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Enhancing Chatter Resistance in Deep Hole Boring Through Modified Tool Design: A Study on Impact of Length-To-Diameter (L/D) Ratio

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Abstract

Deep hole boring is a specialized machining process crucial for creating precise bores with high length-to-diameter (L/D) ratios, particularly vital in aerospace, automotive, and oil and gas industries. The L/D ratio is pivotal for stability and performance. Chatter, a detrimental vibration phenomenon, is a significant concern in deep hole boring, influenced by the L/D ratio. Higher L/D ratios increase chatter, leading to poor surface finish and reduced tool life. Longer tool lengths in high L/D ratios reduce damping effects, increasing chatter and impacting machined surface quality. Strategies for mitigating chatter include tailoring tool geometries, implementing damping methods, and adjusting cutting parameters based on specific L/D ratios for optimization. The study employs a three-phase methodology to enhance the dynamic performance of a standard AISI 4340 steel boring tool, S25T SCLCR 09 T3, with a modified version featuring a damper. Modal and harmonic analyses, both numerical and experimental, are conducted to evaluate the natural frequencies, mode shapes, damping ratios, and response to periodic loads. Boring operations are performed under constant conditions, and surface roughness measurements are taken for both the solid and modified tools. The results reveal that the modified tool consistently exhibits lower natural frequencies and higher damping ratios, indicating improved stability during machining. Surface roughness measurements demonstrate a significant percentage improvement for the modified tool, highlighting its effectiveness in enhancing machining precision and chatter resistance. The study contributes valuable insights into the impact of length-to-diameter (L/D) ratio on tool performance, offering practical implications for optimizing machining conditions.

Keywords: Chatter, instability, composite, suppression, monitoring

INTRODUCTION

Deep hole boring, a precision machining technique specialized for creating deep bores with high length-to-diameter (L/D) ratios, places paramount importance on the L/D ratio for stability and performance. This process, vital in industries like aerospace and automotive, employs tools such as gun drills or Boring Trepanning Association (BTA) drills to exceed traditional drilling limits. Chatter, characterized by vibrations leading to compromised surface finish, tool life, and dimensional accuracy, is a significant concern. Increasing L/D ratios intensify chatter likelihood due to longer tool engagements and higher aspect ratios, potentially causing resonance and dynamic instabilities. Inadequate damping, particularly in extended tool lengths, leads to excess chatter, impacting machined surface quality. Chatter-induced vibrations negatively

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affect surface finish, accelerate tool wear, and necessitate conservative cutting parameters, reducing overall efficiency. Mitigating chatter involves tailoring tool geometries, employing effective damping methods, and adjusting cutting parameters based on specific L/D ratios, highlighting the substantial impact of the length-to-diameter ratio on deep hole boring outcomes.

LITERATURE REVIEW

Deep hole drilling, a crucial machining process with diverse applications, is pivotal for creating high depth-to-diameter ratio holes that significantly influence mechanical component performance and reliability. Schmidt *et al*. conducted studies on the Boring Trepanning Association (BTA) deep hole-drilling process, emphasizing the inner force flow within the tool to enhance process control [1, 2]. Zhang *et al*. addressed chatter instability, proposing composite materials for tapered boring bars [3], while Li *et al*. introduced variable stiffness dynamic vibration absorbers (DVA) [4]. Felinks *et al*. focused on deep hole drilling in high-alloyed materials, addressing guide pad wear and chatter vibrations [5]. Research gaps include the need for broader material studies, a deeper understanding of process forces, comprehensive optimization techniques, real-time monitoring, and adaptive control systems.

Bleicher *et al*. investigated low-frequency and high-amplitude vibration-assistance in age-hardened copper-zirconium machining [6]. Li *et al*. optimized cutting parameters for high L/D ratio bottle holes, achieving reduced forces [7]. Reiter *et al*. demonstrated benefits of low-frequency and high-amplitude vibration-assistance in deep hole drilling [8]. Research gaps include model development for high L/D ratios and quantitative comparative analysis. Tang *et al*. used piezoelectric patches to suppress vibration in boring bars, reducing amplitudes [9]. Fallah *et al*. applied adaptive inverse control for internal turning, enhancing stability [10]. Kong *et al*. focused on suppressing vibration modes during deep-hole drilling [11]. Saleh *et al*. introduced an MR damper [12], and Thomas *et al.* presented PID and TMD boring bar models [13]. Sarode *et al*. proposed a particle damping method for chatter suppression [14]. Gaps include integrated techniques, material application, quantitative comparative analysis based on L/D ratios, real-time monitoring, adaptive control systems, and cost-effectiveness.

