© July 2015 | IJIRT | Volume 2 Issue 2 | ISSN: 2349-6002

# Effect of Cutting Parameter on Surface Roughness and MRR for machining High Chrome Steel using CBN 7025 Tool Material

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***Abstract*- The use of hardened steel is increasing rapidly nowadays. Simultaneously the requirement for machining of hardened steel is also increasing. The present research work deal with the optimization of cutting parameters such as spindle speed, feed, depth of cut, MRR and surface roughness value for hardened steel by using Advanced Cutting Tools. Hence the present study use the high chrome steel bar as work piece and CBN 7025 tool with different shape of insert (like C type, D type, W type, T type etc.) and focused on the optimum value of material removal rate(MRR) and surface roughness(Ra) by using the taguchi $L_8$ orthogonal array and ANOVA analysis. The C type cutting insert gives the higher material removal rate and the T type cutting insert gives the higher surface finish and ANOVA analysis suggested that the depth of cut and feed are the main affecting factor for material removal rate and surface roughness.**

## I. INTRODUCTION

CNC is the Computer Numerical Control. it is controlled by the programmatically. In the CNC the machine tool programmatically via computer. The CNC is 3-5 axis machines. The CNC might be controlled using, (punched type, NC and later CNC, and allowed for increase in productivity. The CNC machine could be run automatically without require attention of operator. In the research paper we use the cutting parameter like speed, feed and depth of cut, and nose radius.

**Speed**

Speed is always refers to the spindle speed and work piece. And its unit is revolution per minute (rpm) its show their rotating speed. In the turning operation the surface speed, or the speed at which the work piece material is moving past the cutting tool. The equation of the cutting speed is

$V_c = \frac{\pi DN}{1000}$ m/min

**Feed**

Feed is always refers the cutting tool. In the power fed lathe the feed is directly related to the spindle speed. And it is expressed in mm/revolution of tool and spindle. The equation of the feed is

$F = fN$ mm/min

Where F is the Feed in mm/min, f is the feed in mm/rev, N is the spindle speed in rpm.

**Depth of cut**

Depth of cut is the practically self-explanatory. Its measured by the distance between the uncut surface and cut surface. And also its expressed in mm.

After this cutting parameter we selected an advance cutting tool and hardened material. So we selected a Cubic Boron Nitride insert as a cutting insert and the High Chrome steel material as a work piece material.

**Cubic Boron Nitride (CBN)**

The Cubic Boron Nitride introduced in 1960s. It is the second hardest material after the diamond. CBN tool is used in terms of small solid tips as a 0.5 to 1 mm thick layer of polycrystalline boron nitride. The Cubic boron nitride is use for machining alloy and tool steel with the hardness of 50 Rc or higher.

**High Chrome Steel**

The high chrome steel is the type of hardened steel in the high chrome steel the material is coated with the chromium and this material hardness range is 56-74 Rc (Rockwell c). This material is use in the drill bits, wear resistant parts, metal cutting tool, Heavy machine parts, etc.

**1.1 Problem Definition**

In the production industries the hardened material is difficult to cut by the ordinary tool material and they cannot get the maximum material removal rate and higher surface finish. The CBN is work on the hardness material and easily to cut the material without the tool wear. The hardened material have hardness is above 60 Rc so the CBN is also work in above 60 Rc. So we selected a High chrome steel material as a work piece material and the hardness of this material is 65 Rc and CBN 7025 is selected as a cutting tool material.
Using this work piece material and cutting insert we fo`und the maximum material removal rate and higher surface finish.

**1.3 Research Methodology**

First of all we needed concentrate on the similar kind of problem which has experience by the industries. And from t is different kind of problem author have review the number of paper in which focus in several parameter on turning.

On the basis of literature review and problem encountered in the industries

- Define the cutting condition.
- Define the cutting insert.
- Selection of work piece material..
- Pilot Experimental for hard turning.
- Experimental setup for final experiment
- Design of experiment.
- Final experiment
- Observation and analysis.
- Optimization and validation.

