

MACHINABILITY STUDY ON EN8 MATERIAL IN TURNING PROCESS WITH TEXTURED TOOLS UNDER WET COOLING

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Abstract

In the present work, a novel attempt was made to improve the turning process performance. In the present work, textured tools having microgrooves perpendicular to the cutting edge were developed and compared the turning performance during machining of EN8 material with developed texture tool and untextured respectively under wet cooling condition. From obtained results, it was observed that cutting temperature, rake wear, flank wear and surface roughness significantly reduced by a maximum of 19%, 10%, 18% and 15% respectively in textured tools over untextured tools during machining of EN8 material. Surface roughness decreased when cutting velocity increases whereas it increases in the case of rising condition of feed rate. Further, few surface defects in textured tools indicate stable cutting action. It was observed micro pooling effect with microgrooves present the textured tools under wet cooling condition.

Keywords: EN8 material, Machining, Textured tools, Turning process

Introduction

EN8 material is widely used in the manufacturing of axles and shafts in the automotive industry. So, machinability enhancement of this material is much required. Thangarasu *et al.* (2020) conducted experiments on EN8 steel under dry condition using a conventional tool. They assessed the turning performance characteristics using ANN and noticed a good correlation between the predicted and experimental results with minimum error. Vamsi Krishna and Nageswara Rao (2008) compared the turning performance of conventional tools during machining of EN8 steel under, dry, wet and

developed solid lubrication condition respectively. It was observed significant improvement in turning process performance with solid lubrication condition over other cutting condition. Gugulothu *et al.* (2020) performed experiments based on L9 orthogonal array design and determined the optimum cutting condition using Taguchi analysis in turning of EN8 steel. Murugappan and Arul (2017) noticed a significant decrease in chip reduction coefficient with dry ice cooling condition over dry condition during turning of EN8 steel material. Surface textured tools have shown

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a positive impact on the tool-chip contact area. Recently, few attempts were done by employing the textured tools in turning operation as discussed in the following literature. Palanisamy *et al.* (2019) developed textured tools afterward carried out cryogenic treatment to the developed textured tools. Thereafter, turning experiments were performed on 17-4 PH material with cryo-treated textured tools and determined the optimum cutting conditions using RSM. Further, machinability indices were assessed using RSM and noticed that predicted results followed a good fit with experimental results. Dinesh *et al.* (2017) made linear microgrooves at a different angles on the rake face of the tool and compared the performance of the developed tool with untextured tools respectively during turning of ZK60 alloy under cryogenic and dry condition. It was noticed good improvement in machinability with textured tools over untextured tools under both cutting environments. Further, noticed outstanding results within both tools under cryogenic cooling condition due to micro pool lubrication effect over dry condition. Manikandan *et al.* (2019) compared the turning performance during turning of Ti-6Al-4V alloy with developed textured tools and untextured tools under infused solid lubrication condition. It was observed thin lubrication film at the cutting zone with textured tools under solid lubrication condition leads to significant improvement in turning performance. Sharma and Pandey (2016) evaluated the performance of single, dual pattern textured tools and untextured tools under solid lubrication condition during machining of AISI 4340 material. They noticed that low friction in textured tools responsible for improved turning performance compared to untextured tools respectively. However, found outperformance with dual pattern textured tools compared to single pattern textured tools respectively. Bertolete *et al.* (2018) machined VSM13 steel in dry turning with linear textured tools and observed great turning performance with textured tools due to less tool vibrations over untextured tools. Durairaj *et al.* (2018) different geometry of circular pit textured tools was investigated during turning of aluminum material. It was found that dimple hole diameter was found as an influenced factor on turning performance. Further, low adhesion in textured tools responsible for improved performance when compared to untextured tools respectively. Hao *et al.* (2018) performed turning experiments on titanium alloy using developed dual-textured tools and results were compared with untextured and single pattern textured tools under MQL, dry conditions respectively. It observed paramount performance with dual textured tools over other tools because of more coolant facility in dual

