International Journal of Advanced Mechanical Engineering.
ISSN 2250-3234 Volume 8, Number 1 (2018), pp. 181-190

http://www.ripublication.com

# Comparative study of measured Cutting Force and Surface roughness for machining of Pure Aluminium using Uncoated and Coated Carbide Inserts

**Rakesh Kumar[1], Jyoti Komal Minz[2], Debi Prasad Sahu[3], Smita Sowmya Bishoyi[4]**

*[1,2,3,4] Postgraduate, Mechanical Engineering Department,*
*VSSUT Burla, Sambalpur-768018, India*
*Email- [1]rakesh.kist02@gmail.com, [2]jyotikminz@gmail.com,*
*[3]debi.sahu17@gmail.com, [4]smita.sowmya@gmail.com*

**Abstract:-**
Aluminium, due its peculiar property of good formability, corrosion resistance, weldability, light weight, non-magnetic and mechanical properties is being widely used in automobile and aerospace industries. But machining of Al and its alloy as well as finding the suitable tool is really a challenging task because of its abrasive nature. The objective of this paper is comparative study of process parameter of machining of Aluminium using different tool inserts. In this paper a rolled Al bar is being machined in dry condition using 3 different advanced cutting tool inserts (SPUN WC, WC+TiN and WC+Ti(C, N) TiN+$Al_2O_3$ ) at different cutting speed ($V_c$) ranging between 300 m/min to 550 m/min and feed (f) of 0.045, 0.06 and 0.09 mm/rev at a depth of cut of 0.2 mm (constant throughout the experiment). The experiment was performed on Capstan-Turret Lathe. The measurement of main cutting force ($F_z$) is also observed using Kistler 3-D force dynamometer and compared for the different tool to find out the best tool for the machining of Al. The surface roughness of workpiece after machining and tool wear was also analysed. The characterizations of tool inserts are carried out using SEM, EDX Spectroscopy.
**Key-words** - Dry machining, WC- insert; Force dynamometer; Cutting force; Surface roughness; Tool-wear.

## 1. Introduction

### *1.1 Motivation for the work*

With the increasing demand of lightweight and having more strength material for structural work, Aluminium is the best choice because of its high strength to weight ratio. Aluminium and its alloying with various elements enhance the property drastically. Thus, it is highly popular in the field of aerospace, automobile and space satellites. In fact, Aluminium alloys are considered as the material which offers the highest machinability compared to other lightweight metals like Titanium and

Magnesium alloys. In dry machining chips are being removed from the workpiece by a process of intense plastic deformation at a high strain rate with the primary and secondary shear zones that subjects the cutting face to high temperature and pressure (Fig-1). Thus the surface roughness and tool wear becomes severe during dry machining compared to wet machining because of welding of chips on tool face, high friction and heat accumulation at the contact between tool and work piece.

### *1.2 Literature survey*

Demand of proper and better tools for machining of hyper- eutectic aluminium alloys are increasing day by day. For the good machinability, in addition to tool life, surface finish of the machined part is equally important requirement. In dry machining of an Aluminium alloy the tool wear is mainly caused due to formation of an adhesive aluminium layer and built- up edge, D.A. Stephenson et al. (2006)[1], which also greatly affects the surface finish of the machined surface. A. K. Chattopadhyay et al. (2009) [2] used various carbide tools with different surface quality for the dry turning of aluminium alloy, and they observed that the HFCVD diamond-coated tool had lowest level of deterioration but it didn’t produce the best surface quality. Uncoated WC tool with 6% cobalt and diamond coated WC-Co tools play a significant role in machining of aluminium B. Sahoo *et al*, (2002) [3].