Zhang *et al*. researched composite material boring bars, emphasizing shear deformation effects [15]. Fallah *et al*. developed an adaptive DVF controller for internal turning, improving dynamic stiffness [16]. Takahashi *et al*. investigated prototypes of boring tools with anisotropic dynamic stiffness [17]. Saleh *et al*. introduced an MR damper with bidisperse MR fluid [18]. Lu *et al*. conducted theoretical analysis for a CFRP boring bar [19]. Peterka *et al*. analyzed internal turning with boring bars in long overhangs [20]. Hendrowati *et al*. explored DVA on a customized boring bar. Research gaps highlight the need for passive damping methods using fluid and lightweight materials [21]. Passive damping methods, such as tuning natural frequencies, adding mass, and altering materials in the tool, have effectively reduced cutting chatter [22]. Investigating chatter suppression, studies explored dynamic vibration absorbers, impact mass dampers, and particle damping systems, utilizing materials like copper, aluminium, zinc particles, and lead-silicon mixtures [23]. Hybrid copper-zinc particles are recognized for cost-effective vibration damping [24]. Particle Impact Dampers (PID) and Tuned Mass Dampers (TMD) are modeled, with particle dampers proving more effective in chatter reduction [25]. Material selection, crucial for static and dynamic stiffness enhancement, favors viscoelastic options like Polyurethane (PU) rubber for damping in single-point cutting tools [26]. Chatter suppression potential is also found in copper-based shape memory alloys, MR fluid with aluminium, and impact dampers with concentrated mass [27]. The review advocates Finite Element Analysis (FEA) for modeling boring tools and underscores tool overhang's importance in chatter reduction [28]. Exploring materials like silicone rubber, natural rubber, and piezoelectric materials for damping, the literature review identifies a research gap in passive damping using fluid and lightweight materials in boring tool design. The project aims to fill this gap by developing a lightweight boring tool with a passive fluid damper using rubber and silicone oil.

METHODOLOGY

The procedure is structured into three primary phases. The initial stage involves conducting modal and harmonic analyses on both the solid tool and the modified tool using ANSYS 2021 R1, considering various overhangs. In the second stage, experimental FFT is performed using tap test equipment to ascertain the natural frequency and damping ratio of both the solid and modified tools across different overhangs. The percentage of error between the experimentally obtained values and numerically obtained values is then calculated. The final stage encompasses executing boring operations with both tools while maintaining a constant feed, speed, and depth of cut for different overhangs. Surface roughness is measured after each trial, and the percentage of improvement in surface roughness is determined.

The chosen boring tool, S25T SCLCR 09 T3, is a standard tool made of AISI 4340 steel with dimensions of 300 mm length and a diameter of 25 mm. To enhance its performance, a modified version is developed, maintaining the same material and dimensions but incorporating a damper. The damper consists of a PU rubber tube filled with silicone oil and assembled to an aluminium rod. The silicone oil selected has a viscosity of 1000 cSt, and a density of 971 kg/m^3. Notably, the damper's weight adheres to the criterion of being 10-times lighter than the solid tool, with the solid tool weighing 1080 g and the damper 180 g. Both tools undergo modal and harmonic analyses using ANSYS 2021 R1. Modal analysis is employed to determine natural frequencies, mode shapes, and damping ratios, offering insights into vibration behavior and potential resonance frequencies. Meanwhile, harmonic analysis assesses the response of the tools to periodic loads at specific frequencies. The standard boring tool features AISI 4340 steel and a tungsten carbide insert of grade CTC 2135 (catalogue number CCMT 09T304). The damper, distinct in its composition of rubber and aluminium, is a valuable addition to enhance the dynamic performance of the modified tool (Table 1).

The components in the assembly are assigned specific mesh sizes for the analysis. The tool body is discretized with a mesh size of 2 mm, ensuring a balance between computational efficiency and accuracy. The insert, rubber tube, and aluminium rod, crucial elements of the assembly, are assigned a finer mesh size of 1 mm. This finer mesh resolution allows for a more detailed representation of these components in the numerical simulations. The variation in mesh sizes reflects a thoughtful consideration of the trade-off between computational resources and the need for precise modeling, ensuring a comprehensive analysis of the structural and mechanical behavior of each part in the assembly (Table 2).

The tap test assesses vibration characteristics by generating vibrations through tapping an object and analyzing the resulting sound and vibrations. In Figure 1, the tap test apparatus includes an accelerometer, sensing acceleration signals sent to a data acquisition system (Figure 1). The impact hammer and 8 Channel Data Acquisition (DAQ) System (Figure 2) excite the system and collect data, with Dewe soft Software performing FFT to determine natural frequency and damping ratio for varying overhangs.

Table 1. Material properties.

Material	Young's modulus (Mpa)	Poisson's ratio	Density (kg/mm^3)
Alloy steel 4340	2.09E+05	0.3	7.85E-06
Aluminium	7.00E+04	0.33	2.71E-06
PU Rubber	0.049	0.279	3.19E-08
Tungsten carbide	5.55E+05	0.28	1.58E-05

Table 2. Considerations for L/D Ratio.

