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Study of Effect Coolant Strategy on Surface Roughness and Tool Performance During Machining of Stavax Supreme

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ABSTRACT

This project is to study the effect coolant strategy on surface roughness and tool performance during machining of Stavax Supreme. Machining process will be conducted in two parameters where each parameter used different coolant strategy. Each parameter also used different rotation spindle speed and feed rate but same rate of removal chip per tooth. Feed rate, cutting speed and spindle speed are set according to the design of experiment. Cutting tool used in this project is Titanium Nitride (TiN) and Uncoated Solid Carbide flat end mill. Result obtained shown that the TiN tool is more suitable than uncoated carbide tool for high speed end milling of Stavax Supreme but for finishing process only because fast tool wear in high spindle speed.

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INTRODUCTION

The performance of milling machine performance is depending on how fast the machine can cut the workpiece and maintain product accuracy. Meaning, the faster the milling machine process is done, more finish product are produced in a period of time. At the same time the productivity of the machine can be improved. Inaccuracy of cutting tool like poor surface finish, tool damage, chatter, dimensional accuracy and many other problems that contribute to low productivity and much time to be wasted (Kalpakjian S and Schmid SR, 2003). Use of cutting fluid can help smoothed the machining process. The primary reason for cooling is to retard high rates of face and flank wear by curbing the sharp temperature rise which accompanies short ranges of higher speeds for a given tool life can be obtained. Cutting fluids improve the efficiency of machining in terms of increased tool life, improved surface finish, improved dimensional accuracy, reduced cutting force and reduced vibrations (L. De Chiffre, 1988). Today technology, there are cutting tool can run without using the cutting fluid like coated and solid carbide tool.

Objective:

The Objective of this project is:

1. To study the relationship between the surface roughness value and coolant strategy
2. To investigate tool performance with different coolant strategy.

Design of Experiment:

The machining process will be conducted base on two parameters. First (1st) parameter is machining in dry coolant and second (2nd) parameter is machining in flood coolant. The machining data is obtained in improvement value by referring to manufacture's recommended value. Two types of tools are used to analyze tool and surface performance. Material surface will be inspected several times during tool life (every 1mm depth) and the tools wear will be checked at the end of machining process (the rake wear (VB) had exceeded 0.3 mm in accordance with ISO 8688).

Table 1: Level and Factors Identification.

LEVEL	FACTOR		
	Cutting Speed (Vc) m/min	Feed Rate (Vf) Mm/min	Spindle Speed (rpm)
Dry	130	100	7000
Flood	170	120	9000

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RESULTS AND DISCUSSION

Surface Roughness (Dry Coolant):

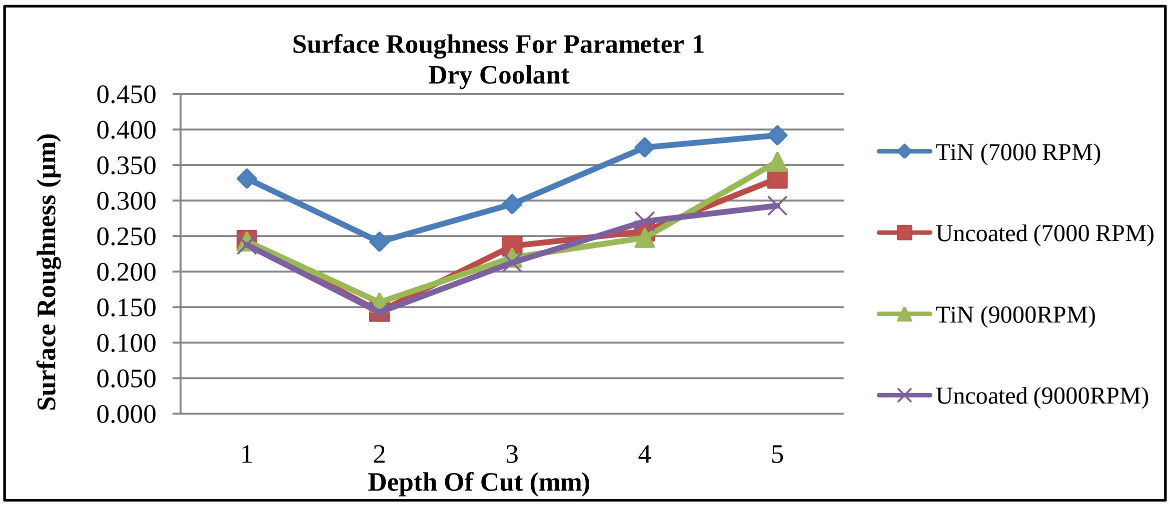

Fig. 1: Surface roughness obtained with Titanium Nitride and Uncoated Solid Carbide for Parameter 1.

