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Performance Measurement of Drilling Process using Micro Textured Drill on Titanium Alloy

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Abstract: In manufacturing industry, machining process and its environmental effect analysis are very important for enhancement of sustainability analysis. In drilling process, the heat is generated due to friction, and this heat can be removed by the application of cutting fluid. The cutting fluid serves as an agent to cool the cutting tool and lubricates between the tool-chip and tool-work piece interface, but it also produces environmental pollution and other operator health issues. Hence, various research works are carried out to achieve sustainable machining by using development of new coated tools, minimum quality lubrication (MQL) and cryogenic machining. It has been observed that in recent times some research works are focused with different types of textured surface on drill tool either on flute or margin surfaces for improvement of tribological properties and sustainable improvement. These textured surfaces are also known as micro grove, micro pool, self-lubricating, self-cooling cutting inserts filled with solid lubricant which has been found, the application of solid lubricant on textured surface is observed to provide lubrication effect. In this work, the application of margin and flute textured drilling tool on drilling of titanium alloy. Input parameters include spindle speed, feed rate and cutting conditions. Output parameters surface roughness, and temperature. The result revealed that textured drill tool provides better machining performance. It also leads to sustainability in manufacturing process.

Keywords: *Drilling, Titanium alloy, Textures, process parameters and cutting conditions*

1. Introduction to DTH hammer

Machining processes is widely used in manufacturing industries as a material finishing operation. While machining ferrous and other high strength alloys, lot of heat is generated due to friction. Most of the machining process is carried out in the presence of cutting fluid and it reduces the co-efficient of friction and cutting zone temperature at the tool-chip interface. further it improves the tribological condition.

However, the application of cutting fluid produces negative environmental impact due to environmental pollution, soil contamination, and ground water pollution, harmful to operator health [7]. As there is negative impact on environment, a research work has been carried out on machining without cutting fluid (dry machining) for reducing the environmental pollution and machining costs. But in dry machining, tool life of the cutting tool inserts was reduced due to high friction, overheating of the cutting tool, reduction of close tolerance, metallurgical damage on machined surface, chip formation can be deteriorating machined surface, unable to wash away, adhesion among tool-chip interface, thermal softening, inducing tensile residual stresses and excessive tool wear [9; Ojolo et al (2008)]. To find a solution the above issues, researchers have focused in development of new cutting tools (i.e.) with textured surface.

In the present study to achieve green eco-nomic and eco-friendly machining and to avoid issues related to mineral oil-based cutting fluid and solid lubricants, vegetable oil has been used with the textured tools. Drilling

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is a significant metal cutting process which has 40 to 60 percentage contribution in material removal industries. Surface roughness measurement of drilled hole is an indication of machinability characteristics. It is influencing functional characteristics such as corrosion resistance, coefficient of friction, and fatigue strength and wear rate, hence manufacturing industries given special attention in drilled surface quality. Cutting tool vibration measurement and its minimization during drilling process leads to improve their efficiency in terms of functional life and dimensional accuracy. Temperature induced during machining process must be removed to increase cutting tool life.

Paulsen et al. [13] investigated that the effect of machining conditions to the properties of machined subsurface in drilling of titanium alloy. In their work, dry and Minimum Quantity Lubrication (MQL) conditions were used. Machined surface properties such as hardness and residual stresses were considered. The result concluded that hardness and tensile residual stresses of the machined component could be controlled by suitable machining conditions. Ahamed and Varote and Joshi [11] analyzed that microstructure and surface integrity in drilling of titanium alloy with dry and coolant environment. L18 orthogonal array was used to perform the experiments and the grain size, orientation, deformation, residual stress, and micro hardness were analyzed. The result revealed that deformed and re-crystallized grains are observed due to higher temperature and mechanical deformation in dry condition. Niketh and Samuel [1] used different machining conditions such as dry, wet and MQL on thrust in drilling of titanium alloy using micro dimple drill bits. The result indicated that reduction of thrust force in dry, wet and MQL conditions using textured tools. Rahim and sasahara [10] used vegetable oil as cutting fluid (palm oil) and their results are compared with synthetic ester oil effect on surface integrity in drilling of Inconel 718. In their work, surface integrity parameters are surface roughness, micro hardness, and sub surface defects. Kuram et al. [12] used Taguchi method for the analysis of drilling AISI 304 steel using vegetable oil as coolant. The effect of cutting speed, feed rate and drilling depth on surface roughness and thrust force were analyzed using Taguchi L9 orthogonal array. The result indicated that feed rate is influenced that thrust force and surface roughness with vegetable oil as cutting fluid.