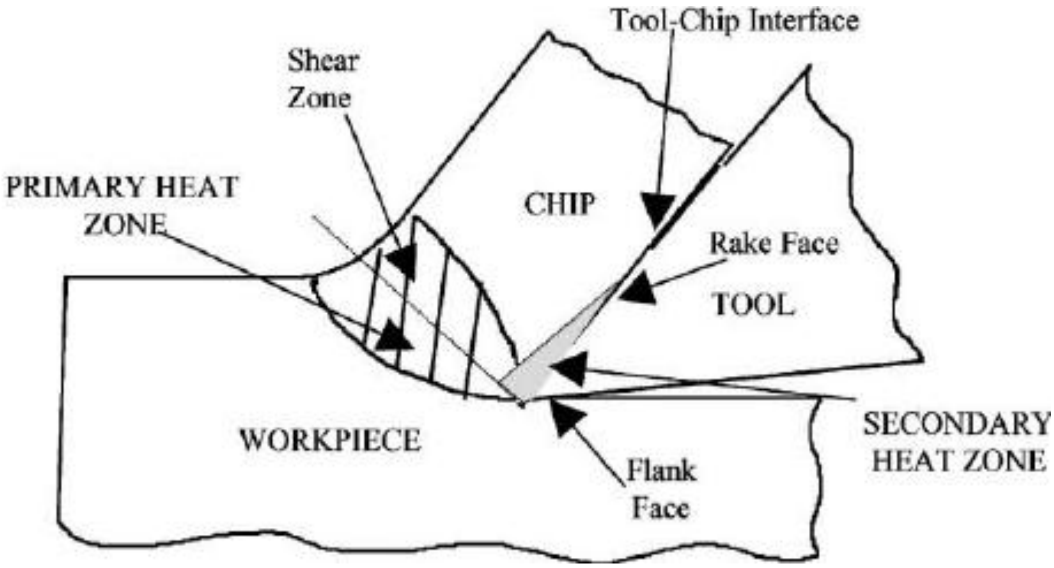


Fig 1:- shear zone and heat affected zones in an orthogonal machining

Recently in his research work S. Gangopadhyay et al. (2010)[4] have investigated the effect of cutting speed and surface chemistry of cutting tool for the dry turning of AA6005 aluminium alloy with regard to formation of built-up edge(BUE). They found that the CVD diamond coating WC-inserts which is inherently free of cobalt with improved rake surface finish has enormous potential in dry machining of AA6005 aluminium alloy. In a research R. Suresh et al. (2012) [5] inspected that for given value of feed rate, the machining force decreases with increase in speed and with further increase in feed rate the force increases. The frequency of the cyclic force being directly proportional to the cutting speed and inversely proportional to the feed rate as observed by S. Sun et al. (2009) [6]. It is again reported that the polished CVD diamond tool inserts improve tool life and reduces cutting force while machining Al-Si alloys [7-8].

The objective of this work is to study of dry machining of rolled Al by analyzing surface finish of machined surface, chip morphology of underface, cutting force measurement and tool wear as well as tool characterization. This work will help to the tool design and tool manufacturing industries for their improvement.

## 2. Experimental setup and procedure

### *2.1 Workpiece Material*

A cylindrical rolled aluminium bar has been taken as a workpiece material. Aluminium is a mostly used in aerospace industries, satellite manufacturing and automobile industries as well as for my research work to study about its machinability using turning. The dimension and basic properties are mentioned in the Table-1. The composition of the workpiece was studied using the Energy Dispersive X-Ray (EDX) analysis, which conforms that the workpiece is 100% pure aluminium (Fig -2).

Table-1 Description of workpiece material

| Workpiece material | Rolled Aluminium |
|---|---|
| Dimension | Ø 190 X 460 mm |
| Young’s Modulus(E) | 70 GPa |
| Bulk Modulus(k) | 76 GPa |

### *2.2 Cutting tools*

For the machining we use various tool inserts are imported from SANDVIK Coromant (table-2). All the inserts are of square shape, but WC+ PVD TiN coated and WC+ CVD Ti(C, N) +TiN+$Al_2O_3$ are grooved type for the purpose of chip breaking to eliminate continuous chip and hence the built-up edge formation due to adhesion of Al with coated layers.

