EVALUATION OF HYBRID TEXTURED TOOLS PERFORMANCE DURING TURNING OF AISI 321 STEEL UNDER DRY, WET CONDITIONS: A COMPARISON WITH UNTEXTURED TOOLS

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ABSTRACT

In most cases, there are numerous factors that can affect the efficiency of a mechanical procedure. The cutting settings, fluid circumstances, tool substance properties, work component properties, machine powers, etc. All cutting factors affect different outcomes when using the same object material and tool material for milling. The edge of the tool blade can be patterned with micro-textured designs to accomplish this. This research focuses on the process of controlling the cutting parameters of speed, depth of cut, and feed rate in order to optimise the CNC turning performance metrics of Tool wear (TW) and surface roughness while milling a specific pattern into a tungsten carbide tool and turning an AISI 321 steel workpiece. This is due to the study's emphasis on quantitative analysis of the relationships between cutting factors like spindle speed, feed rate, and depth of cut and the resulting surface irregularity and tool wear. In this project, we will shape an AISI 321 steel object after creating a custom design on a tungsten carbide tool. Following the experiments, the levels of surface irregularity and tool attrition were measured and documented. The outcomes are then compared to those obtained with non-textured instruments. The acquired findings are being compared to those obtained with untextured instruments. Altogether, the existence of microtextured on cutting tools improved production costs.

Keywords: CNC Turning, Tool Wear, Surface Roughness, Wet, Dry, AISI 321 steel.

1.Introduction

Milling is the process of modifying an object by cutting away excess substance. In this method, material is removed from the component by applying pressure to an instrument made of a stronger substance than the part itself. The most common method of industrial moulding is machining, which goes by a variety of other names, including cutting, metal cutting, and substance elimination. It functions as both an initial and final formative step. The term "machine tool" is commonly used to refer to the equipment that performs the work of cutting or removing substance. To achieve the desired end shape or surface features, nearly all moulds and products made by compression processing (bulk or sheet metal) require some cutting. Chipping is the most common method of substance removal. Machine cutting is preferred over by and because of these two main moulding methods.

- Improve dimensional tolerances.
- Improve surface finish.
- Produce complex geometries.
- Produce low quantities economically because of more flexibility in tooling and fixturing.
- Low operating costs.
- Lower setup times (time to prepare fooling for production)

To achieve the desired measurement accuracy, surface polish, or commies' shape of the component, milling is often performed as a supplementary procedure following casting or moulding. Only the machining method is used for both the main and auxiliary processes of shaping. Because of this special quality, this method has become standard practise. Machining can be broken down into several distinct subfields. One way to categorise surfaces is by the instruments used to create them. When categorising cutting tools, the quantity of blades is considered. Turning, planning, moulding, and piercing are all examples of single-point cutting techniques, while sawing, dicing, and dicing are examples of

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multiple-point cutting techniques (Two edges: drilling, edges: milling, sawing, reaming, broaching, etc, Infinite number of edges: grinding, polishing).

1.1 Machining variables and relationship

There are many different types of milling, each with its own set of factors and interdependencies. The energy needs are heavily dependent on these three factors because they affect the metal clearance rate (MRR). The finances of the procedures are also significantly impacted by these factors.

1.2 Coolant

To lower the temperature of a device, a liquid or petrol refrigerant is used.

Figure 1.1 Coolant.

Varieties of machine-use coolants During milling and particulate removal, it is frequently used to reduce temps. Each of these variations has its own set of advantages and disadvantages. Synthetic, mineral oil, and semi-synthetic are the three main categories of fluids. To minimise instrument damage, this lubricant is crucial.

1.3 Tool Wear

The instrument, the job, and the machine itself are all severely compromised by the first two failure scenarios. Tool failures of this sort can be prevented, however, by carefully selecting the materials and shape for each specific working substance and cutting situation. Nonetheless, wear failure over time is unavoidable and can only be delayed increasing tool life. Whenever feasible, the cutting instrument is removed from the cutting zone just before it completely fails. That requires realising the instrument is broken or soon will be. When the instrument or active edge reaches a certain level of attrition, it must be changed to maintain the intended cutting action. Tool deterioration causes the following issues: 1. higher cutting forces; 2. rougher surfaces; 3. less precise measurements. Turn up the heat: 5. Disturbance; 6. Decreased Production Efficiency; 7. Low-Quality Components 7 Raise prices.

