# COMPARATIVE STUDY OF MACHINABILITY CHARACTERISTICS DURING MACHINING NIMONIC C-263 WITH UNCOATED AND CVD MULTICOATED CARBIDE INSERTS

Thesis submitted in partial fulfilment of the requirements for the Degree of

**B.Tech.**

**In**

## Mechanical Engineering

**By**

**SANJEEB KUMAR NAYAK**

(110ME0031)

**NATIONAL INSTITUTE OF TECHNOLOGY**

**ROURKELA 769008**

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# NATIONAL INSTITUTE OF TECHNOLOGY

# ROURKELA

## CERTIFICATE

This is to certify that the thesis entitled, "**COMPARATIVE STUDY OF MACHINABILITY CHARACTER WHEN MACHINING NIMONIC C-263 WITH UNCOATED AND CVD MULTI COATED CARBIDE INSERTS**" submitted by **Sanjeeb Kumar Nayak (110ME0031)** in partial fulfilment of the requirements for the award of **Bachelor of Technology Degree** in **Mechanical Engineering** at National institute of at National institute Technology, Rourkela .The authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to other Institute/University for the award of any Degree or Diploma.

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Date. - 11th APRIL 2014

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# ABSTRACT

Nickel base super alloy has the combined property of "high mechanical strength" and "High heat and corrosion resistance" at elevated temperature. This is the reason for which Nickel based super alloy are extremely used in 1. Aircraft gas turbine engine due to their superior mechanical property at an elevated temperature, 2. Aerospace component which continuously suffer from Extreme temperature, pressure and velocity for long period, 3. Submarine and chemical industries due to Superior Chemical properties like resistance to corrosion and oxidation, 4. Heat exchanger as subjected to high temperature. Super alloy are difficult to machine due to their high mechanical strength and low thermal conductivity resulting tool wear during machining. Work hardening occur rapidly during machining resulting notching. Chemical reaction occur at high cutting temperature produce diffusion wear during machine. Low thermal conductivity of super alloy results tool wear, which accelerate premature tool failure, short tool life, increase of cutting forces and poor quality of surface finish. NIMONIC is high temperature low-creep super alloy .Major constituents of NIMONIC is nickel , Chromium and cobalt which enhance the resistance to corrosion and oxidation for which NIMONIC got higher chemical property compared to Inconel in which (5-10)% iron concentration present. NIMONIC C-263 alloy has immense uses recent times as mentioned above hence it is necessary to study the machinability aspect of super alloy in order to enhance and productivity of the super alloy. Tool performance were studied ,when C-263 super alloy is machined under coated and uncoated carbide tool insert at dry condition .The operation were performed keeping feed (0.2mm/rev)and depth of cut (1mm) and varying cutting velocity (51-84)m/min.

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# INTRODUCTION

Nickel base super alloy are the most difficult material to machine for its high hardness, high strength at elevated temperature, low thermal diffusivity .It has the tendency to react with tool material resulting tool wear .At least 50% of nickel is present in Nickel base super alloy .The percent of other elements are added to achieve of superior mechanical property .Wrought base super alloy contain 10-20 %chromium, 7% Al and Ti, 5-15% Co in order to improve surface stability. The superior properties in term of high temperature, corrosion resistance and high strength-to-weight ratio it has a wide range of application in aerospace engine manufacture, Turbine blade in power plant etc.

NIMONIC C-263 is basically nickel base super alloy which have high content of cobalt and chromium but possess less amount of iron. The presence of Cr influence to have a unique properties of the material in term of maintained mechanical properties and resistance to corrosion at elevated temperature. Molybdenum is used for solid –solution strengthening. It is used for aerospace equipment. The high work hardening rate ,resistance to penetration are the major challenges for machining of NIMONIC C-263 super alloy .Machining of NIMONICC-263 the tool has to go through tremendous heat, pressure and aberration resulting tool wear, flank wear which leads to differ in the dimensional accuracy as well as surface integrity.

Nickel base super alloy are high corrosion resistance alloy. They resist shock and creep at elevated temperature. Chromium (Cr) is used to for solid strengthening solution .Presence of Tantalum (Ta) in the intermetallic compound improves the oxidation resistance and temperature strength at extreme temperature

The nickel base super alloy has high mechanical properties 1. High tensile strength, 2. High fatigue strength, 3. High yield strength. It has superior chemical properties at high temperature. Resistance to corrosion and resistance.

# 1.1. MACHINABILITY OF NIMONIC C-263 ALLOY

Machinability is the ease of removal of material from work piece to an expected surface finish. Machining performance of a material can determined by machinability.

Factors influence machinability

1. Mechanical properties
2. Physical properties
3. Chemical composition of the material
4. Shape and size of work piece
5. Cutting parameter
    1. Speed
    2. Feed
    3. Depth of cut

Observed criteria for determine machinability

1. Surface roughness
2. Tool wear
3. Chip characteristic
4. Cutting forces
5. Cutting temperature

NIMONIC C-263 has superior properties that influence machinability .They work harden rapidly during machining .they have the tendency to react with tool material during in. They have the tendency to form BUE and the presence of abrasive carbide in the microstructure determine the machinability of this nickel base super alloy NIMONIC C-263.

## 1.1.1. Need for machinability

Nickel base super alloy NIMONIC C-263 have superior mechanical property, high strength and corrosion resistance for which it is widely used in aerospace application ,turbine blade, submarine for which it is a bit of costlier .During machining precision is required in terms of surface finish ,shape with the minimal removal of material from the work piece to achieve economic benefit. The machinability can be improved using different cutting tool, coated and uncoated carbide insert tool provide a bit better machinability

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## 1.1.2. Types of NIMONIC alloy

1. NIMONIC 75
   It has a good mechanical properties and oxidation resistance at elevated temperature.
   Composition -Ni 76.0, Cr 20.0, Fe 4.0

2. NIMONICc80A
   It has the same type of character as that of NIMONIC 75 but the addition of aluminum and titanium hardened the material.it has good oxidation and corrosion resistance property. The tensile and creep rupture point is large at elevated temperature.
   Composition -Ni 76.0, Cr 19.5, Ti 2.4, Al 1.4
3. NIMONIC alloy 86
   Nickel-chromium-molybdenum alloy having good formability and weldability.
   Exceptional creep strength and oxidation resistance at high temperature up to 1000 °C
   Composition - Ni 65.0 Cr 25.0, Mo 10.0, Cerium 0.03
4. NIMONIC alloy 90
   A precipitation hardenable nickel-chromium-cobalt alloy having high stress rupture strength and high creep resistance at a temperature of 920 de c. having good oxidation and corrosion resistance
   Composition - Ni 60.0, Cr 19.5, Co 16.0, Ti 2.5, Al 1.5

