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### CONFERENCE PAPER

## SUSTAINABLE TURNING PERFORMANCE OF AISI 6150 STEEL USING MICRO-TEXTURED ALTiSiN TOOLS UNDER RADIATOR COOLANT BASED MQL

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#### Abstract

The present research explores the machinability of AISI 6150 chromium vanadium steel when it is being turned using micro-textured ALTiSiN-coated carbide inserts under Minimal Quantity Lubrication (MQL) conditions with automotive radiator coolant. Textures of micro-channels and micro-pits were created on the tool rake face to increase tribological behavior. A series of comparative experiments were carried out with non-textured tools at different cutting parameters. The findings show that textured tools large-scale minimize cutting temperature (down to about 25 C), tool wear, and friction and enhance surface finish and tool life. It is believed that these enhancements are due to decreased tool-chip contact area, increased lubricant retention and better heat dissipation. MQL with radiator coolant can also offer a low-cost and greener alternative to the conventional cooling methods and the cost of machining will be lowered by approximately 9%.

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#### Introduction:-

The AISI 6150 chromium-vanadium steel is very common in the automotive industry because it has high strength, toughness and fatigue resistance that are further promoted by heat treatment procedures like austempering [1]. The material is, however, also hard to machine resulting in high cutting temperatures, high tool wear and low surface integrity. Surface integrity is of great importance because it directly affects the fatigue behaviour and service life of machined components [2]. The cutting fluids play a crucial role in minimizing friction and heat production during machining. The traditional flood cooling technologies, though efficient, are environmentally and economically problematic. A new sustainable solution called the Minimum Quantity Lubrication (MQL) has been developed that provides good lubrication with a minimum fluid usage [3,4]. It has been demonstrated that MQL can greatly lower

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cutting temperature, tool wear, and friction in comparison to dry and wet machining conditions [5,8], and recently, new developments further improve its efficiency and sustainability [6,7]. Also, the tool coating like AlTiSiN enhances wear resistance and thermal stability during machining [1012]. In more recent times, there has been interest in micro-texturing cutting tools as a new state-of-the-art to enhance tribological behaviour. Micro-textured tools minimize the tool-chip contact area, and increase the retention of lubricant, which leads to reduced friction and better heat dissipation. Some of the studies have indicated that machining performance with textured tools under MQL conditions has improved significantly [1317]. Despite the above developments, little research has been done on the application of micro-textured tools together with other coolants like automotive radiator coolant in the MQL-assisted machining of AISI 6150 steel. Thus, the current research focuses on exploring the turning of the AISI 6150 steel with micro-textured AlTiSiN-coated tools under MQL with radiator coolant in order to reach a better machining performance and sustainability [18].

### Experimental details:

#### MQL Lubrication System and Cutting Fluid

In this work, the base cutting fluid which had been subjected to minimum quantity lubrication (MQL) machining was automotive radiator coolant. An MQL delivery system (manufacturer: KENCO) was used to deliver the coolant to the machining area and atomized the lubricant into a fine aerosol and directed it to the tool-chip interface. During the machining experiments the pressure of the compressed air was maintained at 6 bar and the rate of flow of the coolant maintained at 60 mL/h to ensure sufficient lubrication and cooling at the cutting station. The direct contact of the coolant with the tool-chip interface increases both the effectiveness of the lubrication and the cutting fluid consumption is greatly decreased.

#### Characterization of Cutting Tool Material and Coating

2.2. Characterization of Cutting Tool Material and Coating. The machining experiments were conducted with AlTiSiN-coated tungsten carbide inserts that were provided by Oerlikon Balzers. The geometry of the inserts was CNMG 1204× with various nose radii, as specified by ISO. AlTiSiN nanocomposite coating was deposited by S3P (Scalable Pulsed Power Plasma) technique which offers good hardness, thermal stability and wear resistance that can be used to machine difficult to cut materials. Scanning electron microscopy (SEM) was done to analyze the coating properties. The S.E.M micrograph (Figure 1a) shows that the coating structure is dense and uniform with small droplets scattered all over the surface. The thickness of the coating was about 5 μm. The energy dispersive spectroscopy (EDS) was used in the elemental analysis, which proved the presence of the main elements, Al, Ti, Si, and N, as illustrated in (Figure 1b).