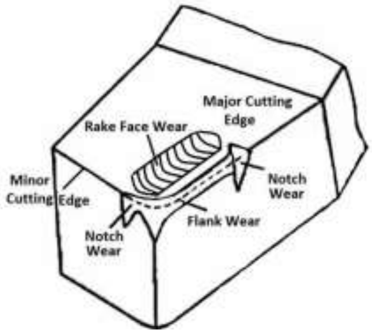

Figure 1.2 Tool Wear phenomenon

1.4 Cutting Parameters

There are three types of relative motion between the object and the instrument being used for cutting in a milling process. Essential for precision substance clearance. Advancement of the cutting instrument towards the task substance is brought about by the three related movements. Cutting factors refer to the three related movements. Rapidity of cutting. (2) The level of slicing depth Amount of Feeding 3.

1.5 Cutting Tool Material

Wear slows output, increases the expense of tools, machines, and labour, and shortens the time between tool changes. To a lesser extent, the cutting tool's substance characteristics can influence wear. As a result, research, and development in the field of cutting materials is ongoing and aims to both enhance existing cutting tool materials and find novel materials for use in the production of cutting tools. To stand up to the demands made of them, the materials used in cutting tools must possess qualities like high hardness and pressure resistance, high bending strength and soughs edge strength, high

temperature strength, oxidation resistance, low propensity to diffusion and adhesion, high abrasion resistance, and reproducible wear behaviour. Tool steels cemented tungsten carbides, ceramics, super-hand boron nitride, and diamonds are the most common types of cutting tool materials.
High rates of material clearance and precision milling have both been made possible by the widespread adoption of computer numerical control (CNC) manufacturing centres. Spindle speed, input rate, depth of cut, etc., are just some of the many variables that can be adjusted while operating a computer numerically controlled lathe. Cost and quality of the final products are considered as motivations for focusing on metal clearance rate and tool fatigue as performance metrics.

1.6 AISI 321 Material

Highly corrosion-resistant Alloy 321 is a titanium-stabilized austenitic stainless steel. When subjected to temps in the chromium. carbide precipitation range of 800 to 1500°F (427 to 816°C), it exhibits exceptional resilience to intergranular rust. The metal has superior creep and tension breakage characteristics to alloys 304 and 304L and is resistant to weathering up to 1500°F (816°C). The material is strong even when cold. Good strength and exceptional rust resistance are hallmarks of AISI 321, an austenitic titanium-stabilized chromium-nickel stainless steel typically provided in the annealed state with a Brinell hardness of 175. Titanium's calming impact as a carbide formation element makes it suitable for welding and/or use within the carbide precipitation range of 430°C - 870°C without the danger of intergranular erosion, expanding the range of possible uses for the material.

1.7 Manufacturing textures on the tools with laser texture machine

The combination device is made through a fibre laser manufacturing procedure. To create a pattern on the border of an instrument, a laser is used, and the process requires a CAD drawing and the provision of precise information.

Figure 1.3 Fiber laser processing of tools.

2. LTERATURE REVIEW

When turning Al-Cu/TiB2 composite material, Arulkirubakaran et al. (2019) found that textured tools under solid lubrication condition required less force to cut the material than untextured tools. This was attributed to the textured tools' increased ability to disperse the cutting edge's frictional heat. The low built up edge development on the cutting edge of textured tools with channels orthogonal to the chip flow direction has also been observed to improve turning performance compared to other textured designs. A dimple-shaped pattern was used as the texture design by Darshan et al. (2019), who then assessed the performance of the textured tools in terms of surface roughness, tool wear, cutting force, cutting temperature, and chip morphology when turning Inconel 718 alloy using dry, solid lubricants and MQL cutting conditions. Because of the low friction coefficient at the cutting zone, it was stated that using rough tools under solid lube aid MQL circumstances greatly enhanced the turning performance. In addition, with the MQL condition, regulated cutting zone temps resulted in pieces that were suitable for use.
Dry turning of VSM13 martensitic stainless steel was studied by Bertolete et al. (2018), who created linear lines parallel to the tool cutting edge at varying distances from the cutting edge and compared the findings to those obtained with an untextured tool. The results showed that the tribological

