RP Current Trends In Engineering And Technology (e-ISSN: 2583-5491)
Vol. 5, No. 2 (April – June 2026) pp. 36–39

Cite this article: S. Mishra, S.R. Das, S.K. Sahu, Enhanced machinability of AISI 6150 steel using micro textured cutting tools under MQL, *RP Cur. Tr. Eng. Tech.* **5** (2026) 36–39.

Original Research Article

Enhanced machinability of AISI 6150 steel using micro textured cutting tools under MQL

Sarita Mishra[1], Sudhansu Ranjan Das[2], Santosh Kumar Sahu[1,*]

[1]Department of Mechanical Engineering, Veer Surendra Sai University of Technology, Burla, Sambalpur, Odisha, India
[2]Department of Production Engineering, Veer Surendra Sai University of Technology, Burla, Sambalpur, Odisha, India
*Corresponding author, E-mail: sksahu_me@gmail.com

ARTICLE HISTORY
Received: 16 April 2026
Revised: 26 May 2026
Accepted: 27 May 2026
Published: 13 June 2026

KEYWORDS
Turning; AISI 6150 spring steel; AlTiSiN coated tool; Surface texturing; Machinability; MQL; Cost estimation.

ABSTRACT
This research is to give comparative machining performance of plain and micro-textured AlTiSiN-coated carbide tools under minimum quantity lubrication (MQL) during turning the AISI 6150 spring steel. These were the machinability in terms of tool wear, tool life, cutting temperature, surface finish, chip morphology and vibration. The micro-textured tool cut down on wear on the flank and crater compared to the plain tool, reduced the cutting temperature, improved the quality and extended the tool life of the surface. The texture tools formed chips more uniformly and lower thermal concentration was detected for the textured tools, while plain tools formed serrated chips that promoted wear, as observed from the results of thermograms. In original formation with texture tools, an economic analysis using Gilbert estimate production cost was nearly 9% lower. These enable reduced friction, better retention of the lubricant and improved heat dissipation which results in higher performance.

1. Introduction

Chromium vanadium steel AISI 6150 is extensively used as a critical engineering component such as gears, crankshafts and connecting rods because of its high strength, good fatigue strength and good hardenability [1]. To improve its mechanical performance even further, heat treatment processes such as austempering and traditional quenching and tempering have also been extensively embraced. Austempering is especially beneficial among them since it results in the development of a bainitic microstructure, which is much more beneficial in terms of strength, toughness, and wear resistance [2]. Nevertheless, these positive characteristics do not eliminate the fact that because of its high strength and ability to resist plastic deformation AISI 6150 steel may be considered as the difficult-to-machine material. This causes the overheating in the cutting area, rapid degradation of the tool, and degradation of the surface integrity when using turning processes [5]. Though flood cooling methods are considered to be effective in lowering cutting temperature, they are related to higher operation costs, environmental risks and possible health risks to operators. To address these issues, Minimum Quantity Lubrication (MQL) has become a viable and environmentally friendly alternative, with a tremendous decrease in the amount of coolant used and still providing sufficient lubrication and cooling effect [6]. Moreover, recent advances in machining research have highlighted the importance of surface texturing of cutting tools as a novel strategy to improve tribological behaviour in the tool chip interface. Micro-texturing of the tool surface reduces friction and minimizes tool-chip contact length and enables effective retention of lubrication, hence enabling enhanced heat dissipation [713]. Also, various texture geometries, such as grooves, pits, and hybrid forms have shown significant increases in machining performance over non-textured tools of the time, so surface texturing presents a promising approach to improving machinability and tool life.

2. Experimental setup

The flow chart illustrating the process of the experiment conducted in this study has been provided in Fig. 1. The geometry design of the cutting tool was done with the CAD software, followed by the micro-textures in the form of spot and channel patterns on the rake face of the tool, in a micro-laser machining process. The ready textured tools and a conventional plain tool were then used in turning operations under a lathe machine under controlled machining parameters. After the machining process, the tools were systematically assessed in terms of their performance by employing various characterization methods. The roughness of the surface of the machined specimens was measured with a roughness tester, and the tool wear and the surface morphology were studied with an optical microscope and SEM. Moreover, the analysis of SEM was conducted in detail to get high-resolution images of the plain, spot-textured, and channel-textured tools. The machining performance was compared by these observations to gain understanding of the impact of micro-texturing on the tool behaviour, and machining characteristics.