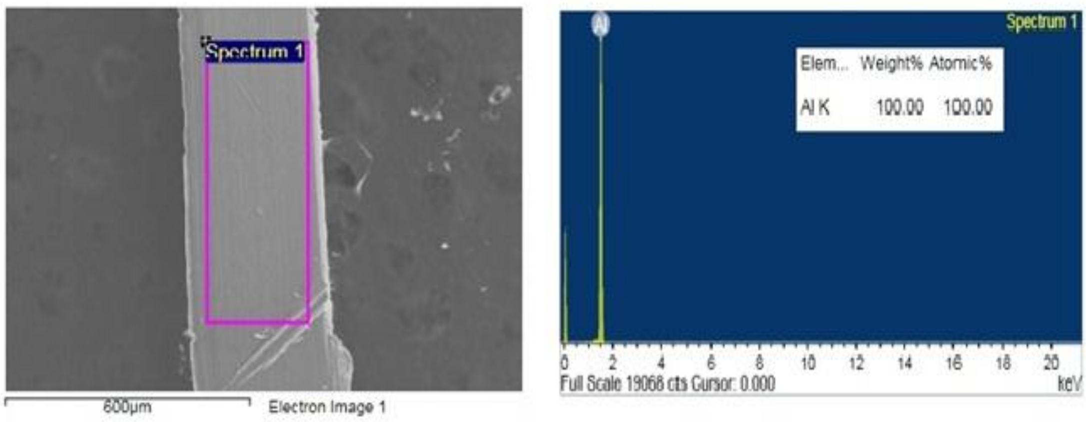


Fig 2:- EDX analysis of chip

Table-2 Description of various cutting tool

| Sl No | Cutting tool material | Designation |
|---|---|---|
| 1. | Cemented Carbide(WC SPUN) | SPUN 120308 |
| 2. | WC + PVD TiN Coated | SNGA 120408 PR 4035 |
| 3. | WC + CVD MT - Ti(C,N) + TiN +$Al_2O_3$ (Multicoated) | SNMG 120408 PR 4235 |

***2.3 Machine setup and machining parameters***

Orthogonal machining operation (Turning) was carried out on Gottwaldov Capstan lathe, Type R5, precision Lathe manufactured by Gottwaldov, ZPS, Czechoslovakia having motor power of 7KW, 5HP.

Here in this experiment, depending upon the tool available and influence of aluminium alloy properties we select the cutting speed and feed rates as specified in Table-3 for dry machining. It was observed that the depth of cut is having lower effect on machinability performance. So, here we take a constant value of 0.2 mm as a depth of cut. All the machining parameters will be listed in Table-3.

Table-3 Working condition and different machining parameters

| | |
|---|---|
| Cutting condition | Dry Turning |
| Cutting speed | 336, 426, 540 m/min |
| Feed | 0.045, 0.06, 0.09 mm/rev. |
| Depth of cut | 0.2 mm |

***2.4 Setup for cutting force measurement***

A three- component dynamometer (Kistler- 9257B) is used for the measurement of change in dynamic cutting force at a frequency of 1 kHz, which works on the principle of piezoelectric material (Quartz). The Schematic diagram in fig-3 represents the process of force measurement. The whole set-up consists of tool force dynamometer, Kistler multi channel charge amplifier-5070A type, type 1687B5 Cable to connect the dynamometer and charge amplifier and the data obtained from dynamometer is being acquired by Data-acquisition hardware NI ENET- 9163 which is stored in the computer system using LABVIEW-2015 software.

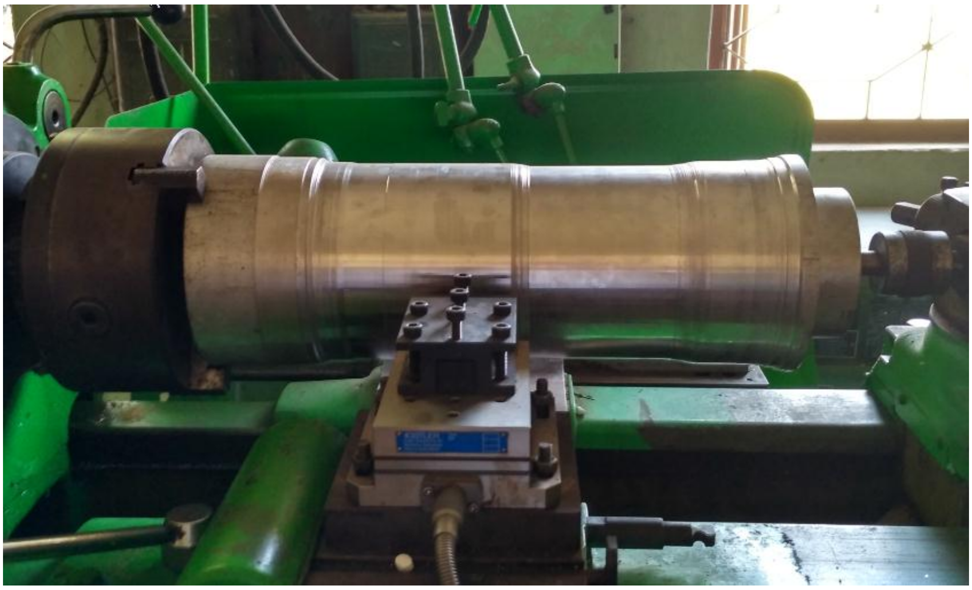

Fig 3:- Image of rolled aluminium and 3-componenet Kistler dynamometer mounted on lathe