## II. LITERATURE REVIEW

[1] Present that the effects of cutting speed, feed rate, work piece hardness and depth of cut on surface roughness and cutting force components in the hard turning were experimentally investigated. AISI H11 steel was hardened to (40; 45 and 50) HRC, machined using cubic boron nitride (CBN 7020 from Sandvik Company) which is essentially made of 57% CBN and 35% TiCN. Four-factor (cutting speed, feed rate, hardness and depth of cut) and three-level fractional experiment designs completed with a statistical analysis of variance (ANOVA) were performed. Mathematical models for surface roughness and cutting force components were developed using the response surface methodology (RSM). Results show that the cutting force components are influenced principally by the depth of cut and workpiece hardness; on the other hand, both feed rate and workpiece hardness have statistical significance on surface roughness. Finally, the ranges for best cutting conditions are proposed for serial industrial production.2] present that the experiment is conduct in the work piece material on EN 8 in CNC turning machine by using TNGA Cutting insert and input parameter is speed, feed, and depth of cut and output parameter is surface roughness. Found the optimum value by using taguchi $L_9$ method and ANOVA analysis. In the ANOVA gives the higher effect on surface roughness. [3] Present that the experiment is conduct on CNC turning machine on AISI 1045 cylindrical bar as a work piece by using tungsten carbide insert. The cutting parameter is speed, feed, and depth of cut. They conclude that the speed is most significant parameter on roundness. Found the optimum condition of surface roughness at cutting speed 0.25 mm/rev feed rate and 0.2 mm depth of cut. [4] conduct the experiment on AISI 1040 MS bar in CNC turning machine by using HSS tool Miranda S-400. Using the cutting parameter like speed, feed and depth of cut. They used the taguchi $L_9$ orthogonal array and set the cutting parameter and find the optimum value of surface roughness. And found that the depth of cut is most significant, spindle speed is significant and feed rate is least significant factor affecting the surface roughness. [5] Investigate the experiment is conduct on AISI 1045 work piece material in CNC turning machine by using the HSS AISI designated grade- 7. The cutting parameter is speed, feed and depth of cut and the output parameter is surface roughness. The ANOVA analysis used to anylise the influence of machining parameters on surface roughness Ra.

[6] have conduct the experiment on AISI 304 authainatic stainless steel using chemical vapor deposition coated cimented carbide insert and the cutting parameter is speed, feed, depth of cut and nose radius and found the optimum value for material removal rate and surface roughness by the taguchi $L_8$ orthogonal array. And using the ANOVA analysis to approach the most significant parameter. Found that the depth of cut is the most significant parameter for surface roughness and nose radius is significant

parameter for surface roughness. [7] Present that the experiment is conduct on EN 8 and EN 31 steel with 55 HRc work piece material in cnc turning machine by using TN66 and TN0500 cutting insert. Using the cutting parameter like speed 200, 250, 300 m/min, feed 0.08, 0.12, 0.15 mm/rev, and depth of cut is 0.5mm and get the TN 60 tool get the minimum surface roughness with low feed rate. [8] present that the experiment is conduct on aluminum alloy and resin work piece material in CNC turning machine by using the HSS tool. And the process parameter is speed , feed and depth of cut. Found that in allumimium alloy the roughness is 1.18µ and material removal rate is 1387.83 $mm^3$/min. and in resin the roughness value is 2.295 µ and material removal rate is 182.899 $mm^3$/min.[9] present that the experiment is conduct on AISI 4340 in CNC turning machine by using the CBN-L cutting insert. In this paper the input parameter is speed, feed and depth of cut. Speed is set 270 m/min that time the material removal rate is 343 $cm^3$ and set the speed at 150 m/min that time the material removal rate is 180 $cm^3$[10] investigate the experiment is conduct on AISI D2 steel with hardness of 62 HRc in CNC turning machine using PCBN. In this paper the cutting parameter is speed, feed, and depth of cut. Optimize the cutting parameter the cutting speed 70-120 m/min and feed is 0.08-0.21 that time the material removal rate is 70m/min.