5. NIMONIC alloy 105
   A precipitation hardenable nickel-chromium-cobalt alloy with molybdenum for solid solution strengthening. It has relatively high amount of aluminum enhance the strength as well as oxidation resistance.
   Composition - Ni 54.0, Co 20.0, Cr 15.0, Mo 5.0, Al 4.7, Ti 1.3
6. NIMONIC alloy 115
   It is similar to that of NIMONIC alloy 105 but the amount of aluminum and titanium is high in order to have improve strengthening.
   Composition - Ni 60.0, Cr 14.2, Co 13.2, Al 4.9, Ti 3.8, Mo 3.2
7. NIMONIC alloy C-263
   A precipitation hardenable nickel-chromium-cobalt alloy with addition of molybdenum for solid solution strengthening .high resistance to corrosion and oxidation up to 850 °C
   Composition - Ni 51.0, Cr 20.0, Co 20.0, Mo 5.8, Ti 2.2, Al 0.5

# 1.2. PROPERTY OF NIMONIC C-263 ALLOY

**Physical properties**

Density, $g/cm^3$ - 8.36

Liquidus temperature, °C 1355

Solidus temperature, °C 1300

Specific Heat, J/kg, 461 in the range of 20-100 °C

**Thermal properties**

Thermal expansion co-efficient (21-100) 10.3 µm/m°C

Thermal conductivity 11.7 W/mK

Low thermal conductivity

## 1.3. ADVANTAGE AND APPLICATION OF NIMONIC C-263 ALLOY

Nickel base super alloy NIMONIC C-263 has the combine properties of high “mechanical strength” and “high heat and corrosion resistance” at an elevated temperature. The austenite nickel matrix reacts with Chromium (Cr), Cobalt (Co), molybdenum (Mo) ,tungsten (W) to become alloy. Chromium present in the alloy reacts with the oxygen present in the air and form a protective scale layer of Chromium Oxide ($Cr_2O_3$).This protective layer prevent outward diffusion of metallic element. Molybdenum and tungsten helps for solid solution strengthening at elevated temperature. Precipitation hardening also strengthening the nickel base super alloy with the addition of aluminum .

**Application of NIMONIC Alloy**

1. Gas turbine engines
2. Compounding of industrial furnace
3. Nuclear power plant
4. Tube supports in nuclear steam generators
5. Exhaust valve in internal combustion engine
6. Aerospace component
7. Submarine and Chemical industries
8. Heat exchanger
9. Food processing equipment
10. Petrochemical plant

# 1.3 CHALLENGES IN MACHINING NIMONIC C-263

Casting ,forging and other advanced technique are used to manufacture nickel base alloy NIMONIC components .It is quite difficult to manufacture and machine intricate shaped component part at reliable cost due to the following reasons

1. During machining high strength and hot hardness of NIMONIC alloy cause deformation of cutting tool.
2. NIMONIC alloy get rapid work hardening during machining due to the austenite matrix. This is the reason for tool wear at depth of cut line.
3. Localization of shear stress and formation of abrasive saw tooth edge resulting notching of cutting tool. High dynamic shear strength is the reason behind notching of cutting tool.
4. Hard abrasive carbide like MC, $M_{23}C_6$ present in the microstructure of NIMONIC alloy resulting abrasive related tool failure.
5. Low thermal diffusivity of the material resulting high temperature gradient in the tool tip. This is due to the localization of cutting temperature (>1000°C) at the tool tip.
6. The work piece get welded with the cutting tool edge resulting unstable build up edge formation ,which hamper the surface roughness of work piece during machining.
7. NIMONIC has the tendency to react with cutting tool material at elevated temperature causing tool wear.
8. Presence of the abrasive particle in the microstructure resulting rapid tool wear due to the different wear mechanism
9. The combined property of mechanical strength and resistance to corrosion at elevated temperature of NIMONIC C-263 resulting poor machinability.

# 1.4 CUTTING T OOL MATERIAL

During machining NIMONIC C-263 the cutting tool is subjected to extreme mechanical and thermal stress near to the cutting tool which accelerate tool wear .Notching at the nose and depth of cut line, flank wear, Crater wear, chipping are the typically observed tool failure during machining of NIMONIC C-263 alloy. To overcome this challenges the cutting tool should have enough hot hardness to withstand high temperature during high speed condition.

Coated carbide tool, ceramic, CBN/PCBN tool are generally used for high speed machining of NIMONIC C-263 alloy while uncoated carbide tool are used for low speed machining condition.
Effective machining of work piece can be achieved depending up on the type of cutting tool material used while machining

### 1.4.1. Different Cutting Tool Materials

#### a. Coated and uncoated carbide tool

Straight and mixed grade carbide are two often used carbide tool material for commercial machining purpose. The straight carbide tool have cobalt 6% by weight, 94% WC with the range of cobalt 5-15 % .The mixed grade carbide are Titanium carbide (TiC),tantalum carbide(TaC). Titanium carbide improve the wear resistance of carbide tool. The tough ness of the carbide id reduced with the increase concentration of titanium. The hot hardness of the tool can be improved with inclusion of tantalum carbide. The plastic deformation can be prevented while machining at high speed. High cobalt content and coarse grain tungsten carbide are required to resist high shock.

The performance of the cutting tool can be achieved using ceramic coating. They have high temperature resistance property and resistance to diffusion wear, high hot hardness, oxidation wear resistance. The lowering cutting temperature during machining can be achieved due to the improved lubricating properties of chip –tool and toll-work piece interface. Higher cutting speed also achieved using coated ceramic tool.

#### b. HSS (High speed steel)

High carbon ferrous alloy with the constituent of Cr, Co, W, Mo and V. In the form of Cast, wrought and sintered (using power metallurgy technique) HSS are available. It is of less expansive compared to other cutting tool material. Fracture toughness and fatigue resistance were the feature properties of HSS .It is applicable for a short range of velocity i.e. 30-50 m/min due to its limited wear resistance and chemical stability.

It is classified depending up on the dominating alloying element

T-type steels having tungsten as the dominant alloying element and M-type steels molybdenum is the dominant alloying element.

#### c. Cemented carbide

Mixing , compacting and sintering are the process of manufacturing cemented carbide cutting tool material .In case of Sintering process primarily tungsten carbide (WC) and cobalt (Co) powders were used. For tungsten carbide (WC) grain Co acts as a binder. The carbide tool have good electrical and thermal conductivity as they have strong metallic character. These cutting tool are chemically stable. They possess high stiffness and lower friction, and operate at higher cutting velocities compared to HSS. These material are expansive and brittle in nature. Generally used for machining gray cast iron, nonmetallic material and nonferrous metal. M grade carbides are alloyed with tungsten carbide (WC) to have the application in machining austenitic stainless steel. The maximum hardness and toughness position of a material is achieved from the number assigned to grade with in a group. P grades are rated from P01 to P50, M grades from M10 to M40, and K grades from K01 to K40. Cobalt percentage and grain size of carbide determine the performance of carbide cutting tool.

d. **Cermets**

Cermets are ceramic material in metallic binder. Co and Mo are the softer binder which held the constituent hard particles of TiC ,TiN, or TiCN..These material are operated on high cutting velocities and hence suitable for machining steel, cast iron. They possess lower thermal conductivity and resistance to fracture

e. **Ceramic**

Ceramic are nonmetallic material and subjected to extreme temperature during machining. The uniqueness of this type material is to retain the stiffness and hardness of the material at elevated temperature equal to 1000° C.