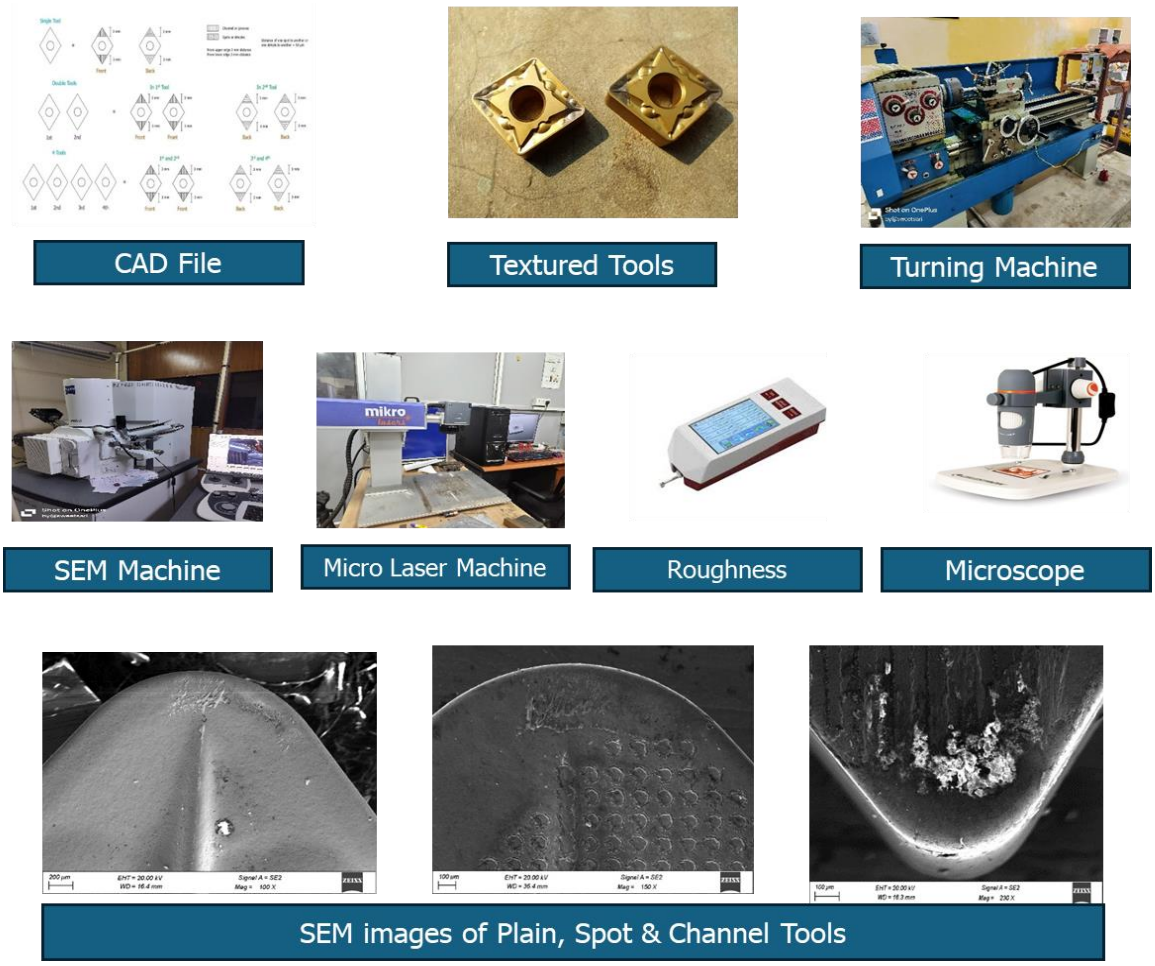

Figure 1: Schematic of experimental layout.

