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ORIGINAL PAPER

Effects of drilling parameters on TI-6Al-4V alloy using different coolants

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Abstract

The formulation or application of coolants plays a critical role in machining to bring out the best finished products. In this scientific article, the study focused on the effects of coolants and machining parameters of Ti-6Al-4V are investigated with consideration of their performances by using drilling operation. The design of experiments (DOE) was considered and the performance of machining was measured with respect to cutting temperatures and surface responses. The final results put forward that the excellent surface finish and minimal cutting temperatures are obtained by application of power metcut s plus when compared with pure water. The factors that impact the surface roughness of Ti-6Al-4V are coolant and feed rate. The coolant also helps in the machining process by reducing temperature at the cutting zone.

Keywords: Ti-6Al-4V, drilling, power metcut s plus, surface roughness, temperature.

1. INTRODUCTION

Drilling is one of the better cutting operations among the traditional machining processes for cutting or enlarging a hole in a work material by allowing for cesona rotating tool called drill. Ti-6AL-4V or titanium grade 5 alloy is also known as the workhorse of the titanium alloys and is referred to as the strongest alloy among the light metal group. Titanium and its alloys have a wide range of applications in aerospace, automobile, chemical, biomedical and other major industries due to their performance. The high strength to weight ratio and excellent corrosion resistance are inherent properties of titanium alloys. However, titanium is one of the most difficult-to-machine materials due to its poor thermal conductivity, strong affinity to the tool material and the fact that it retains its hardness and strength at high temperatures. Hence, titanium machining meets the troubles of tool failure and low productivity for the application of coolants which can control it. Amongst all the machining processes such as milling, turning, grinding and drilling, drilling is most significant and it is used to make a hole. The extensive research works have been carried out in drilling operation with different responses for tool and work piece combinations. Further titanium drilling has been widely utilized in industry but research publications are still limited.Hole making in the TI-6AL-4V component is a very difficult task due to its poor machinability. Hence, the drilling parameter investigations on the titanium alloy material are very important for predicting its performance characteristics. In addition to the modern manufacturing industries, they use conventional drilling machines and CNC drilling machines for hole-making. Drilling can be done with a rotating tool and these operations are widely applied in aerospace, biomedical and automotive sectors due to the hardness of material and the fact that friction is developed between the drilling tool and work material (Gangadhar, Venkateswarlu, & Rajesh 2014; Matsumura & Tamura 2015; Rysava et al. 2016; Tasdelen, Wikblom, & Ekered 2008). During the drilling operation, the chips that are formed washes away with application of coolants and the temperatures which is formed at that particular zone is controlled by introducing various cooling methods (Ahmed & Kumar 2016; Perçin, Aslantas, Ucun, Kaynak, & Cicek 2016). The super lubrication (Liew, Shaaroni,

Figure 1. CNC machining

Sidik, & Yan 2017) plays a crucial role in machining process and brings out the best performances between the two coolants. In this research study, the gaps are filled with investigation of coolants on drilling Ti-6Al-4V. The drilling performances such as temperature and surface roughness are investigated under different machining parameters such as coolant type, feed and, speed by using the full factorial design (Liew, Shaaroni, Razak, Kasim, & Sulaiman 2017; Samy & Kumaran 2017; Sharif, Rahim, & Sasahara 2012; Sharma, Sidhu, & Sharma 2015).

2. EXPERIMENTATION

The drilling was performed using a CNC machine with control system FANUC OM control system. The work material for this experiment was Ti-6Al-4V with a 153 mm diameter and thickness of 12.7 mm. The cutting tool used was carbide coated high speed steel. The coolants used in this machining process were pure water and power metcut s plus. The setup for the experiment is shown in Figure 1. The drilling parameters for all experiments are tabulated and shown in Table 1. The number of experiments conducted and parameter combinations are determined by using two-level-full factorial design. The surface roughness tester and temperature thermo-couple were used for measuring surface roughness and temperature respectively. The surface roughness tester was used for determination of quick and accurate surface roughness. Here material was considered for the roughness testing to measure roughness depth (Rz) as well as the mean roughness value (Ra). The roughness of a surface involves by applying a roughness filter was measured.The complete data was analyzed by using ANOVA. The characteristics of coolant are shown in following Table 2.

The design of experiments (DOE) is a systematic method for determining the relationships between the factors that affect a particular process and its output.

Table 1. Machining Conditions

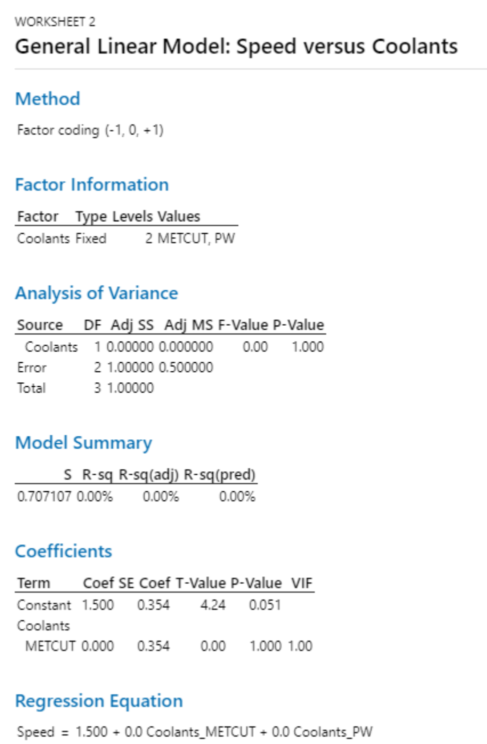
Factors	Level 1	Level 2
Speed (m/min)	250	290
Feed (mm/rev)	0.1	0.2
Coolant types	Pure water	Power METCUT S PLUS