microgrooves. Kang *et al.* (2018) conducted dry turning experiments on aluminum alloy 5038 with different developed linear and pit hole pattern textured tools and results were compared with untextured tools respectively. It was found less BUE with textured tools leads to improved turning performance over untextured tools. Pang *et al.* (2018) made linear and conical-shaped textured tools and evaluated the performance of these tools while turning of AISI 1045 steel. They observed improved performance with textured tools over untextured tools. Further, accelerated coolant towards the cutting zone responsible for paramount performance with conical textured tools over linear microgroove textured tools respectively. Sun *et al.* (2016) solid lubrications were applied on the single pattern and dual pattern textured tools during turning of AISI 1045 and compared the results. It was noticed improved turning performance with hybrid textured tools due to better cooling over single pattern textured tools. Liu *et al.* (2017) fabricated linear microgroove textured tools and evaluated the performance of textured tools in turning green alumina ceramic under dry condition. It was noticed greater turning performance with textured tools over untextured tools respectively. They concluded that the derivative cutting mechanism counted for beneficial results in textured tools. Xing *et al.* (2014) conducted turning experiments on hardened steel using various developed textured tools and found superior turning performance with textured tools over untextured tools under dry and solid lubrication condition. It was reported that low tool-chip contact length was accounted for better results in textured tools under both cutting environments. Recently, sivaiah *et al.* carried out extensive investigation on single pattern textured tools, dual pattern textured tools and untextured tools under MQL, wet and dry cutting conditions respectively. They obtained superior turning performance with textured tools because of effective cooling over untextured tools under considered cutting environments. Further, noted paramount results with dual pattern textured tools over single pattern textured tools under considered condition. It was reported that the micro pooling effect contributed to better results in textured tools under wet and MQL conditions (Sivaiah, 2019; Sivaiah *et al.*, 2019; Sivaiah and Uma, 2020; Sivaiah *et al.*, 2020a, 2020b, 2020c). Kawasegi *et al.* (2017) developed different linear microgroove tools with different geometry and investigated the friction efficient during turning of aluminum and nickel-phosphorus materials. They stated that the friction coefficient is significantly affected by the texture geometry.

Literature indicates that texture design and texture geometry present on the rake face of the tools have shown a significant impact on the turning performance characteristics while machining various difficult-to-cut materials. Therefore, in the present work, the performance of linear microgroove textured tools is evaluated during turning of EN8 steel and compared the results with untextured tools under wet condition respectively.

Materials and Methods

EN8 material is selected and machined this material using a conventional lathe machine with developed textured tools and untextured tools under the wet cooling condition as depicted in Figure 1.

In wet condition, castrol cooledge oil-water emulsion was used in the ratio of 1:20. Laser machined was used to fabricate the textured tools. The laser process variables considered in the present work are as follows: frequency: 45KHz, scanning speed: 10 mm/s, pulse duration: 650 ps and pulse energy was 1.75 μ J respectively. The PVD-coated tungsten carbide cutting tools were used to machine the workpiece material. Experiments were conducted at a constant depth of cut (ap) of 0.6 mm and varying cutting velocity (v), feed rate (f) conditions. The selected cutting velocity (v) values are 28, 57, 85, 113 and 141 m/min whereas feed rate (f) values are 0.12, 0.14, 0.16, 0.18 and 0.2 mm/rev. The pilot experiments were conducted to select the process variables range. A fresh cutting edge was utilized to cut each experiment. Each experiment was run for 600 mm length. PSBNL 2020 K12 ISO designated tool holder was used to fix the SNMA120408 ISO designated cutting tools. Kenna metal catalog was used to select the cutting tool to machine EN8 material. To maintain the accuracy in the output data, each experimental run is repeated three times. HTC IR 68 make IR thermometer was used to record the temperatures at the cutting zone. Zeiss make AXIOLAB A1 model optical microscope was used to measure the rake wear and flank wear of the machined tools. Talysurf tester was used to measure the average surface roughness tester. Scanning Electron Microscope (SEM) was



Figure 1. The cutting zone under cooling condition

used to done the analysis of tool wear mechanisms and surface defect analysis.

