DOE Based Response Surface Regression Methodology for the study of PVD coated cemented carbide tool performance on Surface roughness

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DECLARATION

The work presented in this report was completed by using the facilities available in the PITAC, Lahore, PIDC Sialkot and IME Department University of Engineering and Technology, Lahore, Pakistan. It is purely a research based work and was completed after several discussions and meetings with the thesis supervisor Dr. Awais A. Khan. I hereby declare that I have not presented any part of this work in support of an application for another degree at this university or any other institution.

Farooq Mustafa Joyia

2016-MS-MET-20

I certify that the above statement is correct.

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بسم الله الرحمن الرحيم

لا إله إلا الله محمد رسول الله

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NOMENCLATURE

D	Diameter of Work Piece
Vc	Cutting Speed
fn	Feed/Revolution
d	Depth of Cut
N	RPM
T	TOOL Life (Mins)
P	Power (KW)
MRR	Metal Removal Rate
Lm	Machined Length
Ra	Average surface roughness
VB max	Maximum Flank wear
Hm	Average Chip Thickness
(γ)	Rake Angle
(λ)	Inclination Angle
(χ)	Entering Angle

DEDICATION

To

My parents and Family Members
Without the support and prayers of them
It was never possible for me to accomplish this work

Acknowledgement

First and foremost, I want to present my words of gratitude to **ALLAH** Almighty for His countless blessings. His kindness and consideration being the key to every happening. Millions of salutations upon **The Prophet Mohammad ﷺ and His Family**, who came as the light of knowledge for all mankind. He ﷺ said:

"He, who is not thankful to the people, is not thankful to ALLAH".

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May Allah Bless All These People (Aameen)

Author

Abstract

Now days PVD and CVD coated tools are widely used in different industries to ensure cost effectiveness in terms of tool life and work piece quality. Selection of tool geometry, its material and cutting parameters are very important in machining processes. These stake holders can affect production quality as well as time.. In this research uncoated cemented carbide tools and PVD coated cemented carbide tools are used for the dry machining of aluminum alloy 2024 to evaluate surface roughness and tool wear. Purpose of this research is to compare the performance of two tools. Experiments were conducted on full factorial design of experiments in which three levels of depth of cut, feed rate and cutting speed were taken as input variables and surface roughness and tool wear were the response for both tools. Machining time was taken as 30 minutes. Tool wear is measured by CMM and surface roughness by Surftonic. For the analysis of data response surface regression technique are used. Pareto coefficient and marginal mean plot shows the effectiveness of this approach. It is observed that depth of cut has great dominance on tool wear and surface roughness followed by cutting speed. Optimum levels are investigated to gain minimum tool wear and surface roughness for both coated and uncoated tools.

CHAPTER NO 1

1. Introduction

Metal cutting is most likely one of the recognizable and comprehensive used manufacturing process. A complete recovery in process adroitness might be accomplished by process parameter optimization that decide and separate the zone of precarious process control factors prompting wanted body of work or responses with worthy changes guarantee a decrease cost of produced merchandise. Material cutting is likely the most costly one. This is on account of a lot of material is detached from the crude material in the like of chips with the end goal to accomplish the required measurement. The hugeness of machining procedure can be stressed by the way that every item we use in our day by day life has encountered this procedure either straightforwardly or in a roundabout way. In USA, more than $100 Billion are spent once every year on machining and related tasks [1].

Selection of tool geometry, its material and cutting parameters are very important in machining processes. These stake holders can affect production quality as well as time. Now days PVD and CVD coated tools are widely used in different industries to ensure cost effectiveness in terms of tool life and work piece quality. Till now this field has got interest of many researchers that to increase tool life by using different coating techniques or trying different tool materials according to work piece and to increase surface finish of work piece by using different practices I-e opting optimum cutting parameters to increase surface finish. [2]

History of development of coating of tools is much enriched followed by tool material evolution. In start tungsten cemented carbide tools did not prove to be a healthy choice because of poor crater wear resistance. This problem was abridged by adding TiC, TaC and NbC resulting in less toughness but became more sensitive to crack formation. Introduction to coating of tool addressed these problems of poor crater resistance and less toughness putting a nail in coffin of previous development in cutting tool technology. Now a day's use of coated tools is common practice for many reasons i-e great heat generation when machining without cutting fluid (dry machining) and high speed cutting (HSC), and more recently, dry high speed demand cutting tools with an elevated heat resistance or the presence of a heat insulating coating on the surface but now scientists are developing different types of coating and its methods for specific applications. TiN has been considered as a universal coating. PVD (Physical Vapor deposition) and CVD (Chemical Vapor deposition) are two methods of coating famous now a days and PVD has proven performance over CVD coated tools.[2] [1]

The use of Aluminum alloys in manufacturing industry is noticeably increased in recent few years due to their high strength to weight ratio. Low weight and high strength together combined in aluminum alloys have made them a preferable choice for use in aerospace and automotive industry specially. High strength to weight ratio has made aluminum alloys a fair substitute for steel and cast iron for fabrication of different parts in aerospace and automotive industry. Aluminum Copper Alloy 2024 is aircraft grade material and is of greater importance in said industry. We have chosen this material as our workpiece to aid said industry in machining of this special material.[3][4]

1.1 Machining

The process in which a sharp cutting edge is utilized to pierce the metal to make desired shape is called machining. It is the most fundamental process in manufacturing. The vast variety of materials can be worked through machining. Such plastic and its blends can likewise be cut by machining process. Machining is utilized to make such normal geometries, similar to level surfaces, round and loads. In excess of few machining tasks are utilized to join to get assortment in merchandise measurement and features. Precision up to 0.025 mm and completed measurements can be accomplished. The completed surface is favorable position of machining process wherein by traditional machining we can achieve high surface finish. The negative point of machining is that it requires greater investment of time when compared with various manufacturing processes.

1.1.1 Machining Variables

In machining process there are some variables which affects the results of process. Some are dependent and some are independent. Main independent variables in cutting process are stated below:

i. Tool material
ii. Shape & Geometry of tool
iii. Material and hardness of work piece
iv. Processing parameters (cutting speed, feed rate and cutting depth)
v. Machining environment i-e dry or cutting fluid involved
vi. Work holding and fixtures

Dependent variables are

i. Surface roughness of workpiece
ii. Tool wear and failure
iii. Type of chip formation
iv. Force and energy requirements during cutting
v. Rise in Temperature of work piece and tool

Machining task for example in turning, cutting condition like dry cutting and coolant used cutting expect an effective part in perfect use of a machine.[5]

1.2 Specific Objectives

The aim of this research is to conduct the comparative analysis of performance of PVD coated TiN cemented carbide tools on surface roughness and tool wear in dry machining of Aluminum copper alloy (2024) using response surface methodology. To optimize the main parameters which have significant influence on surface roughness and tool life.

1.3 Turning Process

The Turning is a procedure in machining in which external distance across of workpiece is lessened by a single point cutting tool. Turning term is every now and again utilized for the creating outer surfaces by removing material while same process adapted for inward surfaces, as a rule called boring. In manufacturing applications, turning activity is a common material removal approach. Renowned researchers on this perspective consider different attributes, for example, metallurgical and geometrical topographies of the cutting instrument, workpiece material, effect of handling parameters. Turning is the most conventional metal expulsion procedure to deliver highlighted surfaces and geometries. Turning task is completed on most customary machine apparatus "Lathe machine" controlled by electric vitality. [6]

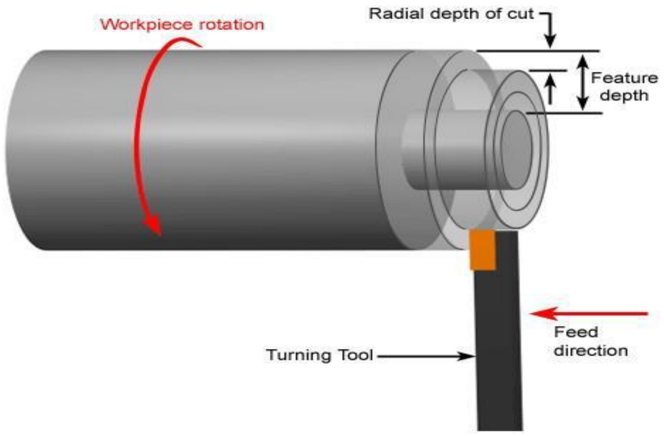

Figure 1 Turning Process [7]

1.4 Processing Parameters

The terms feed, cutting rate and depth of cut, are called process parameters. Surface finish and tool life is firmly subject to preparing parameters given in the past papers. Input factors utilized for experimentation is chosen from suggested cutting paces and feeds for single-point carbide apparatuses table Technology of Machine tools.

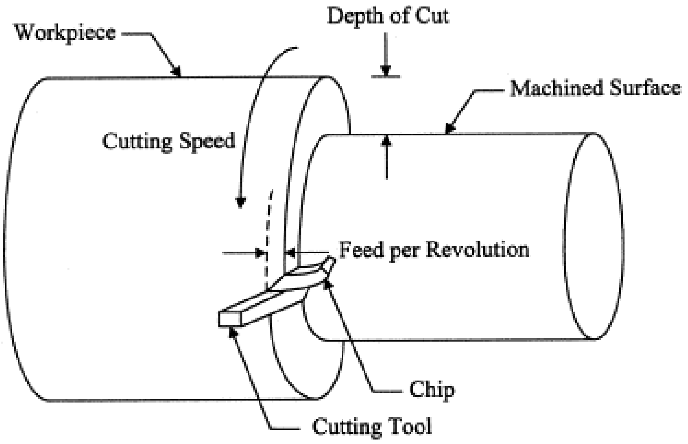

Figure 2 Processing Parameters in Turning Process [8]

1.4.1 Cutting speed(v)

The rotational speed of machine shaft or instrument in revolution per minutes (RPM) and are changed by the ventured pulleys. On a belt-driven machine, set of various paces are acquired by changing belt and back rigging drive. Three stages for slicing speed were chosen to convey tests. Cutting Speed is figured with:

$$Vc = \frac{N \times 1000}{\pi \times D}$$

Where N [rpm] = Spindle speed, V [m/min] = Cutting speed, d, [mm] =Turning diameter

1.4.2 Feed Rate (fn)

Feed rate is axial movement of slicing insert with reference to the rotating work-piece as the TOOL confers a cut. Feed of lathe relies upon lead screw or feed bar. It is controlled by the switch gears in the brisk change liver. An outline mounted on the front of liver in machine shows the different feeds and metric pitches.

1.4.3 Depth of cut

Vertical intrusion of cutting instrument into workpiece material is called depth of cut. In each stroke, transverse travel of cutting instrument towards focus of workpiece on turning process. Expanding depth of slice caused to remove more material while in its revolution.

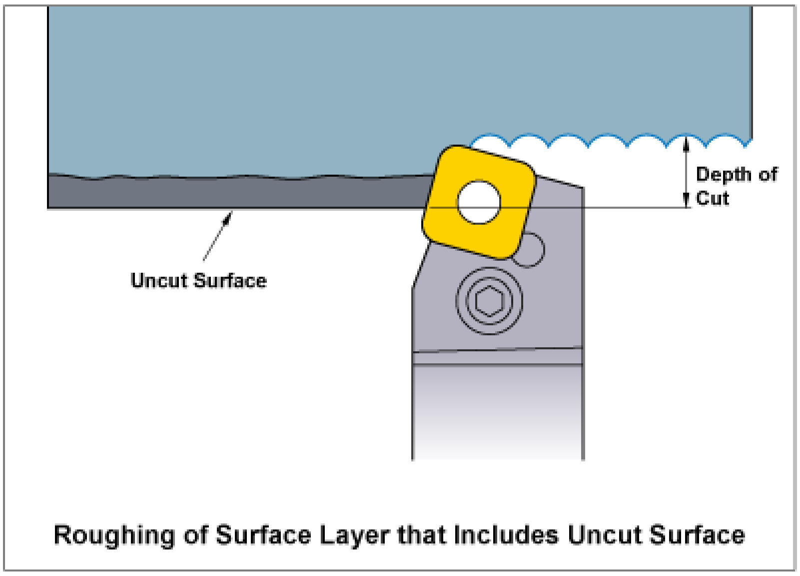

Figure 3 Depth of cut [9]

1.5 Surface roughness

Surface smoothness has taken genuine considerations for a long time. surface finish has turned into a noticeable design characteristic in different applications, similar to parts subjected to accuracy fits, affixing applications and tolerances of machined parts. Surface finish executes the fundamental imperatives for assurance of assets and preparing parameters in procedure layout and planning. Surface roughness and tool life are the most imperative parameter of surveying quality of a component and a factor that fundamentally hold industrialized expense.