Table 2. Characteristics of Coolant Oil

Characteristics	Power METCUT S PLUS
Appearance	Dark brown clear liquid
Specific Gravity 29.5°C	0.890 (T)
Flash point, COC, °C, min	150
PH(5% emulsion D/W)	9.0
Kinematic Viscosity 40°C, cSt, min	20

3. RESULTS AND DISCUSSION

The Full Factorial Analysis is a very powerful tool of DOE to determine the effects of drilling parameters. The factor that affects the surface roughness can be identified and shown in the result graphs. The factors analyzed in this experiment were speed, feed and type of coolant



WORKSHEET 2

General Linear Model: Speed versus Coolants

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Coolants	Fixed	2	METCUT, PW

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Coolants	1	0.00000	0.000000	0.00	1.000
Error	2	1.00000	0.500000		
Total	3	1.00000			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.707107	0.00%	0.00%	0.00%

Coefficients

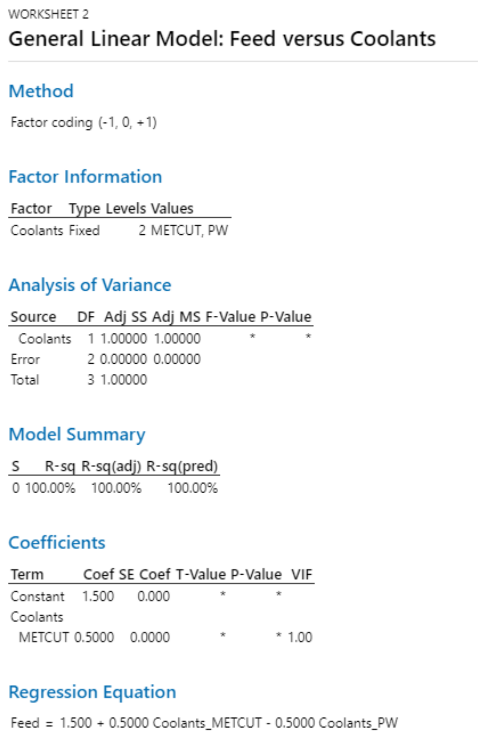
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1.500	0.354	4.24	0.051	
Coolants					
METCUT	0.000	0.354	0.00	1.000	1.00

Regression Equation

Speed = 1.500 + 0.0 Coolants_METCUT + 0.0 Coolants_PW

Figure 2. General Linear Model Speed v/s Coolants

The interactions framed are the interaction between coolant and the speed, the interaction between coolant and the feed denoted by B, C, AC and, BC respectively. From the ANOVA, p value of 0.1 o shows the significance of the model. Based on these results model graphs are framed and compared between coolants that as shown in Figure 2 and 3. In Figure 4 and 5, the coolants pure water is designated as PW and the coolant Power METCUT S Plus is designated as METCUT.


WORKSHEET 2

General Linear Model: Feed versus Coolants

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Coolants	Fixed	2	METCUT, PW

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Coolants	1	1.00000	1.00000	*	*
Error	2	0.00000	0.00000		
Total	3	1.00000			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0	100.00%	100.00%	100.00%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1.500	0.000	*	*	
Coolants					
METCUT	0.5000	0.0000	*	*	1.00

Regression Equation

Feed = 1.500 + 0.5000 Coolants_METCUT - 0.5000 Coolants_PW

Figure 3. General Linear Model Feed v/s Coolants

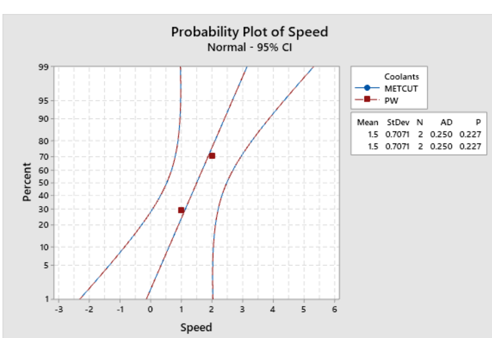


Figure 4. Speed v/s Coolants

4. CONCLUSIONS

The conclusions from this study are framed as follows:

- The surface roughness and temperatures are minimized when using POWER METCUT S PLUS compared to Pure Water.
- By using POWER METCUT S PLUS, high cutting speed and feed rate produce the minimal surface roughness. The temperatures are also reduced significantly with the increase of feed rate.
- Based on the Full Factorial Design,themost significant factor that affected the surface roughness during the drilling process are feed rate and coolant. Meanwhile, coolant is a significant factor to achieve minimal temperatures.

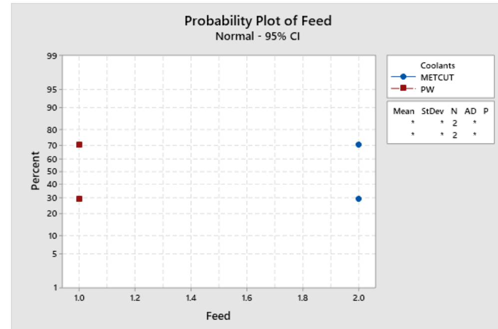


Figure 5. Feed v/s Coolants

Future Scope

This study explains the experiments that were performed on Ti-6Al-4V as the work material and use of pure water and power met cut s plus used as coolants. This work helps to perform experimentation on other hard-to-cut materials such as Inconel, Hastelloy, e.t.c. and also the applications of different fluids and nano additives in achieving better performances. This article used only the full factorial analysis technique but research can also extend to other optimization techniques.

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