Results and Discussion

Cutting temperature is an important outcome to study since it significantly influences the turning performance characteristics. In this work, the effect of type of tool and process variables on cutting temperature was investigated and results were illustrated in Figure 2. It is found the low cutting temperature in textured tools over untextured tools under wet cooling condition. The recorded temperatures in untextured and textured respectively are 50°C and 40°C at a low cutting velocity of 28m/min. In this situation, the observed temperature drop in the textured tool is 20% over untextured tools. Likewise, 120°C and 100°C are the temperatures found in untextured and textured tools respectively. In this condition, the observed temperature drop is 16% in textured tools over untextured tools respectively. At this juncture, it is noticed low temperature drop at the higher cutting velocity condition compared to low cutting velocity condition. The higher friction generation at the high cutting condition is responsible for the low temperature at higher cutting velocity condition. When cutting velocity increases from 28 m/min to 141 m/min, the temperature drop found in the textured tool is the range of 8-20% over the untextured tool under the wet cooling condition as shown in Figure 2(a). Also, the obtained temperatures in the untextured and textured tool are 55°C and 45°C respectively at a low feed rate of 0.12 mm/rev. In this situation, the temperature reduction found in textured tools is 18% over untextured tool. Likewise, the pragmatic temperatures are 130°C and 110°C in untextured and textured tools respectively at a high feed rate of 0.2 mm/rev. In this circumstance, the temperature reduction is 15% in textured tools over untextured tools respectively. Overall, As shown in Figure 2(b), the temperature range found in textured tools is 15-19% over untextured tools when the feed rate increases from 0.1 to 0.2 mm/rev. At this point, the temperature drop noticed at the high feed rate is low compared to the low feed rate condition using both cutting tools. Since high feed rate increases the tool-chip contact length causes more friction between the tool and workpiece. As a whole, a significant reduction of temperature is found in textured tools over untextured tools respectively under wet cooling condition. This is because of storage of coolant in the microgrooves present over the tool rake face causes incessantly of coolant to the cutting zone

results leads to low friction at the cutting zone hence low temperature observed in textured tools. The obtained results in the present work have good agreement with the literature results (Gajrani *et al.*, 2019).

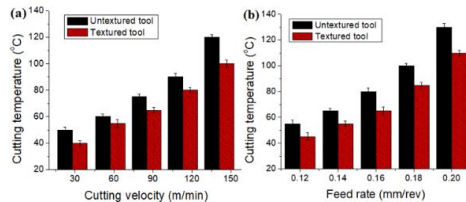


Figure 2. Effect of type of tool and process variables on cutting temperature

Figure 3 indicates the type of tool and process variables on rake wear under wet cooling. From Figure 3, it is observed that textured tools significantly reduced the rake wear over untextured tools respectively under both process variable conditions. Further, it is noticed that rake wear increases when both process variables increasing condition. The rise of temperature at the higher cutting condition contributed to high rake wear. At a low cutting velocity of 28 m/min, rake wear found in the untextured and textured tool is 200 μm and 180 μm respectively. In this circumstance, the rake wear reduction of 10% found in textured tool over the untextured tool. At a high cutting velocity of 141 m/min, 280 μm and 260 μm are the measured rake wear values in untextured and textured tool respectively. In this condition, it is noticed 7% reduction in rake wear with textured tools over untextured tool. Overall, when cutting velocity increases from 28 m/min to 141 m/min, the rake wear drop range observed is 7-10% in textured tools over the untextured tools as shown in Figure 3(a). At a low feed rate of 0.12 mm/rev, the measured rake wear values in untextured and textured tools are 210 μm and 190 μm respectively. In this condition, rake wear is significantly diminished by 10% in textured tools over untextured tools. At a high feed rate of 0.2 mm/rev, the noted rake wear values are 320 μm and 295 μm respectively in untextured and textured tool. In this situation, a 8% reduction was observed in textured tool over the untextured tool. On the other hand, when the feed rate surges up from 0.1 to 0.2 mm/rev, the range of rake wear reductions found in textured tools is 6-10% over untextured tools as shown in Figure 3(b). Overall, a significant reduction in rake wear is observed in textured tools over untextured tools under wet cooling condition. Microgrooves on tool rake face provide micro pooling effect causes low temperatures leads to low rake wear in textured tools. It is evident from

Figure 4 that untextured tool produced more BUE compared to textured tools. Low temperatures in textured tools responsible for low BUE. The results of the present work are supported by the literature results (Vasumathy *et al.*, 2017).