2. Materials and Methods

Drilling process is performed using vertical machining center. Titanium alloy (Grade-5) is used as a work piece (150mm×150 mm×10 mm) material, shown in fig 1. It has light weight and poor machinability material. Machining operation of titanium alloy is a complex manufacturing operation and studying machinability characteristics is a challenging task. Cutting speed and feed rate are selected as input process parameters. The values of process parameters used in this experimental study for conducting drilling process are shown in Table 1. Through hole is drilled using Carbide drill (YG-uncoated) with 8 mm diameter as cutting tool.

Experiments are performed with plain, flute textured and margin textured drills with various cutting fluid environments considered include dry, wet, and vegetable oil (coconut oil). Micro grooves are produced on flute and margin surface of drill tool by using LASER drilling. SEM images of the textured tool are shown in fig 2 and 3. Micro holes drilled on the drill tool have dimension such as diameter (100 µm), depth (60 µm) and pitch (100 µm). The results are compared for understanding output parameters such as surface roughness and temperature generated on workpiece during the operation.

Fig. 1 Titanium Alloy workpiece after experiments

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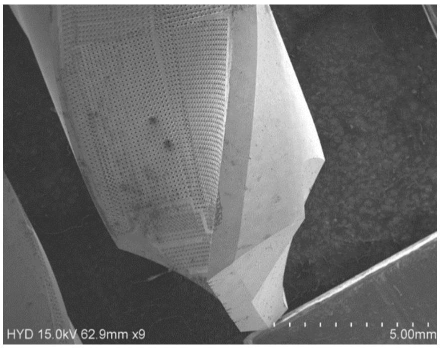


Fig.2 SEM image of Flute Textured Drill

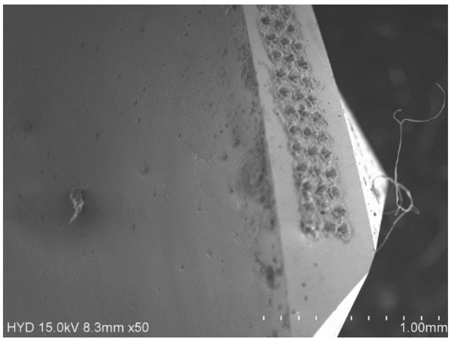


Fig.3 SEM image of Margin Textured Dril

Table 1 Experimental Machine Specification and Process Parameters

Machine Tool Specification	X axis, Y axis, Z axis	7000 mm, 500 mm, 500 mm
	Spindle speed	60 to 6000 (RPM)
	Main motor	5.5 KW
	Table Length	600 mm
	Table width	350 mm
	Control	FANUC
Workpiece material	Material	Ti-6Al-4V
	Dimension	150 mm X150mmX 10mm
Cutting tool	Make	YG Carbide drills
	Diameter	8 mm
	Helix angle	30^0
	Point angle	118^0
ning Condit	Spindle speed (RPM)	600, 800 and 1000
	Feed (f)	0.04 (mm/rev)

	Tool type	Non textured, Flute textured and Margin textured
	ENVIRONMENT	Dry, Wet and Vegetable Oil

3. Experimental results and discussion

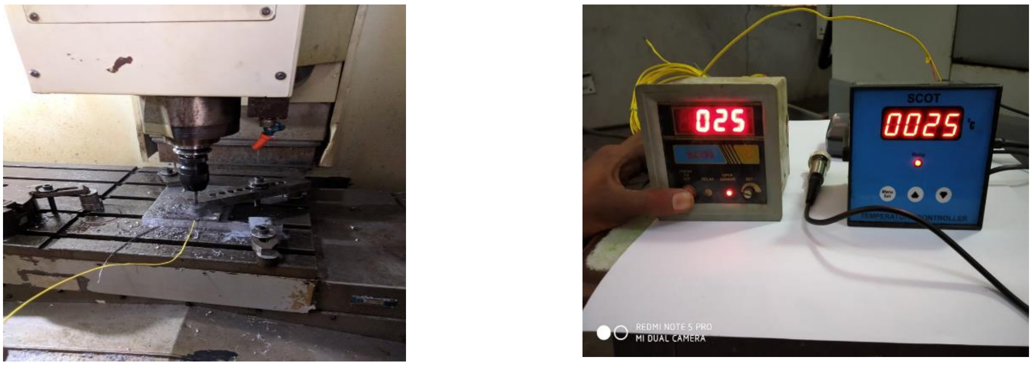
Surface Measurement

Surface roughness, one of the output parameters in this work, is defined as the shorter frequency of real surfaces relative to the troughs and peaks of the surface of drilled hole. Surface roughness influences the functional life of a machined component. The values of surface roughness are found with the help of Talysurf, shown in fig 5.

