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Parameter Study on High Speed CNC Machining of Titanium Alloys for Aircraft Components

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***Abstract*—The aerospace, automotive and biomedical parts manufacturers use Titanium alloys extensively because of their high specific strength and exceptional corrosion resistance. Machinability of titanium alloys poses biggest threat as their low thermal conductivity and elastic modulus are bigger challenges to be addressed; it also gets high hardness at elevated temperature with high chemical reactivity. This article analyses Machinability parameters of titanium alloys, and focuses on optimization of machining process. The possible parameters to be improved are cutting and machining forces, chip formation using alloying and reducing cutting temperature. The CNC milling process of Ti-6Al-4V alloy parameters were identified and being studied in detail for optimization.**

I. Introduction

The Machinability of titanium alloys is reportedly the biggest challenge to be resolved and the researchers of industry and academia reported many times in the journals of repute. The selection of correct cutting speed, feed and depth of cut defines many of the parameters in dynamics of cutting out of all machining parameters. However some other parameters like angle of cutting, tool wear ratio type of cutting tool, type of coating on the cutting edge, thermal conductivity of cutting material, lubricant fluid and flow rate of lubricants, type of chip formation, effect of alloying elements and its crystalline structure unlike other materials of ferrous and non ferrous class the material hardness is not being the indicative parameter for the optimal planning of cutting parameters. Extensive study on the experimental results of diamond milling of metals such as aluminum, stainless steel etc are considered for defining the parameters on titanium alloys. A homogeneous crystalline material forms single crystals, which indicates fluctuation in cutting forces depends on the frictional condition during cutting. Hence, such polycrystalline material in which there is a strong crystallographic texture also requires special attention for Machinability studies. It is understood that the dynamic behavior of different forces and signals is affected by type, location and configuration of the wear mode. Simulation of high speed dry machining of Ti-6Al-4V alloy showed that the cutting force fluctuation can be caused by chip segmentation.

II. Parameter Identification For High Speed Cnc Machining

The following are the parameters identified using the case study method, Cutting speed, Feed rate, Dept of

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cut, Friction Tool wear, Chip Microstructure, Machine Influence, Increasing of cutting speed caused a linear increase of dynamic force frequency, but the respective amplitude changed inversely during dry milling of Ti-6Al-4V alloy, vibration during machining. These parameters were identified as most influential parameters of the machining operation and machinability of titanium alloys are generally governed by this listed parameters. But the case study is conducted to identify the parameters in a standard machine tool using the following steps in variation.

Higher cutting speed resulted in lower dynamic force amplitude, while milling a medium carbon steel with carbide insert. As cutting speed increases, friction is reduced and strain rate increases, which is followed by force decrease leading to a more stable process. Both amplitude and frequency increased and decreased randomly with increasing feed rate, while dry milling Ti-6Al-4V alloy. High cutting speeds and larger feed rate are necessary to eliminate low-frequency vibration, which decreases cyclic force frequency with increasing feed rate results in chip segment spacing. The force fluctuation at low feed rates resulted from low chip stiffness caused by the combination of low elastic modulus of titanium and high cutting temperature, but can be eliminated by increasing the feed rate or changing the tool entry angle. During the first few seconds of the medium carbon steel milling, which is the initial stage of tool wear, the dynamic force signals indicate wider dynamic amplitude for higher feed rate.

Results of dry milling of Ti-6Al-4V alloy showed that the amplitude of force fluctuation increased linearly as the depth of cut increases, but no significant change occurred in the frequency. During the milling of Ti-6Al-4V alloy, vibration increased with increasing depth of cut up to 0.8 mm and then decreased. The jump of vibrations for titanium compared to steel. Thermal conductivity Chemical reactivity Elastic modulus Hardness and strength Work hardening Description Low thermal conductivity causes concentration of heat on the tool cutting edge and face, influencing negatively the tool life. Reactivity with common gases such as oxygen, hydrogen and nitrogen leads to formation of oxides, hydrides and nitrides, respectively. These phases cause embrittlement and decrease of the fatigue strength of the alloy.

Surface hardening by formation of hard solid solution due to internal diffusion of oxygen and nitrogen cause decrease of the fatigue strength of machined surface and increase of tool wear.Reactivity with cutting tool material causes galling, smearing and chipping of the work piece surface and rapid tool wear. Low elastic modulus allows deflection of slender work piece under tool pressure, inducing chatter and tolerance problems. The high temperature strength and hardness of titanium alloys require high cutting forces which results in deformation on the cutting tool during cutting process. High dynamic shear strength during cutting process induces abrasive saw-tooth edges, generating tool notching. The peculiar work hardening of titanium alloys causes absence of built-up edge in front of the cutting tool and increase of the shearing angle, which in turn induces a thin chip to contact a relatively small area in the cutting face, resulting in high bearing loads per unit area.