A study on flank wear is obliged since it decides the surface quality of the machined samples. Figure 5 depicts the effect of the type of tool and process variables on flank wear. As shown in Figure 5, the flank wear followed uptrend in the case of increasing cutting velocity and feed rate conditions respectively. When considered process variables increases causes high friction at the cutting condition hence flank wear increases. From Figure 5, the measured flank wear values are 70 μm and 60 μm respectively in untextured and textured tools at a low cutting velocity of 28 m/min. In this condition, the flank wear reduction in the textured tool is 14% over the untextured tool. Likewise, at a high cutting velocity of 141 m/min, the flank wear found in the untextured and textured tools are 190 μm and 165 μm respectively. In this circumstance, the reduction of flank wear noticed in the textured tool is 13% over untextured tools. Subsequently, when cutting velocity increases from 28 m/min to 141 m/min, the range of 11-18%

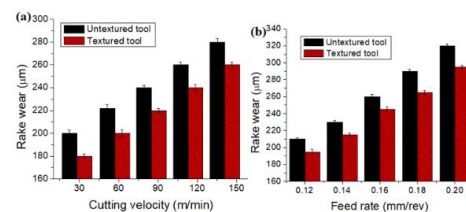


Figure 3. Effect of type of tool and process variables on rake wear

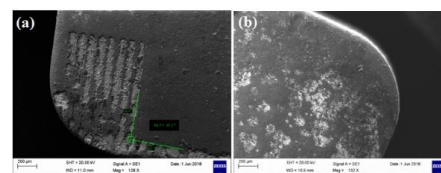


Figure 4. SEM images of tool rake wear at $v = 85$ m/min, $f = 0.16$ mm/rev and $a_p = 0.6$ mm (a) Textured tool (b) Untextured tool

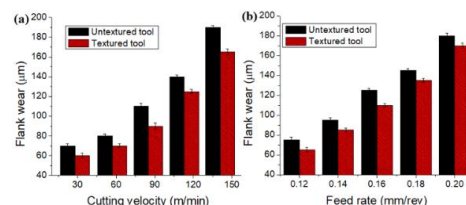


Figure 5. Effect of type of tool and process variables on flank wear

reduction of flank wear is observed in textured tools over untextured tools respectively as depicted in Figure 5(a). At a low feed rate of 0.12 mm/rev, the untextured tool and textured tool produced 75 μ m and 65 μ m respective flank wear values. At this point in time, the flank wear diminished to 13% in textured tool over the untextured tool. Similarly, the observed flank wear values in the untextured and textured tools are 180 μ m and 170 μ m respectively at a high feed rate of 0.2 mm/rev. In this circumstance, the flank wear drop found in the textured tool is 5% over the untextured tool. It is perceived from Figure 5(b) that the percentage of flank wear drop at low feed rate is high over high feed rate condition due to efficient cooling at low feed rate. As a whole, when the feed rate increases from 0.1 to 0.2 mm/rev, the flank wear reduction range are 5-13% in textured tools over untextured tools respectively as seen in Figure 5(b). Overall, flank wear reductions found in textured tools is more compared to the untextured tools. Micro pooling effect with textured tools under wet cooling condition causes effective lubrication at the cutting zone leads to low tool-chip contact length therefore flank wear lesser in textured tools. It is evident from Figure 6 that textured tool formed low flank wear compared to untextured tools. Efficient lubrication accounted for less BUE in textured tools. In the literature, the obtained results in the present work are correlated with literature results (Sugihara and Enomoto, 2013).

The load-bearing capacity of any machined product is substantially affected by the product surface roughness. Figure 7 depicts the effect of type of tool and process variables on surface roughness.