L/D ratio	Fixed support (top and bottom (mm))	Overhang at free end (mm)
4	25	100
5	25	125
6	25	150
7	25	175
8	100	200

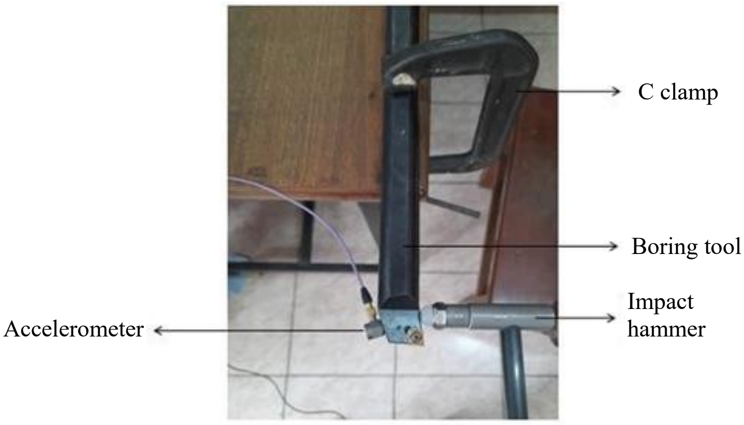

Figure 1. Tap test setup.

Figure 2. Impact hammer and 8 channel data acquisition (DAQ) system.

Table 3. Cutting Parameters.

Cutting parameter	Value
Speed	1000 rpm
Feed	0.2 mm/rev
Depth of Cut	0.8 mm

Boring operation using solid tool and modified tool is performed for L/D=4, 5, 6, 7 and 8 in Kirloskar turn master 45. During the entire experiment speed, speed and depth of cut is maintained constant. Table 3 shows the cutting parameters used for the boring operation.

An EN8 material workpiece, 60 mm in diameter and 80 mm in length with a hardness of 35 HRC, was used in experiments conducted on a Kirloskar lathe Turn master 45. The lathe machine specifications include a 5.5 kW main motor, 415 V power supply, 225 mm height of center and 1000 mm distance between centers. The machining process involved facing, center drilling, turning, 25 mm drilling, and boring operations. Boring operation was performed as per IS 11958. Using a Tungsten Carbide insert of 0.4 mm nose radius. Surface roughness measurements were conducted for each trial of different L/D ratios using both the solid and modified tools. The surface roughness apparatus employed a Mitutoyo 178-561-02A Surf test SJ-210 Surface Roughness Tester, connected to a laptop with dedicated software. Mitutoyo software, facilitated surface roughness measurement according to ISO 1997 standards. The measurement process involved placing the tester probe on the surface, initiating the measurement option in the software, and allowing the probe to move horizontally for 2 to 3 sec to collect roughness data, providing Ra, Rz, and Rq values.

RESULTS AND DISCUSSIONS

Simulation

The Siemens NX software was used to model the tool, and it was then imported into ANSYS Workbench 2021 R1. The SOLID 187 element with degrees of freedom UX, UY, and UZ was employed, representing a 3-D 10-Node Tetrahedral Structural Solid. The obtained aspect ratio and Jacobin ratio were 1 and 1.01, respectively. For the solid tool, there were 215,503 nodes and 149,366 elements, whereas the modified tool comprised 344,165 nodes and 203,973 elements. A 4 mm diameter circular face, corresponding to the impact hammer tip diameter, was generated near the tool tip. Subsequently, a 10 N force was applied along the Y-axis, and the frequency response was analyzed on the opposite face of the tool. Another 4 mm diameter circular face was established on the opposite side of the applied force, and the frequency response was assessed along the Y-axis.

Table 4 presents the natural frequencies for both the solid tool and modified tool at various length-to-diameter (L/D) ratios. Natural frequency is a fundamental parameter in structural dynamics, indicating the inherent vibrational characteristics of a system. The L/D ratio is a critical factor influencing the dynamic behavior of the tools. As the L/D ratio increases, there is a general trend of decreasing natural frequencies for both the solid and modified tools. For the solid tool, the natural frequencies vary between a minimum and maximum for each L/D ratio. The range of natural frequencies widens with higher L/D ratios, indicating increased variability in the vibrational behavior. Similar to the solid tool, the modified tool exhibits a range of natural frequencies for each L/D ratio. The modified tool generally shows lower natural frequencies compared to the solid tool, suggesting the effectiveness of the damping mechanism.

At an L/D ratio of 4, the modified tool's natural frequencies range from 925.37 to 6359.2 Hz, while the solid tool ranges from 1694.9 to 9398.8 Hz. The modified tool consistently demonstrates lower frequencies. As the L/D ratio increases, the modified tool consistently exhibits lower natural frequencies than the solid tool. This trend indicates that the modification, likely the addition of a damper, is effective in reducing vibrational frequencies. Lower natural frequencies in the modified tool suggest improved damping and reduced potential for resonance, which is beneficial for stability during machining operations. The statistical range provides insights into the tool's dynamic behavior under varying L/D ratios, aiding in the selection of optimal machining conditions.