Table 2: Surface roughness (Ra) value for Titanium Nitride and Uncoated Solid Carbide for Parameter 1.

No.	Depth Of Cut (mm) Duration / time (min)	1 21	2 42	3 63	4 84	5 105
	Type of tools					
A1	TiN	0.331	0.242	0.295	0.375	0.392
A2	TiN	0.244	0.144	0.236	0.257	0.331
B1	Uncoated	0.243	0.157	0.220	0.248	0.355
B2	Uncoated	0.238	0.143	0.213	0.271	0.293

*Unit:µm
Corresponding:
A1 = Titanium Nitride (TiN), Parameter 1- Dry Coolant (7000 RPM)
B1 = Uncoated Solid Carbide, Parameter 1- Dry Coolant (7000 RPM)
A2 = Titanium Nitride (TiN), Parameter 1- Dry Coolant (9000 RPM)
B2 = Uncoated Solid Carbide, Parameter 1- Dry Coolant (9000 RPM)

From the tabulated data (Table 2), it is observed that as the depth of cut increases, surface roughness also increases. At the beginning machining process (1 mm depth of cut), Ra value for the entire tool is slightly higher than the Ra value for the second machining process. This situation has occurred due to high pressure and high deformation encountered by the cutting tool when the first time contact to the material. M. A. Elbestawi *et al.*, 1997, stated in their research, a worn tool produces a better surface finish than the new tool (fresh tool cut well defined scallops resulting in a higher surface roughness).

After third (3^{rd}) level machining process, surface roughness value (Ra) started to increase because of tool is start to wear. The main cause for tool wear mechanism observed in this experiment were identified as flank wear, chipping, peeling off of the coatings, and fracture on rake face for both parameters. Flank wear occurred from abrasive wear of the cutting edge against the machined surface on the material machined. Flank wear pattern produced wear lands on the side and end flanks of the account of the abrasive action of the machined surface (Z.Q. Liu *et al*., 2002). The increasing of the depth of cut deteriorates the surface finish of the machined left by the carbide tool (B. Rao and Y. C. Shin, 2001). The best Ra value was achieved by uncoated tool, 0.143µm (B2 – 9000RPM) in 2^{nd} level machining process. For the next level machining process, Ra value for uncoated tool started to increase higher than TiN coated tool. TiN coated tool readings showed more uniform along this experiment compare to uncoated tool.

Overall there was only small differences value between this rpm (7000 and 9000). For dry machining, it can be concluded that TiN coated tool is better than uncoated solid carbide. Even at the beginning of the reading is low but it started to increase more than TiN coated tool for the next level machining process. The graph also shows that Ra value decreased when the rpm was increased.

Surface Roughness (Flood Coolant):

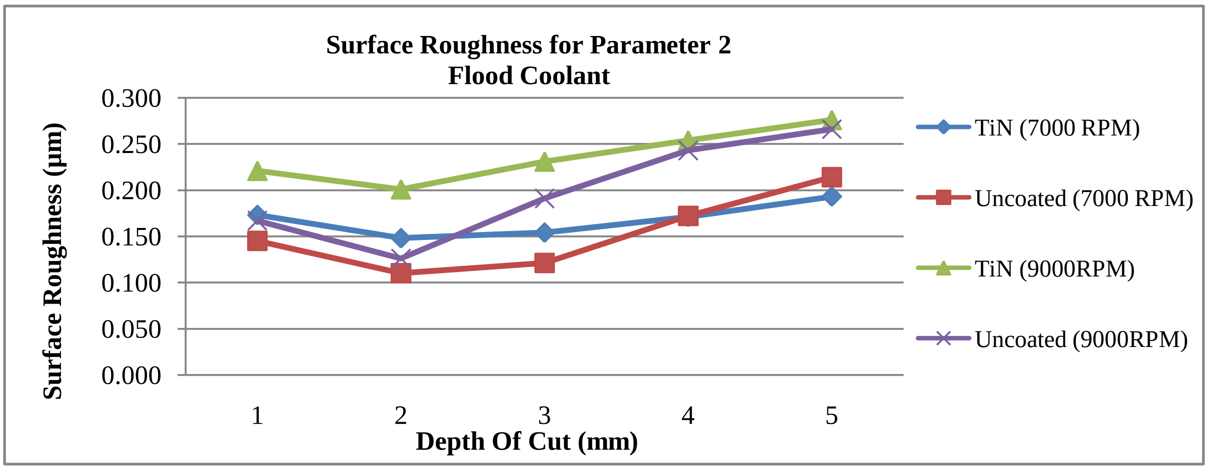

Fig. 2: Surface roughness obtained with Titanium Nitride and Uncoated Solid Carbide for Parameter 2.

Table 3: Surface roughness (Ra) value for Titanium Nitride and Uncoated Solid Carbide for parameter 2.