characteristics were greatly altered in favour of the milling process by using patterned tools. It was also discovered that surface irregularity, tool attrition, and cutting pressures during the turning process are all greatly impacted by the size and distance of the pattern gap from the cutting edge.
During dry turning of aluminium metal, textured tools with circular indentation designs were found to have a smaller cutting force and a bigger shear angle than untextured tools, according to research by Durairaj et al. (2018). One of the benefits of using rough tools is that you can better regulate the workpiece's adherence to the tool, which leads to better outcomes. The depth, pitch, and distance from the cutting edge were also examined using ANOVA, with the indentation dimension emerging as the most significant factor. Moreover, embossed tool design was included in the Taguchi analysis that was used to determine the optimal turning process parameters.
Experiments were conducted by Hao et al. (2018) on titanium metal with dry and MQL cutting circumstances using a variety of tool textures, including single textured tools with linear channels, mixed textured tools, and untextured tools. Low cutting force and tool degradation in patterned tools have been observed due to the low friction coefficient in both the dry and wet cutting conditions. In addition, when compared to single textured tools under MQL cutting circumstances, hybrid textured tools show markedly better turning performance due to a shorter tool-chip contact length and the capacity for fluid storing.
For their study, Palanisamy et al. (2019) etched linear microgrooves parallel to the cutting edge on cryogenically treated tungsten carbide tools and used reaction surface methods to analyse the effects of tool texture on surface roughness and cutting pressures in the milling of 17-4 PH SS (RSM). Cutting rate was found to have a significant impact on surface irregularity. And researchers found that sticky wear was the primary wear process. The RSM-based statistical models that were created also showed a good match between the expected results and the actual findings.
Dry turning of mild steel (EN3B) and aluminium (AA 6351), using single textured pattern tools and untextured tools, respectively, was studied by Thomas and Kalaichelvan (2018). According to the literature, the minimal friction at the cutting zone of patterned instruments significantly improves the turning process. Additionally, distinct differences in crystal form were observed between the results produced using textured and untextured instruments.

Objective of the work

Producing composite textured tools and contrasting the outcomes with those of textured and untextured tools made in dry, Wet cutting conditions.

3.Experimental Work

3.1 Experimental Procedure

Tests were scheduled for the CNC Lathe machine with Hybrid textured and non-textured tools in DRY and Moist environments, respectively, depending on the work component. Dry and damp machining areas are differentiated below. In every trial that has been performed, a brand-new instrument point has been used. The composite patterned instrument shown in Figure 1.3 is made using a fibre laser processing procedure. Machineability was measured in this research by measuring surface imperfection and tool fatigue. The average surface roughness (Ra) of the milled examples has been measured with a Talysurf roughness analyser of Mitutoyo, SJ-301 type. Olympus BX-53M upright optical microscope was used to evaluate the instrument damage. The instrument's temperature was recorded. SEM was used to analyse tool degradation processes and detect surface defects.

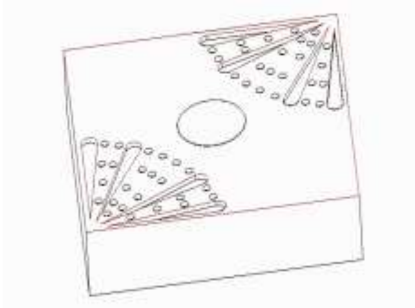

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Figure 1.4 CAD design layout for texture tool.

3.2 Design of Experiments

The experiment was carried out on a computer numerically controlled turning centre. We conduct our research using AISI 321 steel for the examination of the job component. The austenitic chromium-nickel stainless steel AISI 321 is titanium-stabilized. Chromium occupies 19.0 atomic percent, Nickel 12.0, Carbon 0.08, Manganese 2.0, Phosphorus 0.045, Sulphur 0.03 Silica 0.75, Titanium 0.70, Nitrogen 0.10, and Iron provides the foundation (Fe). Various cutting instruments used in high-volume manufacturing make use of its corrosion-resistance and sturdiness. Using carbide inlays, the object is turned to a length of 150 mm and a thickness of 35 mm. Spindle speed, feed, and depth of cut are the experimental controls, with tool attrition and surface irregularity serving as the output reaction and contrast between textured and untextured tools, respectively. Table 1 provides a summary of the factors used for process management and their respective ranges.

Table 1 Control Variables along with the levels

S. No	Control Factors	Units	Level A	Level B	Level C
1	Speed	Rpm	800	1200	1600
2	Feed	Mm/min	0.15	0.15	0.15
3	Depth of Cut	Mm	0.2	0.3	0.4

4.Results and discussion

After carrying out tests in accordance with the plan for doing so, the final reaction is analysed and documented. Surface hardness can be evaluated with a talysurf device, and tool wear can be analysed with a tool maker's lens. The figures below detail the outcome reactions observed for various sets of process control factors and other variables.

Table 2 Experimental Observation for surface roughness.

Surface Roughness

Dry			Wet		
Speed	Untextured	Texture	Speed	Untextured	Texture
800	3.12	2.94	800	2.85	2.62
1200	2.42	2.26	1200	2.31	2.02
1600	1.84	1.64	1600	1.72	1.52

Table 3 Experimental Observation for rake wear.