Tap Test

Figures 3–7 provide the plots generated for amplitude versus frequency during the Tap Test. Table 5 provides valuable insights into the damping ratios for both the solid and modified tools at various L/D ratios, along with the percentage improvement in damping achieved by the modified tool compared to the solid tool. For an L/D ratio of 4, the solid tool exhibits a damping ratio of 0.013, while the modified tool shows an increased damping ratio of 0.020. At an L/D ratio of 5, the solid tool's damping ratio is 0.001, significantly lower than the modified tool's damping ratio of 0.048. The trend continues, with the modified tool consistently displaying higher damping ratios at L/D ratios of 6, 7, and 8. The percentage improvement in damping is calculated by comparing the damping ratios of the modified tool to the solid too. Across all L/D ratios, the modified tool demonstrates substantial improvements in

Table 4. Natural Frequency Values.

l/d ratio	Natural frequency for solid tool (Hz)		Natural frequency for modified tool (Hz)	
	Min.	*Max.*	*Min.*	*Max.*
4	1694.9	9398.8	925.37	6359.2
5	1219.1	7387.5	893.37	4951.7
6	838.41	5787.9	758.837	4032.8
7	616.76	4833.5	558.96	3531.3
8	451.59	3704.2	435.77	2668.8

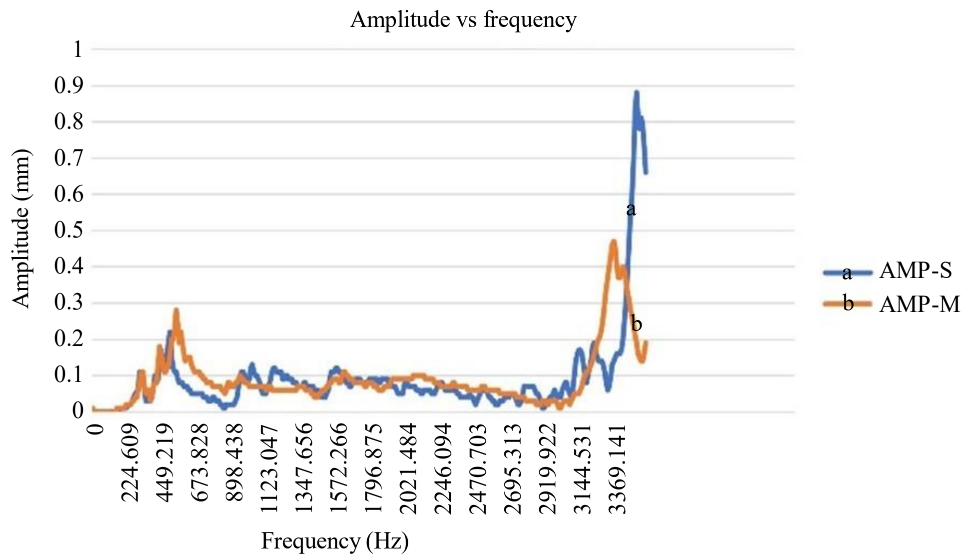

Figure 3. Amplitude vs. frequency for L/D=4.

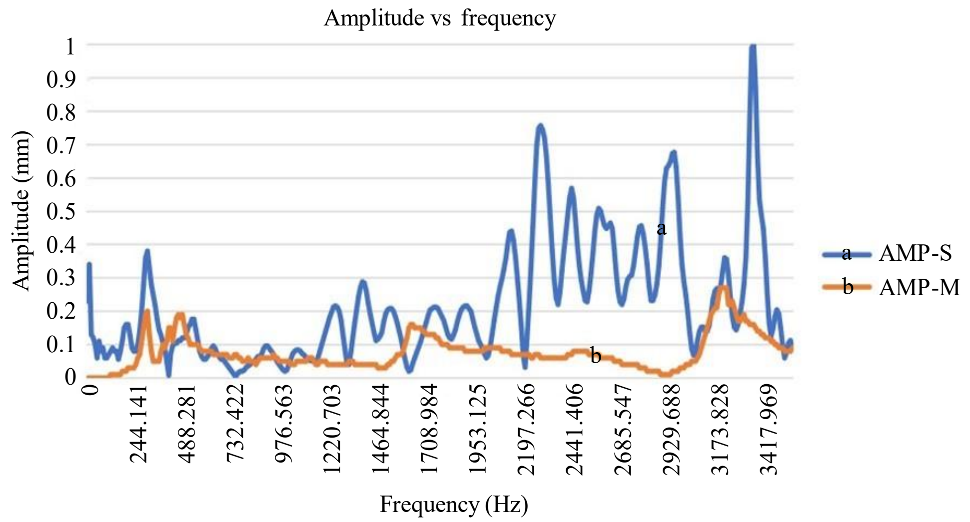

Figure 4. Amplitude vs. frequency for L/D=5.