Additionally, brilliant quality geometric surface is required in enhancing exhaustion quality, creep life and erosion contradicted application. Turning process has turned into another of grinding in numerous mechanical applications. Numerous components influence the surface finish produce by a machining procedure, the most widely recognized are

- ✓ Feed Rate
- ✓ Nose Radius
- ✓ Cutting Speed
- ✓ Vibration
- ✓ Rigidity of machining operation
- ✓ Temperature generated during operation

During machining process if temperature is getting higher it will influence surface unpleasantness as metal particles have a tendency to follow and form developed edges. All surfaces have their very own qualities paying little heed to machining tasks.

Figure 4 Surface Finishing [10]

1.5.1 Surface roughness Measurement

Conventional instruments used to record and measure surface roughness is surface profile-meters, comprise of diamond stylus. Cut off is the separation that a stylus travel along a straight line while estimating surface. With the end goal to feature the roughness profile-meter follows are recorded on vertical scale. The size of scale is called gain on the recorded instruments. Accuracy of instrument rely on its stylus sweep. Littler the range, more noteworthy is the ability to exact measure.

1.5.2 Average surface roughness

Surface roughness is estimated in average surface roughness (Ra) number juggling mean of more often than not in µm. Average surface roughness is a standout among the most utilized units in industry and also R&D associations.

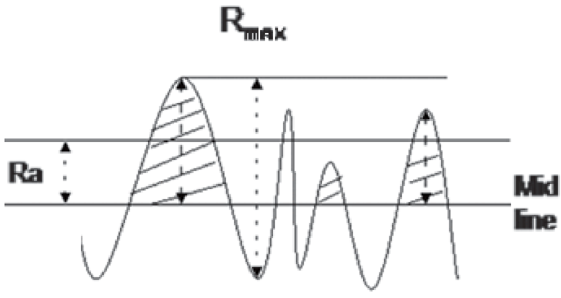

Figure 5 Average surface roughness [7]

Average surface roughness is characterized as average of the vertical expression from the ostensible surface on closed particular length. Number juggling Mean Value

$$R_a = \frac{a + b + c + d + \cdots n}{n}$$

Surface finish is more emotional term to show surface smoothness. Surface roughness is most vital factor to be considered for useful conduct or a mechanical part. Surface roughness is quality pointer for machined surface in manufacturing innovation. Various factors unequivocally impact by average surface roughness in designing applications.

- ✓ Resistance of wear
- ✓ Coefficient of Friction
- ✓ Lubrication
- ✓ Fatigue Strength
- ✓ Resistance to corrosion

The maximum roughness height R_t also used to predict roughness.

1.6 Tool Life

In spite of far reaching research restricted over a century on machining preparing parameters there is no satisfactory hypothesis to foresee tool life. The greater part of the engineer needs to depend on observational conditions like Taylor's has proposed however lamentably there are a considerable measure or obscure constants utilized in this condition making it unfit to utilize. In this period of science, the fundamental reason for analysts is to expand the effectiveness of assembling forms by building up a superior system which creates high yield with low wastage of assets. To accomplish the objective one of the principle objective is to expand device life as the entire procedure is subject to device.

1.6.1 Tool life Monitoring

Tool life monitoring can be classified into two major categories.

- Direct: The real wear is estimated in which wear state can be gotten by electrical obstruction, optical or chemical examination.
- Indirect: where a parameter connected with tool wear is estimated. Wear is analyzed through torque, cutting power, temperature, acoustic outflow and vibration

1.6.2 Tool Life Criteria

a) Permanent failure of cutting edge

b) Visual observation of wear by machinists

c) By applying fingernail testing on cutting edge

d) Chips formation

e) Surface roughness value

f) Power requirement

g) No of manufactured components

h) Cumulative machining time

The following are some of the possible tool failure criteria that could be used for limiting tool life. Based on tool wear

a) Cracks development on cutting edge

b) Wear size

c) Crater depth, width or other parameters

d) Crater depth, width or other parameters

e) A combination of the above two

f) Volume or weight of material

g) Turned length of the part

1.6.3 ISO tool Life Criteria

Tool life values as suggested by ISO [6] are

VB max= 0.3 mm for uniformly wear of cutting edge

VB max= 0.6 mm, if the flank is irregularly itched, chipped or wear cracked

All these different parameters recommended are connected and are utilized relying on the last capacity of a given task.

1.7 Tool wear

Tool life is valuable range of time as far as dynamic wear that experiences on instruments leeway face or rake confront. Apparatus wear is "Constrained deceleration of the cutting material presented by instrument and work part contact and from relative interruption of hardware into work part. As indicated by past research relatively 20% of aggregate downtime of is caused by device disappointment, announced in writing. Because of hardware disappointment add up to creation cost is impact right around 3 to 12% of aggregate expense. Device wear impacts the generation severely as well as in the event that it isn't recognized at appropriate time it delivers an unpleasant surface complete and all the more machining force is devoured by the cutting device.

Our attention on wear is just on single point cutting instrument from flow examine perspective. The most critical reasons of hardware debasement because of wear is the sliding workpiece and shaper. In machining process the temperature goes around 1000 degree C, at this extraordinary temperature there is a possibility of synthetic cooperation among instrument and work piece surface. The device wear are of numerous kind, a portion of the principle instrument wear system are scraped area, concoction response, grip, dispersion. A general methodology which can identify the device disappointment is reason is still in riddle. This is because of variety of hardware to-instrument execution, immense assortment of procedures, and ecological and numerous different components. The interrelationships between apparatus determination and cutting information (e.g. feed rate, cutting velocity) predicts device life however it is extremely mind boggling to get it.

1.7.1 Types of wear

It is accounted for in writing that kinds of hardware wear changes from material to material of hardware, its geometric design and the cutting conditions. Be that as it may, for single point cutting apparatus underneath made reference to wear happens in cutting supplements [11].

- flank wear
- Notch wear
- Crater wear
- Chipping
- Fracture
- Catastrophic Failure

1.7.1.1 Flank wear

The most of the time is the flank tool wear occurs. Since the flank is the surface which slides over the workpiece and the flank surface grains get rubbed and the wear begins. Flank is the surface which is constantly is in intact with the work piece, the hard particles on the surface of workpiece makes the wear start.

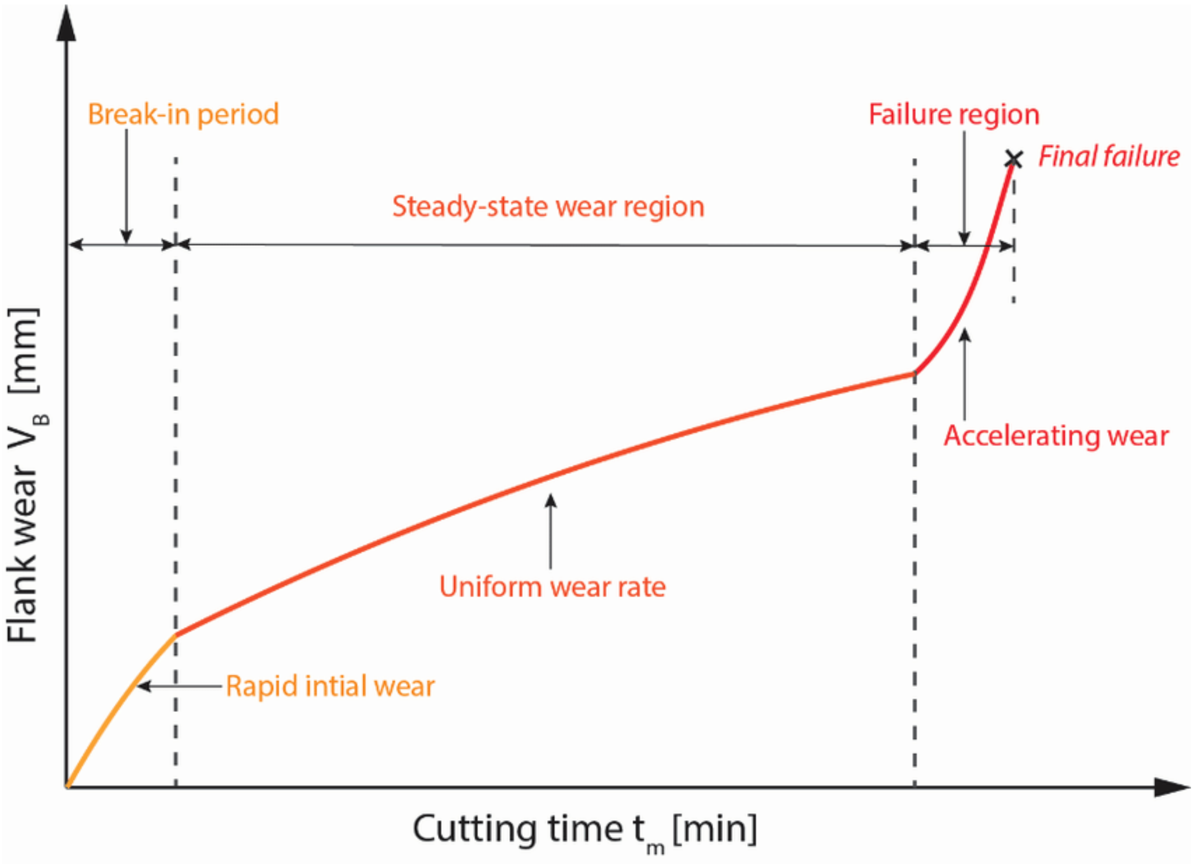

Figure 6 Flank Wear vs Cutting Time [12]

This graph shows the relation between tool flank wear and cutting time in minutes. First locale is the primary locale; in this area the breakage to sharp cutting edges often happen. At the point when wear proliferates in secondary area, there is uniform wear and this locale is caused by scraped spot. In tertiary region, the wear quickens quick and this is caused by typically diffusion, and tool will crack with a little increment in speed or temperature in this area. On the off chance that the cutting pace stays moderate and consistent at that point flank wear can be anticipated.

1.7.1.2 Notch wear

Depth of cut describes the Notch wear. It happens at the same time on flank surface and tool face. This is triggered due to the hard or oxidized surface of workpiece amid inclusion of depth of cut because of grating activity of work solidifying tool material. Notching is exceptionally basic in handling of materials with predominant work solidified.

1.7.1.3 Crater wear

The crater wear is the wear which happens because of chip sliding over the chip apparatus interface. This is a curved like example on the rake surface. This wear is delivered when little particles of cutting device hits with the chips as it travel over the rake surface. This disintegration procedure proceeds till the crater breaks. It shapes a cavity in the cutting tool.

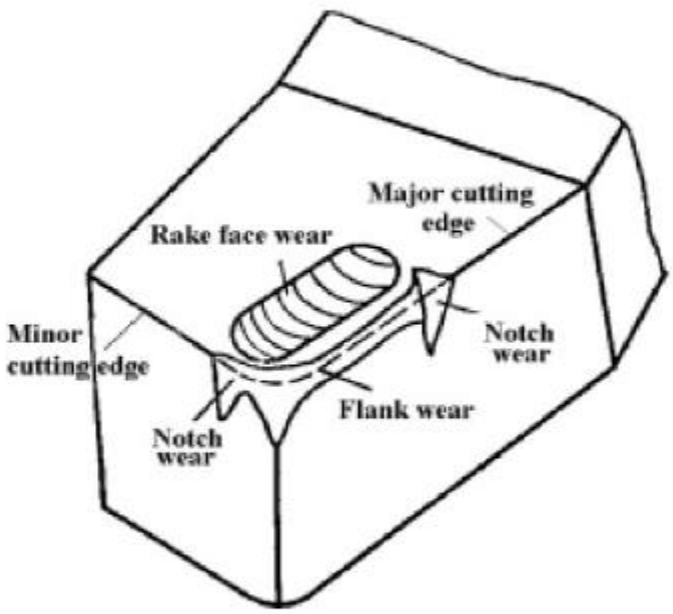

Figure 7 Tool wear [13]

1.7.1.4 Chipping

Chipping splits away the little section of chips from the tool surface bringing about sporadic wear design along the edge of the tool. It is because of the over-burden of ductile worries in the tool, these anxieties are created because of a few conditions, for instance exorbitant feed rate, unnecessary wear on the embed, vibrations amid machining, the vacillations of cutting pace. This wonders is ordinarily gathered in weak device material e.g. ceramics and tungsten carbide.

1.7.1.5 Fracture

Fracture is a definitive disappointment of the instrument. Crack is because of the extreme loads on the tool. At the point when crack wear happen it implies that the a few sorts of wear officially existing in tool for instance hole or twisting. More often than not crack wear happens because of high speed or feed.

1.8 Tool wear Mechanisms

In tools some common wear mechanisms are:

- Abrasion
- Adhesion wear
- Diffusion wear.

1.8.1 Abrasion

Relative movement of tool face and chip and rising temperature between tool and work piece is the cause of abrasion mechanism. Flank wear is caused by scraped spot instrument. Scraped area can be characterized as wearing and scratching ceaselessly of material from bleeding edge of the apparatus. Impact of rough, scratch and wear off from the surface of the material.