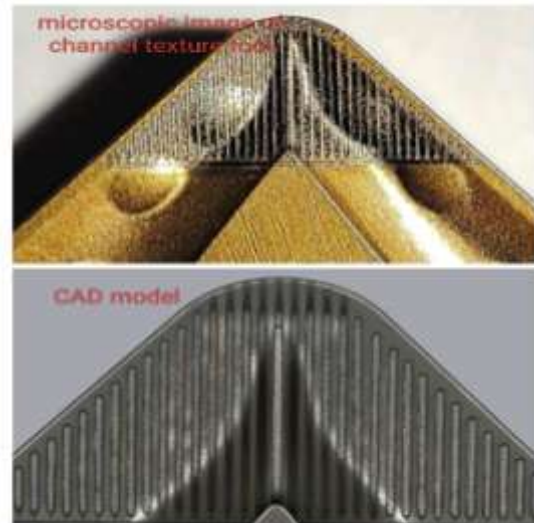
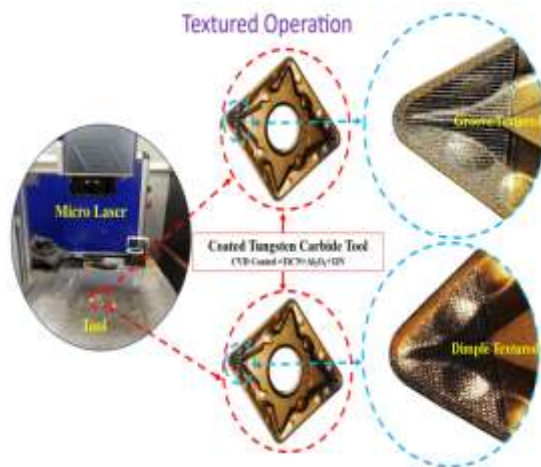


Figure- a

Figure-b

Figure 1 (a) Schematic of the micro-textures fabricating laser machine tool, (b) CAD and optical images of Channel tool developed textured insert

**Fabrication of Micro-Textured Cutting Inserts:**

Micro-textures were fabricated on the rake face of coated carbide inserts using a fibre-laser marking and engraving system (Micro Lasers) equipped with a galvanometer scanning head and field lens. The inserts were positioned on a precision worktable, and the laser beam was controlled using CAD-based tool paths to generate the required micro-patterns.

**Micro-Channel Textured Inserts:**

In the case of the first configuration, the micro-channel patterns were developed on the rake surface of the coated carbide inserts. These channels were created to serve as micro-reservoirs, which entrap and hold lubricant during MQL machining. The approximate width and depth of each channel was 40 and 20  $\mu\text{m}$  respectively with the inter-channel distance maintained at 20  $\mu\text{m}$ . The channels were parallel on the rake face to ensure proper distribution of the lubricant and better tribological behaviour when machining.

**Material of workpiece and machining set up:**

The material of workpiece in this study was AISI 6150 spring steel, which was chosen based on its common usage in industry and difficult machinability. The machining experiments were carried out using cylindrical bars whose diameter was 45 mm and length was 300 mm. Table 1 shows the chemical composition of the work material.

Table 1 Chemical composition of AISI 6150 steel

Element	V	S	P	Si	Ni	Mn	C	Fe
Weight (%)	0.17	0.01	0.01	0.25	0.03	1.03	0.85	0.51

A Mihir 250X precision lathe machine was used to perform turning experiments under highly controlled machining conditions. The cutting inserts were clamped on a matching tool holder PCLNL 2020K12. The machining parameters were chosen according to the suggestions given by the tool manufacturer and experiences gained in the literature on the subject.

**Machining parameters and experiment design:**

This study considered four key machining parameters; cutting speed, feed rate, depth of cut and tool nose radius. The parameters were tested on three levels each to determine their impact on machining performance.