## 3. Results and Discussion

***3.1 Cutting Force Measurement***

The force calculation is an important parameter for the study of machinability of in any machining process. In case of turning 3 types of forces are induced. Out of 3 the tangential force (main cutting force) (Fz) acting along the direction of tangential velocity (Vc). While rest of two forces are radial force (Fy) acting in the direction of depth of cut applied and axial force (feed force) (Fx) acting in the direction of given feed. Among all the forces the contribution of Fz is more than the other two. Fig-6 shows the obtained values of measured force using Kistler dynamometer with a frequency of 3 kHz. From the graph (Fig 7) it is clear that, with the increase in feed rate values, the force values are also increasing. This shows that the cutting forces are directly proportional to the given feed rate.

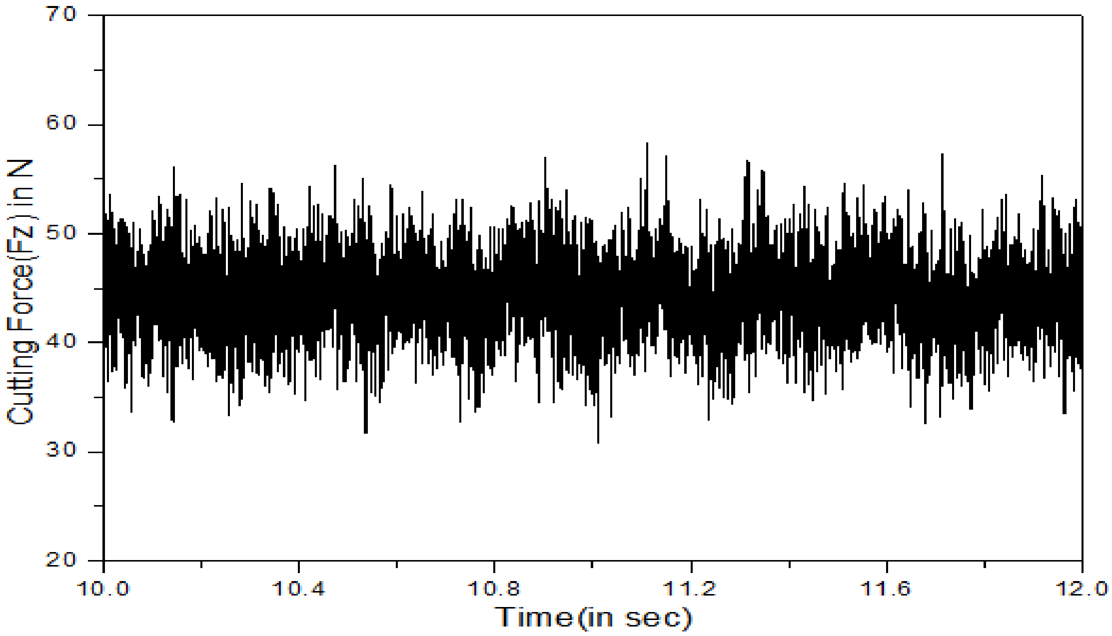


Fig 4:- Obtained force graph using Kistler force dynamometer

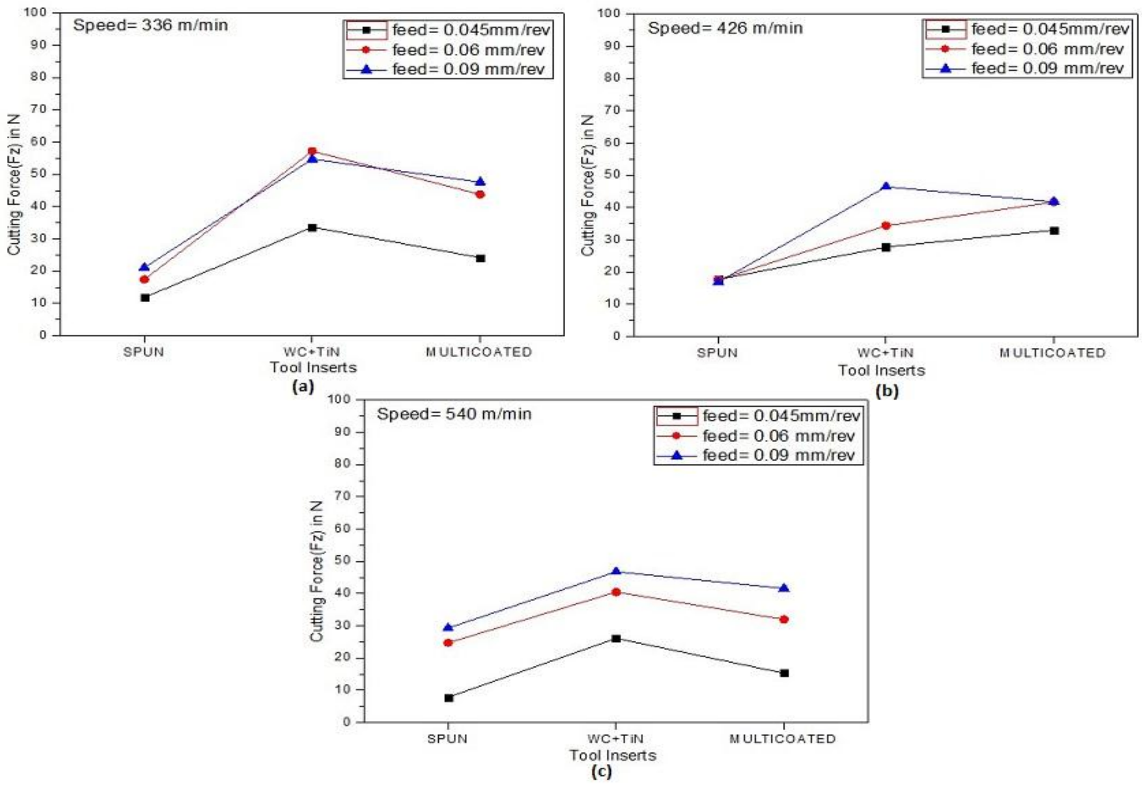


Fig 5:- Graph shows the values of measured cutting forces at different speed and feed rate (a) at Vc= 336 m/min, (b) at Vc= 426 m/min, (c) at Vc= 540 m/min.

### *3.2 Surface Roughness Measurement*

Surface roughness is defined as the waviness of the surface. The surface quality obtained after machining is another measure which determines the machinability performance of a material. The surface roughness is also affects the use and costs of the machined products. As the feed rate is lower the roughness values is also less with increase in speed but as we go for higher feed rate the roughness values also increases. From the graph (Fig -8) we can easily compare the surface roughness obtained using different tools at different cutting speed and feed rate.

