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Development of textured tools and performance evaluation during turning of EN8 material under MQL cooling

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Abstract - *The demand for sustainable manufacturing has been increasing in the present scenario due to many reforms in the environmental conscious regulation. Therefore, current study focused on sustainable machining techniques that textured tools and Minimum Quantity Lubrication (MQL) to meet the demand in the metal cutting industries. In the present work, surface textured tools were fabricated and same tools was used to assess the turning process performance during machining of EN8 material. The obtained results were compared with untextured tools under MQL cooling condition. Results indicated that while turning EN8 material, the largest decreases in cutting temperature, rake wear, flank wear, and surface roughness were reported to be 14%, 22%, 29%, and 38%, respectively, while using textured tools as opposed to untextured tools. Further, noticed that under MQL cooling conditions, the textured tools showed a micro pooling effect with microgrooves.*

Key Words: MQL; EN8; Textured Tool; surface roughness; tool wear

1.INTRODUCTION

En8 material is frequently used in the automobile sector to manufacture shafts and axles. Therefore, it is imperative to improve this material's machinability. Using standard tools, Thangarasu et al. (2020) performed experiments on EN8 steel in a dry state. They used ANN to evaluate the turning performance characteristics and found that there was minimal inaccuracy in the correlation between the experimental and anticipated outcomes. In their 2008 study, Vamsi Krishna and Nageswara Rao examined the turning capabilities of traditional tools when machining EN8 steel in three different lubrication conditions: dry, wet, and developed solid. Compared to alternative cutting. Using Taguchi analysis, Gugulothu et al. (2020) conducted tests based on the L9 orthogonal array design to discover the ideal cutting condition for converting EN8 steel. When turning EN8 steel material, Murugappan and Arul (2017) observed a considerable drop in the chip reduction coefficient under dry ice chilling conditions as opposed to dry conditions.