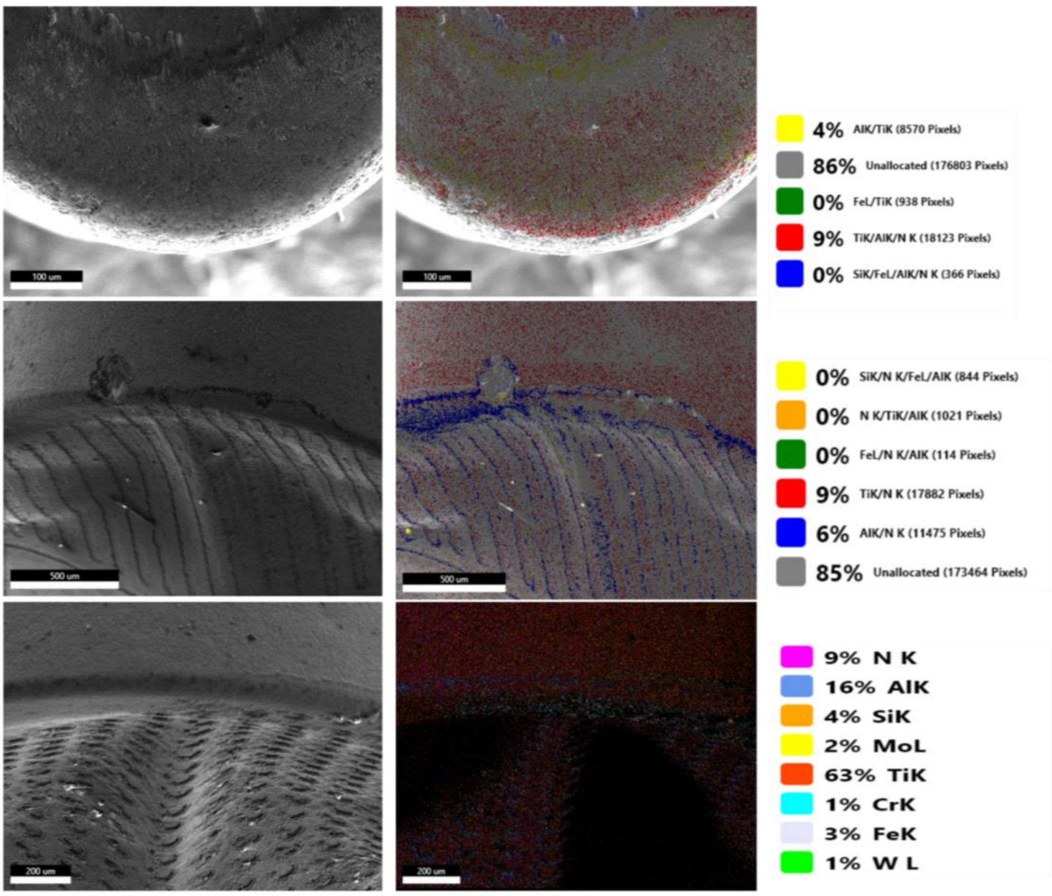

Figure 2: SEM and EDS under cutting conditions with colour mapping images of wear on rake face.

3. Result analysis

3.1 Tool wear analysis (SEM–EDS)

Figure 2 indicates the relative machining performance of plain, spot-textured and channel-textured cutting tools. The findings have shown that textured tools would perform better compared to the plain tool in terms of less tool wear and better surface finish. The channel-textured tool is the best among them because of the low level of tool chip contact and low friction. This enhancement is explained by the fact that micro-textures serve as reservoirs of lubricants and traps of debris, reducing heat generation and wear. Generally, texturing of surfaces can greatly increase the efficiency of machining in comparison to traditional tools.