Basically 2 types of ceramic tool available for commercial machining purpose

1. Alumina-based ceramics which consists of pure oxide, mixed oxides, and silicon carbide

   (SiC) whisker reinforced alumina ceramics.

2. Silicon nitride-based ceramics

# 1.5. **TOOL WEAR**

Machining for a prolonged period the cutting tool destroyed due to high strength and temperature resistance of work piece .major tool wear studied during machining were

A. CRATER WEAR
   During machining chip slide over the tool face resulting formation of concave section in the chip tool interface .Crater wear increase rake angle resulting easier machining but simultaneously it reduces the strength of cutting tool which influences tool failure during machining.

B. FLANK WEAR
   The friction between work piece surface and tool flank resulting flank wear at the tool flank .it generally appear in the form of wear land which affect machining. The increase in flank wear resulting in cutting force which in excess resulting tool failure. VB>0.3mm tool failure occur.
C. CORNER WEAR
   This tool wear took place in the tool corner.it is also called a part of wear land as there were no definite boundary between flank wear land and corner wear .The reduction of cutting tool length results in increase in the dimension of machined surface gradually

Apart from this wear other types of wear are present, these were

- Adhesion wear –the fragment of work piece welded with tool surface at heigh temperature during machining is called adhesion wear
- Abrasion wear –the bottom part of chip rub against the tool surface and part of it is break away which is called abrasive wear.
- Diffusion wear –chip and tool diffuses during machining is called diffusion wear

**TYPES OF WEAR IN CUTTING TOOL**

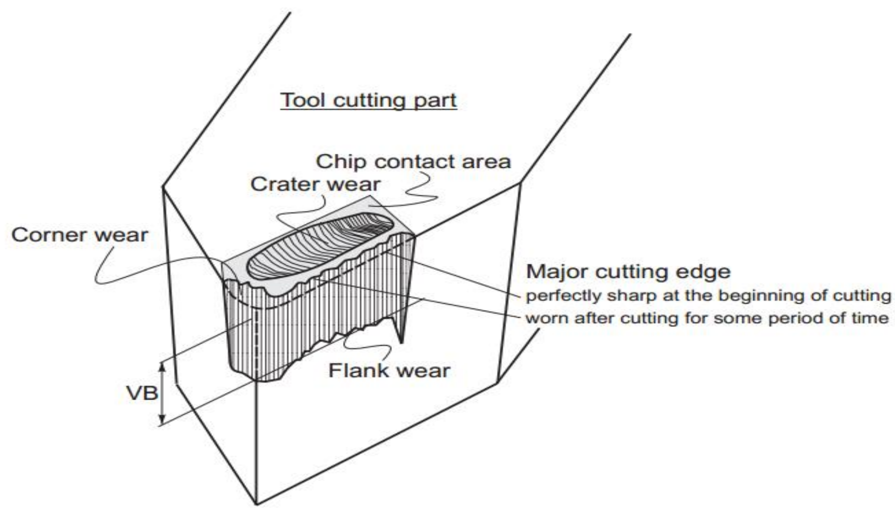



Fig.1. Different types of tool wear observed in cutting tool

## 1.6. DIFFERENT ENGINEERING APPLICATIONS OF NIMONIC C-263

1. Aircraft gas turbine engine due to their superior mechanical property at an elevated temperature
2. Aerospace component which continuously suffer from Extreme temperature, pressure and velocity for long period.
3. Submarine and chemical industries due to Superior Chemical properties like resistance to corrosion and oxidation.
4. Heat exchanger as subjected to high temperature. Super alloy are difficult to machine due to their high mechanical strength and low thermal conductivity resulting tool wear during machining.

# 2 LITERATURE REVIEW

## 2.1. EFFECT OF CUTTING PARAMETER ON SURFACE ROUGHNESS DURING MACHINING ON NIMONIC.

Ezilarasan et al. (2013) carried out analysis of process parameter and the influence of cutting speed ,feed and depth of cut on surface roughness in the dry machining of NIMONIC C-263 .It was observe that Surface roughness decrease with increase of cutting speed and depth of cut and at medium level of feed . Surface roughness Increase with increase of feed rete and decrease with increase of cutting speed. Best surface roughness achieved at higher depth of cut keeping low level of feed rate.

EzugwuZUGWU et al.( 2008) studied the performance of PVD coated multilayer tool (TiN/TiCN/TiN) and single layer TiAlN tool on machining of NIMONIC C-263 at high speed condition .it has been observed that single layer provide better surface finish compared to multilayer PVD inserted tool during high speed and depth of cut condition. The variation in tool geometry and cutting condition has neglected effect on surface roughness.

Ezilarasan et al. (2012) observe the influence of cutting parameter and cutting time on the surface roughness of the C-263 super alloy while turning. It has been observed that the surface roughness improves up to a speed of 190m/min after which surface roughness increase with speed. The least measured surface roughness value was 1.9µm .The increase cutting speed increase cutting temperature, the low thermal conductivity of the work piece accumulate temperature at the cutting tool edge resulting tool wear .This is the reason behind resulting high surface roughness.

Ezugwu et al. (2003) observe that the effect of concentration of coolant on cutting tool during machining NOMINIC C-263 using triple coated TiN/TiCN/TiN carbide insert. It was observed that the varying concentration of coolant has not significantly improve surface roughness of work piece.

Okeke et al. (2002) studied the effect of multicoated TiN/TiCN/TiN and single coated TiAlN carbide insert on machining of NIMONIC C-263 under high speed condition in wet condition. It was observed that the single coated TiAlN carbide insert tool provide better surface compared to multi coated TiN/TiCN/TiN carbide tool. Single layer tool has high oxidizing temperature resulting lower surface roughness below 2.54 mm depth of cut. Lower depth of cut with cutting speed 51m/min-68 m/min mechanical surface damage occurs.

Ezugwu et al. (2000) observe that the effect of coating material on machinability of NIMONIC C-263.IT was observed that the all grades of coated carbide toll has given uniform surface roughness value under the rejection criterion.

Vealyudham et al. (2011) investigate the effect of cutting parameter on machining of NIMONIC C-263 super alloy. It was observed that the process parameter feed rate has highest S/N ratio and the significant effect on surface roughness compared to cutting speed and depth of cut.

### 2.2. EFFECT OF CUTTING PARAMETER ON TOOL WEAR DURING MACINING NIMONIC

Ezilarasan et al .(2013) carried the analysis and measurement of the cutting parameter and the influence of cutting speed on tool were studied .It has been concluded that at lower cutting speed there might be the adhesion of chip to the tool surface due to the weld pressure between chip and tool surface.

Ezugwu et al. (2004) carried out effect of coolant on the tool wear studied 3-6 % coolant flank wear takes place while 9% coolant chipping at the cutting edge the mode of tool failure, increase of cutting speed reduces tool chip interface resulting increase of temp at small zone cause compressive stress at cutting tool edge leads to tool failure. Speed increase low thermal conductivity of material shifts towards tool edge resulting tool wear cause tool failure.