1.8.2 Adhesion

Adhesion happens in low cutting speeds on rake face of the tool. Little chip removal from tool surface is the result of adhesive wear. Inspiration of unique metal particles to stick each other is called adhesion. Inter molecular forces are in charge of interlocking in self-atoms of the metals in a part.

1.8.3 Diffusion

Exchange of atoms between two materials causes diffusion wear. Diffusion is quickened amid fast increment of cutting temperature. Diffusion is exchange of iotas from one surface to other. Diffusion brought about cavity wear. Diffusion is blending of atoms because of their dynamic vitality.

1.9 Tool Failure

Tool wear can be said to be disappointment of the tool. The disappointment isn't simply because of poor plan of the tool, there are in every case some prior imperfections present in the material. Regardless of whether we makes a best structure of the tool there will be as yet inconspicuous and unusual moment imperfections accessible at first glance and these blemishes spread the break and eventually towards tool wear. The main thing tool wear needs is the instatement of the break, when the split introduces because of any of the reason the tool wear begins. This is a direct result of the way that we can't achieve perfect conditions amid assembling forms. What's more, if fake perfect conditions are made and still, at the end of the day tool wear happens, in light of the fact that tool wear is likewise a period subordinate process.

Diverse parts of the individual tool may include distinctive wear instruments. The tool wear can be a steady procedure or it can happen unexpectedly. The steady procedure of tool wear is generally time ward and it is distinguished by the planner of that particular tool. Tool wear is an obligatory wonder and steady tool wear is the most alluring. Be that as it may, the unexpected disappointment happens on account of some unusual conditions. So it very well may be presumed that tool wear is an indistinct variable.

CHAPTER NO 2

2 Theoretical background

A great deal of modern exertion has completed by numerous researchers on tool life and surface roughness examination utilizing uncoated and covered cutting tools. Surface roughness is one the very pinnacle of esteemed parameter to evaluating nature of a made item and a factor that normally impacts fabricating cost. Expanding tool life is as yet a hot issue in industry to limit cost and additionally to advance creation rate. Phenomenal nature of surface complete is critical in enhancing creep life, exhaustion qualities, and protection from erosion. Surface roughness and TOOL life are the real parameters that influence the item quality and power utilization and also these impact efficiency. Expanding power utilization because of grating and diminishing TOOL life causes sensible loses like mite up of work piece or reducing of required surface quality and item quality.

2.1 Previous Literature

Qehaja et. all [14] Developed a model of surface roughness using response surface to investigate the effect of machining parameters such as feed rate, tool geometry, and nose radius on roughness of surface in dry turning process.

Swain et. all [15] used Response Surface Methodology (RSM) for developing a surface roughness prediction model on machdevised full factorial design of experimentto optimize the machining conditions to reduce flank wear on tool surface. For uncoated micro tool optimized machining conditions were found to be cutting speed 13m/min and feed rate 6 mm/min.

Rao et. all [16] studied influence of cutting parameters on cutting force and surface finish in turning operation using Taguchi Method. This research reports the significance of influence of speed, feed and depth of cut on cutting force and surface roughness while working with tool made of ceramic with an Al2O3+TiC matrix (KY1615)and the work material of AISI 1050 steel (hardness of 484 HV). Experiments were conducted using Johnford TC35 Industrial type of CNC lathe. Taguchi method (L27 design with 3 levels and 3 factors) was used for the experiments. Analysis of variance with adjusted approach has been adopted. The results have indicated that it is feed rate which has significant influence both on cutting force as well as surface roughness. Depth of cut has a significant influence on cutting force, but has an insignificant influence on surface roughness.

Selvaraj et. all [17] used two different grades of nitrogen alloyed duplex steel to optimize dry turning parameters by using Taguchi method. The turning operations were carried out with TiC and TiCN coated carbide cutting tool inserts. The experiments were conducted at three different cutting speeds (80, 100 and 120 m/min) with three different feed rates (0.04, 0.08 and 0.12 mm/rev) and a constant depth of cut (0.5 mm).

Aslantas et. all [18] studied the performance of NCD coated tools by comparing it withTiN coaed , AlCrN- coated and un coated tools in milling of titanium alloy. A series of micro-milling tests was carried out to determine the effects of coating type and machining conditions on tool wear, cutting force, surface roughness and burr size. Flat end-mill tools with two flutes and a diameter of 0.5 mm were used in the micro-milling process. The minimum chip thickness depending on both the cutting force and the surface roughness were determined.

Correia et.all [19] measured surface roughness in turning steel AISI 1045 using wiper inserts. This study investigated influence of wiper inserts as compared to conventional inserts on surface roughness. AISI 1045 has been selected due to its importance and abundant use in manufacturing industry. On high feed rates wiper inserts has low value of Ra (surface roughness) than of using conventional inserts but on low feed rates results are same for both.

Vyas et. all [20] investigated experimentally surface roughness in turning of AISI 1040 steel with coated carbide inserts. Prediction model for surface roughness in terms of speed, feed and depth of cut is developed using artificial neural network based on gradient descent back-propagation with adaptive learning rate procedure.

Kivak et. all [21] applied the Taguchi method and regression analysis to evaluate the machinability of Hadfield steel with PVD TiAlN- and CVD TiCN/Al2O3-coated carbide inserts under dry milling conditions. Several experiments were conducted using the L18 (2 3 3) full-factorial design with a mixed orthogonal array on a CNC vertical machining center. Analysis of variance (ANOVA) was used to determine the effects of the machining parameters on surface roughness and flank wear. The cutting tool, cutting speed and feed rate were selected as machining parameters. The analysis results revealed that the feed rate was the dominant factor affecting surface roughness and cutting speed was the dominant factor affecting flank wear.

Davim et. all [22] concluded that surface roughness and dimensional precision are real attributes that could assume a huge job in the execution of the item quality and its creation cost. Analysts presumed that it is conceivable to accomplish exact work piece surface in swinging procedure to take out granulating process. Trials were directed on AISI 1045 steel utilizing wiper embeds on CNC turning focus with limit of 18 kW. High surface complete could be accomplished utilizing wiper embeds while working with high feed rate.

Xavier et. all [23] summarizes the TOOL WEAR and surface roughness for various process parameters utilizing both uncoated and covered TOOLs amid irregular cutting in processing procedure of AISI 1030 steel. There was no consistent contact of processing shaper edges with the workpiece in irregular cutting. Exploratory outcomes were executed to watch the TOOL WEAR system and examples of Titanium Nitride, uncoated and covered solidified carbide embeds on vertical machining focus (VMC-Deckel Maho make) with shaft speed of around 10000 rpm. Amid discontinuous cutting with uncoated and covered cutters, grating WEAR instrument was watched. 0.7 mm of most extreme flank WEAR was utilized for catching WEAR pictures. The main TOOL disappointment was caused by introductory effect on the shaper and its size. Feed rate had least impact on shaper life.

Sahoo et. all [24] explored the version of uncoated and multilayered covered tungsten carbide embeds as indicated by the flank WEAR and surface roughness on high carbon high chromium D2 steel. Surface roughness was estimated with Surtronic-25. Bit by bit presenting of WEAR was the noticeable instrument for the TOOL disappointment for covered tungsten carbide embeds. It was seen that at same cutting conditions, TOOL life was roughly 30%

higher, contrasted with uncoated additions. Per part cost of machining for uncoated carbide embeds was 10.5 occasions more noteworthy than the multilayered TiN covered carbide embeds at comparable handling parameters. Surface roughness was bring down if there should arise an occurrence of covered carbide even at higher feed rates. Analysts announced that covered additions has 30 times inordinate MRR as opposed to uncoated. Add up to machining cost was about Rs 21 for uncoated carbide TOOLs and Rs 2 for covered carbide TOOLs, a solid decrease in machining costs.

Chinchanikar [25] announced TOOL life, surface roughness and vibration estimation amid machining in turning procedure of nodular solid metal by utilizing clay TOOLs in regular machine. Quick WEAR of the embed demonstrated that blended alumina artistic TOOL was not appropriate for machining nodular cost press. Surface complete was emphatically affected by handling parameters as opposed to TOOL WEAR. Cutting procedure turned out to be increasingly steady with expanding speeds. Vibration abundancy diminished with expanding speeds; anyway it climbed again with the augmentation of feed or profundity of cut. They proposed a great feed rate of 0.22 mm/rev with the end goal to accomplish better surface wrap up. They likewise presumed that the surface complete was unaffected by WEAR development.

Chinchanickar et.al [26] regarded the result of work material outfit and cutting parameters amid machining of solidified AISI 4340 steel at two diverse hardness levels. ISO assigned a privilege given TOOL holder for CNMG P10 review cutting supplements that was utilized in experimentation. While working with covered multilayered carbide TOOLs, cutting rate alongside profundity of cut wound up a standout amongst the most affecting components on the TOOL life. In a similar case, higher feed rate and profundity of cut influenced the surface roughness. Surface roughness was controlled by surface roughness meter QUALITEST TR100RSM helping in improving the cutting parameters like 0.15 mm/rev, cutting velocity of 235 and profundity of cut of 1mm which subsequently were good cutting conditions for diminished surface roughness, cutting powers and more advantageous TOOL life.

Choudhury et. all [27] taken a shot at uncoated TOOLs utilized amid machining of bearing steel EN31 steel (identical to AISI 52100 steel) to investigate the mix of handling parameters with the end goal to show signs of improvement execution. A full factorial plan was utilized to anticipate the cutting power model and surface roughness. The most powerful factor on cutting powers joined with feed rate was the profundity of cut. The expanding of profundity of cut with all mix feed rate brought about expanded surface roughness. A vitality productive cut consequently could be accomplished by utilizing generally moderate cutting parameters.

Okada et.al [28] examined the cutting execution of PVD covered and CBN TOOLs in end processing technique on solidified steel. Apparatus execution was resolved based on cutting power, TOOL tip temperature, TOOL WEAR and surface roughness of solidified steel in processing. In hard processing, the unnecessary warmth age and higher cutting powers expanded the WEAR rate bringing about lessening the TOOL life. PVD covered TiAlN carbide TOOLs brought about more prominent execution against WEAR at lower speeds in hard processing. CBN TOOLs created great surface complete and low flank WEAR amid rapid machining contrasted with the covered carbide TOOLs which as per surface roughness perspective, had no critical preferred standpoint.

Osmani et. al [29] explored on nose range, machining parameters and machining time impact on the surface roughness amid dry machining on generation machine with 10 kW control. It was presumed that the cutting parameters, for instance feed rate, nose span, and cutting time were the essential powerful factors, which influenced the surface quality. Feed rate had most extreme impact contrasted with the nose span and cutting time with covered carbide TOOLs. The best blend of configuration gave relapse condition for accomplishing the enhanced parameters.

Nalbant et. al [30] summarized surface roughness of AISI 1030 steel amid turning process with CVD covered P 20 graduate TNMG embeds on CNC turning focus. Expanding nose range had negative effect on surface roughness since expanding nose sweep brought about higher surface wrap up. The surface roughness expanded by expanding profundity of cut and speed rate. A decent mix of preparing parameters delivered better surface wrap up.

Lalwani et.al [31] inquired about on MDN 250 steel (50 HRC) with clay TOOLs utilizing Response Surface Methodology. Three levels of factorial structure were utilized to recognize the non-linearity amid turning. Results demonstrated that feed rate given essential commitment and influenced fundamentally on the surface roughness. Cutting pace had no critical impact on surface roughness. Better surface complete was gotten when cutting rate and profundity of cut were chosen at larger amount and feed rate at lower level of test extend. Unpleasantness was estimated utilizing the 10x amplification surface profile-meter. Tests were led on Johnford CNC machine utilizing covered clay embeds with assigned TOOL holders. He closed the impact of handling material hardness, cutting parameters and sort of covering on surface roughness, TOOL life and chip morphology amid turning task. Better surface complete was found on solidified workpiece and with PVD connected single-layer TiAlN covered carbide TOOL. Workpiece hardness with the blend of feed rate and cutting rate indicated huge outcomes on TOOL life. They suggested an upper speed point of confinement of 200 m/min with PVD covered TOOL for work material hardness of 35 and 45 HRC.

Schramm et. al [1] explored on the machining capacities of chromium-constructed coatings in light of machine with shaft speed extending from 30 to 5000 rpm. TiAlN covering was equipped for forcing higher warm and mechanical load requirements on the front line. It measured that with expanding flank WEAR cutting powers additionally expanded, at last lessening the surface quality. Cutting powers were estimated with a dynamometer, SURFACE ROUGHNESS with profile-meter, while flank WEAR was estimated with computerized video magnifying lens.