## III. EXPERIMENTAL SETUP

### 3.1 Define cutting condition

In the cutting condition we found the CNC turning machine, cutting insert, cutting parameter, work piece material.

3.1.1 CNC turning machine.

In the CNC turning machine the Chamunda 305 L CNC machine is selected.

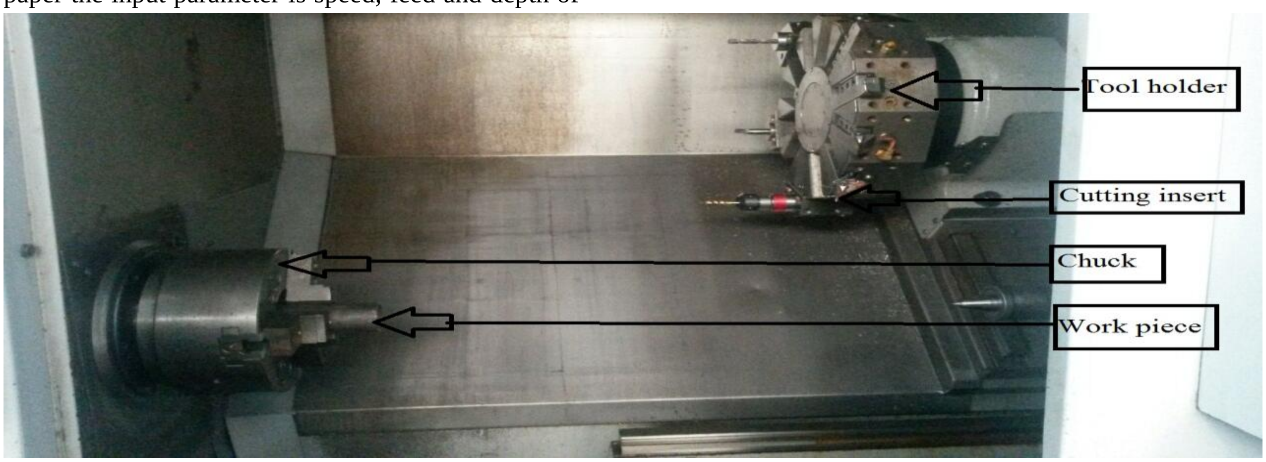



Fig.1 Chamunda 305 L CNC turning machine.

**TABLE 1** Specification of CNC turning machine

| | DESCRIPTION | UNIT | SIZE |
|---|---|---|---|
| CAPACITY | center length | Mm | 550 |
| | Minimum turning length (without tail stock) | Mm | 500 |
| | Standard chuck size | Mm | 200 |
| | Standard chucking cylinder | | P-110 |
| CNC SYSTEM | | | Siemens 828d Basic T |
| | Spindle type | | Cartridge |