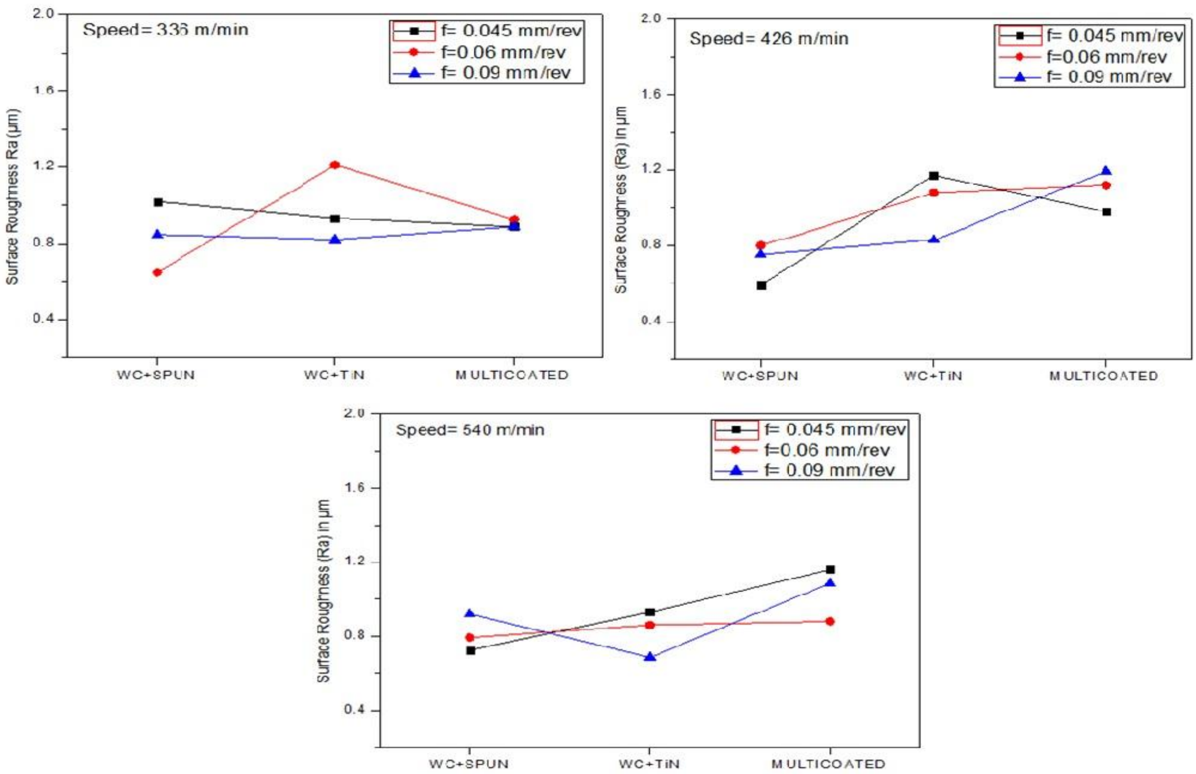


Fig 6:- Graph shows the average surface roughness (Ra) values obtained after machining at speed of 336, 426, 540 m/min with various feed rate.

### *3.3 Study of tool wear*

Tool wear is an important factor for study of machinability. How faster the tool gets worn-out, poorer the machinability. Microscopic study is the best suitable way to characterize the tool wear. Hence the tool inserts were inspected by SEM to study the tool wear. Before the microscopic study the tool inserts was cleaned ultrasonically with the help of trichloroethylene for five minutes and then dried and again washed using acetone. In case of WC-SPUN tool only few feed marks are observed were as in case of coated tools complete removal of coating materials from the tool tips is clearly visible. Out of two coated tool the wear pattern is more sever in TiN coated tool.