Srihari et. al [32] investigated that diverse methodologies were required to appraise the TOOL life in industry including (a) Number of segments required to be machined, (b) Total length of cut amid machining, (c) Metal evacuation rate in machining. Device life was obtained utilizing the Taylor's TOOL life condition while steady utilized in Taylor's conditions were taken from Machine information handbook for indicated cutting pace, profundity of cut and feed rate. From the tests, ideal parameters were 0.15 mm/rev unify 0.4 mm profundity of cut and 1200 rpm shaft speed for better quality surface complete and longer TOOL life.

Krolczyk et al. [33] worked on the TOOL life and surface geography of covered carbide TOOLs. Studies anticipated the result of cutting conditions on TOOL life in turning activity. A more drawn out TOOL life was seen when cutting DSS with lower feed rate. TNMG cutting supplements with ISO assigned TOOL holder was utilized to perform cutting activity on turning machine. Covered carbide TNMG slicing embeds gave more noteworthy protection from grating WEAR and could be utilized for unpleasant work. Expanding WEAR was caused by fast increment in cutting rate.

Arseculratane et.al [34] utilized AISI 1045 and AISI 1022 plain carbon steel to chip away at accuracy turning machine. Brazed tungsten carbide additions of P20 graduate were utilized with extraordinarily structured TOOL holders. The outcomes acquired in the examination work demonstrated that TOOL life was for the most part impacted by cutting pace, feed, and TOOL's rake edge and carbon substance of work piece material. Parameters, for example, TOOL tendency point, nose span, and profundity of cut, for the chosen ranges, did not influence fundamentally on the TOOL life.

Attanasio et.al [9] utilized RSM and Artificial Neural Network philosophies to anticipate TOOL life utilizing AISI 1045 steel as work material and single point cutting TOOL uncoated carbide embeds. ANN given preferred outcomes over some other technique. Profundity of cut was kept consistent in all investigations. Both flank WEAR and cavity WEAR were observed. Hole WEAR and flank WEAR was estimated with Profilo-Meter and CMM individually. They discovered that ANN given much preferred guess over RSM (ISO Standard 3685:1993)

[35] According to ISO the criteria for TOOL life of WC embeds 0.3 mm for normal flank WEAR. A TOOL-life standard was outlined as a pre-evaluating estimation of TOOL-WEAR measure or the WEAR spread wonder. Beforehand the exhaustive research was centered around flank WEAR and pit WEAR. ISO 3685 (1993) standard proposal expressed that flank and hole WEAR is to be taken as TOOL life criteria in single point cutting TOOLs.

Basavarajappa et. al [36] Crisp TOOLs were utilized to research WEAR for a particular interim of time amid turning of AISI H13 steel was accounted for. PVD TiN covered clay embeds were utilized to assess WEAR on various cutting parameters on CNC turning focus under dry cutting conditions. Slicing speed was observed to be most prevailing variable which affected TOOL WEAR while surface roughness was influenced by feed rate pursued by profundity of cut.

Arseculratne et.al [37] in machining various WEAR instruments created like scraped spot, bond, dissemination and oxidation could spread all the while. Predominant TOOL WEAR component for tungsten carbide TOOLs was because of dispersion. Dispersion WEAR was because of the exchange of iotas from TOOL to workpiece. Test results clarified states of low speed result that TOOL WEAR was basically reliant after cutting separation and was autonomous of temperature. Prevailing WEAR system for tungsten carbide was dispersion at higher velocities, attachment at medium paces and scraped area at lower speeds.

Fulemova et.al [38] anxious planning and TOOL front line affect on TOOL life and surface complete at various level of bleeding edge sweep of submicron sintered carbide embeds in processing shaper utilizing ferrite-martensitic steel as workpiece material. Processing shaper contained just a single wiper embed. The goal of front line arrangement was to strengthen the bleeding edge, increment life of the tool, decrease worries of the covering, limit danger of edge chipping, readiness of the tool surface for affidavit and to make the characterized shape and size of the forefront. Expanding edge sweep brought about expanding of TOOL life. Unpleasantness of machined surface was straightforwardly connected with TOOL WEAR 0.15 mm criteria was set to examine too wear against time interim.

Sahoo et. al [39] took a shot at flank wear, chip morphology, surface roughness in completed hard turning of AISI 4340 steel. Results demonstrated that multilayered covered carbide embeds gave preferred execution over uncoated additions concerning flank wear and surface roughness. Lower surface roughness could be accomplished on transitional interim of feed rate, speed and 0.4 mm profundity of cut wrapping up. For HRC 47 covered carbide tools brought about better surface complete and tool life.

Sanntos et.al [40] examined distinctive coatings utilized on carbide and HSS penetrate amid their exploration. TiN and TiCN were more traditional PVD coatings to expand TOOL abilities. Four sorts of coatings utilized on HSS and carbide penetrate were examined for TOOL life. SEM examination shown TOOL WEAR in penetrating utilizing HSS and carbide drills. Better covering for HSS bore for cutting was TiN/TiAlN because of its multilayered structure. The best covering for solidified carbide drills as per experimentation was TiAlN.

Ducros et.al [41] cited PVD coatings were utilized to upgrade mechanical and WEAR properties of cutting TOOLs. Covering was sent on substrate utilizing a mechanical size cathodic circular segment dissipation gadget comprises of four cathodes. The 10-4 Pa weight was kept up in covering chamber before statement. Mirror complete affidavit was substrate temperature before statement was 350C0. Cutting tests were performed on 718 super amalgams on machine utilizing CNMG 120408 with assigned TOOL holder.

P.S Sreejith et.al. [42] Dry cutting is a machining procedure without cutting liquid use. Cutting liquid straightforwardly contribute approx 16% in machining cost detailed in by researchers. Dry cutting was just adequate on the off chance that it didn't influence the surface quality, machining time and TOOL life amid machining. Another favorable position of dry machining was that it doesn't hurt the earth when contrasted with liquid utilize. At the point when ointment utilized in machining activities it decays to perilous gases at high temperature and making hurt human wellbeing.

Diniz et.al [43] revealed dry machining was one of the target specialists searching for because of human wellbeing and biological issues. Cutting TOOLs utilized in dry machining much of the time were carbides with coatings. TiN coatings were most basic utilized coatings for carbide cutting TOOLs. Cutting conditions for dry cutting amid turning process for same TOOL life if there should be an occurrence of wet machining was explored. The goal was to decide better cutting conditions in dry cutting for better surface complete, longer TOOL life and least power utilization. Lessened cutting pace, expanded nose range and feed rate come about better execution in dry slicing relatively like cutting with coolant.

Kumar et.al [44] five distinct kinds of carbon steel were tested by researchers to decide the impact of axle speed in turning process.Surface roughness was critical for resistances as it diminished optional activities e.g. granulating and lessened get together time at last affecting the generally operational expenses. Surface roughness diminished with expanding axle speed and feed rate while keeping profundity of cut steady in turning process. It was reasoned that low feed rate and high axle speed had incremental impact on surface wrap up.

Elmunafi et. al [45] et.al took a shot at solidified tempered steel AISI 420 prepared on a CNC machine with TiAlN covering tungsten carbide. Three mixes of cutting velocities 100, 135, 170 m/min alongside feed rate 0.16, 0.2, 0.24 mm/rev with consistent profundity of cut 0.2 mm was utilized in experimentation. Most extreme flank WEAR of 0.12 mm criteria was set to watch greatest TOOL life. Instrument WEAR was estimated with a computerized magnifying instrument. Device WEAR was watched keeping embed in TOOL holder. It was presumed that little measure of oil amid turning process enabled TOOL to perform at higher speeds and feed rates.

Jindal et.al in [46] portrayed mechanical properties of substrate and coatings. PVD TiN, TiAlN and TiCN PVD covered TOOLs progressively act from TiN to TiCN to TiAlN in the turning task.

Bouzakis et.al [47] expressed PVD covering innovation in his examination article Physical Vapor Deposition, a system in which covered material is physically expelled from source by vanishing and sputtering process then it is transported by the vapor particles, vitality and consolidated as layer on the coveted surface under vacuum. Covering execution in this manner relied on arrangement of covering thickness amid.

CHAPTER NO 3

3 Methodology

The methodology, instrumentations and measurements for the study are described in this section.

3.1 Work piece Material

The use of Aluminum alloys in manufacturing industry is noticeably increased in recent few years due to their high strength to weight ratio. Low weight and high strength together combined in aluminum alloys have made them a preferable choice for use in aerospace and automotive industry specially. High strength to weight ratio has made aluminum alloys a fair substitute for steel and cast iron for fabrication of different parts in aerospace and automotive industry. Aluminum Copper Alloy 2024 is aircraft grade material and is of greater importance in said industry. We have chosen this material as our workpiece to aid said industry in machining of this special material.[48]

Aluminum Copper Alloy 2024 is widely used in Aircraft manufacturing, gears, computer parts and coupling. Due to its hardness it is difficult to machine using conventional tools. Due to great importance of said material in manufacturing industry especially in aerospace and automobile industry it will be beneficial to conduct this type of research for industry that giving optimum cutting conditions and preferred tooling for this alloy reducing their time and cost.

2024 aluminum composite is an aluminum compound, with copper as the essential alloying component. It is utilized in applications requiring high solidarity to weight proportion, and in addition great weariness obstruction. It is weld able just through erosion welding, and has normal machinability. Because of poor erosion opposition, usually clad with aluminum or Al-1Zn for security, despite the fact that this may lessen the exhaustion strength.[49] In more established frameworks of wording, this amalgam was named 24ST.

Al 2024 is normally expelled, and furthermore accessible in alclad sheet and plate frames. It isn't regularly manufactured (the related 2014 aluminum amalgam is, however).

3.1.1 Material Composition

Table 1 Chemical composition of Aluminum copper Alloy 2024 [50]

Component	Wt. %
Al	93
Cu	4.2
Mg	1.5
Mn	0.6
Fe	0.2
Si	0.4
Ti	0.1

3.1.2 Basic Properties

Table 2 Basic Properties [51]

Property Name	Value
Density [g/cm³]	2.78
Electrical Conductivity	30% IACS
Melting Point [ºC]	500

3.1.3 Mechanical Properties

Table 3 Mechanical properties of Aluminum Copper Alloy 2024 [52]

Ultimate Tensile Strength [MPA]	469
Modulus of Elasticity [GPa}	73.1
Elongation at break [%]	20
Ultimate Bearing Strength [MPa]	814
Yield Tensile Strength [MPA]	324
Poisson Ratio	0.33
Shear Modulus [GPA]	28

3.1.4 Work Material Hardness

Work Piece Aluminum copper alloy 2024-T4 has Brinell hardness of 120. It is tempered and quenched at Amin Metal Industries.

3.2 Measuring Instrument

Calibrated Mitutoyo vernier dial caliper with 0.02 mm slightest tally is utilized to gauge distance across amid experimentations. Perusing was taken before each dad of TOOL keep caliper standard way. Metal evacuation rate estimation is subject to exact estimation of shaft distance across.

Shaft distance across estimation is key factor to keep up wanted cutting rate in experimentation. In turning process shaft distance across is diminished with each TOOL pas on shaft. With diminishing breadth cutting rate additionally diminishes. To the extent shaft speed is worried to keep up want slicing speed we have to figure wanted axle speed. Along these lines an exact estimation is considered for keeping up wanted cutting velocity.

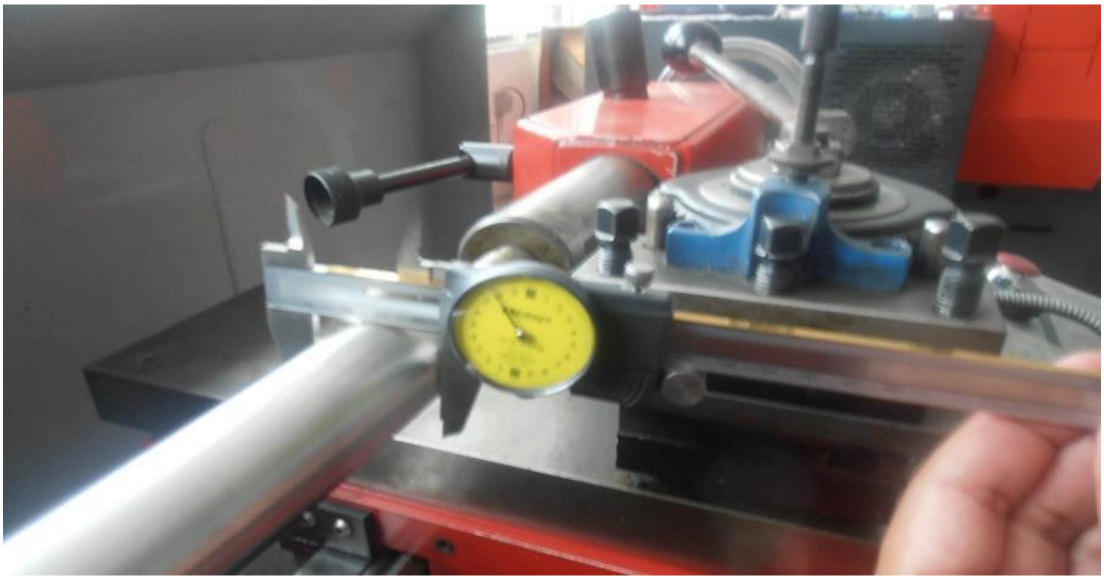

Figure 8 Vernier Dial Caliper

3.3 Cutting Inserts

Following are the parameters to think about while picking turning embed. Painstakingly select insert geometry, insert grade, insert shape (nose point), insert size, nose radius and entering (lead) edge, to accomplish great chip control and machining execution.