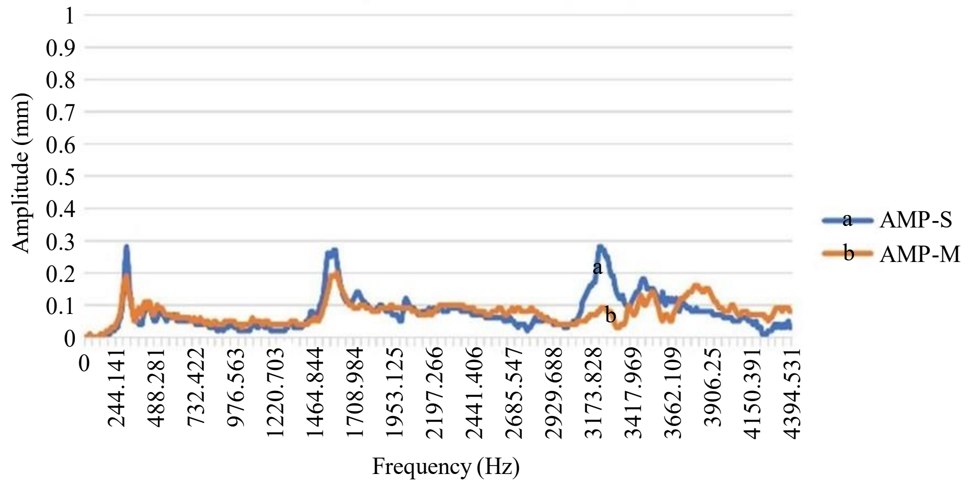

Figure 5. Amplitude vs. frequency for L/D=6.

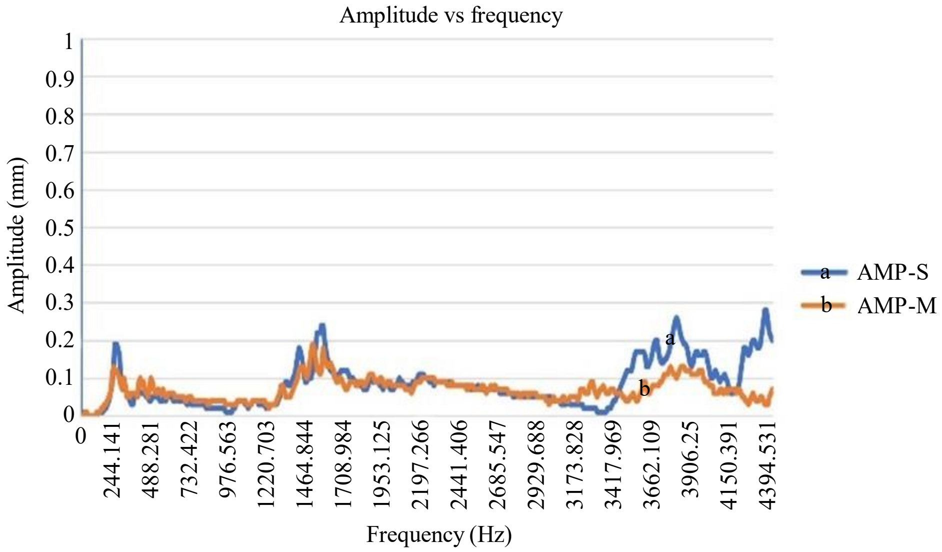

Figure 6. Amplitude vs. frequency for L/D=7.