Rake Wear

Dry			Wet		
Speed	Untextured	Texture	Speed	Untextured	Texture
800	589	456	800	461	390
1200	643	632	1200	601	488
1600	658	564	1600	647	519

Table 4 Experimental Observation for flank wear.

Flank Wear

Dry			Wet		
Speed	Untextured	Texture	Speed	Untextured	Texture
800	344	304	800	324	282
1200	488	442	1200	427	285
1600	699	623	1600	664	594

Table 5 Experimental Observation for temperature.

Temperature

Dry			Wet		
Speed	Untextured	Texture	Speed	Untextured	Texture
800	395	362	800	272	245

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1200	445	427	1200	332	308
1600	520	502	1600	390	381

4.1 Effect of cutting condition and process parameters on surface roughness

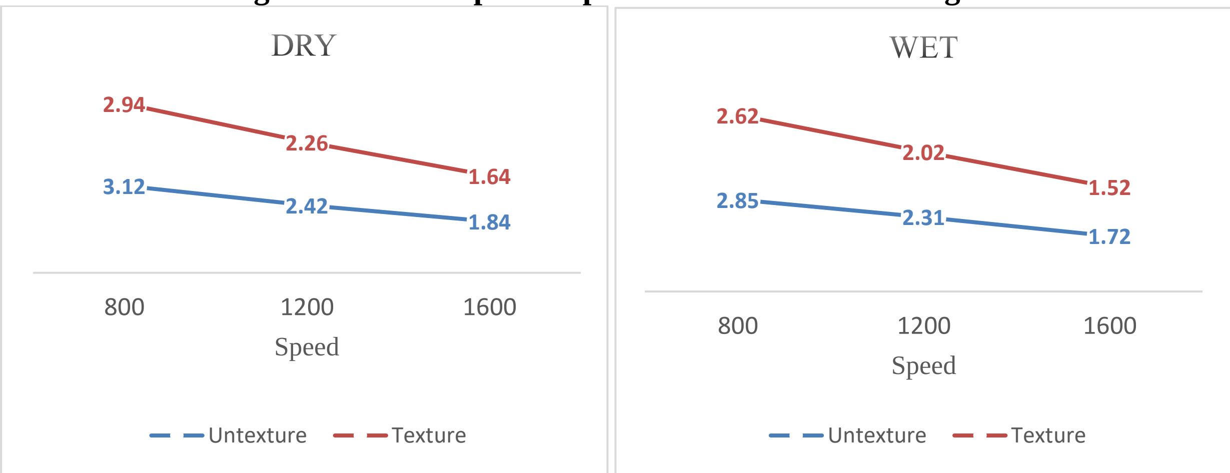

Figure 1.5 Influence of cutting condition and speed on surface roughness.

This study compared the surface roughness values obtained from dry and moist milling of AISI 321 SS using hybrid textured and untextured tools with the specifications listed in Table 1. As shown in the Fig. 1.5. The cutting speed and depth of cut have been increased while the input rate has remained unchanged. For the reasons stated above, the untextured tool outperforms the textured tool across both circumstances shown in the preceding image. Textured surfaces have a roughness value almost three times lower than smooth surfaces when dry, and their velocities are decreased by 20-25 percent. The surface irregularity value of a textured surface is decreased by 25-30% compared to an untextured surface when moist.

4.2 Effect of cutting condition and process parameters on rake wear

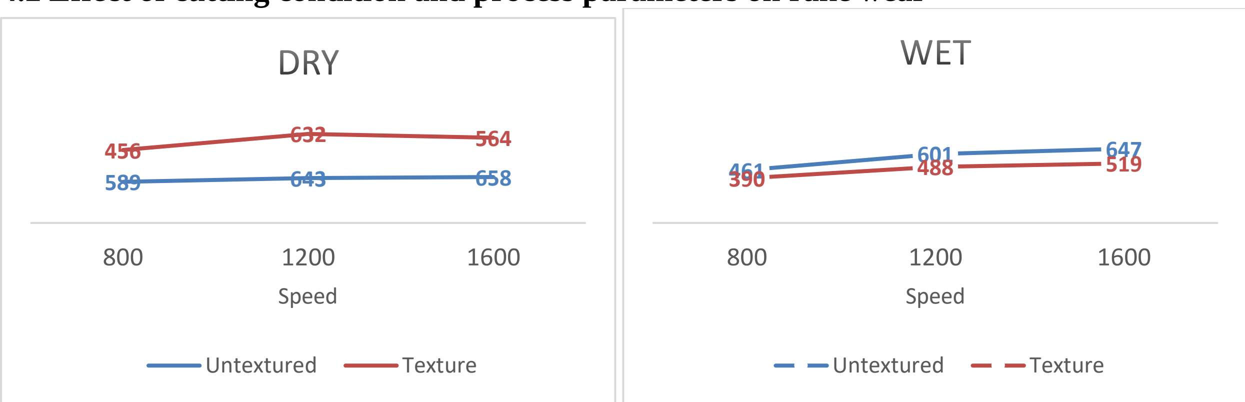

Figure 1.6 Rake Wear at different conditions (Dry, Wet)

