and toolholder

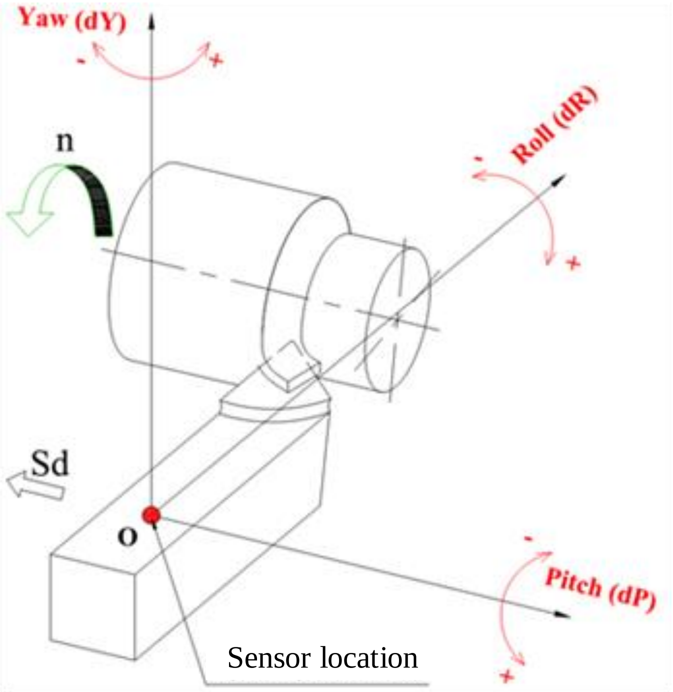


Figure 5: Vibration angle

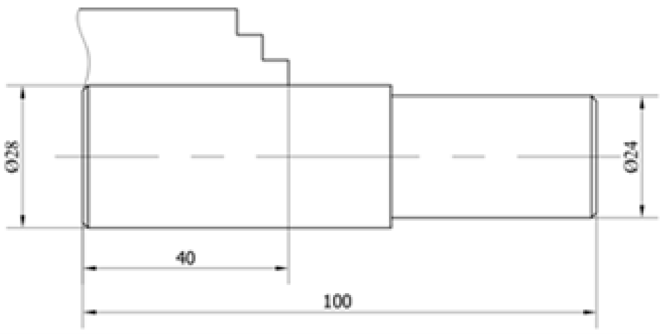


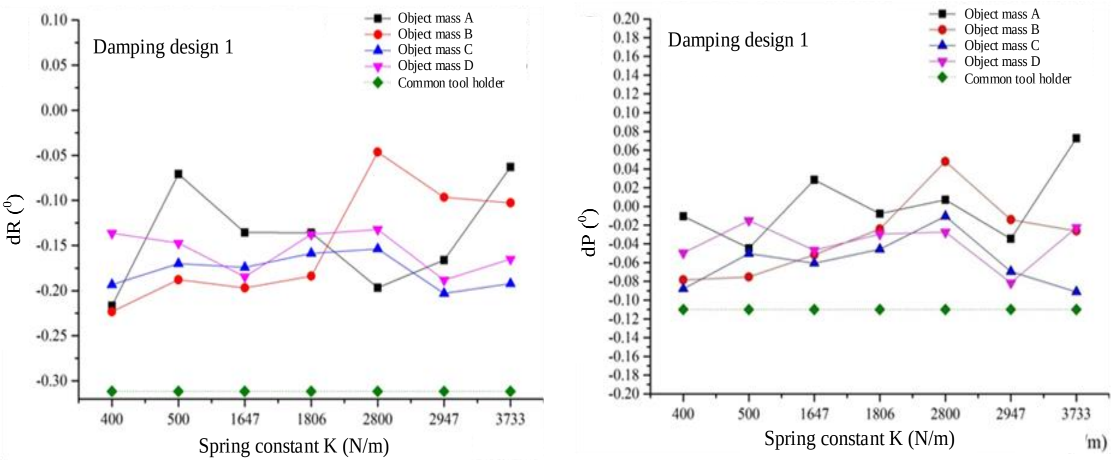
Figure 6: Workpiece dimensions

To evaluate the effect of vibration as well as the damping system on the surface quality of the wrokpiece, it was prepared with a diameter of 28 mm and length of 100 mm. This workpiece was placed on the machine in the position shown in Fig. 6. For measuring the surface roughness, the cutting process was performed at a cutting length of 60 mm. This surface was used for the roughness measurement. The set of damping parameters listed in Table 2was used for 10 workpieces. After the turning process was finished, the roughness was measured five times for each part. Then, the average roughness value was calculated. This result was compared with the vibration-angle result for evaluating the damping effect. In addition, for observing the effect of the damping system on the turning process, a common toolholder was used. Then, the vibration and surface-roughness results were collected and compared. In all the cases, cutting was performed with a cutting depth of 0.5 mm, velocity of 0.05 mm/rev, and spindle speed of 1000 rev/min.