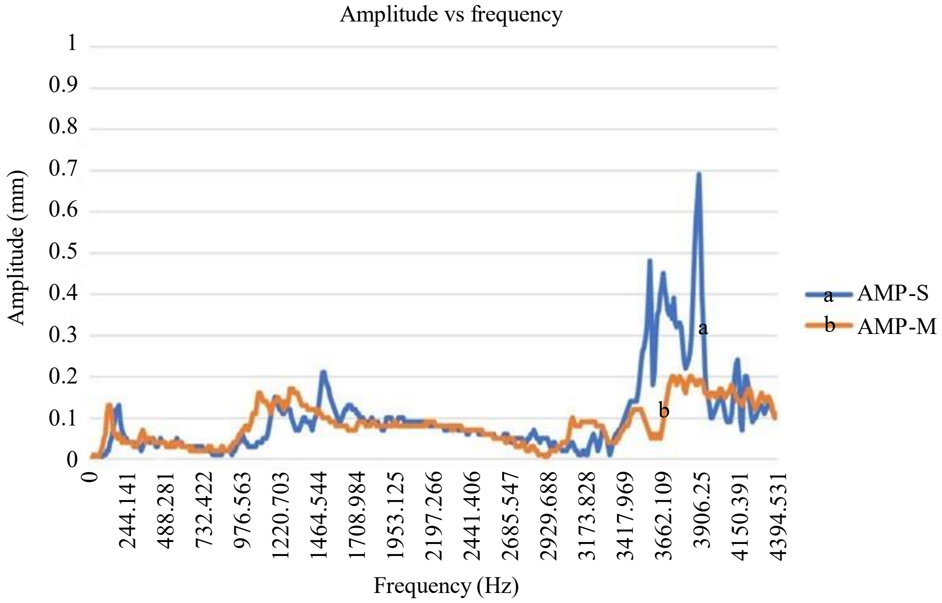

Figure 7. Amplitude vs. frequency for L/D=8.

Table 5. Comparison of damping ratio values.

L/D	Overhang (mm)	Damping ratio solid	Damping ratio modified	Percentage improvement (%)
4	100	0.013	0.02	53.8
5	125	0.001	0.048	47.2
6	150	0.053	0.083	56.6
7	175	0.045	0.067	48.8
8	200	0.005	0.007	40

damping over the solid tool, with percentages ranging from 40 to 56.6%. In summary, the modified tool consistently outperforms the solid tool in terms of damping ratios, with notable percentage improvements at each L/D ratio. This indicates that the modifications made to the tool design contribute to enhanced damping characteristics, potentially leading to improved machining performance and stability.

Surface Roughness Measurement

Table 6 provides surface roughness (Ra and Rz) measurements for both solid and modified tools at different length-to-diameter (L/D) ratios and overhang distances. It also includes the percentage of improvement in surface roughness for the modified tool compared to the solid tool. Ra values for the solid tool range from 2.3 to 11.49 µm, and Rz values range from 10.92 to 54.33 µm. Modified tool Ra values range from 1.46 to 8.79 µm, and Rz values range from 8.04 to 41.29 µm. The modified tool consistently demonstrates a percentage improvement in surface roughness (Ra and Rz) compared to the solid tool. Ra improvement ranges from 27.2 to 37.8%, and Rz improvement ranges from 24 to 28%. The overhang distances vary from 100 to 200 mm for different L/D ratios. The modified tool consistently outperforms the solid tool in terms of surface roughness improvement across different L/D ratios and overhang distances.

The percentage of improvement metrics shows relatively consistent improvements in both Ra and Rz for varying L/D ratios. The modified tool consistently produces a smoother surface finish (lower Ra and Rz values) compared to the solid tool, indicating enhanced machining precision. The percentage of improvement metrics provides insights into the practical benefits of using the modified tool under different machining conditions. Detailed statistical measures such as standard deviation and confidence intervals could provide additional insights into the variability and reliability of the surface roughness data. In summary, the table highlights the consistent improvement in surface roughness achieved by the modified tool across various L/D ratios and overhang distances, demonstrating its effectiveness in enhancing machining quality (Figure 8).

In Figures 9 and 10, the distinction between chatter and chatter-free surfaces for L/D=8 is evident. Chatter occurred during machining with the solid tool, while the modified tool yielded a chatter-free surface. The comparison reveals higher surface roughness with the solid tool and reduced surface roughness with the modified tool under the same L/D ratio.

Table 6. Comparison of Surface Roughness Values.

l/d	Overhang (mm)	Ra of solid tool (µm)	Ra of modified tool (µm)	Rz of solid tool (µm)	Rz of modified tool (µm)	% improvement in Ra	% Improvement in Rz
4	100	2.3	1.46	10.9	8.04	36.3	26
5	125	2.65	1.72	13.4	10.08	35.09	25
6	150	5.94	3.69	28.1	20.16	37.8	28
7	175	8.81	5.68	44.2	31.66	35.5	28
8	200	11.5	8.79	54.3	41.29	27.2	24