Ezugwu et al.(2008) ingle coated carbide tool Higher thermal conductivity increase abrasive wear lead to adhesion wear and accelerating flank wear in speed of 54 -68 m/min resulting premature tool failure, short tool life . While multilayer tool have high mechanical strength to cutting edge due to high hardness and thick layer coating.

Ezilarasana et al (2013) studied the influence of cutting parameter on tool wear .feed rate influence flank wear, for low flank wear low level of feed rate and DOC with middle speed is required.

Ezugwu et al.(2002) studied the influence of coated and uncoated carbide insert am machining of NIMONIC C -263 at low cutting speed of 54m/min.it was observed that The higher thermal conductivity, hardness and friction coefficient of single layer TiAlN coated insert resulted in better tool life than that of multilayer at lower depth of cut of less than 1.25 mm. Thicker layer of multilayer coated tools provided high resistance to wear at high cutting speed of 68 m/min and at depth of cut 2.54 mm, hence outperforming single layer coated inserts.

Okeke et al. (2000) carried out experiment to determine the performance of PVD coated carbide insert when machining a NIMONIC C-263 alloy at high speed condition. Multi-layer TiN/TiCN/TiN coated carbide insert with positive, chamfered and honed edges performed better in terms of tool life than that with similar tool having no edge protection and double positive edges. Feed rate has significant influence on tool life. Tool wear decrease with decrease feed rate while increase with increase of depth of cut and cutting speed.

### 2.3. OBJECTIVE OF THE WORK

From the literature review it has been clear that a lot of study has been carried out for nickel base super alloy Inconel 718, and Inconel 825.There exist a lot to find the influence of cutting parameter on machining NIMONIC C-263.An attempt was made to study comparatively the machining character of NIMONIC C-263 in terms of tool wear and character of chip morphology. During machining cutting speed was varied keeping feed and depth of cut constant for both the cutting tool material with different time interval .the object of the work is to find

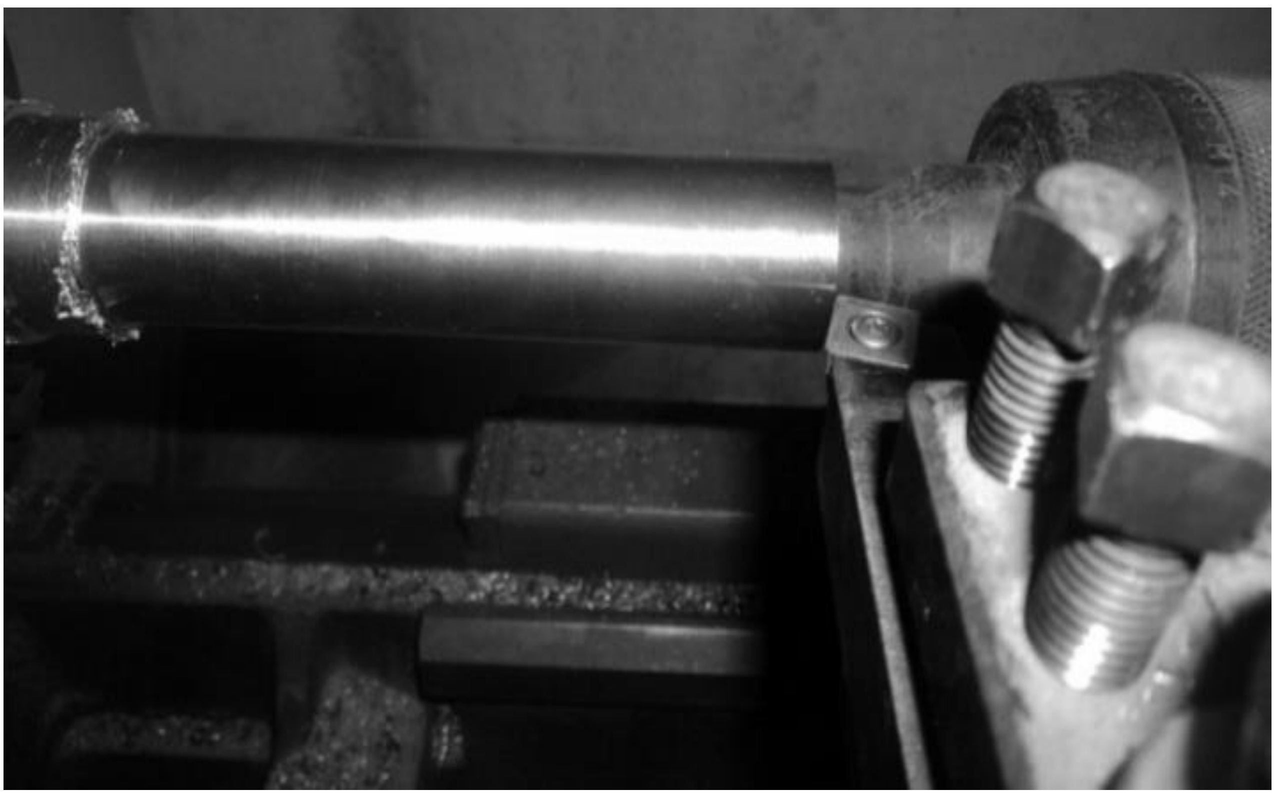
1. Effect of cutting parameter on surface roughness during machining of NIMONIC C-263 while Uncoated ISO P30 grade cemented carbide and CVD deposited multilayer coating of TiN/TiCN/$Al_2O_3$/ZrCN tool wear used.
2. Effect of cutting parameter on tool wear during machining of NIMONIC C-263 using different tool
3. Effect of cutting parameter on chip character during machining of NIMONIC C -263 during machining at constant feed and depth of cut.

# 3. EXPERIMENTAL METHODS AND CONDITIONS

The turning of NIMONIC C-263 was carried out using coated and uncoated carbide insert in the HMT NH26 lathe machine. The grade of cutting tool material were specified below. The experiment was proceed with varying cutting speed of VC 51 m/min and 84 m/min keeping constant feed of 0.2 mm/rev and depth of cut 1mm respectively. ISO SSBR 2020K12 (Kennametal, India) tool holder is used for the experiment. A heavy duty Lathe machine was used for the turning of NIMONIC C-263under dry condition. A comparative tool performance was studied using uncoated and CVD multilayer coated carbide ceramic insert .The set fig of the experimental was given below

## 3.1. THE EXPERIMENTAL SET UP

**Fig.2. Experimental set up for machining.**



**Experimental condition for turning**

| | |
|---|---|
| **Work piece material** | NIMONIN C-263 |
| **Inserts used** | Uncoated ISO P30 grade cemented carbide and CVD deposited multilayer coating of (TiN/TiCN/$Al_2O_3$/ZrCN) |
| **designation of insert** | SCMT 120408 |
| **Geometry of tool** | −6°, −6°, 6°, 6°, 15°, 75°, 0.8 (mm) |
| **Cutting velocity** | 51m/min,84m/min |
| **Cutting feed (constant)** | 0.2 mm/rev |
| **Depth of cut** | 1mm |
| **Cutting condition** | Dry |

**Table 1 - Experimental details**

## 3.2. CUTTING TOOL DESCRIPTION

**Designation of tool**

SCMT 12 04 08

S Stands for square shape insert =90$^o$

C stands for clearance angle =7$^o$

M stands for medium tolerance=+/- 0.005”