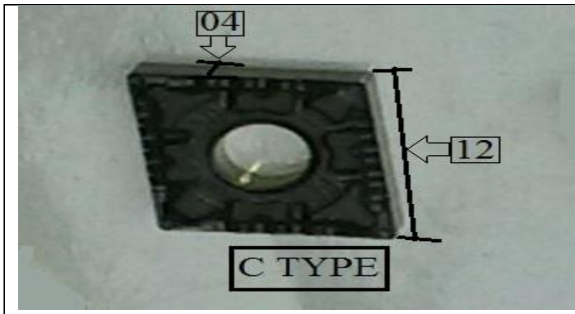
| | | | |
|---|---|---|---|
| **SPINDLE** | Spindle nose | | A2-6 |
| | Spindle bore | Mm | 63 |
| | Standers bar capacity | Mm | 42 |
| | Front bearing bore | Mm | 100 |
| | Std spindle speed | Rpm | 3500 |
| **POWER** | Spindle motor power continues | Kw | 7.5 |
| | Spindle motor power intermitted(15 min) | Kw | 11 |
| **TOOLING** | Turret number of tool maximum | | BTP-80 8 |
| | Number of station | | 8 |
| | A/f of turret disc | Mm | 280 |
| | Maximum boaring bar dia | Mm | 40 |
| | Od turning tool size | Mm | 25x25 |
| **AXES** | Axes motor model | | Siemens FX7080 |
| | x-y axis guide way x- axis stock | Mm | LM Guide way 150 |
| | z- axis stock | Mm | 500 |
| | X&y Ball screw dia. and pitch | Mm | 32x10 |
| | x-y axis Rapid rate | m/min | 20 |
| **TAIL STOCK** | Tail stock quill travel | Mm | 100 |
| | Tail stock base travel | Mm | 410 |
| | Tailstock thrust(max) | Kgf | 500@20kg/cm2 |
| | Tailstock quill dia. | Mm | 80 |
| | Quill taper | | MT-4 |
| | Tailstock center type | | Add on |

**3.2 Define Cutting Insert**

In the cutting insert the CBN 7025 insert is selected because the CBN 7025 insert is work on a harden material. The shape of the CBN 7025 insert is C type, D type W type T

3.2.1 Cutting Insert Specification for C Type

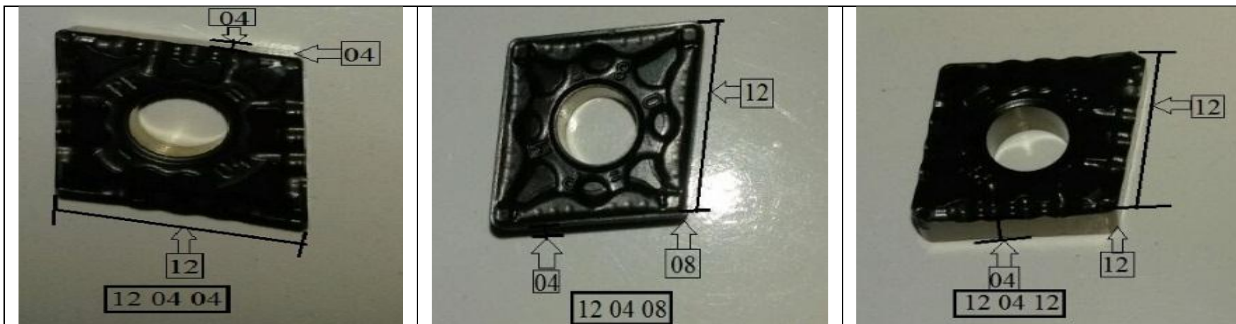
Type and R type but in the pilot experiment we using the C, D, W and T type insert with different nose radius 0.4, 0.8 and 1.2




C TYPE

Fig 2 C Type insert

Fig. 2 Shows that the C type insert have a 12 mm length and 4 mm width type negative cutting insert and the angle of the cutting insert is $80^0$.

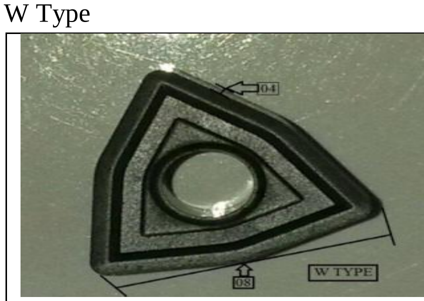



| | | |
|---|---|---|
| C TYPE (12 04 04) | CTYPE (12 04 08) | C TYPE (12 04 12) |

Fig. 3 Description of C Type inserts

Fig 3 shows the different nose radius of the C type cutting insert like (0.4, 0.8, 1.2) respectively.