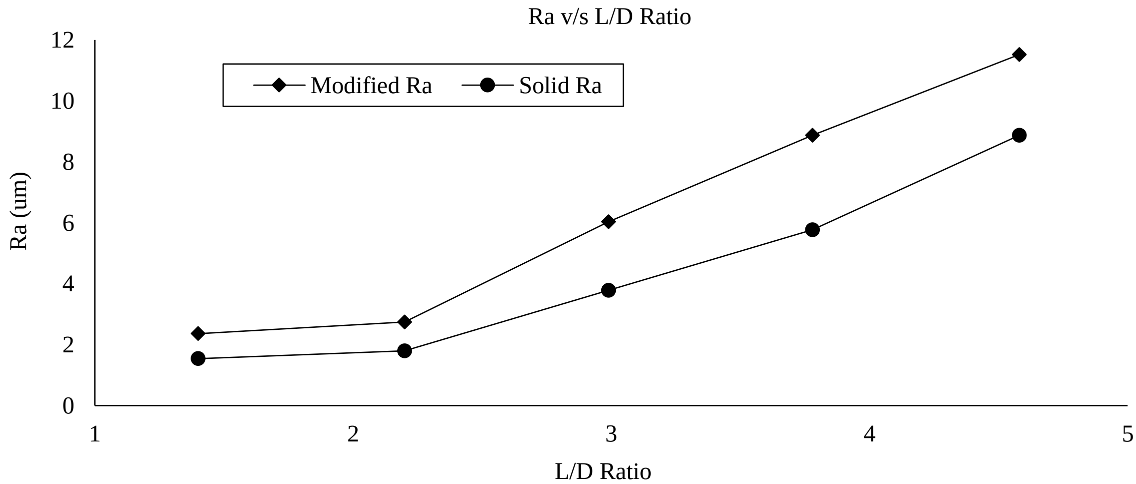

Figure 8. Ra vs. L/D ratio.

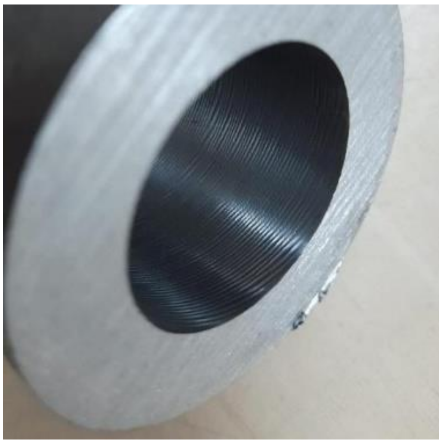

Figure 9. Machined surface with chatter.

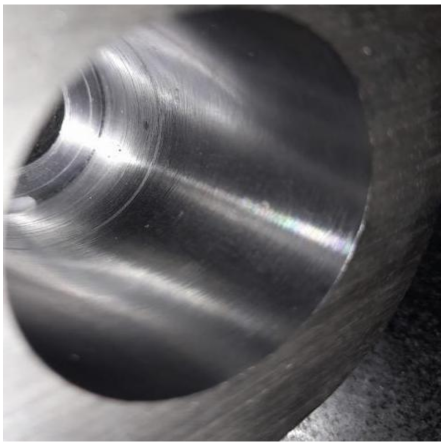

Figure 10. Chatter free machined surface with modified tool.

CONCLUSION

The simulation, tap test, and surface roughness measurements provide a comprehensive understanding of the dynamic behavior and performance of both the solid and modified tools. Natural frequencies for both tools were presented for varying L/D ratios. The solid tool exhibited higher natural frequencies across all L/D ratios. The modified tool consistently showed lower natural frequencies, indicating improved damping characteristics. Clear distinction between chatter and chatter-free surfaces was observed for L/D=8, with the solid tool exhibiting chatter and the modified tool providing a chatter-free surface. Table 6 presented damping ratios for both tools at different L/D ratios, demonstrating significant improvement percentages for the modified tool. The modified tool consistently demonstrated a percentage improvement in both Ra and Rz compared to the solid tool.

The simulation results indicate the modified tool's superiority in damping and reduced natural frequencies, contributing to enhanced stability during machining. The tap test confirmed the chatter-free performance of the modified tool compared to the solid tool, aligning with the simulation predictions. Surface roughness measurements highlighted consistent improvements in the modified tool, affirming its potential for achieving superior machining quality. In summary, the integration of simulation, experimental tap testing, and surface roughness analysis provides a comprehensive evaluation of the modified tool's performance, emphasizing its potential for improved stability and machining quality compared to the solid tool.

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REFERENCES

1. Schmidt R, Strodick S, Walther F, Biermann D, Zabel A. Influence of the process parameters and forces on the bore sub-surface zone in BTA deep-hole drilling of AISI 4140 and AISI 304 L. Procedia CIRP. 2020; 87: 41–46.
2. Schmidt R, Strodick S, Walther F, Biermann D, Zabel A. Analysis of the functional properties in the bore sub-surface zone during BTA deep-hole drilling. Procedia CIRP. 2020; 88: 318–323.
3. Zhang C, Ren Y, Ji S, Zhang J. Analysis of the vibration and chatter stability of a tapered composite boring bar. Shock Vibr. 2020; 2020: 4190806(11p).
4. Li L, Sun B, Hua H. Analysis of the vibration characteristics of a boring bar with a variable stiffness dynamic vibration absorber. Shock Vibr. 2019; 2019: 5284194.