•Select insert geometry dependent on chosen task, for instance finishing

•Select the biggest possible nose point on the insert for quality and economy

•Select the insert size contingent upon the depth of cut

•Select the largest possible nose radius for insert strength

Experiments are performed with uncoated and PVD coated cemented carbide cutting inserts with 0.8 mm nose radius. Uncoated insert geometry is ISO designated VNMG 160408 general purpose grade manufactured by Deksar.

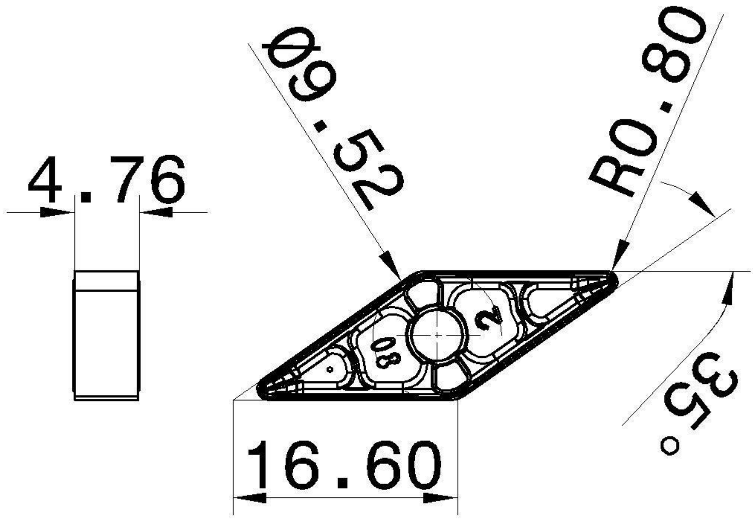

Figure 9 Specification of Tip [53]

Typical nomenclature of VNMG is

V = represents shape of cutting insert

N=represent clearance angle

M= represent tolerance class

G= represents fixing and chip breaker type

16= cutting edge length,

04= insert thickness,

08= insert radius.

VNMG cutting inserts were selected due to its wide range of machining operations. Some of them listed below [54].

- Light Roughing
- Finishing
- Turning

Following factor are considered to select VNMG 160408 inserts.

- Light roughing/Semi finishing
- Finishing
- Limited machine power
- Reduced vibration tendencies

- Small lead angles

3.4 Tool Holder

SVJBR 2525 M16 tool holder is used for said experimentation. It has following properties:

Table 4 Tool Holder Specifications[55]

Properties	
Tool Cutting Edge angle (KAPR)	93 deg.
Tool lead angle (PSIR)	-3 deg.
Max. Ramping Angle (RMPX)	44 deg.
Max. Overhang (OHX)	37.6 mm
Hand	Right
Shank Width (B)	25 mm
Shank Height (H)	25 mm
Functional Length (LF)	150 mm
Functional Width (WF)	32 mm
Functional Height (HF)	25 mm

The cutting inserts were screwed with ALLEN-KEY and TOOL holder was mounted on the TOOL post of the lathe machine for cutting in the axial direction.

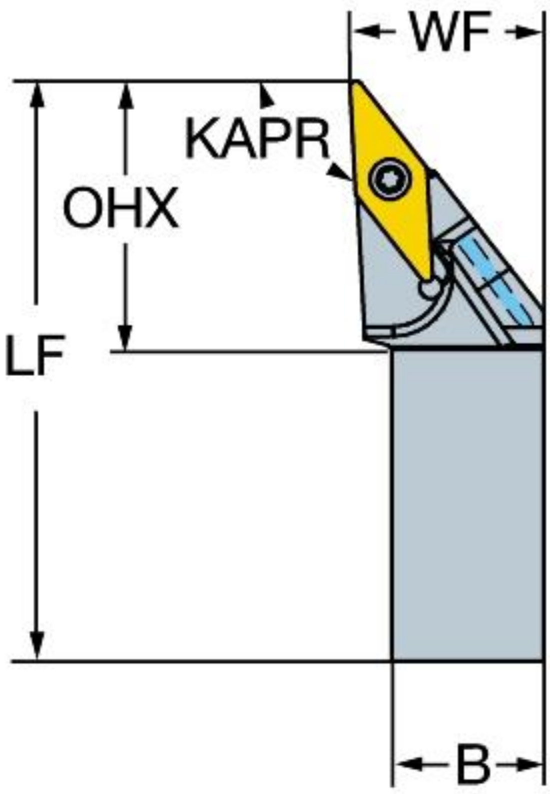

Figure 10 Front View of Tool Holder [55]

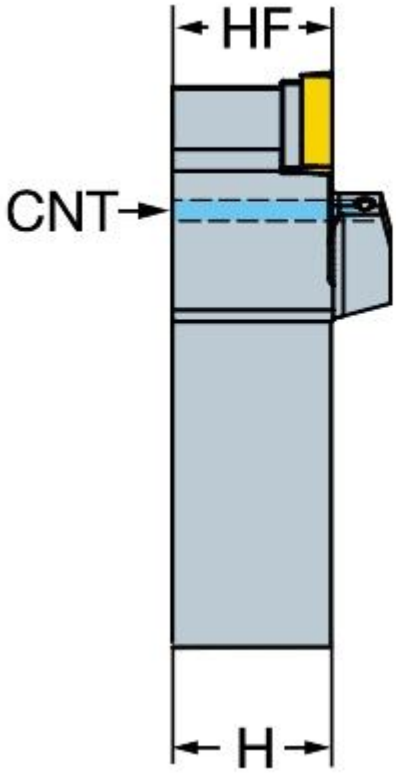

Figure 11 Side view of Tool Holder [55]

Figure 12 Tool Holder

3.5 Machine Tool

Figure 13 Lathe Machine

3.5.1 Machine tool Specifications

Table 5 Machine Specifications

Specifications of Lathe Machine	
Turning Diameter Over Bed	340 Ø
Turning Diameter Over Cross Slide	190 Ø
Spindle Bore	50 Ø
Maximum Chuck Diameter	200 Ø
Bed Width	260 mm
Spindle Speed	40-3000 rpm
Automatic Longitudinal Feed Rate	0.045-0.787
TOOL Cross Section	20×20
Maximum Length of Turning Workpiece	600 mm

3.6 Coordinate Measuring Machine

Flank WEAR was measured after machining each length for 30 min. 3D coordinate measuring machine model no. CE-450DV is used to observe flank WEAR manufactured by CHEN WEI Precise Technology Co, Ltd

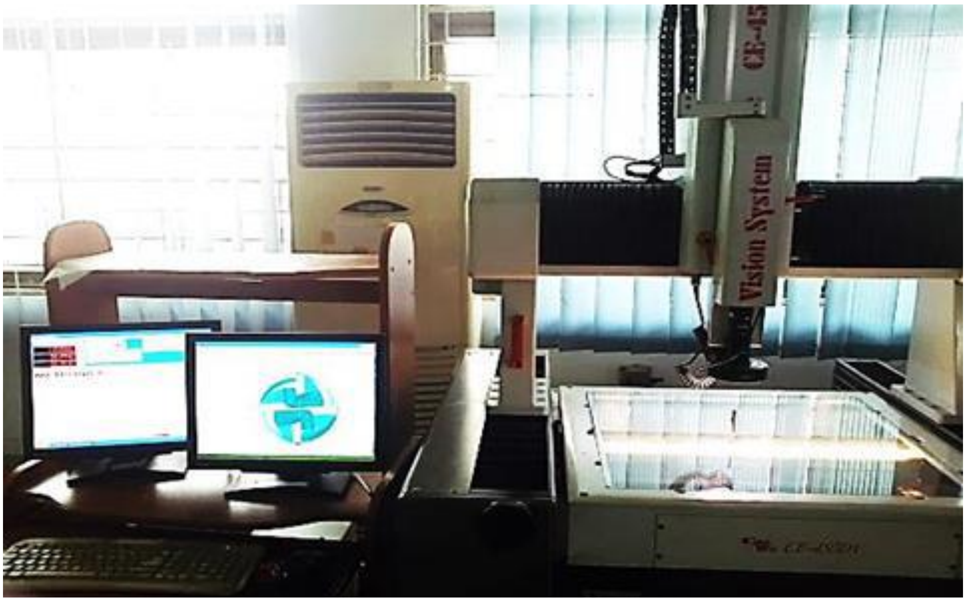

Figure 14 Coordinate Measuring Machine

3.6.1 Working Principle of CMM

Estimation of co-ordinates of any point with reference to absolute or incremental co-ordinate frameworks for complex parts and machine segments with high exactness utilizing Quadra-Chek 5000. It is a propelled programming application for coordinate measuring machines (CMM).

3.7 Surface Texture Meter (SURTONIC-25)

There are some parameters used to identify surface finish. In this research normal surface roughness (Ra) is chosen for identification of surface finish in the process of finish turning process. Which is most generally utilized surface finish parameter in industry.

Figure 15 Surface roughness Meter (SURTRONIC-25)

The parameters and other capacity of the surface finish estimating instrument depend on microchip. LCD screen show demonstrates the estimation esteems. These qualities can be taken out from discretionary printers. The hardware is fueled by and basic non-revive battery.

3.8 Experimental Procedure

The work piece of 40mm diameter was turned using VNMG 160408 turning inserts mounted with the help of tool holder (SVJBR 2525M16) for 30 min for each experimental setting for both uncoated (Cemented Carbide) and coated (PVD TiN). After 30 min work piece and insert for each experiment was analyzed using surf tonic and CMM for the measurement of surface roughness and tool wear. Values of surface roughness and tool wear are then analyzed statistically to get optimum results

Figure 16 Experimental Setup

3.8.1 Factorial Design of Experiments

An examination in which more than one autonomous variable is considered is said to be factorial design. Factorial design is as often as possible embraced in analyses comprising of a few impacts in which their joined impact is contemplated on a reaction. Least complex factorial structure comprises of two levels of components. 3 level of factorial design is a significant complex plan and helpful in building more unpredictable structures. In two level factorial structure or three level factorial plans every one of the variables have a similar number of levels. Three level factorial plan isn't usually in practices [56].

3.8.2 Full Factorial Design

Design in which all the factors have same levels (more than one) is called full factorial design. For this study we have chosen three levels for cutting speed, three levels for depth of cut and three levels for feed rate.

3.8.3 Experimental Design Table

Full Factorial Experimental Design is adopted for the execution of experimentations. Three levels of feed rates (0.09, 0.12, 0.15) mm/rev, three levels of cutting speed (80,90,100) m/min, while three levels of depth of cut (0.5, 1, 1.5 mm) were taken for conducting experiments on CNC Lathe Machine in PITAC, Lahore facility and then for surface roughness measurement in PITAC facility and PIDC Sialkot and IME department University of Engineering & Technology, Lahore. Surface roughness was measured in three different places for accuracy. Tool wear was measured on CMM in IME department University of Engineering & Technology, Lahore. Experiments were conducted in two phases to cover whole research.

1st Phase: Twenty Seven experiments were executed using uncoated cemented carbide inserts on designed processing parameters and surface roughness and TOOL life is evaluated as output parameters.