The selected machining conditions are summarized below:

Parameter	Levels
Cutting speed (v)	55, 95, 135 m/min
Feed rate (f)	0.05, 0.10, 0.15 mm/rev
Depth of cut (d)	0.2, 0.3, 0.4 mm
Nose radius (r)	0.4, 0.8, 1.2 mm

Each experimental run was machined at a constant length of 280 mm, with the cutting parameters systematically changed. Comparative machining tests were conducted, plain (non-textured) cutting tools, micro-channel textured cutting tools, and micro-pit textured cutting tools.

**Experimental Procedure:**

An experimental study was conducted in a systematic fashion to assess the relative performance of various cutting tools. The laser texturing system was used to create micro-textured pattern on the rake surface of coated carbide inserts initially. Then, the turn under experiments were done under MQL conditions with the prepared inserts. The collected data was used in the analysis of machining data, such as cutting temperature, tool wear development, chip morphology, and surface finish. Plain inserts, micro-channel textured inserts and micro-pit textured inserts were then compared to determine the effectiveness of surface texturing in enhancing machining performance. Figure 2 shows a schematic diagram of the overall experimental procedure and assessment process.

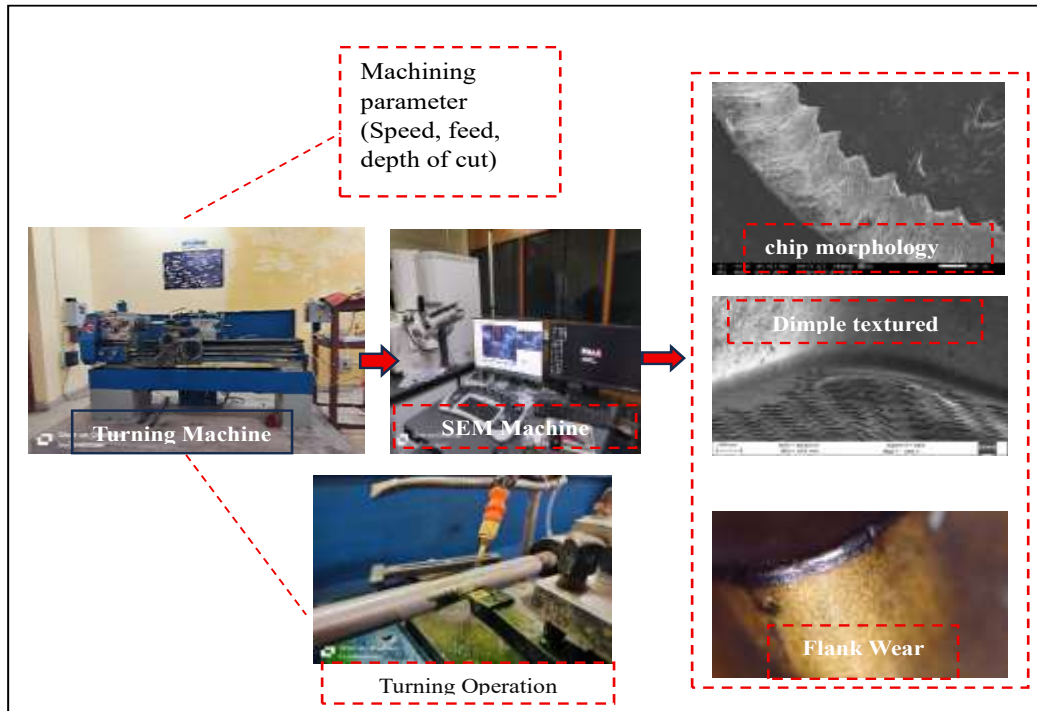


Figure 2 Schematic of experimental layout

**Results and Discussion:-**

**The effect of cutting speed**

Figure 3 and Table 2 indicate that cutting speed greatly affects cutting temperature of both textured and non-textured cutting tools. In the case of the non-textured tool, the temperature increases to around 137 °C at 55 m/min up to around 194-195 °C at 135 m/min. The same trend is followed in the case of the texture tool where the temperature rises between about 122 0 C and about 175 0 C. The behaviour is mainly attributed to the greater generation of frictional heat and greater plastic deformation at higher cutting speeds. Nevertheless, the textured tools always have lower temperatures at all speeds. The decrease is approximately of the order of -15 o C at 55 m/min and the maximum of approximately 25 o C at 95 m/min. This is made possible by the existence of micro-textures, which decrease the area of tool-chip contact, improve lubricant retention during MQL as well as heat dissipation.