3.2 Analysis on chip morphology

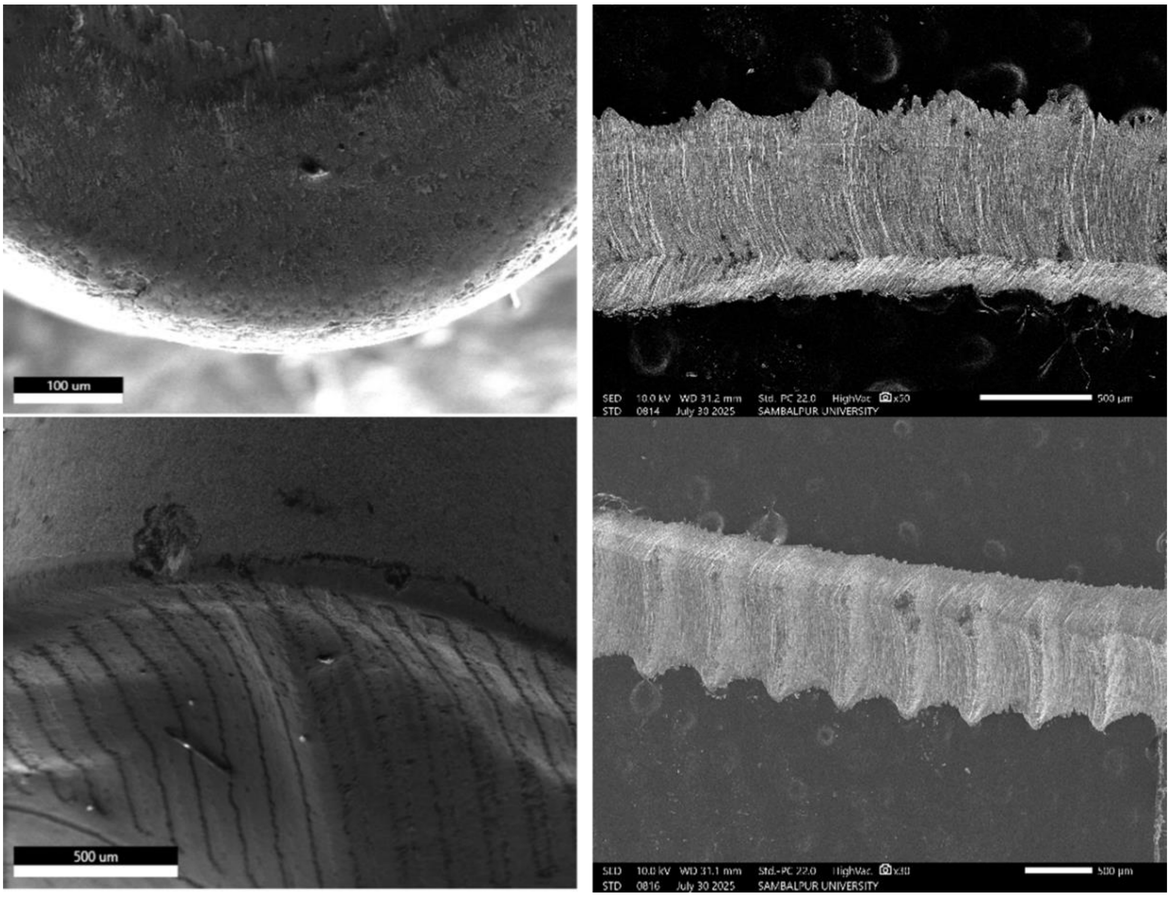

Figure 3: SEM images of chip morphology and tools working at various conditions and rotating with: (a) non-textured and (b) textured tools.

Table 1: Comparative analysis of chip morphology and deformation characteristics.

Aspect	**Conventional (Plain) Tool**	**Textured Tool**
Chip morphology	Irregular, coarse, wavy chips	Fine, regular, uniform chips
Serration pattern	Non-uniform, large amplitude, irregular pitch	Uniform, smaller pitch, reduced amplitude
Chip thickness	Highly variable along length	More consistent thickness
Deformation behaviour	Non-uniform deformation with severe plastic instability	Controlled deformation with stable shear localization
Shear bands	Non-uniform, irregular spacing	Distinct, evenly spaced shear bands
Chip edges	Pronounced serrations and shear lips	Smooth chip surfaces
Thermal effects	High heat generation due to friction and adhesion	Reduced shear band temperature
Material flow	Inconsistent and unstable	Smooth and consistent
Chip control	Poor chip control	Improved chip control
Failure mechanism	Tearing and micro-fractures at serration tips	Controlled segmentation without tearing
Surface interaction	High friction and adhesion at tool–chip interface	Reduced friction due to texturing
Overall performance	Unstable cutting with defects	Stable cutting with improved chip formation

4. Conclusions

The results show that the micro-channel textured inserts are easier to machine compared to plain inserts as evidenced by less flank and crater wear, longer life, and higher-quality surface finish, decreased cutting temperature, and reduced tool vibration.