The tool-chip contact area has been positively impacted by surface-textured tools. As covered in the literature below, there have been a few recent attempts to transform using textured tools. Palanisamy and colleagues (2019) created textured tools and then subjected them to cryogenic treatment. After that, turning tests were carried out on 17–4 PH material using cryo-treated textured tools, and RSM was used to identify the ideal cutting parameters. Furthermore, it was shown that there was a good match between the anticipated and experimental findings when machinability indices were evaluated using RSM. Dinesh et al. (2016) created linear microgrooves at various angles on the tool's rake face and evaluated how well the designed tool performed during the turning of ZK60 alloy in dry and cryogenic conditions, in comparison to untextured tools. In both cutting settings, machinability with textured tools was shown to be much better than that of untextured tools. Furthermore, because of the micro pool lubricating effect over dry conditions, exceptional results were seen with both tools under cryogenic chilling conditions. Manikandan et al. (2018) examined the differences in turning performance between untextured and created textured tools for turning Ti–6Al–4V alloy under conditions of infused solid lubrication. A small layer of lubricant at the cutting zone while using textured tools under solid lubrication conditions has been shown to significantly enhance turning performance. In their 2016 study, Sharma and Pandey assessed the machining performance of AISI 4340 material using single, dual pattern textured, and untextured tools with solid lubrication. They discovered that, in comparison to untextured tools, textured tools' reduced friction was responsible for better turning performance. However, it was discovered that dual pattern textured tools performed better than single pattern textured tools. When using linear textured tools to mill VSM13 steel in dry turning, Bertolete et al. (2018) found that the textured tools performed better than the untextured ones in terms of turning performance. Different circular pit textured tool geometries were studied by Durairaj et al. (2018) for turning aluminum material. The diameter of the dimple hole was discovered to be a component that affected turning performance. Furthermore, as compared to untextured tools, textured tools perform better due to their lower stickiness. Using newly created dual textured tools, Hao et al. (2018) conducted turning tests on titanium alloy. Under MQL, dry circumstances, the results were compared with untextured and single pattern textured tools. Because there was greater coolant capacity in the two microgrooves, it saw superior performance with the dual-textured tools than with the other tools. In order to compare the outcomes with untextured tools, Kang et al. (2018) performed dry turning tests on aluminium alloy 5038 using various created linear and pit hole pattern textured tools. It was discovered that turning performance is better with textured tools than untextured ones when there is less BUE. Pang et al. (2018) created textured tools with linear and conical shapes and assessed how well they turned AISI 1045 steel. When using textured tools as opposed to untextured ones, they saw better performance. Additionally, conical textured tools work better than linear microgroove textured tools due to faster coolant flowing towards the cutting zone, respectively. Sun et al. (2016) examined the outcomes of applying solid lubrication to AISI 1045 that was textured in both single and dual patterns during turning. Due to superior cooling over single pattern textured tools, hybrid textured tools were seen to have greater turning performance. Liu et al. (2017) created linear microgroove textured tools and assessed how well they turned green alumina ceramic in a dry environment. More turning performance was seen while using textured tools as opposed to untextured ones. They came to the conclusion that the derivative cutting mechanism produced useful outcomes for textured tools. In turning trials on hardened steel, Xing et al. (2014) used a variety of textured tools that had been produced. They discovered that, in dry and solid lubrication conditions, textured tools performed better than untextured tools. Low tool-chip contact duration was shown to be associated with improved performance with textured tools in both cutting conditions. Under MQL, wet, and dry cutting circumstances, respectively, Sivaiah et al. recently conducted a thorough analysis on single pattern textured tools, dual pattern textured tools, and untextured tools. Because textured tools effectively cool faster than untextured tools in well designed cutting conditions, they achieved greater turning performance using textured tools. Furthermore, under examined conditions, dual pattern textured tools produced superior outcomes than single pattern textured tools. Kawasegi et al. (2017) created several linear microgroove tools with various geometries and examined the efficiency of friction while turning materials made of nickel phosphorus and aluminum. They claimed that the texture shape has a major impact on the friction coefficient. When dry turning aluminum alloy, Durairaj et al. (2018) observed that textured tools with circular dimple patterns had a wider shear angle and a lower cutting force than untextured tools. According to a research, controlling the workpiece's adherence to the tool produces good outcomes for textured tools. After doing an ANOVA, it was discovered that, out of all the parameters—which also included depth, pitch, and distance from the cutting edge—the circular dimple dimension is the most notable. Additionally, Taguchi analysis was used to find the ideal turning process parameters, which included textured tool design. Using single textured tools with linear grooves, hybrid textured tools, and untextured tools under dry and MQL cutting conditions, respectively, Hao et al. (2018) conducted studies on titanium alloy. Low friction coefficients in both cutting environments were found to result in low cutting force and reduced tool wear in textured tools, respectively. Furthermore, as compared to single textured tools under MQL cutting settings, hybrid textured tool tools dramatically shortened the tool-chip contact duration and provided a capacity for coolant storage, which resulted in enhanced turning performance. Due to the low coefficient of friction at the cutting zone, Sharma and Pandey (2016) observed exceptional turning performance with various textured tools, including hybrid texture design tools, in comparison to the untextured tools, when conducting turning experiments on 4340 hardened steel material under solid lubricant conditions. Because the fluid had a higher heat conductivity than MQL, dry, and textured tools filled with graphene particles, Singh et al. (2019) observed better turning performance when machining titanium with textured tools that had circular dimples on the rake face of the tool under graphene nano particle based MQL cutting conditions. Research suggests that the rake face of the tools' texture geometry and design have a major effect on the turning performance characteristics while machining a variety of tough-to-cut materials. Thus, the purpose of this work is to compare the performance of textured tools with untextured tools under MQL conditions when turning EN8 steel.

2. EXPERIMENTAL PROCEDURES

EN8 material is chosen and manufactured using an NC lathe machine equipped with produced textured and untextured tools while the machine is cooled by MQL. The textured tools were made with a laser machine. Fabricated textured tools are shown in Figure 1. Studies were carried out using the Taguchi L9 design. After cutting each experiment, a new cutting edge was used. A 200 mm length was used for each experiment. Every experimental run is conducted three times to ensure output data accuracy. An infrared thermal imaging camera was utilized to capture the temperatures at the cutting zone. The rake and flank wear of the machined tools were measured using an optical microscope. The average surface roughness tester measured using the Talysurf tester. Tool wear processes and surface defect analysis were performed using a scanning electron microscope (SEM). MQL setup used in the machining operation are shown in Figure 2.

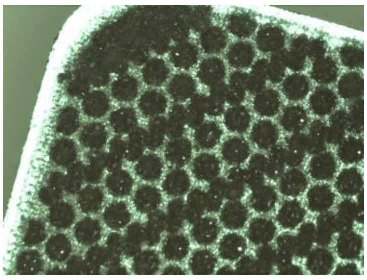

Figure 1 Hybrid surface texture consists of linear grooves and circular dimples

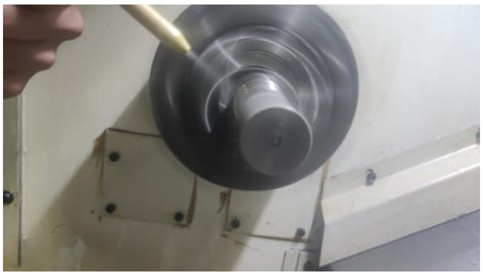

Figure 2 Machining zone images at MQL cutting environments.