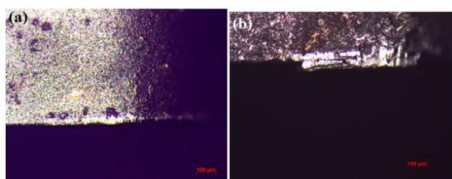


Figure 6. Optical micro scope images of flank wear at $v = 85$ m/min, $f = 0.16$ mm/rev and $a_p = 0.6$ mm (a) Textured tool (b) Untextured tool

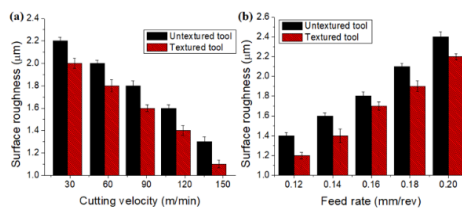


Figure 7. Effect of type of tool and process variables on surface roughness

As seen in Figure 7, surface roughness followed the decreasing trend with a rise in cutting velocity due to low tool-chip contact length at the higher cutting velocity condition. However, the surface roughness followed an increasing trend in the case of the rise of feed rate due to high tool-chip contact length at the high feed are condition. Further, Figure 7 show that textured tools significantly lower the surface roughness value under wet cooling condition. At a low cutting velocity of 28m/min, the measured surface roughness values in the untextured and textured tool are 2.2 μ m and 2 μ m respectively. In this situation, the surface reduction noticed in the textured tool is 9% over the untextured tool. Likewise, untextured and textured tools produced 1.3 μ m and 1.1 μ m surface roughness respectively at a high cutting velocity of 141 m/min. At this condition, the textured tool substantially diminished the surface roughness to 15% over the untextured tool. As a whole, when cutting velocity increases from 28 m/min to 141 m/min, the surface roughness reductions found in the textured tools is in the range of 9-15% over untextured tools as illustrated in Figure 7(a). Similarly, the observed surface roughness values are 1.4 μ m and 1.2 μ m respectively in the untextured and textured tools at a low feed rate of 0.12 mm/rev. In circumstance, 14% surface roughness reduction was found in the textured tool over the untextured tool. Also, at a high feed rate of 0.2 mm/rev, the obtained surface roughness in the untextured and textured tools is 2.4 μ m and 2.2 μ m respectively. At this situation, it is found 8% surface roughness in textured tool over untextured tool. Overall, when feed rate increases from 0.1 to 0.2 mm/rev, the surface roughness is significantly reduced in the textured tool in the range of 5-14% over untextured tools respectively as shown in Figure 7(b). Taken as a whole, textured tools significantly reduced the surface roughness over untextured tools under wet cooling condition. This is because when wet coolant is supplied on the textured tool causes reaching of more accelerated coolant to the cutting zone leads to smooth cutting action at the cutting zone results in reduced surface roughness in textured tools. Figure 8 is the witness for textured tools produce low roughness machined surface. From Figure 8, it is noticed that untextured tools produced different surface defects such as metal debris, tool groove marks and adhesion of microchip particles. It is observed that high cutting temperature and high tool wear are responsible for more surface defects in untextured tools. The obtained results found good agreement with the literature results (Rajbongshi and Sarma, 2019).

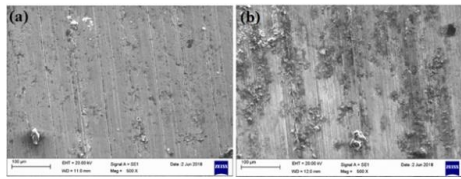


Figure 8. SEM images of machined surface at $v = 85$ m/min, $f = 0.16$ mm/rev and $a_p = 0.6$ mm
(a) Textured tool (b) Untextured tool

Conclusions

The noted maximum reductions observed in cutting temperature, rake wear, flank wear and surface roughness were 19%, 10%, 18% and 15% respectively in textured tools over untextured tools during machining of EN8 material.

Surface roughness decreased when cutting velocity increases whereas it increases in the case of rising condition of feed rate.

When cutting velocity and feed rate increase from low to high values, the cutting temperature, rake wear and flank wear values increased.

It was observed micro pooling effect with microgrooves present the textured tools under wet cooling condition.

Metal cutting industries could use the so developed textured tools to improve the productivity during turning of EN8 material under wet cooling condition.

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