T stands for, central hole and with groove

12 which means each cutting edge length is 12 mm

04 nominal thickness insert is 4mm

08 means the nose radius of 0.8 mm

**Table 2. Tool designation**

| Sl. no. | Cutting tool | ISO grade specification | Composition |
|---|---|---|---|
| 1 | Uncoated cemented carbide insert P30 | SCMT120408 | WC+Co+TiC+TaC |
| 2 | CVD deposited multilayer coated tool | SCMT120408 | $TiN/TiCN/Al_2O_3/ZrCN$ |

Uncoated ISO P30 grade cemented carbide and CVD deposited multilayer coating of $TiN/TiCN/Al_2O_3/ZrCN$ from the substrate to top layer of the tool were used during the dry machining condition. ZrCN has the antifriction property and possess excellent toughness suitable for better tool life .Owing to its excellent toughness and anti-friction properties, ZrCN is used as a top layer. Both uncoated and coated inserts were commercially available tools with ISO insert designation of SCMT 120408. Positive rake angle and strong cutting edge used at medium to high feed.

## 3.3. TOOL HOLDER DESIGNATION

ISO SSBR 2020K12 (Kennametal, India)

## 3.4. WORK PIECE DETAILS

A cylindrical shaped of 75mm diameter and 195 mm of length of NIMONIC C-263 super alloy was the work material for the machining operation. The chemical Composition of the work piece was given in the table

### 3.4.1. Composition of NIMONIC C-263

**Table 3. Composition**

| Compound | Al | C | Co | Cr | Mo | Ni | Ti |
|---|---|---|---|---|---|---|---|
| Nominal wt.% | 0.45 | 0.06 | 20. | 20 | 5.85 | Bal | 2.15 |

### 3.4.2. Properties

I. Low thermal conductivity
II. High resistance to corrosion and oxidation at elevated temperature
III. High temperature low creep of work material.
IV. Work hardening rate is high.

### 3.4.3. Application

1. Unique property of mechanical strength and corrosion and oxidation resistance at extreme temperature and pressure is used to serve in aerospace engine manufacturing, the turbine components and the compounding of furnace.
2. The superior chemical property helps to use of the material n chemical industries and in submarine

## DESCRIPTION OF THE EXPERIMENT

P 30 grade cemented carbide generally possess high hardness, toughness and wear resistance characteristics. The coated and uncoated carbide insert off ISO grade SCMT 120408 tool has been used for the turning of NIMONIC C-263 in dry condition.

In the first phase of experiment the Uncoated cemented carbide insert P30 tool is used for machining purpose with cutting speed 0f 51m/min a, constant feed of 0.2mm/rev and depth of cut 1mm.the experiment were carried out for 30 sec. then the chip is collected for study chip characteristics like size, shape, color, chip thickness and chip reduction coefficient .**Chip thickness ratio** is the ratio between uncut chip thickness to the cut chip thickness, denoted by "r" .cut chip thickness is measured in Vernier calipers while the uncut chip thickness is obtain by the formula $t_{uncut}$=f.sin($\Phi$),where f is feed and $\Phi$approach angle The tool life can be observed based up on the average flank wear measured on the stereo zoom optical microscope .VB=0.3 mm criteria is used for average flank wear calculation. The carbide tool is cleaned for further experiment.

The same experiment were conducted for the cutting speed 0f 51m/min keeping all other parameter constant for 60 second.in the similar fashion the chip is collected and the tool wear is measured in the stereo zoom optical microscope. The carbide insert is again cleaned for 15 min and then the experiment were carried out for another 30 second and repeat the observation technique.

In the second phase of experiment the uncoated cemented carbide insert P30 tool is used for machining NIMONIC C -263 with cutting speed of 84m/min ,keeping depth of cut 1mm and feed rate of 0.2 mm/rev. The tool wear is measured based upon the average flank wear using VB=0.3mm criteria and the chip were collected for further observation ,then the tool re removed and cleaned in the similar manner as in case of phase one. The experiment were carried out for another 60 second followed by another 90 second keeping cutting parameter speed 86m/min, feed 0.2mm/rev and depth of cut 1mm and same observation technique is followed.

For CVD deposited multilayer coated tool both the two phase of experiment were conducted and the same observation technique is followed. And the observe result is tabulated for further calculation.

# 4. RESULTS AND DISCUSSION

**For cut chip thickness**

**Table 4. Values of cut chip thickness for different machining duration with the cutting parameter of, cutting speed (Vc)-51 m/min,feed-0.2mm/rev, depth of cut 1mm**

| Machining duration ,s | Cut chip thickness ,µm | |
|---|---|---|
| | Uncoated | Coated |
| 30 | 0.3393 | 0.2685 |
| 90 | 0.3876 | 0.3709 |
| 120 | 0.4662 | 0.4501 |

**Table 5. Values of cut chip thickness for different machining duration with the cutting parameter of, cutting speed (Vc)-84 m/min,feed-0.2mm/rev, depth of cut 1mm**

| Machining duration (s) | Cut chip thickness(µm) | |
|---|---|---|
| | Uncoated | Coated |
| 30 | Tool fails | 0.2144 |
| 90 | | 0.3458 |
| 120 | | 0.3825 |

**For flank wear**

**Table 6. Values of flank wear for different machining duration with the cutting parameter of cutting speed (Vc)-51 m/min,feed-0.2mm/rev, depth of cut 1mm**

| Machining duration (s) | Flank wear (VB) mm | |
|---|---|---|
| | Uncoated | Coated |
| 30 | 0.235 | 0.17 |
| 90 | 0.325(tool fail) | 0.185 |
| 120 | | 0.25 |

**Table 6. Values of flank wear for different machining duration with the cutting parameter of cutting speed (Vc)-84 m/min,feed-0.2mm/rev, depth of cut 1mm**

| Machining duration (s) | Flank wear (VB) mm | |
|---|---|---|
| | Uncoated | Coated |
| 30 | 0.45 (tool fails ) | 0.17 |
| 90 | | 0.21 |
| 120 | | 0.42(tool fails) |

## 4.1. **CHIP THICKNESS RATIO**

Machining parameter has a great influence in chip thickness ratio which is observed during machining of NIMONIC C-263 at different cutting speed of (51-84) m/min with coated and uncoated carbide inserts. With the increase of machining time chip thickness ratio decrease due to the formation of tool wear resulting thick chip thickness. At higher cutting speed chip thickness ratio increase as speed increase ,reduction of coefficient of friction between chip tool interface takes place resulting reduction of shear zone or cut chip thickness ultimately increase chip thickness ratio. In the similar fashion Multilayer tool also produce reduced shear zone which increase chip thickness ratio compared to uncoated tool.At higher cutting speed chip thickness ratio increase.

The uncoated carbide at 84m/min cutting speed while machining NIMONIC C-263, chip thickness ratio decrease after the duration of 90s.When cutting speed increase from 51 to 84 m/min chip thickness ratio increase. The increase in cutting speed decrease the chip tool inter face friction.