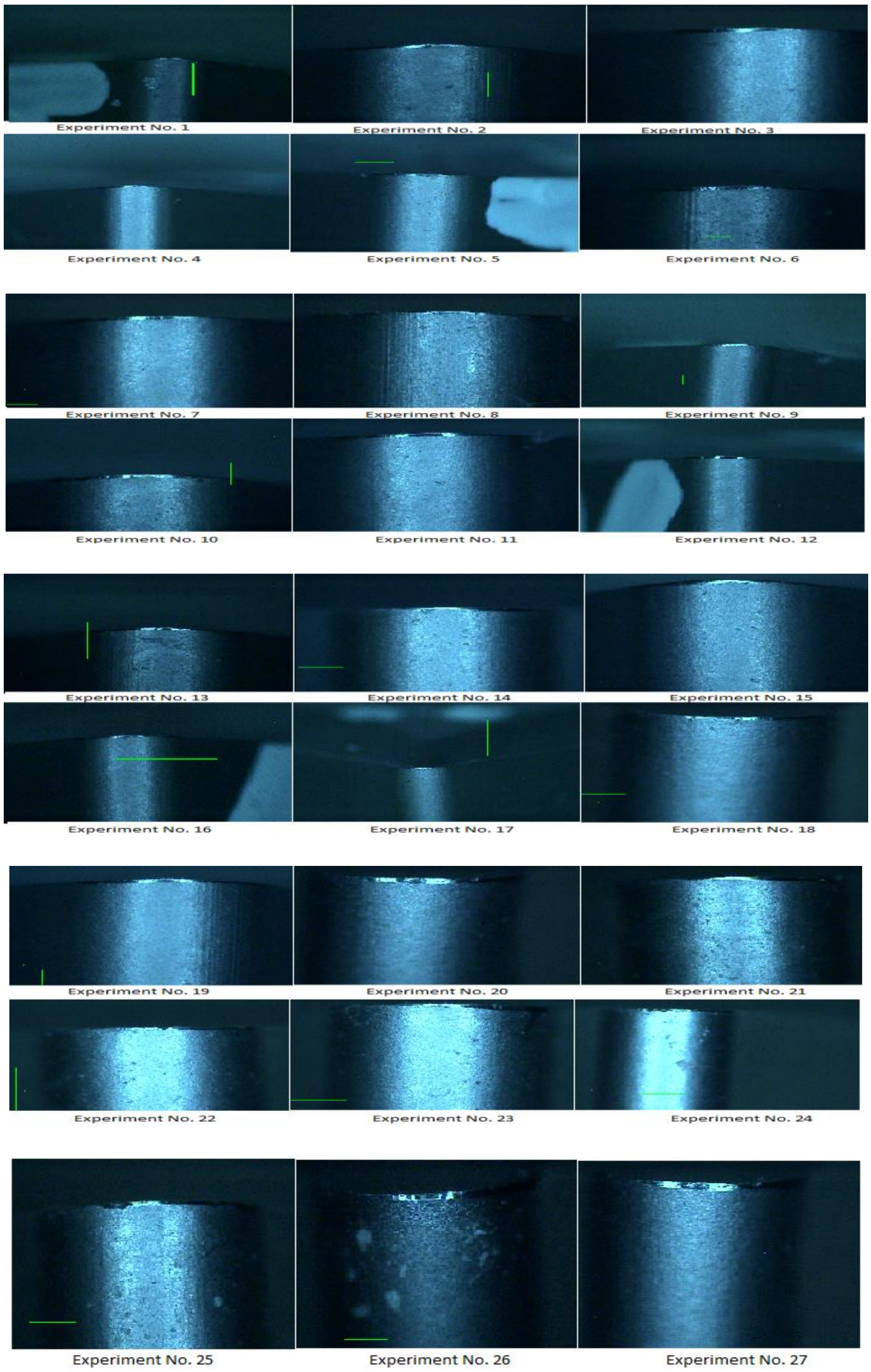

Figure 17 CMM Tool wear Pictures of Cemented Carbide tool

Second Phase PVD-TiN coated VNMG cutting inserts were used for second phase and same no of experiments were performed on these inserts on designed processing parameters and surface roughness and TOOL life were investigated.

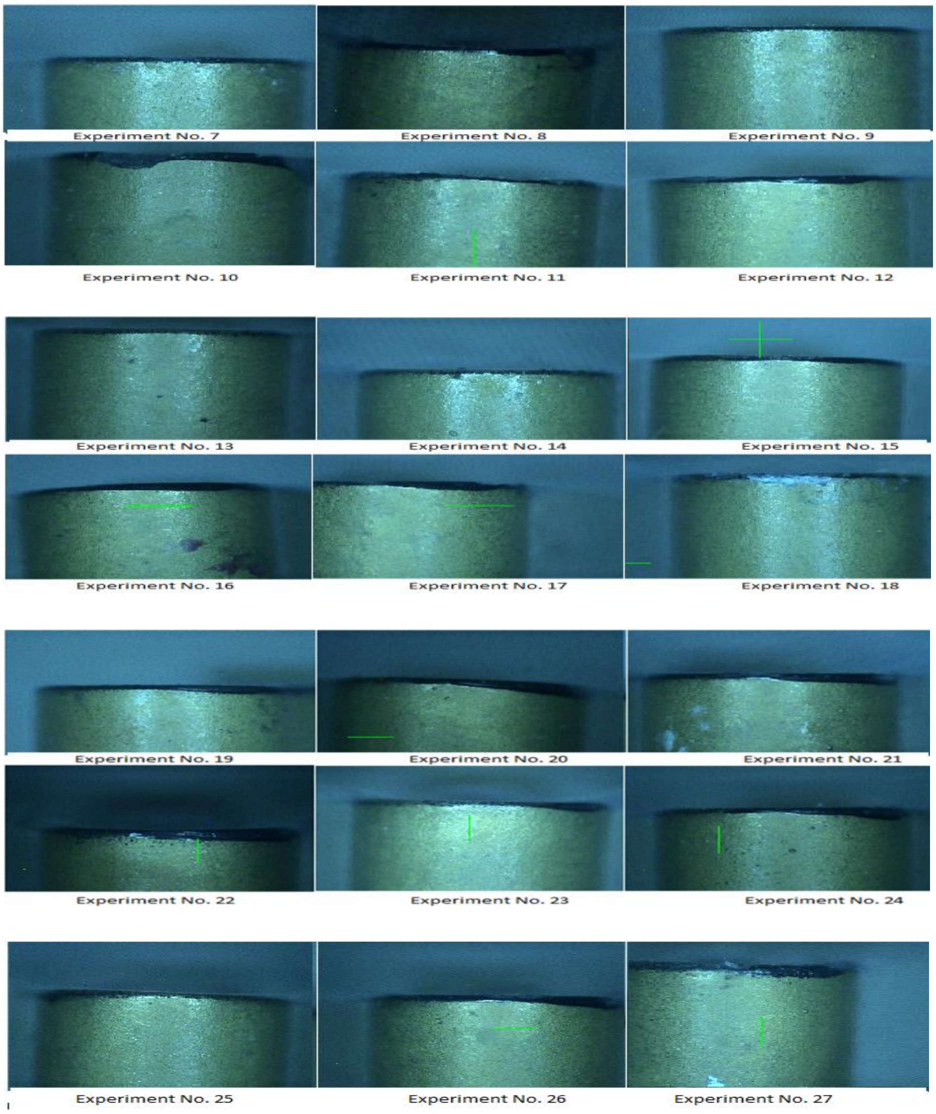

Figure 18 CMM Pictures of PVD coated TiN Cemented carbide tools

3.8.4 Uncoated Experiments

Table 6 Experiment design with uncoated cutting inserts

Experiment No.	C.S (m/min)	F.R (mm/rev)	DOC (mm)	TW CC (Microns)	SR CC (Microns)
1	80	0.09	0.5	25	0.546
2	90	0.09	0.5	37	0.507
3	100	0.09	0.5	41	0.479
4	80	0.12	0.5	37	0.672
5	90	0.12	0.5	46	0.607
6	100	0.12	0.5	47	0.566
7	80	0.15	0.5	29	0.965
8	90	0.15	0.5	45	0.85
9	100	0.15	0.5	58	0.714
10	80	0.09	1	50	0.63
11	90	0.09	1	41	0.51
12	100	0.09	1	34	0.489
13	80	0.12	1	51	1.557
14	90	0.12	1	47	0.991
15	100	0.12	1	42	0.658
16	80	0.15	1	67	0.9
17	90	0.15	1	63	0.769
18	100	0.15	1	41	1.729
19	80	0.09	1.5	57	0.851
20	90	0.09	1.5	40	0.783
21	100	0.09	1.5	36	0.584
22	80	0.12	1.5	70	2.206
23	90	0.12	1.5	47	0.83
24	100	0.12	1.5	32	0.724
25	80	0.15	1.5	61	2.303
26	90	0.15	1.5	59	2.062
27	100	0.15	1.5	41	1.925

3.8.5 PVD Coated Experiments

Table 7 Experiment design for PVD-TiN coated cutting inserts

Experiment No.	C.S (m/min)	F.R (mm/rev)	DOC (mm)	TW TiN (Microns)	SR TiN (Microns)
1	80	0.09	0.5	34	0.45
2	90	0.09	0.5	59	0.519
3	100	0.09	0.5	63	0.586
4	80	0.12	0.5	20	0.745
5	90	0.12	0.5	39	0.78
6	100	0.12	0.5	46	1.375
7	80	0.15	0.5	24	0.682
8	90	0.15	0.5	43	0.877
9	100	0.15	0.5	47	0.9
10	80	0.09	1	32	0.822
11	90	0.09	1	37	0.568
12	100	0.09	1	79	0.459
13	80	0.12	1	47	1.95
14	90	0.12	1	70	1.65
15	100	0.12	1	75	1.55
16	80	0.15	1	47	1.87
17	90	0.15	1	57	1.53
18	100	0.15	1	96	1.509
19	80	0.09	1.5	79	0.698
20	90	0.09	1.5	96	1.884
21	100	0.09	1.5	100	2.207
22	80	0.12	1.5	55	1.53
23	90	0.12	1.5	80	1.171
24	100	0.12	1.5	88	3.489
25	80	0.15	1.5	82	1.688
26	90	0.15	1.5	95	2.484
27	100	0.15	1.5	120	3.678

CHAPTER NO 4

4 Results and comparisons

4.1 Response Surface Methodology:

Response surface regression model was built considering all the linear, quadratic, two way and three way interactions. Cutting Speed is represented by Symbol "A", Feed Rate is represented by "B" and "C" represents depth of cut. For the cases of Surface roughness of C.C and TiN and tool wear of CC and TiN, R^2 values of 0.88, 0.92, 0.90 and 0.092 respectively exhibits excellent fit of the RSM models. Insignificant values of standard error for surface roughness and tool life represent effectiveness of designed experimental model.

Table 8 Response Surface Regression table for Tool wear of uncoated and Coated cutting inserts

Y-hat Model		TW CC				TW TiN			
Factor	Name	Coeff	P(2 Tail)	Tol	Active	Coeff	P(2 Tail)	Tol	Active
Const		119.52	0.0000			67.741	0.0000		
A	FR	-14.417	0.0202	0.2000	X	-13.833	0.0000	0.2000	X
B	CS	-17.972	0.0064	0.2000	X	-17.278	0.0000	0.2000	X
C	DOC	-52.861	0.0000	0.2000	X	-22.444	0.0000	0.2000	X
AB		-3.458	0.2549	1	X	1.083	0.2225	1	X
AC		2.292	0.4421	1	X	0.33333	0.6974	1	X
BC		6.958	0.0354	1	X	3.083	0.0041	1	X
ABC		-3.313	0.3671	1	X	0.87500	0.4111	1	X
AA		-4.306	0.3126	1	X	2.111	0.1033	1	X
BB		-4.639	0.2786	1	X	2.278	0.0819	1	X
CC		-12.139	0.0134	1	X	1.611	0.2013	1	X
AAB		-7.292	0.1722	0.3333	X	0.41667	0.7786	0.3333	X
ABB		-2.625	0.6081	0.3333	X	0.75000	0.6144	0.3333	X
AAC		-2.708	0.5969	0.3333	X	-1.333	0.3771	0.3333	X
ACC		9.125	0.0956	0.3333	X	9.000	0.0001	0.3333	X
BBC		6.292	0.2333	0.3333	X	-1.583	0.2981	0.3333	X
BCC		4.458	0.3898	0.3333	X	2.417	0.1248	0.3333	X
	R^2	0.9832				0.9950			
	Adj R^2	0.9564				0.9870			

Std Error	9.9181			2.8849		
F	36.6127			124.0131		
Sig F	0.0000			0.0000		
F_{LOF}	NA			NA		
Sig F_{LOF}	NA			NA		
Source	**SS**	**df**	**MS**	**SS**	**Df**	**MS**
Regression	57624.8	16	3601.5	16514.0	16	1032.1
Error	983.7	10	98.4	83.2	10	8.3
$Error_{Pure}$	NA	0	NA	NA	0	NA
$Error_{LOF}$	NA	0	NA	NA	0	NA
Total	58608.5	26		16597.2	26	