**Effect of Feed Rate**

Table 3 indicates that both tool conditions exhibit an increase in cutting temperature with feed rate. When the feed rate is increased up to 0.15 mm/rev, the non-textured tool registers an approximate temperature of 158 o C, whilst the one with a texture registers a lower temperature of 132 o C. As the feed rate is reduced to 0.05 mm/rev, the temperature is reduced to approximately 137 C and 111 C with non-textured and textured tools, respectively.

**Table 2: Cutting Temperature vs Cutting Speed**

Cutting Speed (m/min)	Non-Textured Tool Temp (°C)	Textured Tool Temp (°C)
55	~137	~122
95	~170	~145
135	~194–195	~175

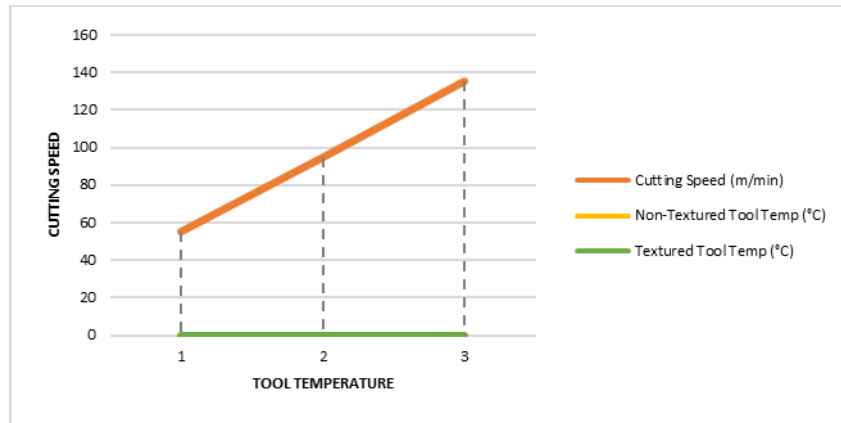


Figure 3: Variation of cutting speed with corresponding tool temperature for textured and non-textured AlTiSiN-coated inserts during turning of AISI 6150 steel under MQL conditions.

Table 3: Cutting Temperature vs Feed Rate

Feed Rate (mm/rev)	Non-Textured Tool Temp (°C)	Textured Tool Temp (°C)
0.15	~158	~132
0.10	~145	~120
0.05	~137	~111

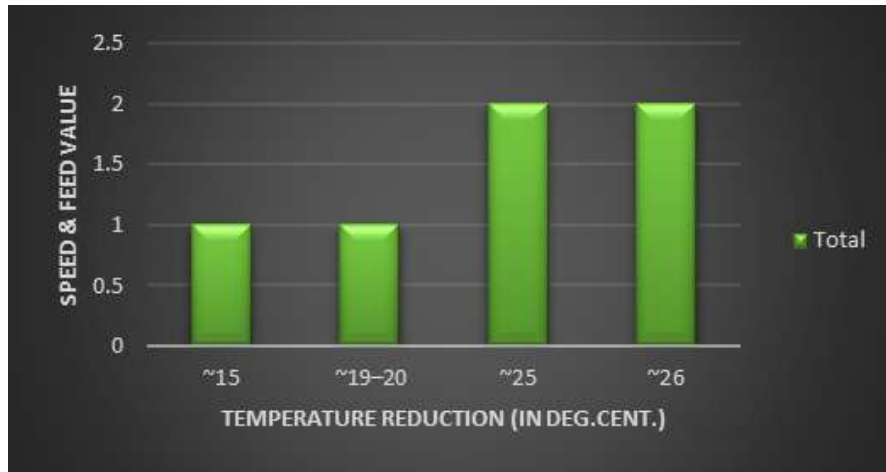
Table 4: Comparative Temperature Reduction (Textured vs non-textured)