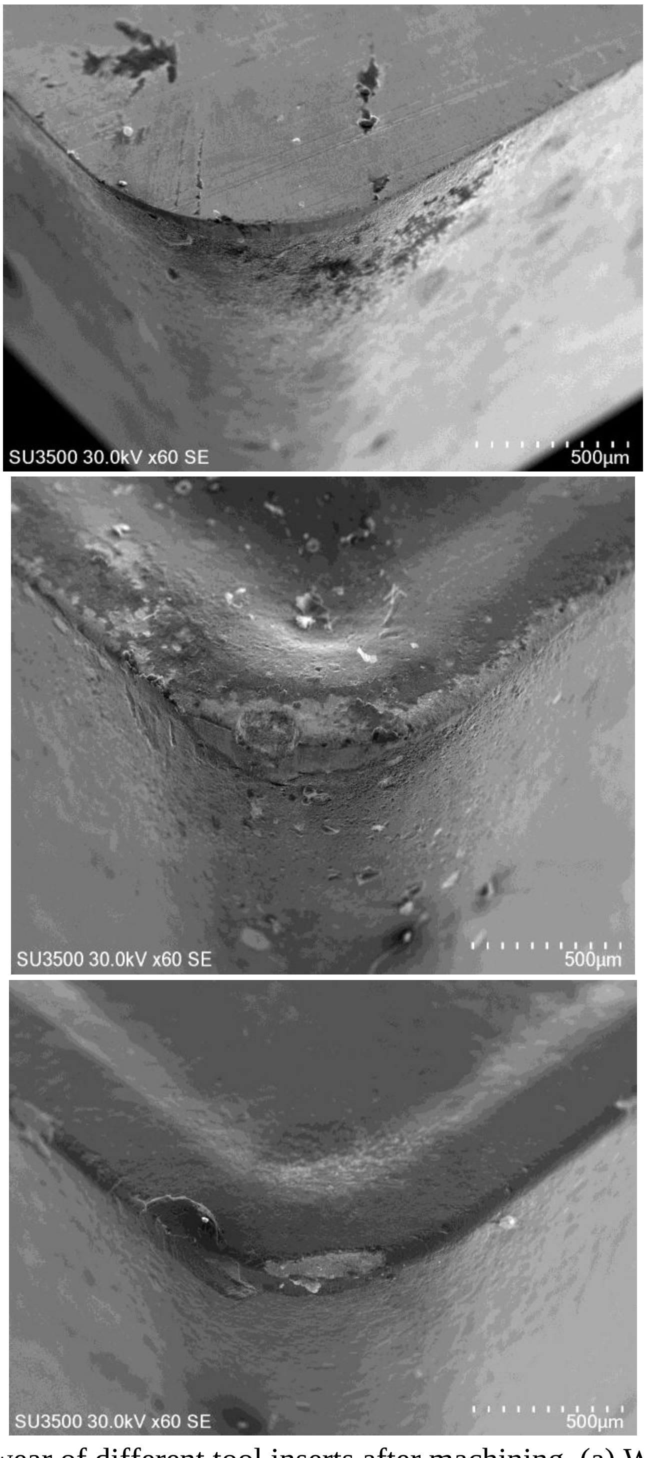


Fig 7:- Tool wear of different tool inserts after machining, (a) WC SPUN, (b) WC+PVD TiN Coated, (c) WC + CVD MT - Ti(C,N) + TiN +$Al_2O_3$ Coated

## 4. Conclusions

The main cutting force as well as surface roughness obtained after dry machining is studied at various speed and feed rate and compared for the different tools. From the above experimentally obtained data we can conclude that,

- Force value obtained for WC SPUN tool is less than other and for PVD TiN coated WC tool is more than rest tools.
- With increase in feed rate the force values goes on increasing for all the tools.
- At low feed rate the roughness values are less and as we go on increasing feed rate the values increases, but as speed increases the roughness values goes on decreasing.
- From the above roughness values WC SPUN gives better surface finish compared to other to which shows inertness of aluminium toward coating of WC insret.
- Tool wear was least for the uncoated WC and is more for TiN coated tool, which shows the adhesive nature of Al with coating material.

## 5. References

[1] D.A. Stephenson, J.S. Agapiou (2006), Metal cutting theory and practice, Second Edition, CRC Press, Florida, 17-20,371-416,459-478,551-697.

[2] Chattopadhyay, A. K., Roy, P., Ghosh, A. and Sarangi, S. K. (2009) Wettability and machinability study of pure aluminium towards coated and uncoated carbide cutting tool inserts. Surface Coating Technology 203(8), 941-951.

[3] Sahoo, B., Chattopadhyay, A. K. and Chattopadhyay, A. B. (2002) Development of diamond coated tool and its performance in machining Al – 11 % Si alloy, Bull Mater. Sci. Indian Academy of Sciences, *25*(6), 487–491.

[4] Gangopadhyay, S., Acharya, R., Chattopadhyay, A. K. and Sargade, V. G. (2010), Effect of Cutting speed and Surface chemistry of cutting tools on the formation of BUL or BUE and surface quality of generated surface in Dry Turning of AA6005 aluminium alloy, Machining Science and Technology. 14, 208-223.

[5] Suresh, R., Basavarajappa, S., Gaitonde, V. N. and Samuel, G. L.(2012), Machinability investigation on hardened steel AISI 4340 steel using coated carbide inserts. Int. J of Refractory Metals and Hard materials, 33, 75-86.

[6] Sun, S., Brandt, M. and Dargusch, M. S. (2009) Characteristics of cutting forces and chip formation in machining of Titanium alloys, Int. J. Of Machine tools & manuf, 49, 561-568.

[7] Martini, C. and Morri, A. (2011), Face milling of the EN AB-43300 aluminum alloy by PVD- and CVD-coated cemented carbide inserts, Int. J of Refractory Metals and Hard materials, 29, 662–673.

[8] Davim, J. P. and Baptista, A.M. (2000), Relationship between cutting force and PCD cutting tool wear in machining silicon carbide reinforced aluminium, J. Of Materials Processing technology, 103, 417–423.