Table 9 RSM Table of Surface roughness of Uncoated and TiN

Y-hat Model			**SR CC**				**SR TiN**			
Factor	**Name**	**Active**	**Coeff**	**P(2 Tail)**	**Tol**	**Active**	**Coeff**	**P(2 Tail)**	**Tol**	**Active**
Const			0.72604	0.0000			0.61456	0.0000		
A	FR	X	0.17122	0.0155	0.2000	X	0.14394	0.0165	0.2000	X
B	CS	X	0.06556	0.2910	0.2000	X	0.04411	0.3987	0.2000	X
C	DOC	X	-0.29550	0.0005	0.2000	X	-0.24022	0.0007	0.2000	X
AB		X	0.06225	0.0821	1	X	0.12842	0.0009	1	X
AC		X	-0.15558	0.0007	1	X	-0.14592	0.0003	1	X
BC		X	-0.08200	0.0291	1	X	-0.12792	0.0009	1	X
ABC		X	-0.01713	0.6734	1	X	-0.12138	0.0047	1	X
AA		X	0.08122	0.1049	1	X	0.11917	0.0118	1	X
BB		X	0.05139	0.2856	1	X	0.01533	0.7007	1	X
CC		X	0.22422	0.0006	1	X	0.17167	0.0013	1	X
AAB		X	0.11442	0.0674	0.3333	X	0.14658	0.0115	0.3333	X
ABB		X	0.06592	0.2647	0.3333	X	0.03358	0.4955	0.3333	X
AAC		X	-0.06475	0.2727	0.3333	X	-0.08892	0.0906	0.3333	X
ACC		X	0.09742	0.1114	0.3333	X	0.05808	0.2492	0.3333	X
BBC		X	-0.02700	0.6388	0.3333	X	0.02008	0.6812	0.3333	X
BCC		X	0.01517	0.7913	0.3333	X	0.06308	0.2134	0.3333	X
	R^2		0.9758				0.9781			

Adj R^2	0.9371			0.9430		
Std Error	0.1116			0.0949		
F	25.2190			27.8939		
Sig F	0.0000			0.0000		
F_{LOF}	NA			NA		
Sig F_{LOF}	NA			NA		
Source	**SS**	**df**	**MS**	**SS**	**df**	**MS**
Regression	5.0	16	0.3	4.0	16	0.3
Error	0.1	10	0.0	0.1	10	0.0
$Error_{Pure}$	NA	0	NA	NA	0	NA
$Error_{LOF}$	NA	0	NA	NA	0	NA
Total	5.1	26		4.1	26	

4.2 Pareto of Coefficient

PARETO OF COEFFICIENTS outline the essentialness of effect of linear, non-linear and connection terms as for a particular key performance parameters. Figures 19, 20, 21 and 22 underneath present the S.R and T.W's pareto coefficient. The terms like "A(A)" speak to linear component of the significance of a specific control variable. The terms like "AA" speak to the essentialness of non-linear/quadratic component of the respective control variable. The terms like "AB" and "ABC" speak to the centrality of two way or three way collaborations.

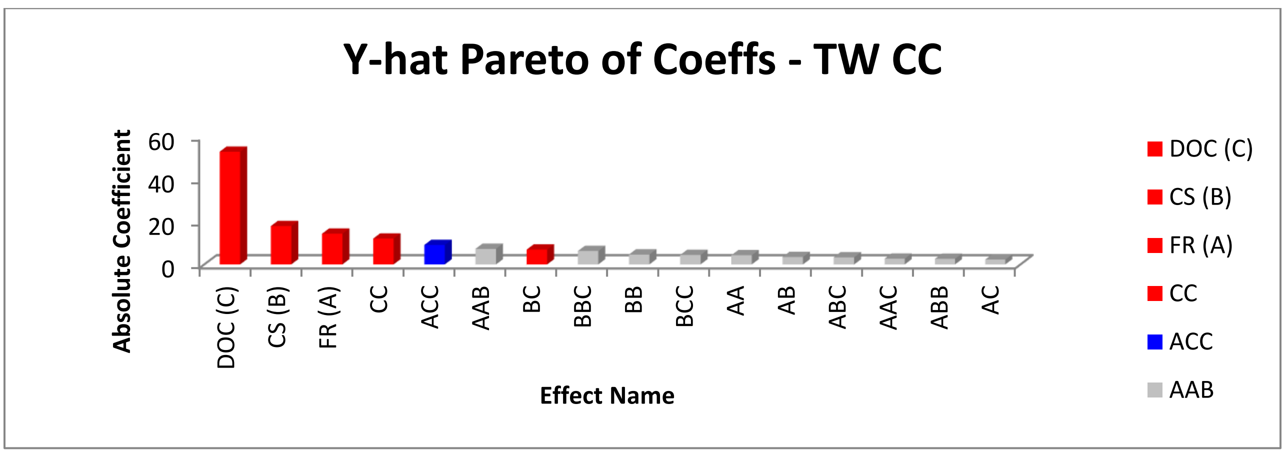

Figure 19 Y-hat Pareto of Coeffs - TW CC

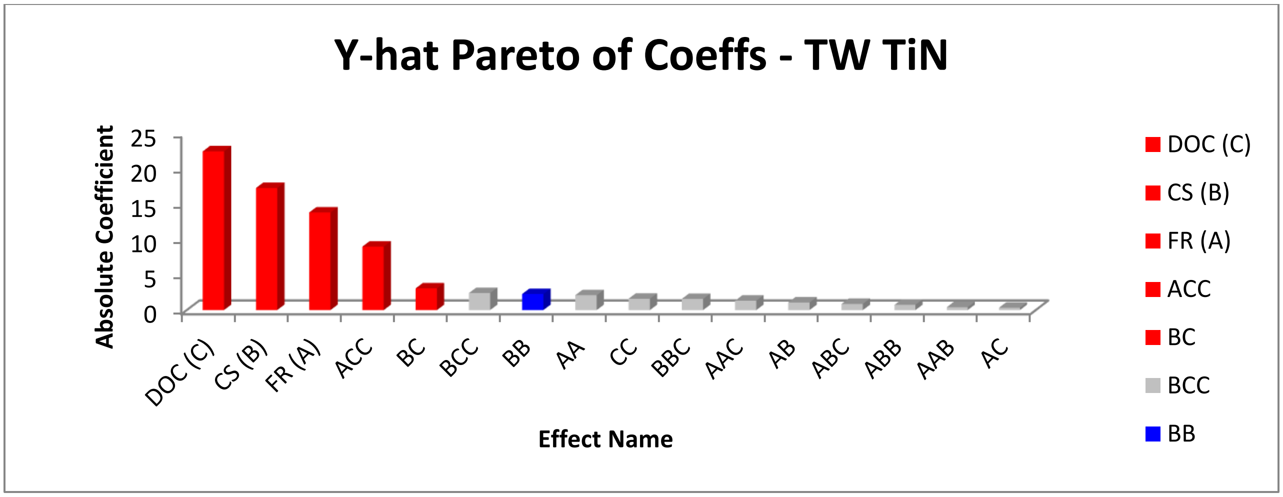

Figure 20 Y-hat Pareto of Coeffs - TW TiN

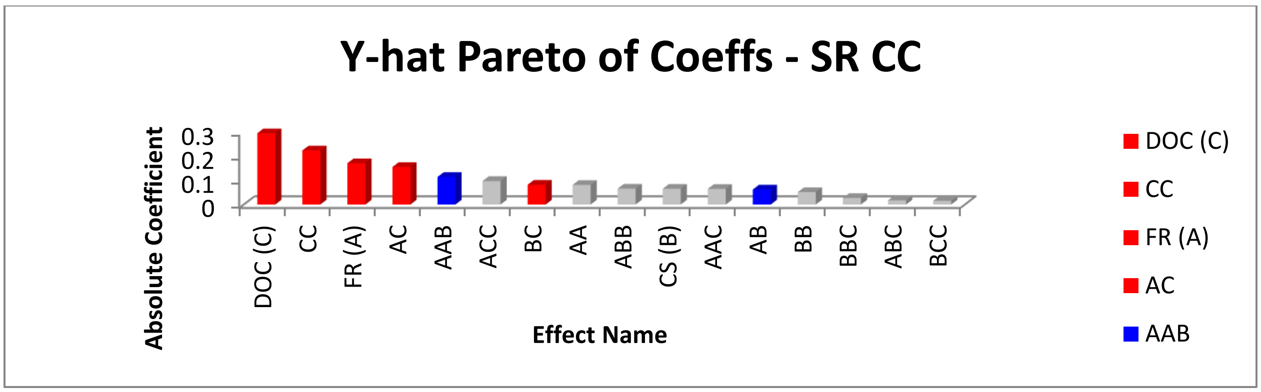

Figure 21 Y-hat Pareto of Coeffs - SR CC

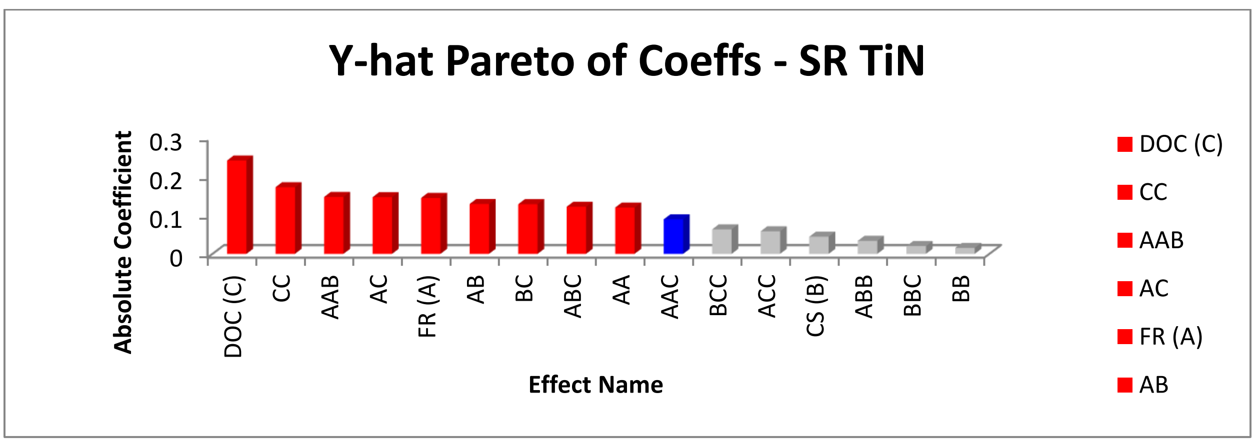

Figure 22 Y-hat Pareto of Coeffs - SR TiN

Figure 20 and 21 shows the Pareto of Coeffs of tool wear of Cemented Carbide and TiN. As shown it is clear that depth of cut, cutting speed and feed rate have significant influence on surface roughness for both but depth of cut has more significance than cutting speed and then from feed rate.

Figure 22 and 23 shows the Pareto of Coeffs. Of surface roughness of cemented carbide and TiN. Analysis shows that depth of cut, cutting speed and feed rate are significant parameters but depth of cut is more significant but there one thing is important that in response of SR TiN nonlinear interaction between feed rate and cutting speed is also significant but lesser. PVD TiN coating has no effect on system control variables. However the quantitative analysis of impact of tool wear and surface roughness is necessary to assess the impact of coating on machinability. That's why we discuss marginal mean plots for tool wear and surface roughness for regression tables.