Uncut chip thickness, $t_{uncut} = f.\sin(\Phi)$, where f is feed and $\Phi$approach angle

f = 0.2 mm/rev, approach angle is $75^o$

Cut chip thickness is measured from Vernier calipers

**Figure 3. Effect of machining duration and cutting speed on chip thickness ratio for coated and uncoated ceramic carbide inserts.**

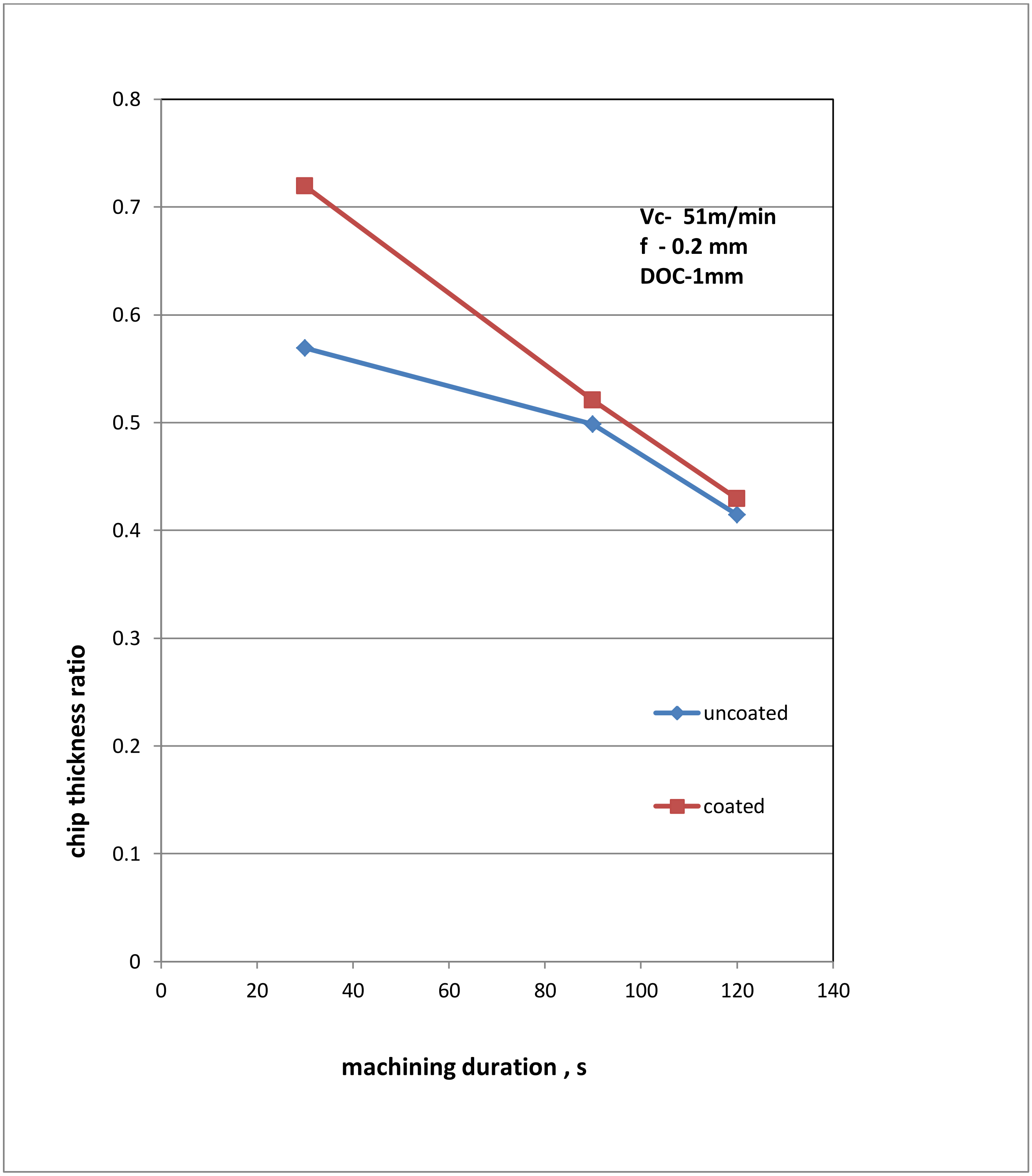
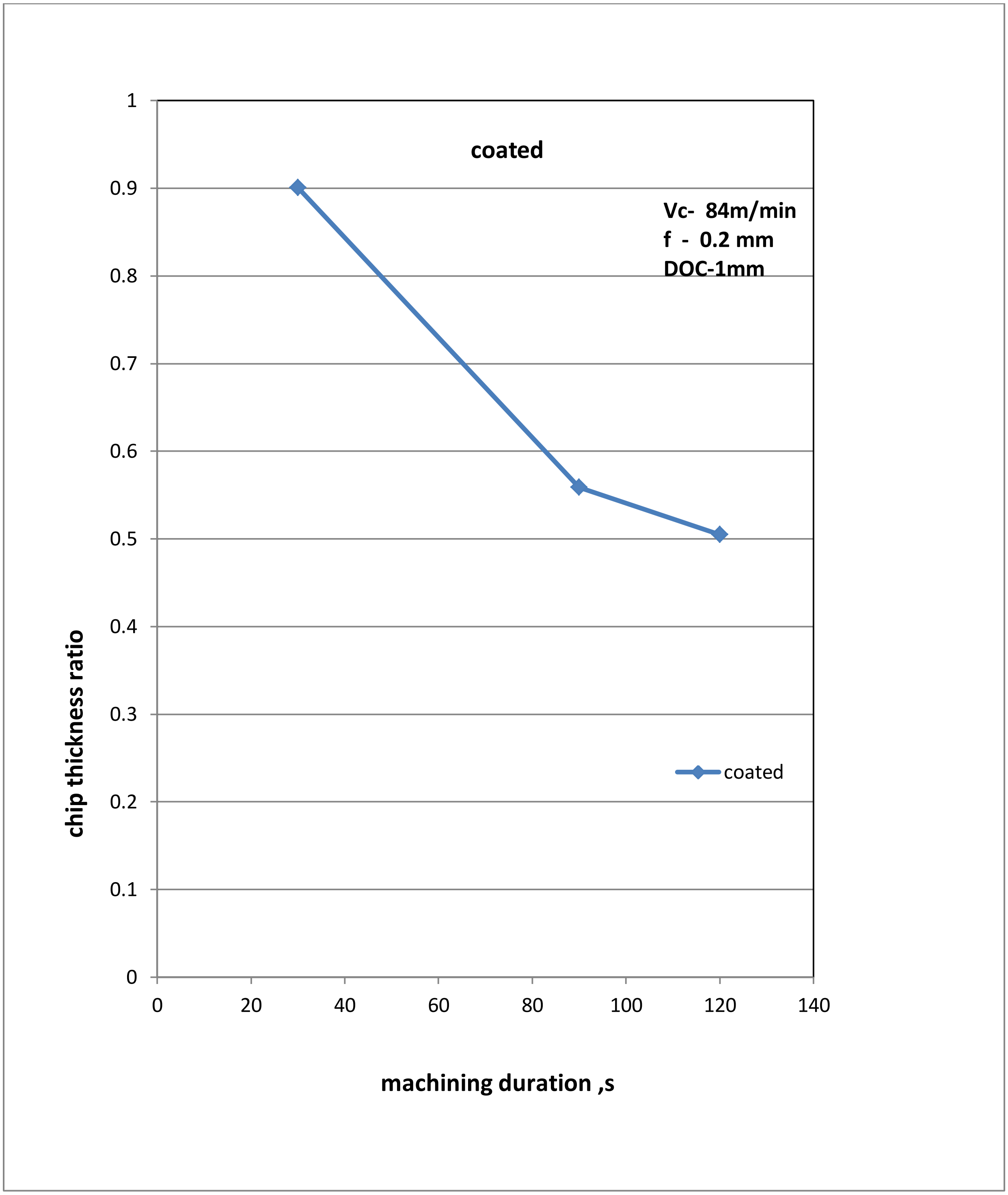