III. RESULTS AND DISCUSSION

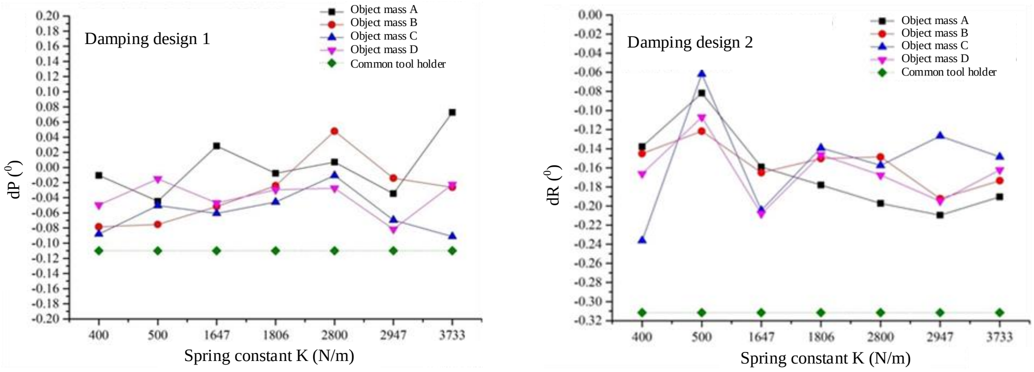
Based on the results obtained through the sensor (Fig. 4 and 5), the vibration angle of the toolholder was measured. These results were compared with Design 1 (Fig. 7) and Design 2 (Fig. 8). The vibration results show that with Design 1, when the spring constant increased from 400 to 3733 N/m, the magnitude of the vibration angle (dP and dR) was smaller than the angle of the common toolholder. When using Design 1, at both vibration angles, the object masses B and C showed a better behavior than the other two. However, when using Design 2, only object mass B showed a good behavior in the vibration result. In detail, when the object mass B was used and the spring constant increased from 400 to 2800 N/m, the angle dR decreased from 0.22331º to 0.04632º with Design 1; however, when the spring constant continually rose to 3733 N/m, the vibration angle increased to 0.10273º. With design 2, when the spring constant increased from 400 to 500 N/m, the angle dR reduced to 0.122º. Comparing Design 1 and 2, the former showed better stability with different object masses and spring constants.

Figure 9a shows the effect of the spring constant and object mass on the surface roughness when Design 1 was used. This result shows that when the spring constant increased from 400 to 3733 N/m, the surface roughness varied in the range of 1.759–0.931 µm, 1.62075–1.005 µm, and 2.963–2.0625 µm with the object masses A, C, and D, respectively. In particular, based on this result, the variation in surface roughness when object mass B was used is unclear. This shows that object mass B is the best option for improving surface roughness with Design 1. This result was obtained with Design 2 as well (Fig. 9b). Therefore, the object mass B was selected for evaluating the effect of the damping system on the surface roughness. Figure 10 shows that the surface roughness varies from 0.925 to 1.169 µm and from 1.22225 µm to 0.84225 µm with design 1 and 2, respectively.



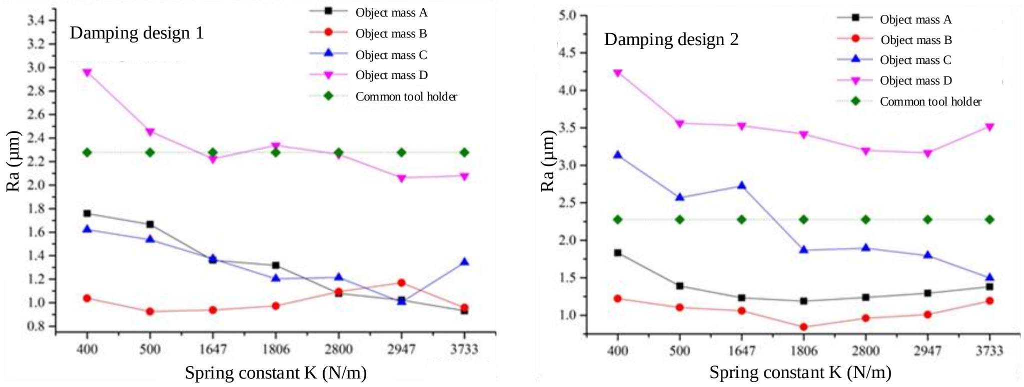
(a) (b)

Figure 7: Vibration angle at dR (a) and dP (b) directions with Design 1 of the damping system



(a) (b)

Figure 8: Vibration angle at dR (a) and dP (b) directions with Design 2 of the damping system



(a) (b)

Figure 9: Surface roughness with Design 2 of the damping system

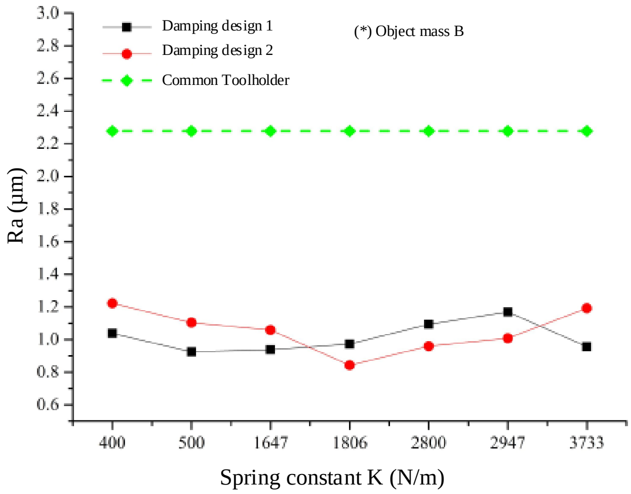


Figure 10: Roughness comparison between Design 1 and 2 and the common toolholder with the object mass B

IV. CONCLUSION

In this study, a turning process was performed for four types of object masses using a damping-system-assisted toolholder with seven different values of the spring constant. The vibrations in the directions of the dP and dR angles were observed. In addition, after performing cutting with different damping systems, the surface roughness were measured and compared. Based on these results, the following conclusions were obtained:

- In general, for both damping designs, the vibration results show that when the spring constant varies from 400 to 3733 N/m, the vibration angles of dR and dP are smaller than the angle of the common toolholder. The object mass B shows a better vibration behavior than the other masses.
- When the spring constant varies, the variation in the surface roughness when object mass B is used is unclear.

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