ANALYZING THE EFFECT OF DIFFERENT PROCESS PARAMETERS ON TOOL WEAR, CHIP FORMATION AND SURFACE INTIGRITY DURING CNC MILLING OF HASTELLOY C-276

Tarun Batra[1] , P.S Rao[2]

[1,2] *Department of Mechanical Engineering*
National Institute of Technical Teachers Training and Research
Chandigarh, Punjab, India

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Abstract-*The paper presents the three main process parameters such as cutting speed, feed rate and depth of cut were selected for experimentation. Machining parameters have predominant effect on the tool wear ,chip formation and surface integrity for that the manufactures needs the optimal values of operating parameters in order to reduce the experimental as well as the minimizing simulation in order to reduce machining cost. The experiments were carried out on a CNC Milling machine under dry conditions and wet conditions using PVD coated inserts and tool wear, chip formation and surface integrity is studied in process. SEM-EDS analyses were performed at different cutting conditions. The results of experiment have showed that the flank wear has most common type of wear occurred during milling of nickel based alloy. During the machining of Hastelloy C-276 high pressure and temperature was generated, micro chipping and buildup edges generated even at low cutting speed. It was evident that, when the cutting speed increased the buildup edges was vanished. During the experimentation two different types of chips formed such as serrated chips and fragment chips. With increase in cutting speed there is transition in formation of chips from serrated chips into fragment chips.*

Keywords: **Milling, Tool Wear, Chips, PVD Coating, Surface Integrity.**

1. INTRODUCTION

Hastelloy C-276 (Nickel Based Super alloy) which is not easy to machine because of its high strength and low diffusive properties at high temperature. Due to present of Cr-Mo in high content it provides good resistance against pitting and crevice corrosion. It is therefore used in petro chemical industries, marine industries, chemical industries, filters, evaporators, pipes and flanges. Kadirgama et al. [1] had performed experiment on Hastelloy C-22HS to study the wear mechanisms and other microstructure defects under Scanning Electron Microscopy. Two distinct types of carbide coated inserts were used such as- coated with TiAlN /TiN and TiCN / TiN. They concluded that both types of inserts suffered from high thermal cracking and crater wear. The investigation results that performance of carbide tools coated TiAlN/ TiN cutting tool was better than tools coated with TiCN/TiN. Habeeb et al. [2] experimentally study about the influence of tool holder's geometry and input variables on output response studied such as tool wear and tool life when milling of nickel based alloy 242 with carbide insert having different type of coatings such as TiAlN, TiCN/TiN, TiAlN/TiN and TiCN/Al_2O_3. They concluded that the tool wear rapidly increases when tool holder geometry is 90º than 70º. Also observed that flank wear suffered from high abrasion wear. Kadirgama et al. [3] studied the effect of carbide insert coated with physical vapour deposition and chemical vapour deposition on surface roughness of Hastelloy C—22HS through development of surface roughness prediction model. They concluded that as the cutting speed reduced the surface roughness increases. Also the physical vapour deposition coated cutting tool performs better than chemical vapour deposition during machining of Hastelloy C-22HS. Akıncıoğlu et al. [4] experimentally studied the infleuence of input variables on surface roughness during CNC milling of Hastelloy C-22 super alloy. They selected the cutting parameters such as cryogenic treatment, cutting speed, and feed rate. They concluded that the surface roughness improved by shallow and deep cryogenic treatment applied on cementite carbide tools. They also concluded that wear resistance of tungsten carbide insert increased by shallow and deep cryogenic treatments. Zhu et al. [5] had experimentally studied that during the machining different types of plastic deformations occur at tool and work piece interface. This result in intense heat generation which causes work hardening, excessive tool wear, frequent tool changing and large amount of power consumption. Du Jin and Zhanqiang Liu [6] had carried out experiment to study the effect of cutting speed on the micro hardness, surface roughness and plastic deformation on FGH95 PM Super alloy on CNC milling using coated carbide insert. The results of experiment show that with increases in cutting speed surface roughness decreases. They concluded that different kind of surface defects appeared such as tearing, micro crack, nonmetallic dragging, void and smearing. Kaitao et al. [7] experimentally study the influence of input vaiables on the tool wear during the machining of Hastelloy C-276 by using Ti(C_7N_3)-based cermet insert manufactured by a hot-pressing. They concluded that the optimal cutting condition for machining of Hastelloy C-276 i.e cutting speed of 50000 mm/min, depth of cut of 0.4 mm and feed rate of 0.15 mm/rad. Tool wear which was predominately found micro chipping, micro cracks, flank wear and build up edges .