Fig.4 Talysurf (make: MITUIOYO)

Temperature Measurement

Temperature of the workpiece is measured. Thermocouples are used to measure temperature near drilled hole during the drilling operation. A thermocouple produces a temperature-dependent voltage as a result the thermoelectric effect, and this voltage can be interpreted to measure temperature. The arrangement and measurement of temperature is shown fig 5.



(a) Temperature Measurement Arrangement **(b) Temperature value of thermocouples**

Fig 5. Temperature Measurement arrangement during Drilling operation

Surface Roughness:

In this work, drilling experiments were carried out on Ti-6Al-4V work material under dry, wet, vegetable oil cutting fluid conditions using non-textured, flute textured and margin textured carbide drill tools in a vertical machining center. Process parameters are chosen based on their preliminary experiments and literature studies. The input parameters are considered as cutting speed and feed rate.

The output parameters are considered as surface roughness and temperature. Table 2 shows the experimental results. Surface roughness measurement is used to predict the functional life of the machined component. Figure 6(a, b, c) shows the effect of process parameters, different machining conditions and different tools on surface roughness.

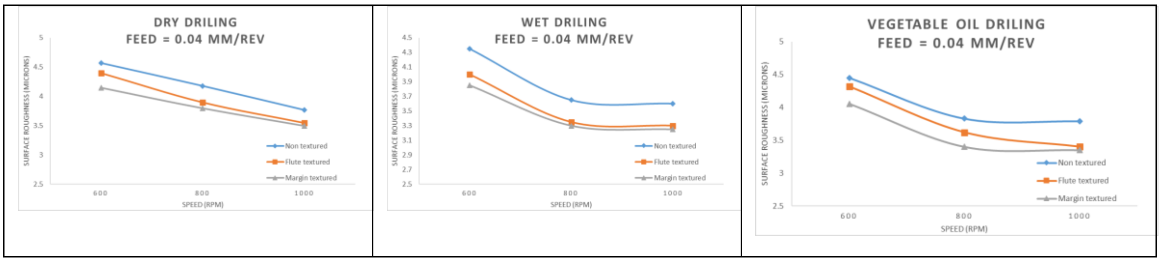
It is observed that surface roughness of the machined hole is decreased with higher cutting speed. This is the result of more heat is generated at higher spindle speed which leads to softening of the work piece material. Also, at lower spindle speed there is a chance of built-up edge formation and followed by deteriorate the machined surface. This is also due to the reduction in frictional forces and hence heating due to the presence of micro scale textures at the contact interfaces, quality of machined surface seems to be better in the case of drilling using flute textured and margin textured tool with little chip adhesion and side flow.

The micro textured tools used in the current work were also found to be successful in minimizing the built-up edge formation due to lesser adhesion of titanium on the tool surfaces. As the contact area at the helical groove is shortened by the micro textures, chip disposal will be faster resulting in lesser adhesion on the tool surfaces. From the comparative studies using non-textured, flute textured and margin textured tools, it was observed that under all machining conditions the margin textured tool performed better than all other tool types. This is since at low aspect ratio machining (10 mm depth used in this study) the contribution of sliding friction occurring at the margin side will be more predominant in drilling forces than the frictional effect occurring at the flute side.

Moreover, the surface integrity study revealed the formation of lesser built-up edge in case of textured tools when compared with non-textured tools, which is a clear indication of adhesion reduction phenomenon of textured surfaces. Thus, it is found to be demonstrated the feasibility of using micro textured drill tools in dry machining of Ti-6Al-4V for better drill hole quality (S. Niketh et al.2017). From this result, it is also noticed that surface roughness of the machined hole is decreased by using vegetable oil cutting fluid, percentage of reduction is (5- 10%) by using flute textured tool and 12% in case of margin textured tool. (Arulkirubakaran et al.2016, Debnath et al .2014)

Table 2 Experimental values of surface roughness during drilling at various conditions