**Figure 4. Effect of machining duration and cutting speed on chip thickness ratio for coated and uncoated ceramic carbide inserts.**



## 4.2. STUDY OF TOOL WEAR

**Figure 5. Flank wear observed on optical microscope at speed of 51m/min of coated and uncoated carbide tool**

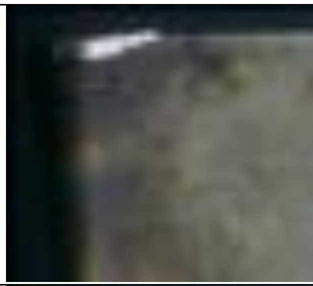
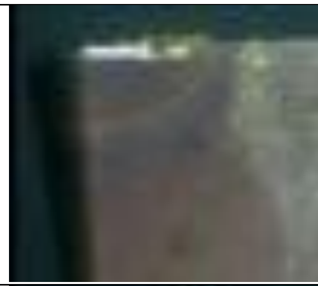
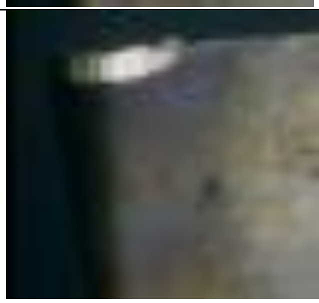
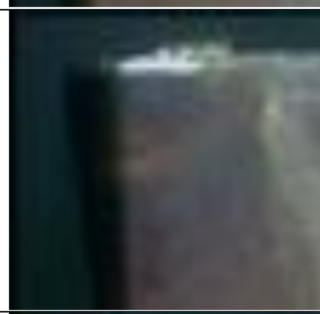
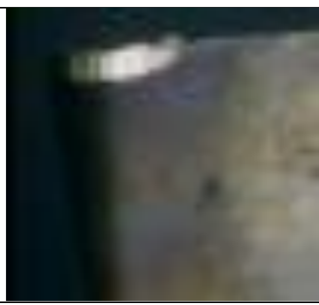
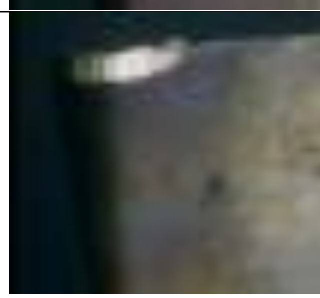
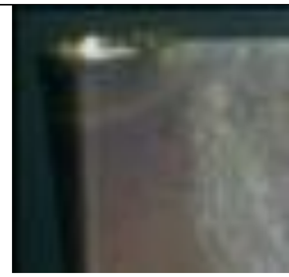
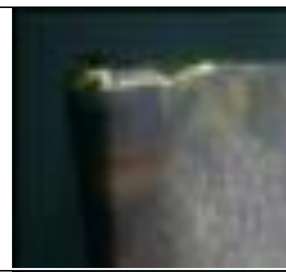
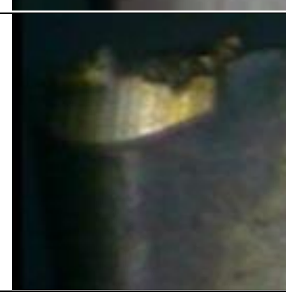
| Machining duration ,s | Uncoated tool | Coated tool |
|---|---|---|
| | Flank surface image of insert at cutting speed of 51 m/min | |
| 30 |  |  |
| 60 |  |  |
| 90 |  |  |

**Figure 6. Flank wear observed on optical microscope at speed of 84 m/min of coated and uncoated carbide tool**

| Machining duration ,s | Uncoated tool | Coated tool |
|---|---|---|
| | Flank surface image of insert at cutting speed of 51 m/min | |
| 30 |  |  |
| 60 | TOOL FAILS |  |
| 90 | |  |

Flank wear studied in the optical stereo zoom optical microscope at 40 X zoom at Variable cutting speed of 51m/min and 84 m/min keeping depth of cut 1mm and feed rate 0.2mm/rev ,the studied figure were in the figure 5and 6 respectively .

Crater wear and flank wear are observed during machining of C-263 alloy at cutting speed of 51 m/min and 84 m/min. Uncoated tool fail after the machining of 90 sec at the speed of 51m/min whereas multicoated tool can perform without tool failure . for the cutting speed of 84m/min the catastrophic tool failure occur at the early stage of the uncoated tool where the multi coated tool provide tool life upto 90sec then it fails. Increase in machining speed and duration flank wear increase for both coated and uncoated tool

**Figure 7. Variation of machining duration and cutting speed on flank wear for uncoated and multilayer coated inserts.**