2. EXPERIMENTAL PROCEDURE

2.1 Experimental Step Up

The experimentation was performed on CNC milling machine (Hurco VM10) as shown in Figure 1. The work material used for experimentation was Hastellloy C-276 (Ni-Cr-Mo-W) having hardness 87 HRC. The chemical composition of the Hastelloy C-276 is shown in Table 1 given below [8].

Table -1 Composition of Hastelloy C-276

Composition of Hastelloy C-276		
Sr. No	Chemical Compound	Percentage
1	Ni	57 max
2	Co	2.5 max
3	Mo	16
4	Cr	16
5	Fe	5
6	W	4
7	Mg	1
8	Si	0.08 max

The cutting tool used PVD coating with grade 09T3-EM TT3450, which is manufactured by Taegu Tec; is a effective class of inserts for Nickel Based alloys. It has good thermal shock resistance which makes it ideal for dry machining and good in wet conditions.

2.2 End Milling Testing

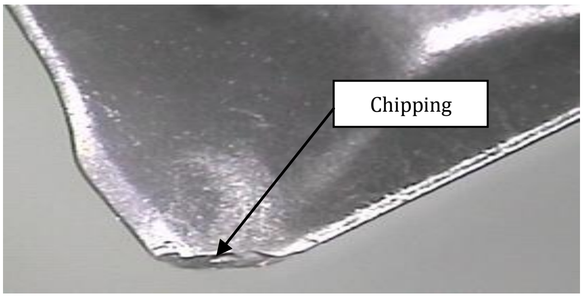
The experiment had performed on three axis CNC milling machine centre with spindle speed 10000 rpm. End milling operations were performed under dry conditions and wet conditions.

Figure 1 Schematic of end milling

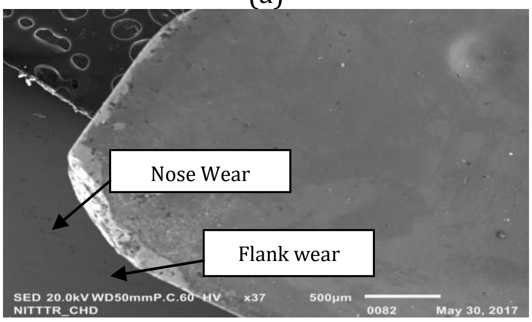
3. RESULT AND DISCUSSIONS

3.1 Tool Wear

Tool wear developed during experimentation on Hastelloy C-276 as flank wear and chipping as shown in Figure 2(a) and 2(b). Chipping wear is developed at the line depth of cut due to high thermal, high work hardness and high strength of the work-piece. The worn out edges of inserts were observed under SEM. After observing the images it was clear that wear primarily developed in two areas when the experiment performed: at the depth of cut line and the nose. However, wear occurring at nose radius influence the surface finish when the nose edge comes in contact with the new work-piece which is to machine. The problem related to chipping wear is solved by using the tools having negative and larger approach angle with bigger nose radius.



(a)



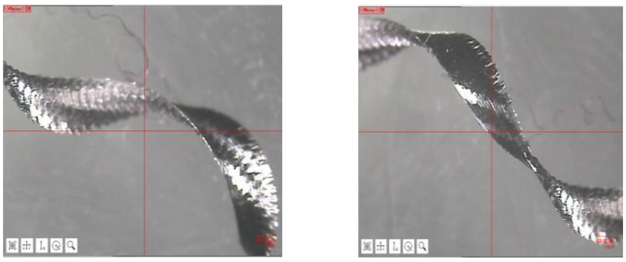
(b)