3. RESULTS AND DISCUSSION

3.1 Influence of textured tool on cutting temperature

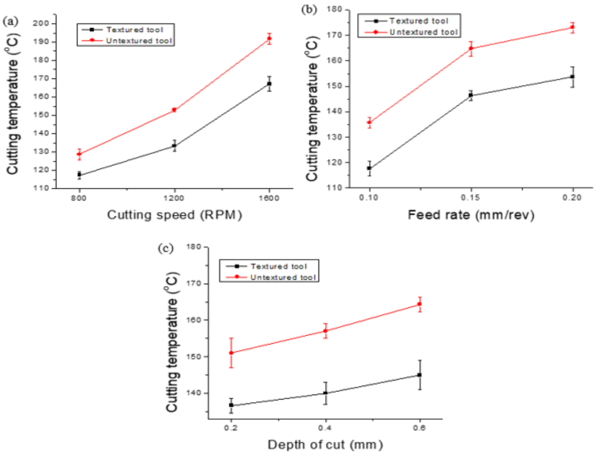

Figure 3 Impact of textured tool and process variables on cutting temperature.

This study examined the impact of process factors and tool type on cutting temperature; the findings are shown in Figure 3. When wet cooling, it is discovered that textured tools have a lower cutting temperature than untextured tools. At a low cutting speed of 800 RPM, the observed temperatures for textured and untextured materials are 117.3 oC and 128.7 oC, respectively. In this case, textured tools show a 13% temperature drop over untextured tools. Similarly, as Figure 3(a) illustrates, when cutting speed is changed from 800 RPM to 1600 RPM, the textured tool's temperature drops by 8–13% relative to the untextured tool under MQL cooling conditions. Overall, when feed rate increases from 0.1 to 0.2 mm/rev, the temperature range discovered in textured tools is 11–14% greater than that of untextured tools, as seen in Figure 3(b). According to Figure 3(c), as the depth of cut increases from 0.2 mm to 0.6 mm, the textured tool experiences a temperature reduction of 9–12% more than the untextured tool under MQL cooling conditions. Low tool chip contact length causes low friction in the cutting zone, which is addressed by the derivative cutting mechanism. Another reason is that the presence of microgrooves on the rake face of the tool, where cutting fluid is sprayed in the form of MQL mist, helps to store cutting fluid. Additionally, a constant supply of cutting fluid to the cutting zone promotes efficient cooling and lubrication, which reduces heat generation there.

3.2 Influence of textured tool on tool rake wear

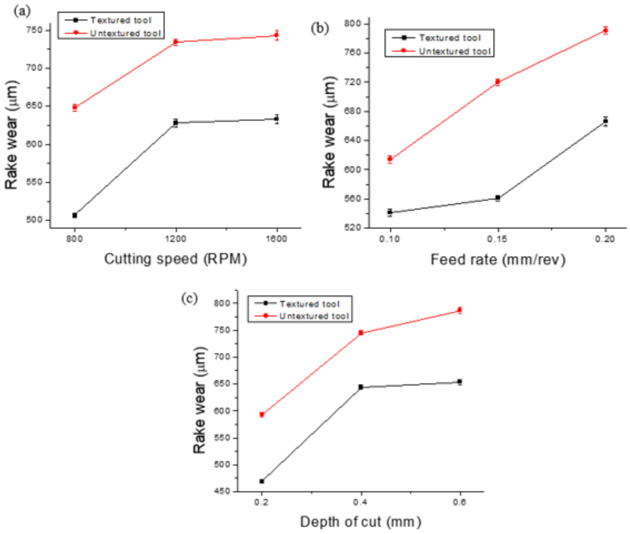

Figure 4 Impact of textured tool and process variables on tool rake wear.

The kind of tool and process factors on rake wear during wet cooling are shown in Figure 4. Figure 4 shows that under all process variable conditions, textured tools greatly decreased the rake wear compared to untextured tools. Rake wear is 648µm in untextured tools and 507µm in textured tools at a low cutting velocity of 800 RPM. In this case, textured tools have a 22% lower rake wear than untextured tools. It makes sense that, as Figure 4(a) illustrates, the tool rake wear reduction range for textured tools is 19–22% when compared to untextured tools when cutting speed surges from 800 RPM to 1600 RPM. Overall, the rake wear reduction range noticed in textured tool is 12-22% compared to untextured tools when feed rate increases from 0.1 to 0.2 mm/rev as shown in Figure 4(b). As seen in Figure 4(c), the range of rake wear reduction in textured tools as the depth of cut increases from 0.2mm to 0.6mm is 13-21% more than that of untextured tools. As can be seen in Figure 4, under MQL conditions at all process variables, textured tools generated less tool rake wear than untextured tools. The rationale is that minimal rake wear results from textured tools' substantial reduction of the cutting zone's temperature. Figure 5 makes it clear that textured tools resulted in less rake wear than untextured tools.