- Findings include Micro-pit textured inserts are more easily machined compared to plain inserts which have lower flank and crater wear, longer tool life, improved surface finish, reduced cutting temperatures, and reduced tool vibration. Textured inserts provide better performance by decreasing friction and contact with tool chips, increasing heat dissipation and lubricant retention, improving better chip control, and reducing BUE formation.

Serrated chips with high shear bands result in formation of burrs at edges making the tool work interface to be more prone to be frictional. Such chip edges may wear the tool at an accelerated rate by producing micro-grooves on the flank face because of repeated abrasion.

Authors' contributions

All authors contributed equally to the conception, design, experimental work, data analysis, interpretation of results, and preparation of the manuscript. All authors reviewed and approved the final version of the manuscript for publication.

Conflicts of interest

The author declares no conflict of interest.

Funding

This research received no external funding.

Data availability

No new data were created.

References

[1] H. Li, J. Hu, J. Li, G. Chen, X. Sun, Effect of tempering temperature on microstructure and mechanical properties of AISI 6150 steel, *J. Cent. South Univ*. **20** (2013) 866–870.

[2] J.M. Tartaglia, K.L. Hayrynen, A comparison of fatigue properties of austempered versus quenched and tempered 4340 steel, *J. Mater. Eng. Perform.* **21** (2011) 1008–1024.

[3] D. Edmonds, K. He, F. Rizzo, B. De Cooman, D. Matlock, J. Speer, Quenching and partitioning martensite—a novel steel heat treatment, *Mater. Sci. Eng. A* **438–440** (2006) 25–34.

[4] F.S. Shen, G. Krauss, The effect of phosphorous content and proeutectoid carbide distribution on the fracture behaviour of 52100 steel, *HTM J. Heat Treat. Mater*. **2** (1982) 238–249.

[5] W.F. Sales, J. Schoop, L.R. da Silva, Á.R. Machado, I.S. Jawahir, A review of surface integrity in machining of hardened steels, *J. Manuf. Process*. **58** (2020) 136–162.

[6] E. Kuram, A. Bagherzadeh, E. Budak, Application of cutting fluids in micromilling—A review, *Int. J. Adv. Manuf. Technol*. **133** (2024) 25–58.

[7] O. Pereira, A. Rodríguez, A.I. Fernández-Abia, J. Barreiro, L.L. de Lacalle, Cryogenic and minimum quantity lubrication for an eco-efficiency turning of AISI 304, *J. Clean. Prod*. **139** (2016) 440–449.

[8] M. Pang, Y. Nie, L. Ma, Effect of symmetrical conical micro-grooved texture on tool–chip friction property of WC–TiC/Co cemented carbide tools, *Int. J. Adv. Manuf. Technol*. **99** (2018) 737–746.

[9] Y. Wei, M.R. Kim, D.W. Lee, C. Park, S.S. Park, Effects of micro textured sapphire tool regarding cutting forces in turning operations, *Int. J. Precis. Eng. Manuf.-Green Technol*. **4** (2017) 141–147.

[10] Y. Liu, J. Deng, F. Wu, R. Duan, X. Zhang, Y. Hou, Wear resistance of carbide tools with textured flank-face in dry cutting of green alumina ceramics, *Wear* **372** (2017) 91–103.

[11] S.K. Mishra, S. Ghosh, S. Aravindan, Characterization and machining performance of laser-textured chevron shaped tools coated with AlTiN and AlCrN coatings, *Surf. Coat. Technol*. **334** (2018) 344–356.

[12] J. Sun, Y. Zhou, J. Deng, J. Zhao, Effect of hybrid texture combining micro-pits and micro-grooves on cutting performance of WC/Co-based tools, *Int. J. Adv. Manuf. Technol*. **86** (2016) 3383–3394.

[13] Y. Xing, J. Deng, J. Zhao, G. Zhang, K. Zhang, Cutting performance and wear mechanism of nanoscale and microscale textured Al_2O_3/TiC ceramic tools in dry cutting of hardened steel, *Int. J. Refract. Met. Hard Mater*. **43** (2014) 46–58.