Figure 2 (a) Machine vision image of insert and (b) SEMs image of insert

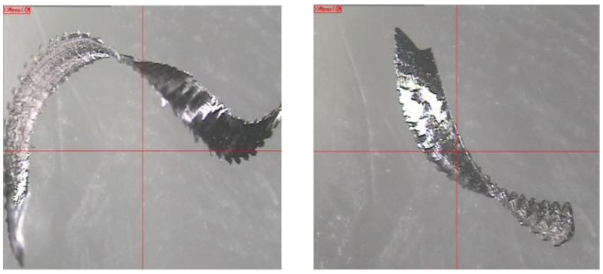
3.2 Chip formation

Chip formed during the machining of Hastelloy C-276 was of different pattern, i.e. continuous, discontinuous depend on the mixed response of work piece and insert material, input parameters. The shape of chip formed had significant effect on optimization of output responses and surface integrity. During the hard machining at low cutting speed discontinuous chips generated and represent an essential feature of the chip morphology (Ning K et al. [8]). Discontinuous chip formed in two phases; in the first case the work piece plastically deformed in front of tool causing it to bulge. When a critical strain level is developed, catastrophic failure occurs. The influence of cutting speed on the chips developed during machining is shown in Figure

3(a) and 3(b) shows the amount of serrated increases with the increase in cutting speed. When cutting speed is 47000 mm/min, the chip formed is massively segmented. When cutting speeds decreases to 20000 mm/min, serrated chips changed into fragment chips. Also there is transition of continuous chips to discontinuous chips as shown in Figure 4(a) and 4(b).



(a) Serrated Chip



(b) Fragment Chip

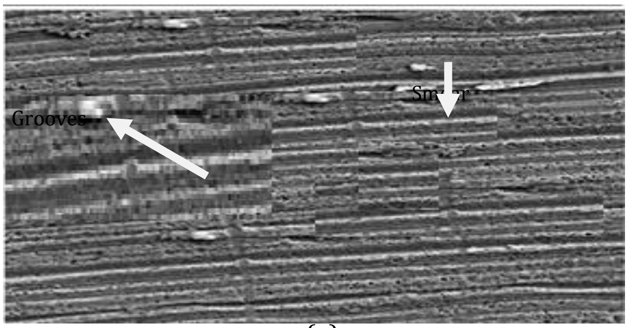
Figure 3 (a) Schematic diagram of Serrated Chip and (b) Fragment Chip

(a) (b)

Figure 4 (a) Schematic diagram of Continuous and (b)Discontinuous Chips

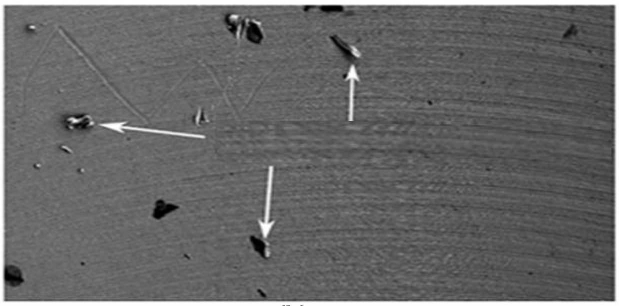
3.3 Surface Integrity Aspects

Different types of surface defects can be observed through SEM images of the machined surfaces under dry and wet conditions as shown in Figure 5(a) and 5(b). It was evident during the dry machining the grooves and smears appeared on the machined surface. But during the wet conditions micro chips adheres with the surface machined surface. Grooves occur in case of dry machining and starches on wet machined because of build up edges of insets in both the cases.



(a)

Micro Chip Re Deposition



(b)

Figure 5 SEMs images of machined surface in (a) dry condition and (b) wet conditions

3.4 Effect on composition of Hastelloy C-276 after machining in dry and wet condition

After machining of Hastelloy C-276, it was observed that there is change in composition of work piece in both dry and wet conditions, proved true after SEM-EDS showing the increase in percentage of each element of work piece. Moreover amount of Si elements observed was higher in comparison to dry machining. It is because of use of Silicon as lubricant.

3.5 Micro Hardness

According to the result shown in the Figure 6 the average Viker's micro hardness of un-machined surface was 31.4 HRC where as Viker's micro hardness of machined surface in dry conditions was 55.6 HRC and for wet conditions was 47.5 HRC at 1 kgf load.