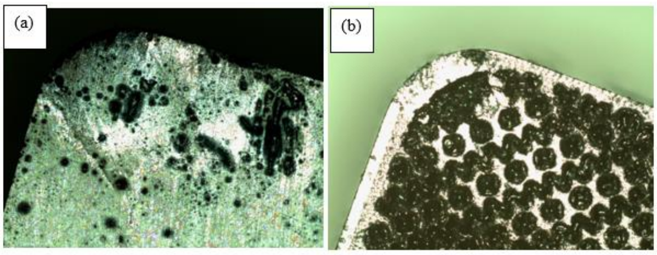

Figure 5 Captured SEM images for tool wear at V = 1600 RPM, f = 0.15 mm/rev and a_p = 0.6 mm (a) Untextured tool (b) Textured tool.

3.3 Influence of textured tool on tool flank wear

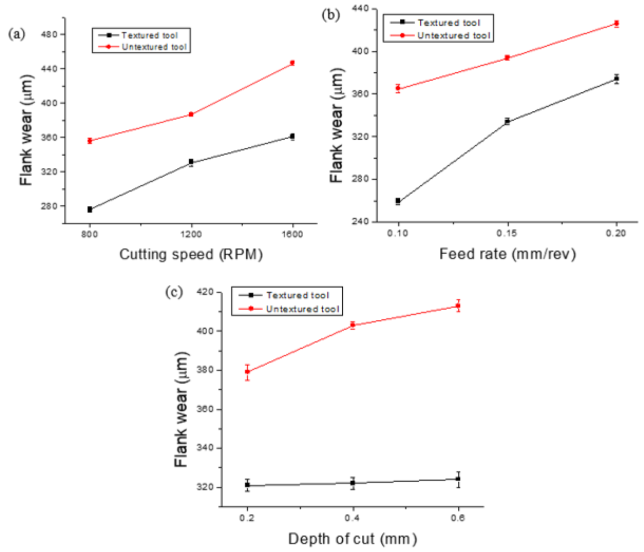

Figure 6 Impact of textured tool and process variables on tool flank wear.

Figure 6 illustrates the type of tool and process variables that affect flank wear during MQL cooling. In comparison to untextured tools, Figure 6 demonstrates that textured tools significantly reduced the rake wear under all process variable situations. At a low cutting speed of 800 RPM, flank wear is 358µm for untextured tools and 276µm for textured tools. In this scenario, textured tools have 22% less flank wear than untextured tools. It makes logical that, as shown in Figure 6(a), textured tools reduce tool rake wear by 14-22% when cutting speed rises from 800 RPM to 1600 RPM. Figure 6(b) shows that when the feed rate is increased from 0.1 to 0.2 mm/rev, the rake wear reduction range in textured tools is 12-29% more than in untextured tools. Figure 6(c) shows that as the depth of cut rises from 0.2mm to 0.6mm, textured tools reduce rake wear 15-22% more than untextured tools. Figure 3 shows that under MQL settings at all process variables, textured tools produced less tool rake wear than untextured tools. The tool's rake face has microgrooves that allow cutting fluid to be continuously supplied. This effectively lubricates the tool's flank face and machined surface, resulting in little flank wear. Figure 7 demonstrates that textured tools caused less flank wear than untextured tools.

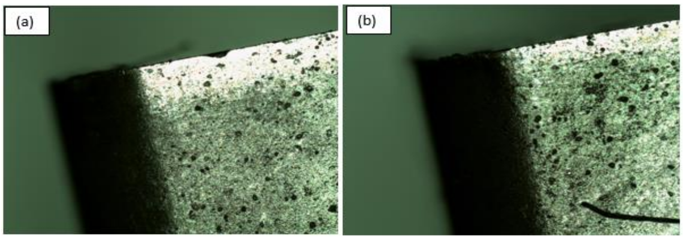

Figure 7 Captured SEM images for tool wear at V = 1600 RPM, f = 0.15 mm/rev and a_p = 0.6 mm (a) Untextured tool (b) Textured tool.