Condition Type	Parameter Value	Temperature Reduction (°C)
Speed	55 m/min	~15
Speed	95 m/min	~25
Speed	135 m/min	~19–20
Feed	0.15 mm/rev	~26
Feed	0.10 mm/rev	~25
Feed	0.05 mm/rev	~26

This rise in temperature as the feed rate increases is attributed to the increased material removal per unit time which leads to increased cutting forces and friction. Again, the textured tools have better performance, with a lower temperature of around 2526 o C. It means that micro-textures are especially efficient in higher load conditions when the entrapment of lubricants and decreased adhesion are of great importance.

**Comparative Temperature Reduction**

The total temperature drop percentage was summarized in figure 4 and table 4 and was obtained with the use of textured tools. The cut down is between -15 C to -26 C depending on the cutting condition. The greatest reductions (~2526 C) are recorded at medium cutting speed (95m/min), and at all the feed rate, indicating the most effective use of micro-textures in the balanced machining conditions. At extremely high cutting speed (135 m/min) the decrease is somewhat smaller (around 1920 C), presumably because the heat generation rate is too great to be removed by the cooling and lubrication system of the MQL system. However, the tool with the texture continues to have a definite advantage over the tool without the texture.



**Figure 4. Comparative temperature reduction achieved using micro-textured tools under MQL, highlighting performance improvements across different cutting conditions.**

The steady decrease in cutting temperature is evidence that the micro-textured AlTiSiN-coated tools have a substantial on the machining performances. The net effects of low friction, high tribological performance and better coolant retention under MQL are decreased thermal loads. Not only does this enhance the tool life and surface integrity but also helps in sustainable machining by minimizing thermal damage and energy use.

### Conclusion:-

Micro-textured AlTiSiN MQL tools were discovered to significantly improve the turning action of AISI 6150. The cutting temperature (which was reduced to approximately 1526 o C) was considerably less than the actual values (at all cutting speeds and feed rates) due to reduced tool-chip contact and retained better the lubricant. Although cutting speed and feed rate increased temperature, textured tools always worked better in comparison to non-texted ones. Additionally, the use of radiator coolant in MQL proved to be an effective, eco-friendly, and cost-efficient alternative, reducing machining cost by ~9%. Overall, the hybrid approach enhances the performance of machining, the life of the tool and its sustainability.

### References:-

1. Han, X., Zhang, Z., Rong, Y., Thrush, S. J., Barber, G. C., Yang, H., & Qiu, F. (2020). Bainite kinetic transformation of austempered AISI 6150 steel. *Journal of Materials Research and Technology*, 9(2), 1357-1364. <https://doi.org/10.1016/j.jmrt.2019.11.062>
2. Sales, W. F., Schoop, J., da Silva, L. R., Machado, Á. R., & Jawahir, I. S. (2020). A review of surface integrity in machining of hardened steels. *Journal of Manufacturing Processes*, 58, 136-162. <https://doi.org/10.1016/j.jmapro.2020.07.040>
3. Kuram, E., Bagherzadeh, A., & Budak, E. (2024). Application of cutting fluids in micro milling—A review. *The International Journal of Advanced Manufacturing Technology*, 133(1), 25-58. <https://doi.org/10.1007/s00170-024-13752-z>
4. Sharma, A. K., Tiwari, A. K., & Dixit, A. R. (2016). Effects of Minimum Quantity Lubrication (MQL) in machining processes using conventional and nanofluid based cutting fluids: A comprehensive review. *Journal of cleaner production*, 127, 1-18. <https://doi.org/10.1016/j.jclepro.2016.03.146>
5. Roy, S., Kumar, R., Panda, A., Sahoo, A. K., Rafiqhi, M., & Das, D. (2023). A comparative performance investigation of single-and double-nozzle pulse mode Minimum quantity lubrication systems in turning super-Duplex steel using a weighted pugh matrix sustainable approach. *Sustainability*, 15(20), 15160. <https://doi.org/10.3390/su152015160>
6. Padhan, S., Mishra, S., Sahu, S. K., Das, A., Das, S. R., & Mohapatra, S. (2025). Enhancing machining performance and sustainability: a comprehensive review of minimum quantity lubrication. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, 47(7), 316. <https://doi.org/10.1007/s40430-025-05626-6>