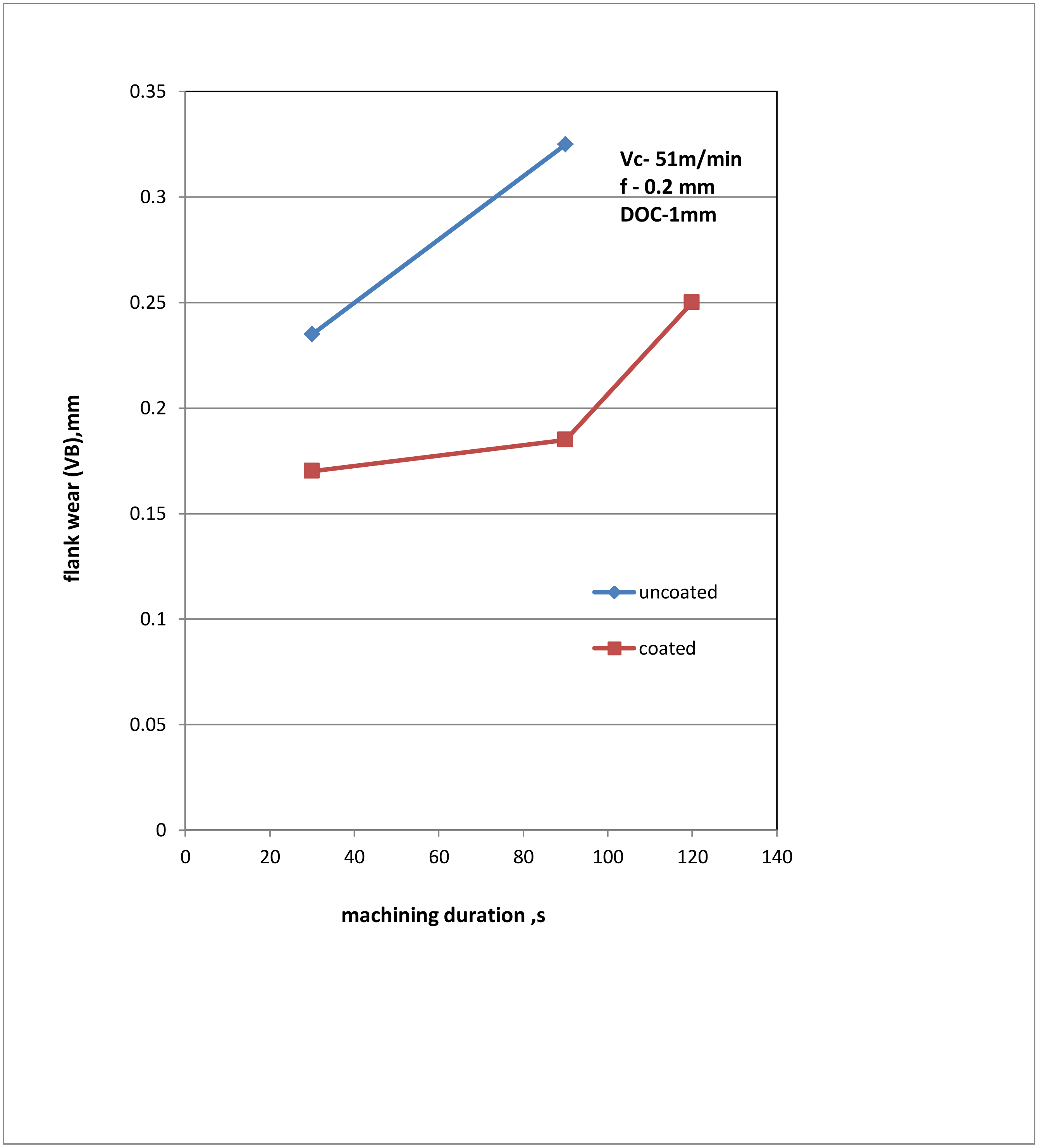


**Figure 8. Variation of machining duration and cutting speed on flank wear for uncoated and multilayer coated inserts.**

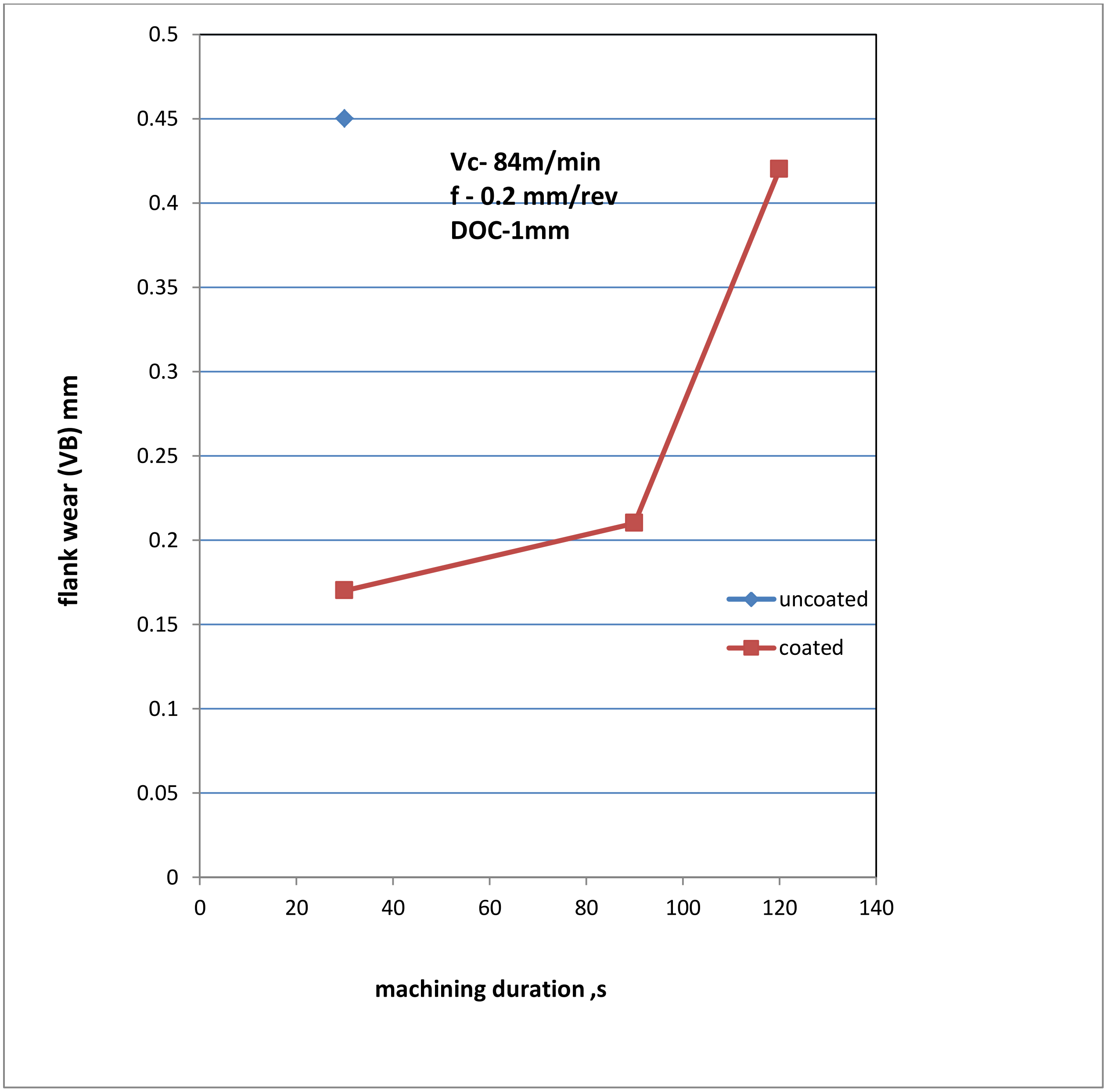



Table 7 and 8 represents the Variation flank wear with machining duration and cutting speed for uncoated and coated inserts cutting speed of 51m/min Cutting speed of 84m/min.

# 5. CONCLUSION

The present work on machinability of NIMONIC C-263 was performed with variable cutting speed and tool coating and their effect in tool wear and chip reduction coefficient was studied and the following inference were made ,these are

1. Chip thickness ratio increase with increase of cutting speed due to the reduction of shear zone.
2. At lower cutting speed chip thickness ratio is high due to the higher coefficient of friction between Tool Chip inter face resulting thick cutting chip thickness.
3. Flank wear increase with increase of cutting speed and machining time and can minimized with the CVD multilayer tool insert.
4. From the above experiment it is recommended that the use of coated carbide tool for the machining of Super alloy C-263.

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