Figure 1.6 shows that in arid conditions, the value of blade wear is 20% lower for a serrated implement than for an untextured one. Rake wear on a textured tool is decreased by 23% compared to an untextured tool in wet chilling conditions. Wet and dry chilling circumstances offer superior performance for both textured and untextured tools, as shown in table 1 and contrasted with the cutting factors.

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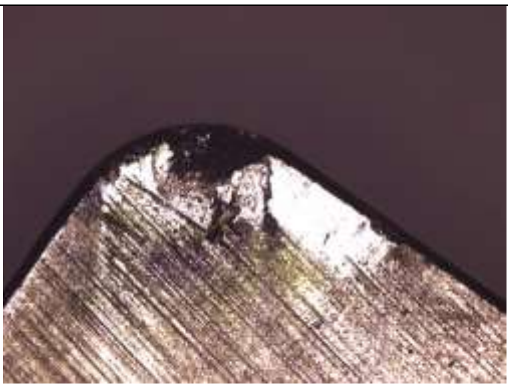
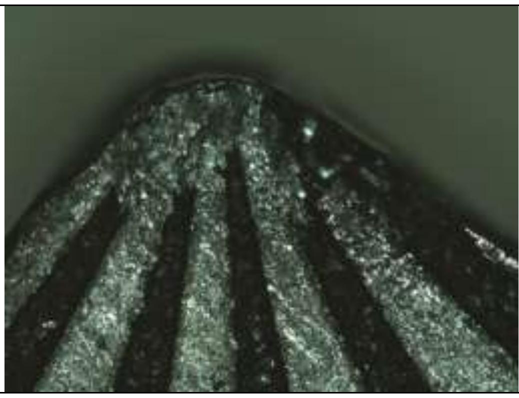
Untextured	Texture
	
Dry condition(rakewear) at N=1200RMP,F=0.15,d=0.3	

Figure 1.7 Observed rake wear of textured and untextured tool at cutting velocity(v)=1200m/min, feed rate(f)=0.15mm/rev, depth of cut=0.3mm cutting parameters and dry condition.

Figure 1.7 shows us without a doubt that arid conditions cause a great deal of tool attrition and build up edge (BUE), as measured by average cutting speed. Wear on textured tools is reduced compared to untextured tools, as shown in Figure 1.7.

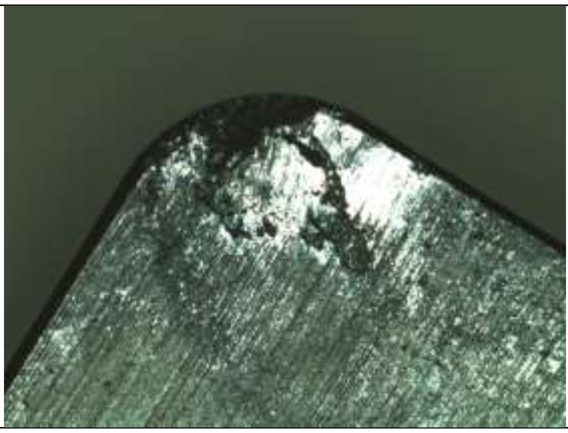
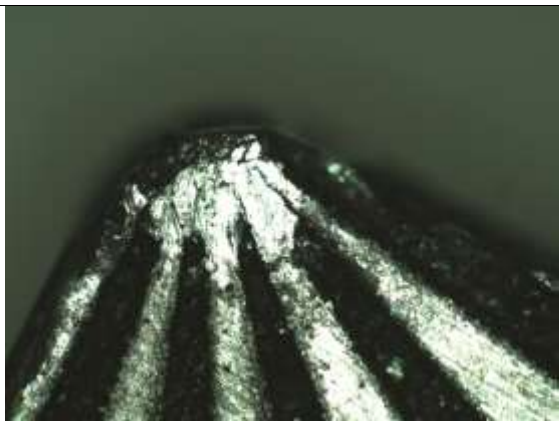
Untextured	Texture
	
wet condition(rakewear) at N=1200RMP,F=0.15,d=0.3	

Figure 1.8 Observed rake wear of textured and untextured tool at cutting velocity(v)=1200m/min, feed rate(f)=0.15mm/rev, depth of cut=0.3mm cutting parameters and wet condition.