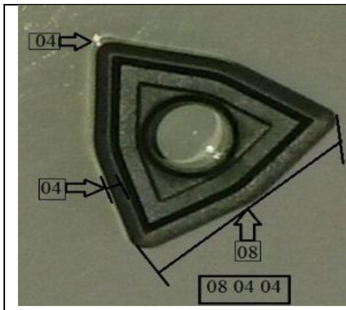
3.2.2 Cutting Insert Specification for W Type

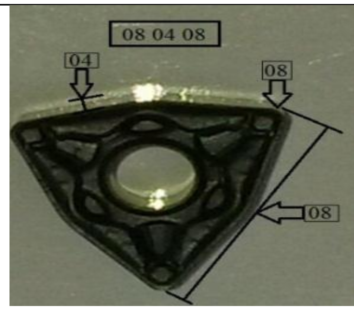


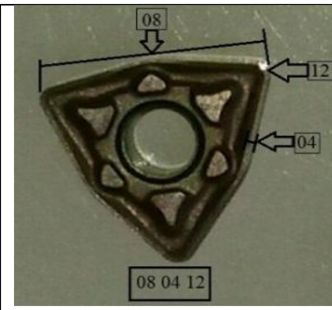

W TYPE

Fig 4 W Type insert

Fig. 4 Shows that the C type insert have a 08 mm length and 4 mm width type negative cutting insert and the angle of the cutting insert is $60^0$.



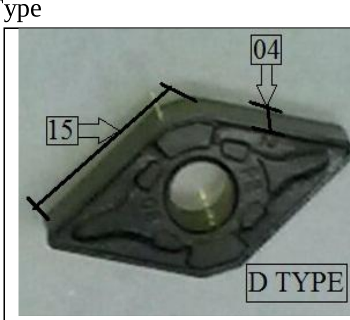




| | | |
|---|---|---|
| W TYPE(08 04 04) | W TYPE(08 04 08) | W TYPE(08 04 12) |

Fig 5 Description of W Type Insert

Fig 5 shows the different nose radius of the W type cutting insert like (0.4, 0.8, 1.2) respectively.

3.2.3 Cutting Insert Specification for D Type

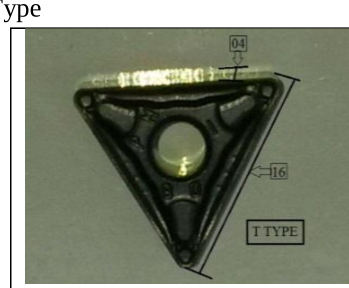



D TYPE

Fig 6 D Type insert

Fig. 6 shows that the D type insert have a 15 mm length and 4 mm width type negative cutting insert and the angle of the cutting insert is $54^0$.

3.2.4 Cutting Insert Specification for T Type




T TYPE

Fig 7 T Type insert

Fig. 7 shows that the T type insert have a 16 mm length and 4 mm width type negative cutting insert and the angle of the cutting insert is $80^0$.

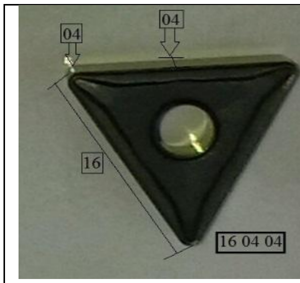
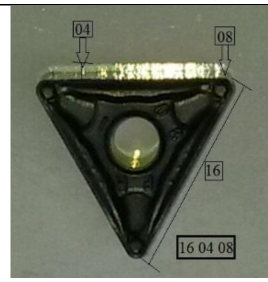
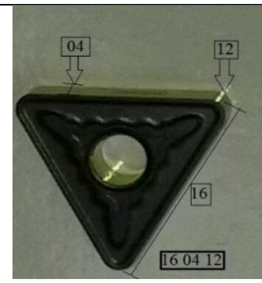
|   |   |   |
|---|---|---|
| T TYPE (16 04 04) | T TYPE (16 04 08) | T TYPE (16 04 12) |

Fig 8 Description of T Type inserts

Fig 8 shows the different nose radius of the T type cutting insert like (0.4, 0.8, 1.2) respectively.