3.4 Influence of textured tool on surface roughness

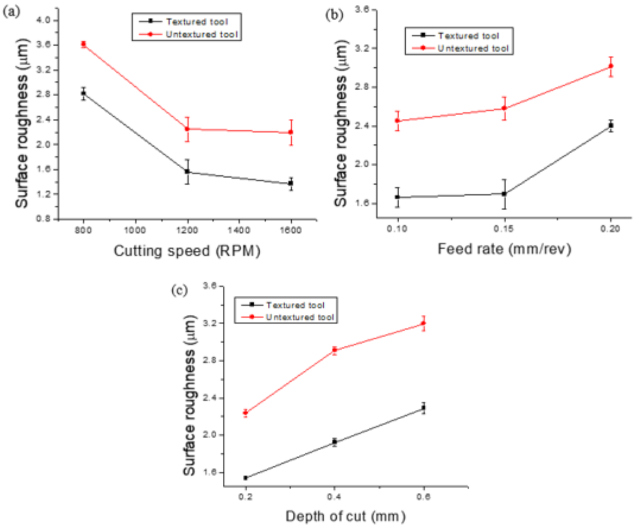

Figure 8 Impact of textured tool and process variables on surface roughness.

Surface roughness has a substantial impact on any product's functional performance. As a result, research into surface roughness is crucial, and it is now being studied. Figure 8 demonstrates the influence of textured tools and MQL on surface roughness under various process conditions. As cutting velocity increases, Figure 8(a) shows that surface roughness decreases due to a decrease in tool-chip contact length. As shown in Figures 8(b) and 8(c), roughness increases at high feed rates and depth of cut situations because of the increased cutting temperature as opposed to low feed rates and depth of cut settings. The surface roughness values of textured and untextured tools at a low cutting speed of 800RPM m/min are 2.821 µm and 3.606 µm, respectively, as seen in Figure 8(a). Under these circumstances, textured tools show a 22% decrease in surface roughness compared to untextured tools. When cutting speed increases from 800 RPM to 1600 RPM, the overall surface roughness reduction range discovered in textured tools is 22-38% over untextured tools, as illustrated in Figure 8(a). Figure 8(b) shows that there is a reduction in surface roughness of 20-34% in textured tools compared to untextured tools when the feed rate is increased from 0.1 to 0.2 mm/rev. As shown in Figure 8(c), the surface reductions observed with textured tools are in the range of 28-34% as compared to untextured tools when the depth of cut increases from 0.2mm to 0.6mm. In every process variable circumstance, textured tools performed better overall than untextured tools in reducing surface roughness. The source of the low surface roughness is because textured tools have less tool wear, which leaves fewer tool marks and surface imperfections on the machined surface. Another explanation is that the textured tools' efficient lubrication caused by the MQL mist application results in a smooth cutting action at the tool-workpiece interface and reduced surface roughness. As shown in Figure 9, it is clear that the textured tool has less material side flow, adherence of micro-chip particles, and microgrooves as surface defects than the untextured tool.

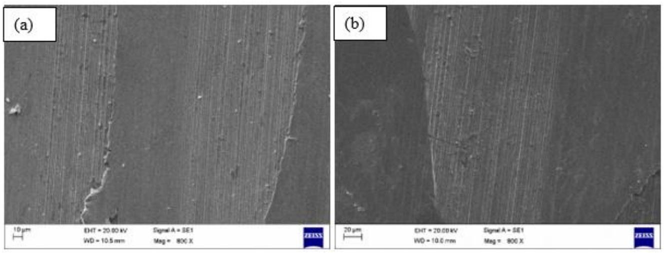

Figure 9 Captured SEM images for tool wear at V = 1600 RPM, f = 0.15 mm/rev and a_p = 0.6 mm (a) Untextured tool (b) Textured tool.

3. CONCLUSIONS

In the present work, surface textured tools were fabricated and same tools was used to assess the turning process performance. The obtained results were compared with untextured tools under MQL cooling condition.

- while turning EN8 material, the largest decreases in cutting temperature, rake wear, flank wear, and surface roughness were reported to be 14%, 22%, 29%, and 38%, respectively, while using textured tools as opposed to untextured tools.

- When cutting velocity rises, surface roughness decreases, but when feed rate increases, it increases.

- Cutting temperature, rake wear, and flank wear values rose when cutting velocity and feed rate increased from low to high values.

- Under MQL cooling conditions, the textured tools showed a micro pooling effect with microgrooves.

- By using the textured tools that have been created, the metal cutting industries may increase productivity when turning EN8 material while it is MQL cooling.

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