We can see from Fig. 1.8 that the average pace of cutting and the amount of tool attrition and build up edge (BUE) are both elevated under damp conditions. Figure 1.8 shows that rough tools last longer than their smooth counterparts in terms of attrition. When it's raining, there's less of a chance that a build-up border will develop, and less damage overall.

4.3 Effect of cutting condition and process parameters on flank wear

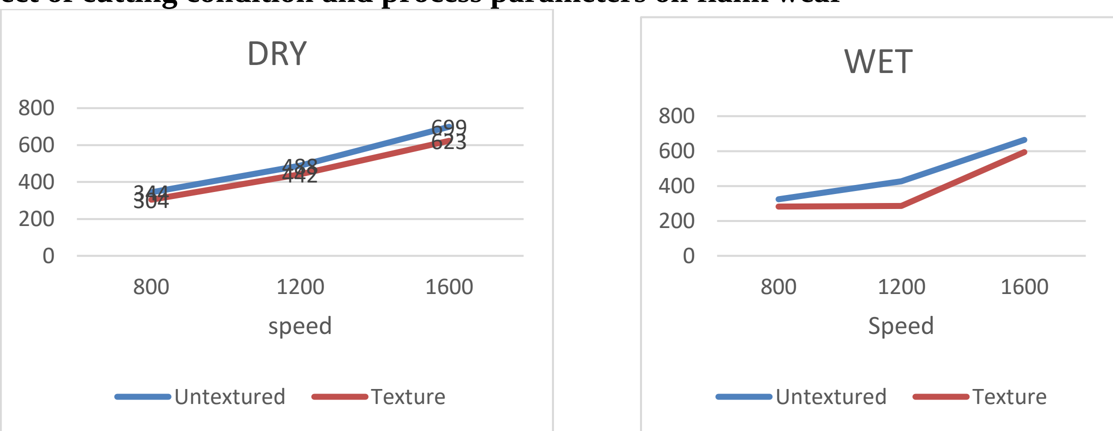


Figure 1.9 flank Wear at different conditions (Dry, Wet)

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Figure 1.9 shows that in arid conditions, the value of a textured tool's side wear is 15% lower than that of an untextured tool. Rake wear on a textured tool is decreased by 10% compared to an untextured tool in wet chilling conditions. Table 1's values are compared to the threshold values. Textured tools performed better than their smooth counterparts under both damp and dry chilling circumstances.

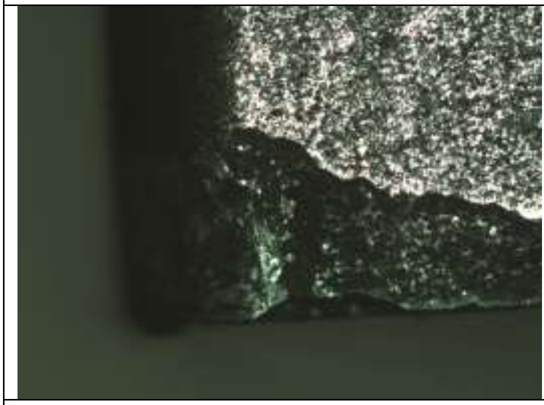
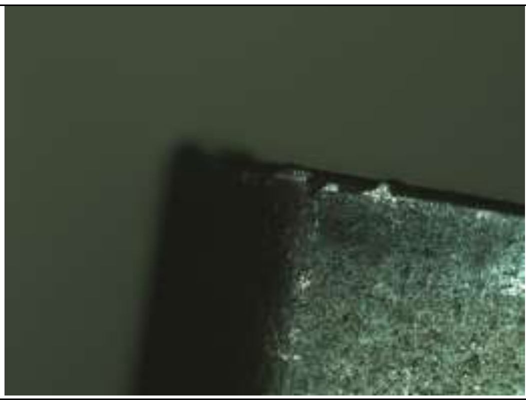
Untextured	Texture
	
Dry condition(flank wear) at N=1200RMP,F=0.15,d=0.3	

Figure 2.0 Observed flank wear of textured and untextured tool at cutting velocity(v)=1200m/min, feed rate(f)=0.15mm/rev, depth of cut=0.3mm cutting parameters and dry condition.