3.3 Selection of Work Piece Material

High chrome steel has coated with the high chromium also in the high chrome steel the carbon percentage is higher so this material is known as a high carbon high chrome steel or a AISI D2 steel. Hardness of the high crome steel is 65 HRc. The chemical composition of the high chrome steel is shown in table 2

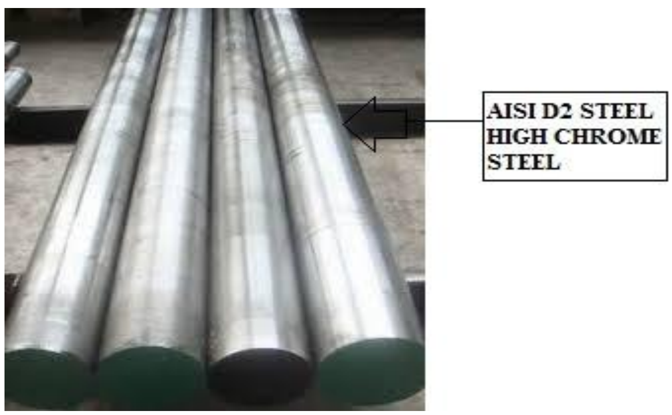



Fig 9 High Chrome Steel Materials, Ref [11]

**TABLE 2** Chemical Composition of High Chrome Steel [12]

| C | Si | Mn | S | P | Ni | Cr | Mo | Cu | Fe |
|---|---|---|---|---|---|---|---|---|---|
| 0.8 | 0.5 | 0.57 | 0.026 | 0.023 | 0.5 | 12 | 0.081 | 0.042 | Balance |

3.4 Pilot experiment setup

In this pilot experiment we found the material removal rate and surface roughness for different cutting insert with different nose radius. And selected the suitable cutting insert for final experiment and find the material removal rate and surface roughness.

The material removal rate is find by the equation

**MRR=** $\pi \times D \times ap \times fd \times N(mm3/min)$

and surface roughness is find by the surface measuring instrument (TR110)

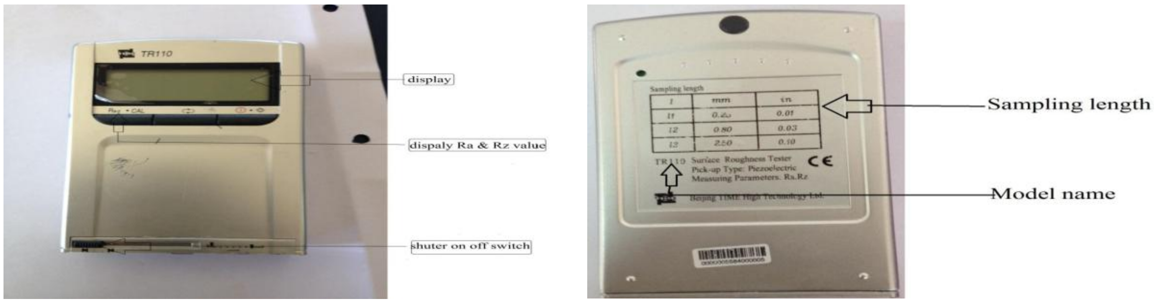



Fig 10 Surface measuring instrument

(TR110)

3.4.1 Pilot experiment for C type insert

**TABLE 3** Pilot experiments for C type insert

| Tool **C type** | Feed (Fd) mm/rev | Cutting velocity (vc) | Depth of cut (ap) Mm | Material Removal Rate(MRR) $mm^3$/min | Surface roughness (µm) | speed (N) RPM |
|---|---|---|---|---|---|---|
| 12 04 04 | 0.18 | 180 | 1 | 32386 | 1.132 | 955 |
| 12 04 08 | 0.28 | 155 | 1 | 43415 | 1.218 | 823 |
| 12 04 12 | 0.32 | 145 | 1.1 | 51064 | 1.317 | 770 |