No.	Depth Of Cut (mm) Duration / time (min)	1 21	2 42	3 63	4 84	5 105
	Type of tools					
A3	TiN	0.173	0.148	0.154	0.171	0.193
A4	TiN	0.145	0.110	0.121	0.172	0.214
B3	Uncoated	0.221	0.201	0.231	0.254	0.276
B4	Uncoated	0.167	0.126	0.191	0.243	0.266

*Unit: µm
Corresponding:
A3 =Titanium Nitride (TiN), Parameter 2- Flood Coolant (7000 RPM)
B3 = Uncoated Solid Carbide, Parameter 2- Flood Coolant (7000 RPM)
A4 =Titanium Nitride (TiN), Parameter 2- Flood Coolant (9000 RPM)
B4 = Uncoated Solid Carbide, Parameter 2- Flood Coolant (9000 RPM)
The best result is the 0.110µm for TiN coated tool at 9000 rpm. From the tabulated data (Table 3), it is presented that as the cutting speed and the rpm increases, surface roughness value is decreases. For flood coolant machining, Ra value for titanium Nitride (TiN) is better than uncoated solid carbide. For 1mm depth of cut in machining process, same situation happened like Parameter 1 which value of surface roughness is high.

Surface Roughness (Dry Coolant VS Flood Coolant):

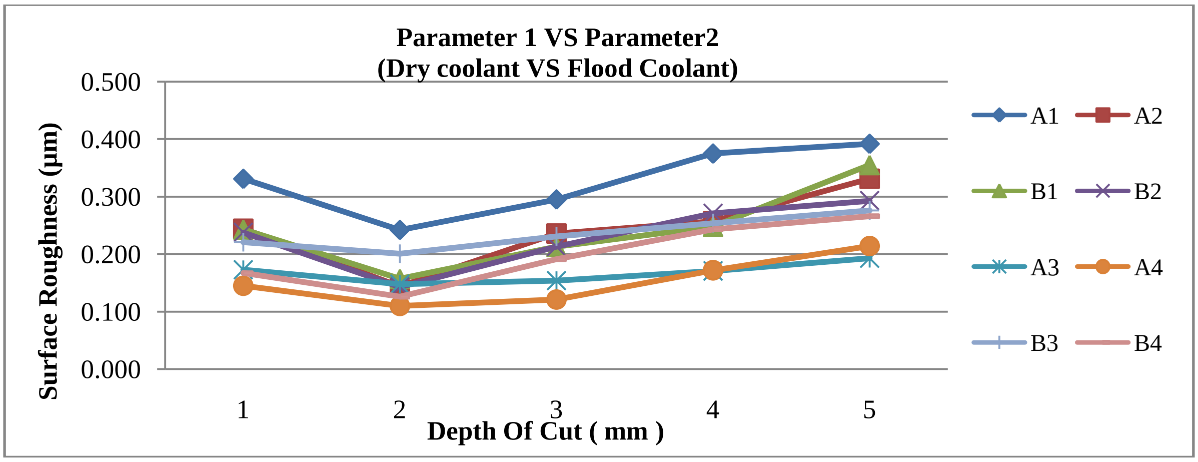

Fig. 3: Surface roughness obtained with Titanium Nitride and Uncoated Solid Carbide for Parameter 1 VS Parameter 2.

Figure 3 shows that flood coolants gave the best surface roughness value compared to dry coolant strategy. This is due to the coolant function which can reduce the friction between tool tips and work surface during machining process. Furthermore coated on TiN tool are not function as protection for reducing tool wear compare to uncoated solid carbide tool. According P. Chockalingam *et al*., different cooling condition required for different parameters in order to obtain lower surface roughness and cutting force (P. Chockalingam and Lee Hong Wee, 2012). Type of coolant used in this experiment not suitable for machining Stavax Supreme.

Generally, an increase in the spindle speed leads to an improvement of surface finish. As the spindle speed increased up to 9000 rpm, the surface roughness values of this material at both coolant strategies were found to be increasing. This could be due to the increasing of cutting forces at higher speed. Previous research stated that when high cutting speed, low feed rate and low depth of cut were adopted, good surface finish can be obtained in semi finish and finish machining of hardened steel (Ghani J.A *et al*., 2004).