We can see in Figure 2.0 that the average pace of cutting and the amount of tool attrition and build up edge (BUE) are both elevated when working in arid conditions. As can be seen in Figure 2.0, detailed tools last longer than their untextured counterparts.

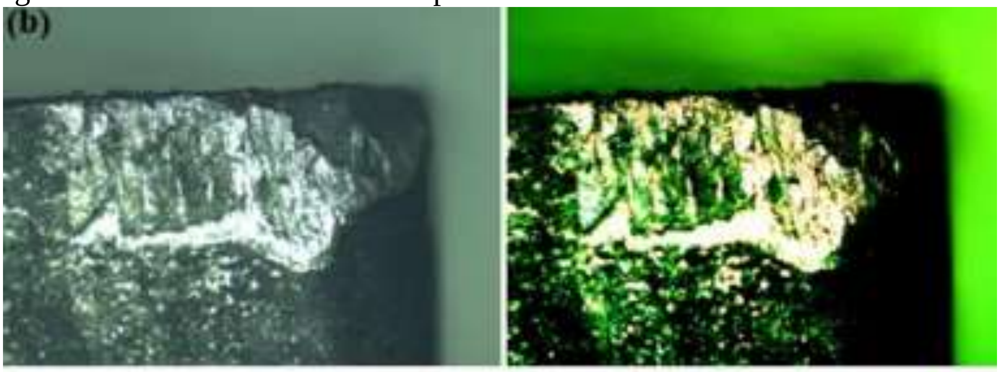


Figure 2.1 Observed flank wear of textured and untextured tool at cutting velocity(v)=1200m/min, feed rate(f)=0.15mm/rev, depth of cut=0.3mm cutting parameters and wet condition.

We can see from Fig. 2.1 that the average pace of cutting, and tool attrition are both exceptionally high in damp conditions. A clearer comparison between textured and untextured tool deterioration is shown in figure 2.1. When it's raining, there's less of a chance that a build-up border will develop, and less damage overall.

4.4 Effect of cutting condition and Temperature

Figure 2.2 shows that in arid conditions, the serrated instrument has a higher temperature value than the untextured one. In wet chilling conditions, a rough instrument maintains a more consistent temperature than a smooth one. It is derived from Table 1 and compared to the threshold values. It was also discovered that textured tools performed better than untextured tools in both damp and arid chilling environments. It was easily seen in figure 2.2 below that temperature pictures in dry and moist circumstances correspond to textured and untextured instruments, respectively.

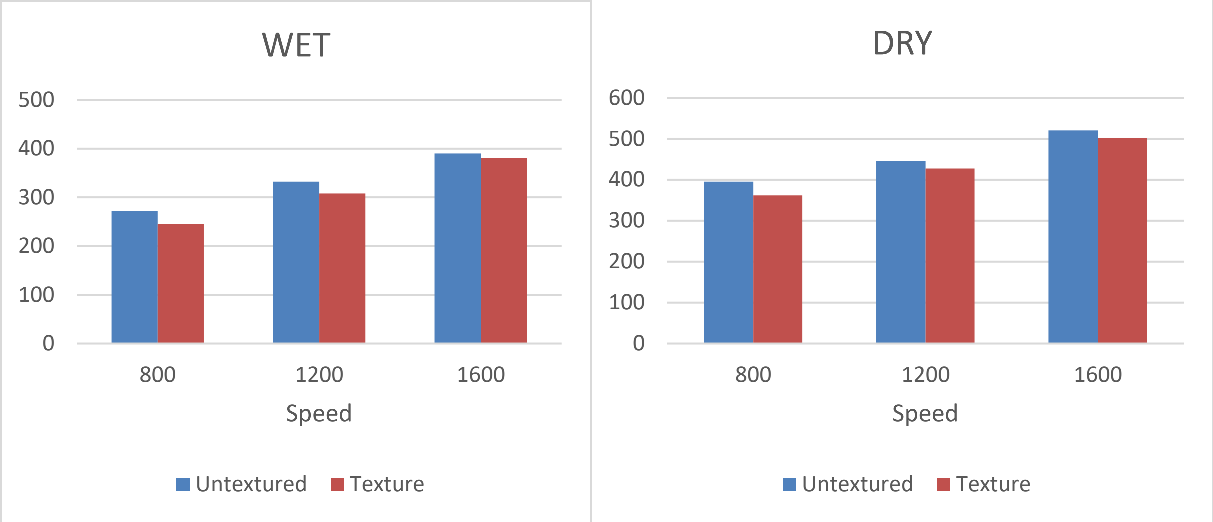


Figure 2.2 Observed temperature of textured and untextured tools.