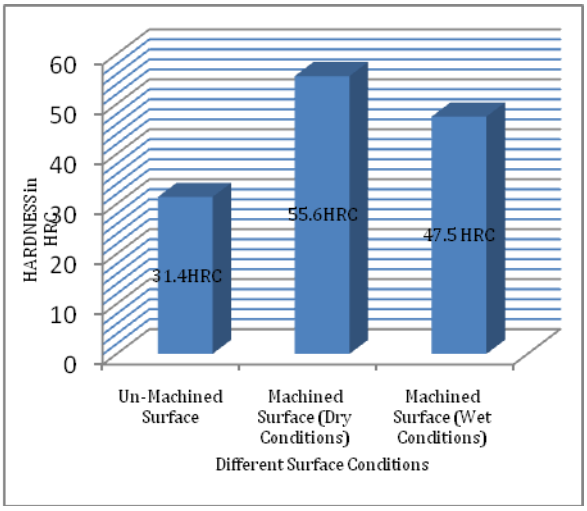


Figure 6 Effect of different machining conditions on Hardness

4. CONCLUSIONS

- Tool wear which predominately occur during machining of Hastelloy C-276 is flank wear and due to high temperature generation chipping of tool and build up edges occur.
- Chip form during the machining of Hastelloy C-276 is of two types such as serrated chips and fragment chips. At cutting speed 47000 mm/min, the chip developed is massively segmented. When the cutting speed is about 20000 mm/min, serrated chips transform into fragment chips. Also there is transition of continuous chips to discontinuous chips.
- The grooves and smears appeared during the dry machining but in case of wet machining re deposition of micro chips occurred which form the buildup edges.
- The composition of work piece changes during the wet condition with slight increase in silicon percentage because of use of silicon as lubricant.
- Micro hardness during the dry condition is more than wet condition.

REFERENCES

[1] K.Kadirgama, K.A. Abou-El-Hossein, M.M.Noor, B.Mohammad and Habeeb H.H, "Aspects of Wear Mechanisms of Carbide Tools when Machinining Hastelloy C-22HS", International Conference on Advance Material & Processing Technology, Elsevier, 2008, pp. 2-5.

[2] H.H Habbeb, K.Kadirgama, M Noor, M.M Rahman, B.Mohammad, R.A Bakar, and K.A. Abou-El-Hossein, "Prediction Tool Life Tool Life when Machining Nickel based alloy 242", Journal of Applied Science, Research Gate, Vol. 12,2013 , pp. 322-327.

[3] K. Kadirgama, K. A. Abou-El-Hosseirr, B. Mohammad and H.H Habeeb, "Statistical Model to Determine Surface Roughness when Milling Hastelloy C-22HS", Journal of Mechanical Science and Technology, Science Direct, Vol. 21, 2007, pp. 1651-1655.

[4] Sıtkı Akıncıoğlu, Hasan Gökkaya and İlyas Uygur, "The Effects of Cryogenic-treated Carbide Tools on Tool Wear and Surface Roughness of Turning of Hastelloy C22 Based on Taguchi Method", Springer, International Journal of Advanced Manufacturing Technology, Vol. 21, 2015, pp. 7356-7369.

[5] Dahu Zhu, XiaomingZhang and HanDing, "Tool wear characteristics in machining of nickel-based superalloys ", International Journal of Machine Tools & Manufacture, Elsevier, Vol. 64, 2013, pp. 60-77.

[6] Du Jin and Zhanqiang Liu, "Damage of the machined surface and subsurface in orthogonal milling of FGH95 super-alloy", International Journal of Advance Manufuring Technoogyl, Springer, Vol. 60 ,2012, pp. 893-899

[7] Kaitao Xu, Bin Zo, Chuanzhen Huang,Yang Yao, Huijun Zhou and Zhanqiang Liu, " Machinability of Hastelloy C-276 using Hot-pressed sintered Ti(C7N3)-based cermet cutting tools", Chinese Journal of Mechanical Engineering, Springer,Vol.28, 2012, pp. 599-606.

[8] http://haynesintl.com/docs/default-source/pdfs/new-alloy-brochures/corrosion-resistant-alloys/c-276.pdf?sfvrsn=4

[9] Ning Y, Rahman M, and Wong YS, "Investigation of chip formation in high speed end milling", Journal of Material Process Technology Vol. 113,2002, pp. 360–367.