Environment	**Speed (rpm)**	**Surface Roughness**			**Percentage reduction (%)**	
		Non textured	**Flute textured**	**Margin Textured**	**Flute textured**	**Margin textured**
Dry (Coolant Off)	600	4.57	4.40	4.15	4%	9%
	800	4.18	3.90	3.80	7%	9%
	1000	3.77	3.55	3.50	6%	7%
Wet (Soluble cutting oil)	600	4.35	4.00	3.85	8%	11%
	800	3.65	3.35	3.30	8%	10%
	1000	3.60	3.30	3.25	8%	10%
Vegetable Oil (Coconut Oil)	600	4.45	4.32	4.05	6%	12%
	800	3.83	3.62	3.40	5%	11%
	1000	3.79	3.40	3.35	10%	12%



a) Dry Drilling b) Wet drilling c) Drilling using Veg Oil as lubricant

Fig. 6 (a, b, c) Values of surface roughness under different machining conditions

Workpiece Temperature

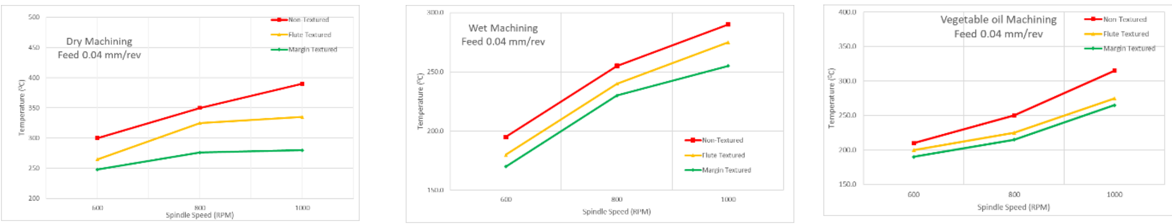
The following section gives a note on the temperature rise on the workpiece during drilling of titanium aluminide under dry, wet, vegetable environment with textured and non-textured tools. Table 3 shows the detailed result of workpiece temperature during drilling at various machining conditions

In the absence of coolant, the temperature generated during the drilling process is conducted away through the workpiece, cutting tool and chips produced. The use of cutting fluid significantly decreases the temperature of the workpiece.

Table 3 Experimental values of workpiece temperature during drilling at various conditions

Environment	**Speed(rpm)**	**Workpiece temperature °C**			**Percentage reduction (%)**	
		Non textured	**Flute textured**	**Margin textured**	**Flute textured**	**Margin textured**
Dry (Coolant Off)	600	300	265	248	12%	17%
	800	350	325	276	7%	21%
	1000	390	335	280	14%	28%
Wet (Soluble cutting oil)	600	195	180	170	8%	13%
	800	255	240	230	6%	10%
	1000	290	275	255	5%	12%
Vegetable Oil (Coconut Oil)	600	210	200	190	5%	10%
	800	250	225	215	10%	14%
	1000	315	275	265	13%	16%

Fig.7 (a, b, c) presents the experimental values of Workpiece temperature recorded at various conditions. For all the curves of temperature behavior in the workpiece, an increase of temperature as function of cutting speed was found. This behavior is found in the technical literature for conventional machining as well as for the environment friendly machining. (Debnath et al.2014).



(a) Dry Drilling (b) Wet drilling (c) Drilling using Veg Oil as lubricant

Fig. 7 (a, b, c) Values of workpiece temperature under different machining conditions

The results indicate higher temperatures under dry cutting conditions for non-textured tools. It is observed that micro textured tools reduce the temperature by 14% (390–335°C) and with fluted textured reduced by 28% (390–280°C), in comparison to dry conditions at 1000 rpm, and it clearly shows that textured tools are very effective at higher cutting speeds.

This is due to the reduction in frictional forces and hence heating due to the presence of micro scale textures at the contact interfaces. **(**Davoodi et al.2014). It is also noted that the experimental results using combination of vegetable oil and textured tools effectively reduces the temperature of the workpiece by 13% (390°C–275°C) and 16% (390°C–265°C) With fluted textured and margin textured tools respectively, seems to be better in the case of margin textured tools under all cutting conditions.

Due to the presence of micro-textures can enable the effective cooling area to be further expanded to the close contact area of tool/chip and tool/workpiece. In addition, the tiny adhesions and hard abrasive can be intercepted and trapped by the micro-grooves, which is another reason for the improvement of cooling and lubricating performance. (DalinGuo et al.2016). It clearly shows that combined effect of vegetable oil and textured tools are very effective at higher cutting speeds.

4. Conclusions

Textured tools have better performance over non textured tools in terms of Surface Roughness and Temperature. The Margin Textured tool fared well.

Vegetable oil *i.e.* Coconut Oil, giving a decent output.

To drill a hard material such as Titanium Alloy using textured tool with vegetable oil shown less Temperature, and good quality of the finished product.
This experimental study provides that the vegetable oil is a potential candidate to use as an eco-friendly lubricant.

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