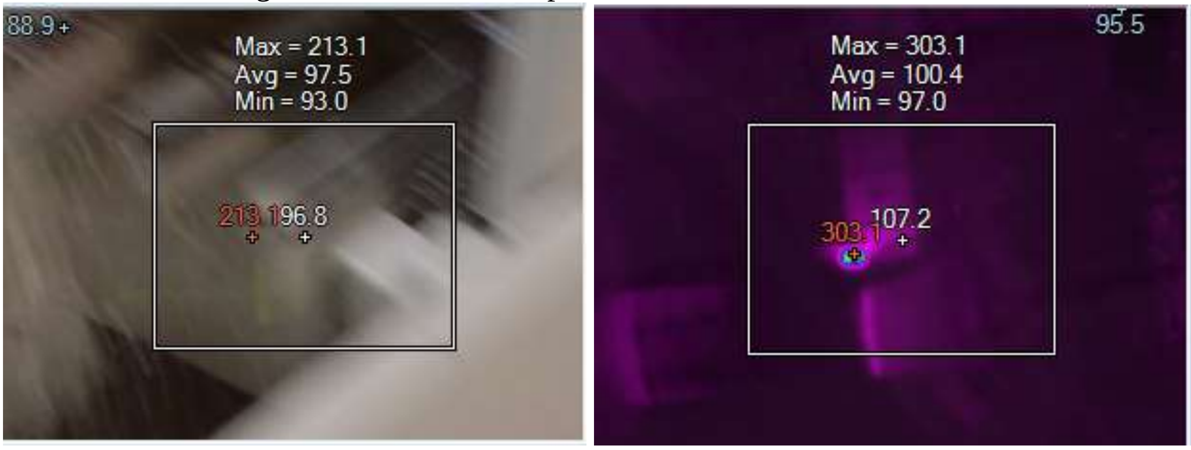


Figure 2.3 Observed temperature.

4.5 Chip Formation

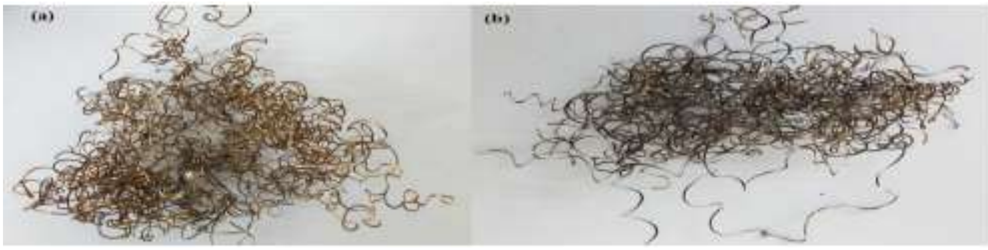


Figure 2.4 Observed chips of untextured tool different cutting environments (a) Dry (b) wet.

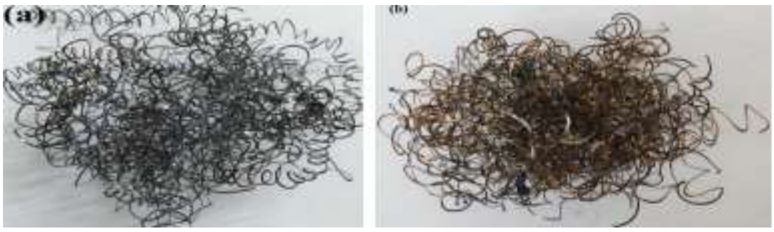


Figure 2.5 Observed chips of textured tool different cutting environments (a) Dry (b) wet.

5 Conclusion

Pulsed fibre laser milling was used to create a composite patterned surface on the rake face of carbide tools for this project. In the following experiments, cutting tools with composite textures were used to cut AISI 321 material, and the impact of these textures on cutting performance was analysed in both dry and moist circumstances. These findings are deduced. Tools with a hybrid substance are more durable in both damp and dry settings. Reservoir storage is uninterrupted by breaks thanks to the

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smooth, curved surface, which is dotted with channels. The slanted slots also act as guides, halting the escape of lubricant oil and fragments from storage. Rake wear is decreased by 19% with a serrated tool compared to an untextured tool. Rake wear on a textured tool is decreased by 23% compared to an untextured tool under damp chilling conditions. Hybrid textured tools wore down primarily due to adhesion wear in both dry and damp cutting situations. Tool fatigue was decreased by up to 20% in both cases using the composite textured tool compared to using an untextured tool.

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