Tool Wear:

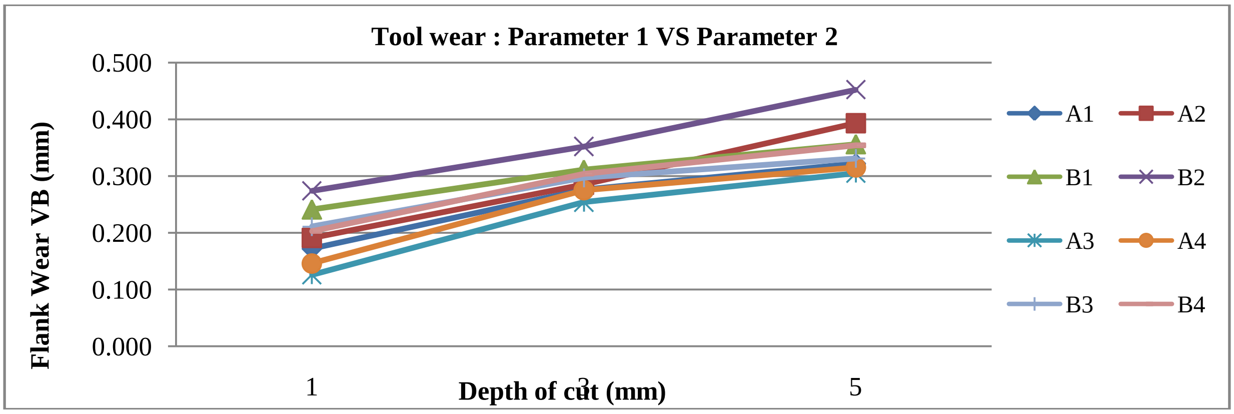

Fig. 4: Cutting tool performance (VB: 0.30 mm): work material: Stavax Supreme, tool substrate: TiN coated tool and Uncoated solid carbide for Parameter 1 and Parameter 2

Table 4: Coating performance (VB: 0.30 mm): work material, Stavax Supreme; for Parameter 1 and Parameter 2.

No.	Depth Of Cut (mm) Duration / time (min)	1 21	3 63	5 105
	Type of tools			
A1	TiN	0.172	0.276	0.322
A2	TiN	0.191	0.285	0.393
B1	Uncoated	0.241	0.311	0.356
B2	Uncoated	0.274	0.352	0.452
A3	TiN	0.126	0.254	0.305
A4	TiN	0.146	0.275	0.315
B3	Uncoated	0.211	0.297	0.331
B4	Uncoated	0.203	0.304	0.354

*unit: mm

It can be seen (Table 4) that the flood coolants is more effective in reducing the tool wear compared to dry coolant however tool still wear. From the microscopic views, chipping and flank wear was the initial wear mode in milling under flood coolant strategy. For dry coolant chippings, flank wear and fractures were found on tool after machining process.

The tool was worn out terribly after five times (105min) machining process have been conducted. Referring to microscopic results, it can be concluded that coolant is important in reducing the tool wear. TiN tool is better than uncoated tool based on reducing in tool wear. This is because the tool was coated with Titanium Nitride. However, the tool also had exceeded the rake wear (VB) after five times machining process.

It shows that reaction between coolant and TiN coated give unsatisfactory result in reduced tool wear

In summary, tool life is increased when the rpm is increased. This indicates that although in both parameters uses the same depth of cut and feed per tooth but the rotation spindle speed, feed rate and cutting speed affecting the tool wear. A study on this matter has been analyzed by Altin, *et al*., 2007. At the same time coolant strategy also can be a factor in increasing the tool life. In addition, the material chemical compositions also affecting the tool wear mechanism. Alloying element in Stavax Supreme, nikel (Ni) and molybdenum (Mo) promote diffusion wear (Laizhu Jiang *et al*., 1996). Al_2O_3 coated grade like CVD, MTVCD and TiCN can be used to reduced tool wear and produced better surface finis during machined Stavax Supreme.

Conclusion:

From the result obtained, it is found that:

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1. Higher spindle speed can produce better Ra value but the cutting tool cannot withstand wear mechanism. Deposition technology for cutting tools should be focused on producing very fine and ultra-smooth coated surfaces. This is to obtain a good surface roughness at the same time to increase the durability of the cutting tool. Decreasing the friction of coefficient and thermal conductivity of the cutting tool will decrease the average surface roughness of the machining material. The increasing of cutting speed, surface roughness value first increased then decreased with the tool wear progression in milling using hard solid mills (L.N. Lopez de lacalle *et al*., 2000).
2. TiN coated and uncoated carbide tool can be used in higher spindle speed only for finishing process. In this experiment coolant give more benefit compared to dry machining in producing better surface roughness. It keeps the workpiece at a stable temperature but not in maximize the life of cutting tool.
3. Tool life was longer when used flood coolant than the dry machining process for both cutting tools. This behaviour is inconsistent with other previous researchers in similar process such as Y. Su *et al*., 2006 and Y.S Liao *et al*., 2007 .
4. Generally, the chips generated in hard machining are referred to saw-tooth chips. This chip can be classified under continuous chip. Two theory happen in saw-tooth chips first crack theory and second is adiabatic shear theory. Both parameters have resulted in continuous chip with saw-tooth.

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