4.3 Marginal Means Plot

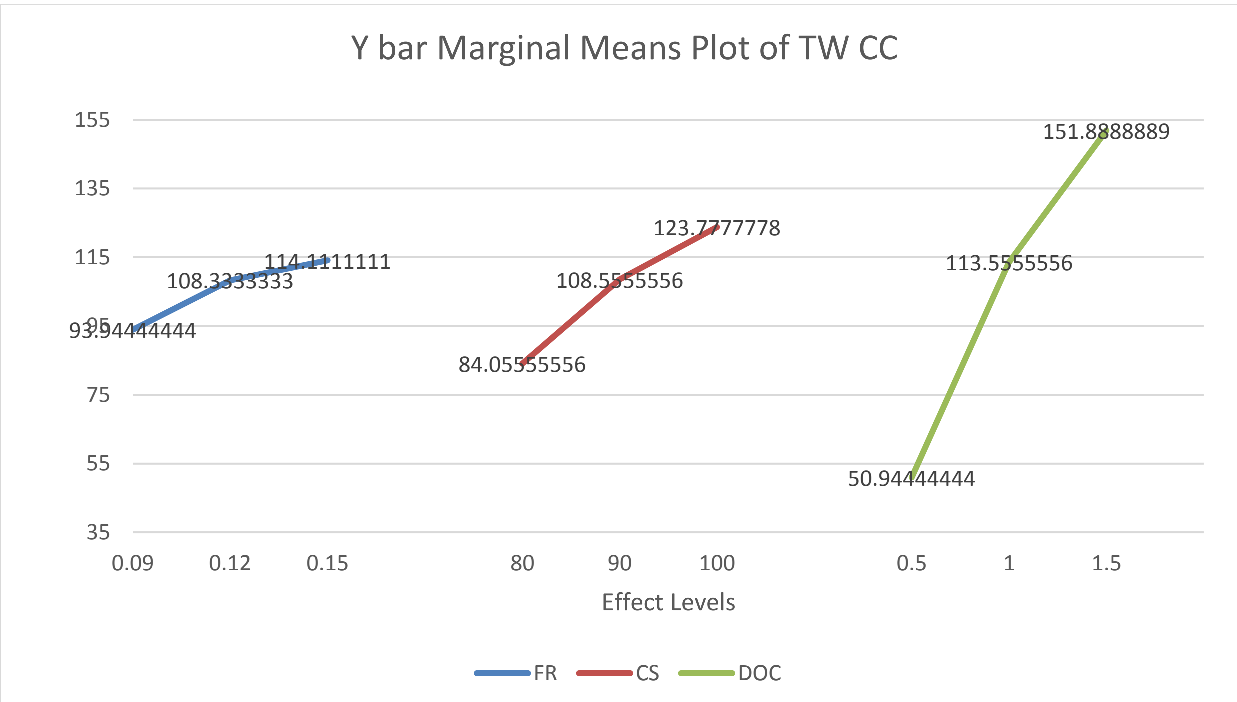

Figure 23 Marginal Means Plot of TW CC

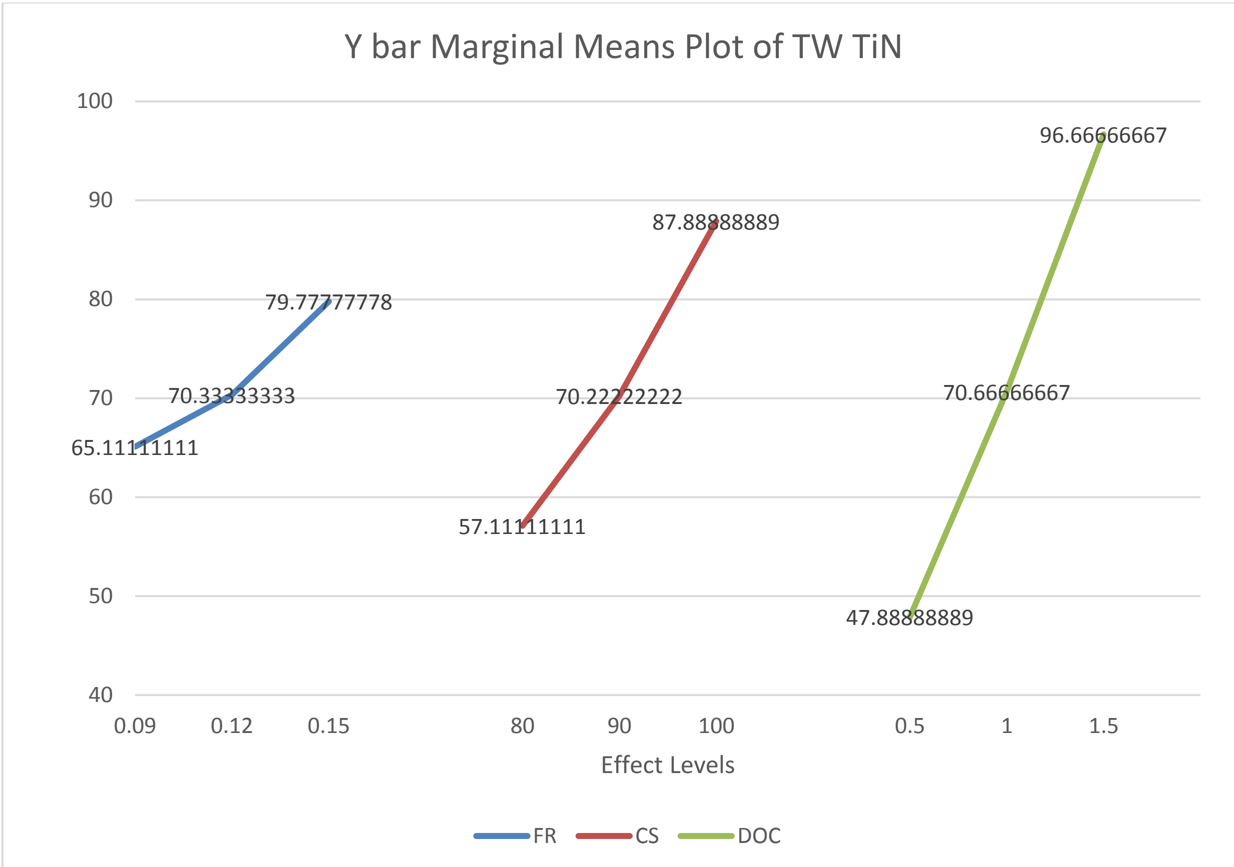

Figure 24 Marginal Means Plot of TW TiN

Figure 24 and 25 are the marginal means plot of tool wear for both cemented carbide and TiN coated inserts which is quantitative assessment of process parameters on tool wear. This shows the trend of effect of each variable with respect to tool wear and is plotted at the average value of other two variables. Increase in feed rate has positive relation with tool wear for both cases i-e uncoated cemented carbide and coated TiN however comparing the extreme values (114.1 and 77.77) of tool wear for both cases respectively show 31.8 % improvement in tool's efficiency using PVD coated TiN tools. There is slightly nonlinear increase in tool wear of cemented carbide and linear increase in case of TiN coated tools with increase in cutting speed but there is 28.99 % improvement for TiN case in tool efficiency when extreme values for both uncoated and coated are compared i-e 123.77 and 87.88 respectively. For the third control parameter i-e depth of cut there is slightly nonlinear increasing response of tool wear in case of uncoated and linear increasing response in case of coated with increase in this parameter. Based on extreme values of tool wear (151.88 and 96.66) for uncoated and coated respectively there is 36.35 % improvement in tool's efficiency.

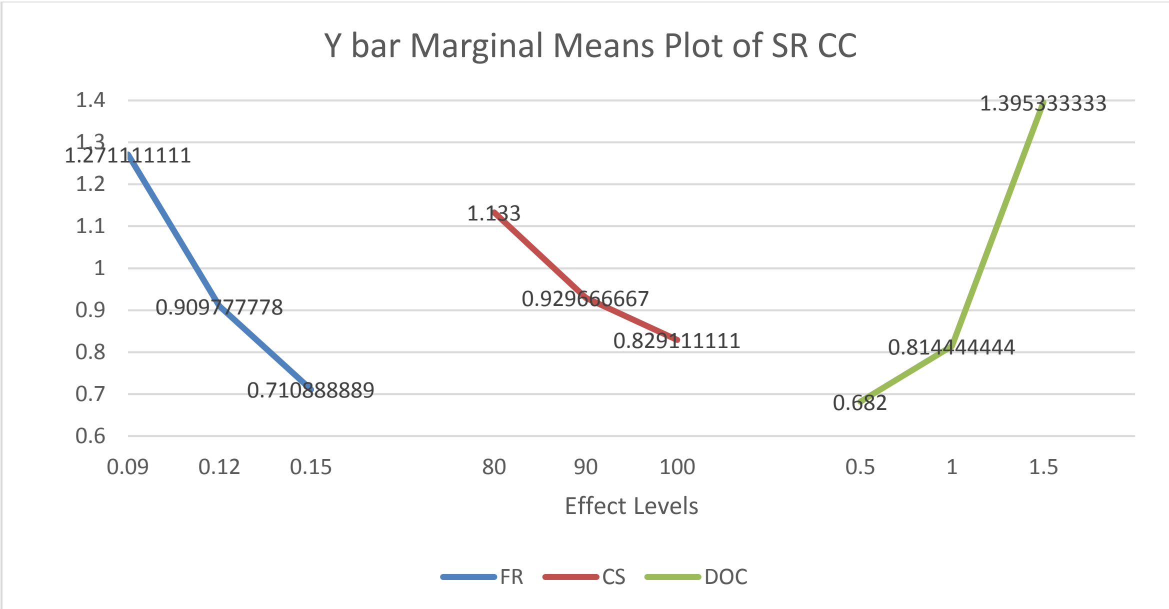

Figure 25 Marginal Mean Plot of SR CC

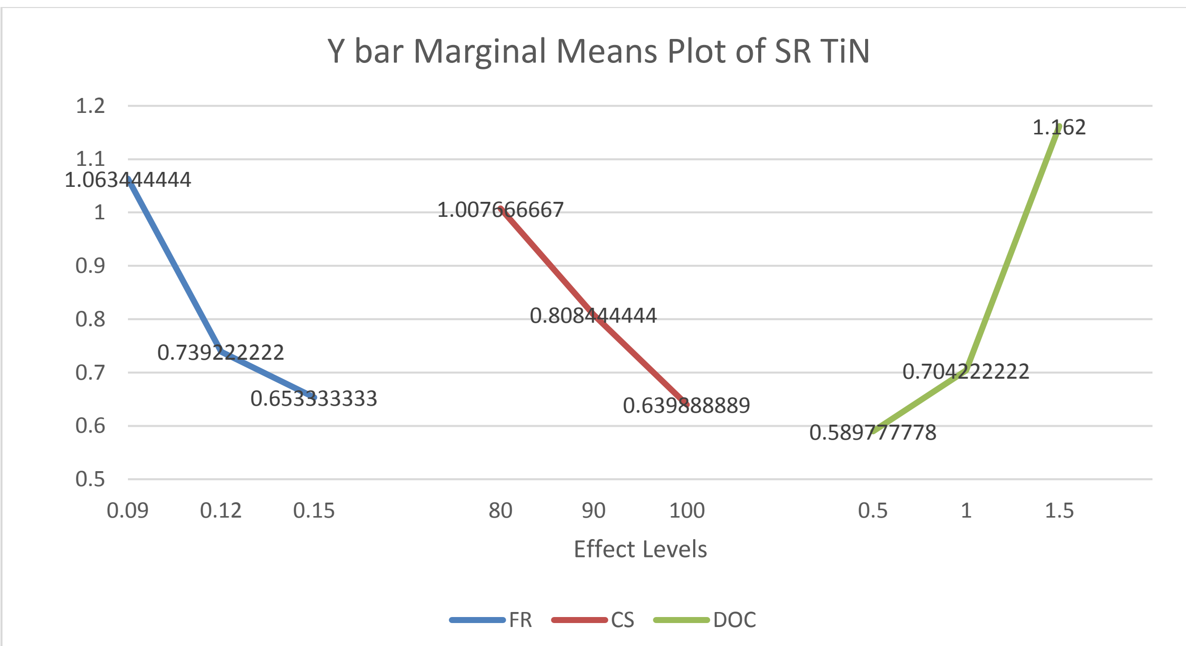

Figure 26 Marginal Means Plot of SR TiN

Figure 26 and 27 are the marginal means plot of surface roughness for both cemented carbide and TiN coated inserts which is quantitative assessment of process parameters on surface roughness. This shows the trend of effect of each variable with respect to surface roughness and is plotted at the average value of other two variables. Increase in feed rate has negative relation with surface roughness for both cases i-e uncoated cemented carbide and coated TiN however comparing the extreme values (1.27 and 1.06) of surface roughness for both cases respectively show %

improvement in surface finish using PVD coated TiN tools. There is slightly nonlinear decrease in surface roughness of cemented carbide and linear decrease in case of TiN coated tools with increase in cutting speed but there is % improvement for TiN case in surface finish when extreme values for both uncoated and coated are compared i.e., 1.133 and 1.007 respectively. For the third control parameter i-e depth of cut there is nonlinear increasing response of surface roughness in both cases i-e uncoated and coated with increase in this parameter. Based on extreme values of tool wear (1.395 and 1.162) for uncoated and coated respectively there is % improvement in surface finish.

CHAPTER NO 5

5 Conclusions

Aluminum Alloy 2024 was machined with uncoated and coated VNMG cutting inserts on stated processing parameters. Experiments were done in PITAC facility and then responses were measured at PITAC, Lahore PIDC, Sialkot and IME Department of University of Engineering & Technology. Lahore.Machining time was 30 minutes. Tool wear was measured and pictures were taken at maximum magnification of CMM. For each experiment a new cutting edge was used.

Following conclusions were drawn from this experimental investigation.

- Depth of cut has maximum effect on tool wear. According to results with increasing depth of cut tool wear increases.
- Cutting Speed is the second effective processing parameter which largely effected tool wear after depth of cut. Tool wear increased linearly with increasing cutting speed.
- Feed Rate varying also affected tool life but as compared to cutting speed and depth of cut it has lee influence. In case of coated TiN inserts Feed Rate influenced greatly as compared to with uncoated.
- PVD coating has decreasing effect on tool wear while it has also decreasing effect on surface roughness.
- By use of PVD coated inserts tool wear decreased by 36% with respect to depth of cut.
- PVD coated insert usage showed 31.8% increasing effect on tool wear with respect to feed rate.
- Cutting Speed has 28.99% on average effect with PVD coated tools w.r.t tool wear.
- Surface roughness with PVD coating increased 63% on average on same depth of cut.
- With use of PVD coated inserts surface roughness increased 65% on average as compared to uncoated on same feed rates.
- Surface roughness increased 67% on average with use of PVD coated tool same cutting speed.
- Optimal processing parameters for uncoated and PVD coated
- Optimal processing parameters for tool life
- PVD coated tool showed improved performance when compared with un coated cemented carbide tools

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