5. Felinks N, Rinschede T, Biermann D, Stangier D, Tillmann W, Fuß M, Abrahams H. Investigation into deep hole drilling of austenitic steel with advanced tool solutions. Int J Adv Manuf Technol. 2021; 118(2): 1087–1100.
6. Bleicher F, Reiter M, Brier J. Increase of chip removal rate in single-lip deep hole drilling at small diameters by low-frequency vibration support. CIRP Ann. 2019; 68(1): 93–96.
7. Li W, Zheng H, Feng Y. Optimization of Cutting Parameters for Deep Hole Boring of Ti-6Al-4V Deep Bottle Hole. Materials. 2023; 16(15): 5286.
8. Reiter M, Bleicher F, Bleicher F, Brier J. Affectation of chip formation in single-lip deep hole drilling at small diameters by application of low-frequency vibration support. MM Sci J. 2019; 2019(04): 3107–3113.
9. Tang B, Akbari H, Pouya M, Pashaki PV. Application of piezoelectric patches for chatter suppression in machining processes. Measurement. 2019; 138: 225–231.
10. Fallah M, Moetakef-Imani B. Adaptive inverse control of chatter vibrations in internal turning operations. Mech Syst Signal Process. 2019; 129: 91–111.
11. Kong L, Cao S, Chin JH, Si Y, Miao F, Li Y. Vibration suppression of drilling tool system during deep-hole drilling process using independence mode space control. Int J Mach Tools Manuf. 2020; 151: 103525.
12. Saleh MK, Nejatpour M, Acar HY, Lazoglu I. A new magnetorheological damper for chatter stability of boring tools. J Mater Process Technol. 2021; 289: 116931.
13. Thomas W, Peterka J, Szabó T, Albuquerque MV, Pederiva R, Kiss LP. Analytical and Experimental Investigation of the Dynamic Stability in Passive Damper Boring Bars. Procedia CIRP. 2023; 117: 187–192.
14. Sarode MK, Nehe P, Deshpande MS. Chatter mitigation in boring machining process. Int J Adv Sci Res Eng Trends. 2020; 5(9): 27–34.
15. Zhang C, Ren Y, Ji S, Zhang J. Analysis of the composite boring bar dynamic characteristics considering shear deformation and rotational inertia. Appl Sci. 2020; 10(4): 1533.
16. Fallah M, Moetakef-Imani B. Design, analysis, and implementation of a new adaptive chatter control system in internal turning. Int J Adv Manuf Technol. 2019; 104(5–8): 1637–1659.
17. Takahashi W, Suzuki N, Shamoto E. Development of a novel boring tool with anisotropic dynamic stiffness to avoid chatter vibration in cutting: Part 2: Analytical and experimental verification of the proposed method. Precis Eng. 2021; 68: 20–34.
18. Saleh MK, Nejatpour M, Acar HY, Lazoglu I. A new magnetorheological damper for chatter stability of boring tools. J Mater Process Technol. 2021; 289: 116931.
19. Lu L, Ni C, Liu G, Qian B, An Q, Cao Z, Zhang L, Li J. Analysis and Development of the CFRP Boring Bar for Stability Improvement. Fibers Polym. 2023; 24(12): 4413–4427.
20. Peterka J, De Silva WT, Straka R, Vopát T, Hrbál J, Kritikos M. Analysis of form Error and Roughness of Hardened Steel Workpieces Internally Turned with Different Tools in Long Overhangs. Research Papers Faculty of Materials Science and Technology Slovak University of Technology. 2022; 30(50): 21–29.
21. Hendrowati W, Merdekawan N. Modeling and analysis of boring bar vibration response in internal turning due to variation of the amount of DVA rubber in finish boring cut. J Mech Sci Technol. 2021; 35(10): 4353–4362.
22. Rubio Ruiz de Aguirre ML, Loya Lorenzo JA, Miguélez Garrido MH, Fernández-Sáez J. Optimization of passive vibration absorbers to reduce chatter in boring. Mech Syst Signal Process. 2013; 41(1–2): 691–704.
23. Altintas Y, Lappin D, van Zyl D, Östling D. Automatically tuned boring bar system. CIRP Ann. 2021; 70(1): 313–316.
24. Ramesh K, Alwarsamy T, Jayabal S. Investigation of chatter stability in boring tool and tool wear prediction using neural network. Int J Mater Prod Technol. 2013; 46(1): 47–70.
25. Paul P, Varadarajan AS. Effect of Impact Mass on Tool Vibration and Cutting Performance During Turning of Hardened AISI4340 Steel. Rom J Acoust Vib. 2014; 11(2): 154–163.
26. Chen F, Lu X, Altintas Y. A novel magnetic actuator design for active damping of machining tools. Int J Mach Tools Manuf. 2014; 85: 58–69.
27. Lawrance G, Sam Paul P, Varadarajan AS, Ajay Vasanth X, Raj SB. Suppression of tool vibration in boring process: a review. J Inst Eng (India): Ser C. 2019; 100(4): 1053–1069.
28. Chockalingam S, Natarajan U, George Cyril A. Damping investigation in boring bar using hybrid copper-zinc particles. J Vib Control. 2017; 23(13): 2128–2134.