7. Padhan, S., Mishra, S., Sahu, S. K., Das, A., Das, S. R., & Mohapatra, S. (2025). Enhancing machining performance and sustainability: a comprehensive review of minimum quantity lubrication. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, 47(7), 316. <https://doi.org/10.1007/s40430-025-05626-6>
8. Gürbüz, H., & Gönülaçar, Y. E. (2022). Experimental and statistical investigation of the effects of MQL, dry and wet machining on machinability and sustainability in turning of AISI 4140 steel. *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering*, 236(5), 1808-1823. <https://doi.org/10.1177/09544089221076243>
9. Özbek, O., & Saruhan, H. (2020). The effect of vibration and cutting zone temperature on surface roughness and tool wear in eco-friendly MQL turning of AISI D2. *Journal of Materials Research and Technology*, 9(3), 2762-2772. <https://doi.org/10.1016/j.jmrt.2020.01.010>
10. Revuru, R. S., Zhang, J. Z., & Posinasetti, N. R. (2020). Comparative performance studies of turning 4140 steels with TiC/TiCN/TiN-coated carbide inserts using MQL, flooding with vegetable cutting fluids, and dry machining. *The International Journal of Advanced Manufacturing Technology*, 108(1), 381-391. <https://doi.org/10.1007/s00170-020-05378-8>
11. De Ávila, R. F., Abrão, A. M., & de Godoy, G. C. D. (2006). The performance of TiN coated carbide tools when turning AISI 8620 steel. *Journal of materials processing technology*, 179(1-3), 161-166. <https://doi.org/10.1016/j.jmatprotec.2006.03.066>
12. Sargade, V. G., Gangopadhyay, S., Paul, S., & Chattopadhyay, A. K. (2011). Effect of coating thickness on the characteristics and dry machining performance of TiN film deposited on cemented carbide inserts using CFUBMS. *Materials and Manufacturing Processes*, 26(8), 1028-1033. <https://doi.org/10.1080/10426914.2010.526978>
13. Mallikarjuna, P., Prasanna, P., Sivaiah, P., & Chengal Reddy, V. (2025). MQL turning processing of EN24 alloy steel material with novel textured tools. *Materials and Manufacturing Processes*, 40(13), 1713-1724. <https://doi.org/10.1080/10426914.2025.2549261>
14. Mishra, S. K., Ghosh, S., & Aravindan, S. (2020). Machining performance evaluation of Ti6Al4V alloy with laser textured tools under MQL and nano-MQL environments. *Journal of Manufacturing Processes*, 53, 174-189. <https://doi.org/10.1016/j.jmapro.2020.02.014>
15. Singh, R., Gupta, M. K., Sarikaya, M., Mia, M., & Garcia-Collado, A. (2021). Evaluation of machinability-based sustainability indicators in the eco-benign turning of Ti3Al2.5V alloy with textured tools. *The International Journal of Advanced Manufacturing Technology*, 116(9), 3051-3061. <https://doi.org/10.1007/s00170-021-07667-2>
16. Fouathiya, A., Meziani, S., Sahli, M., & Barriere, T. (2021). Experimental investigation of microtextured cutting tool performance in titanium alloy via turning. *Journal of Manufacturing Processes*, 69, 33-46. <https://doi.org/10.1016/j.jmapro.2021.07.030>
17. Jahaziel, B. R., Krishnaraj, V., & Geetha Priyadarshini, B. (2022). Investigation on influence of micro-textured tool in machining of Ti-6Al-4V alloy. *Journal of Mechanical Science and Technology*, 36(4), 1987-1995. <https://doi.org/10.1007/s12206-022-0334-0>
18. Salem, A., Hegab, H., & Kishawy, H. A. (2023). Experimental investigation of the derivative cutting when machining AISI 1045 with micro-textured cutting tools. *Metals*, 13(9), 1587. <https://doi.org/10.3390/met13091587>