The high bearing stress, combined with the friction between the chip and bearing area causes a significant heat raises in a very small area of the cutting tool and production of cratering close to the cutting edge, resulting in rapid tool breakdown. However, the formation of built-up edge is referred to be detrimental for tool coating. The other options like dry cutting, dry electrostatic cooling, Flood cooling, Minimum quantity lubrication, Water vapor High pressure coolant, Cryogenic cooling, Cold-air cooling, Solid lubricants hot machining were also studied.

It is reported that researches are needed to address optimization of air-oil moisture ratio and coolant pressure. The use of water vapor is not only an economical, environmentally compatible, and health friend lubrication technique for machining, but also reduce cutting force and extend tool life which is cumulative component of Speed Feed and Depth of cut of the spindle and also associated with the tool dimension. It is interesting to note that the water removes heat from the point of cutting faster than oil do and is encouraging when mixed with soluble oils because this last provides better lubrication.

III. Design of Experiments

The machinability of Titanium alloys is considerably low in comparison to other materials. The material behavior during high-speed milling operation is being studied; the structure of material needs to be checked after machining. Surface roughness is a measure of the technological quality of a product and has influence on manufacturing cost and the quality of the product. Therefore, industries always choose to maintain the good quality of the machined components. The researchers all over the world used statistical analysis methods in the area of high speed machining, considered different sets of input parameters, output parameters and tried various analysis techniques based on statistics, including structured equation modeling (SEM) analysis, robust design, and Taguchi design approaches have reported high-speed milling for testing the suitability of high-speed milling for different kinds of materials. So far the researchers addressed issues with better machinability materials like steels, aluminium alloys, graphites and polymer matrix composites.

TABLE I.

Sl No	Parameter	Range	Levels
1	Spindle speed (a)(rpm)	3000- 16000rpm	3
2	Feed rate (b) (mm/min/rev)	0.1 -3.0 mm	3
3	Depth of cut (c) (mm)	0.1-1.0mm	3
4	Dia meter of the cutting tool (d) (mm)	12-16mm	3
5	Tool wear rate (e) (mm/min)	0.010 – 0.030	3
6	Coolant flow rate(f)	6-10 bar	3

But here the high-speed milling operation is considered with standardized CNC vertical machining center DEKEL MAHO 64V with spindle speed range of 16000 rpm and the parameters identified are listed in table 1. The most influencing factors are being given equal weightage and design of experiments were done using the initial analysis of case study is completed.

IV. CONCLUSION

This study can be a basis for future researchers as more input parameters need to be taken into consideration in order to predict the surface roughness through simulation at much higher speeds. The interaction effects, if any, can also be studied for continuous optimization of research results, which could be used by industries. There is a scope to consider more such tough material with various combinations of constituent parameters under high-speed cutting conditions in order to compute the optimum values of input machining conditions for better design of manufacturing processes. The microstructure analysis will be carried out to find out the effect of work hardening due to machining in HSM and its effect during the functional performance of the material. The problem out of the parameter study is completely non-linear and needs better solution in genetic algorithm based solution for parameters.

REFERENCES

[1] S. Madhukar,.A. Shravan,P. Vidyanand sai,Dr .V.V. satyanarayana, A critical review on cryogenic machining Of titanium alloy (ti-6al-4v), International Journal of Mechanical Engineering and Technology (IJMET)Volume 7, Issue 5.

[2] Narasimhulu Andriya, P Venkateswara Rao, and Sudarsan Ghosh, Dry Machining of Ti-6Al-4V using PVD Coated tialn Tools, Proceedings of the World Congress on Engineering 2012 Vol III,WCE 2012, July 4 - 6, 2012, London, U.K..

[3] Nambi Muthukrishnan, Paulo Davim, Influence of Coolant in Machinability of Titanium Alloy (Ti-6Al-4V), Journal of Surface Engineered Materials and Advanced Technology, 2011, 1, 9-14 doi:10.4236/jsemat.2011.11002.

[4] C. Veiga, J. P. Davim and A.J.R. Loureiro, review on machinability of titanium alloys: The process perspective, Rev.Adv. Mater. Sci. 34 (2013) 148-164.