Table 3 shows that the maximum material removal rate is found at the speed is 145 m/min, feed is 0.32 mm/rev and depth of cut 1.1 mm and nose radius 1.2mm and minimum surface roughness is found at speed is 180 m/min, feed is 0.18 mm/rev., depth of cut is 1mm and nose radius is 0.4mm.

3.4.2 Pilot experiment for W type insert

**TABLE 4** Pilot experiments for W type insert

| Tool **(WNGA)** | Feed (Fd) mm/rev | Cutting velocity (vc) | Depth of cut (ap) Mm | Material Removal Rate(MRR) $mm^3$/min | Surface roughness (µm) | speed (N) RPM |
|---|---|---|---|---|---|---|
| 08 04 04 | 0.18 | 145 | 1 | 26112 | 1.295 | 770 |
| 08 04 08 | 0.28 | 130 | 1 | 36398 | 1.325 | 690 |
| 08 04 12 | 0.32 | 125 | 1.1 | 43969 | 1.358 | 663 |

Table 4 shows that the maximum material removal rate is found at the speed is 125 m/min, feed is 0.32 mm/rev and depth of cut 1.1 mm and nose radius 1.2mm and minimum surface roughness is found at speed is 145 m/min, feed is 0.18 mm/rev., depth of cut is 1mm and nose radius is 0.4mm.

3.4.3 Pilot experiment for D type insert

**TABLE 5** Pilot experiments for D type insert

| Tool (DNGA) | Feed (Fd) mm/rev | Cutting velocity (vc) | Depth of cut (ap) Mm | Material removal Rate (MRR) $mm^3$/min | Surface roughness (µm) | speed (N) RPM |
|---|---|---|---|---|---|---|
| 15 04 04 | 0.08 | 180 | 0.5 | 7197 | 0.852 | 955 |
| 15 04 08 | 0.18 | 170 | 0.5 | 15260 | 0.935 | 900 |
| 15 04 12 | 0.28 | 160 | 0.5 | 22394 | 0.964 | 849 |

Table 5 shows that the maximum material removal rate is found at the speed is 160 m/min, feed is 0.28 mm/rev and depth of cut 0.5 mm and nose radius 1.2mm and minimum surface roughness is found at speed is 180 m/min, feed is 0.08 mm/rev., depth of cut is 0.5 mm and nose radius is 0.4mm.

3.4.4 Pilot experiment for T type insert

**TABLE 6** Pilot experiments for T type insert

| Tool T type | Feed (Fd) mm/rev | Cutting velocity (vc) | Depth of cut (ap)Mm | Material Removal Rate (MRR)$mm^3$/min | Surface roughness (µm) | speed (N) RPM |
|---|---|---|---|---|---|---|
| 16 04 04 | 0.08 | 190 | 0.5 | 7588 | 0.792 | 1007 |
| 16 04 08 | 0.18 | 180 | 0.5 | 16192 | 0.861 | 955 |
| 16 04 12 | 0.28 | 170 | 0.5 | 23739 | 0.983 | 900 |

Table 6 shows that the maximum material removal rate is found at the speed is 170 m/min, feed is 0.28 mm/rev and depth of cut 0.5 mm and nose radius 1.2mm and minimum surface roughness is found at speed is 190 m/min, feed is 0.08 mm/rev., depth of cut is 0.5 mm and nose radius is 0.4mm.

3.4.5. Summary of maximum MRR and minimum surface roughness for C, W, D, and T type insert.

1) Summery of maximum material removal rate for C,W, D, and T type insert

**TABLE 7** Summery of maximum material removal rate for C,W, D, and T type insert

| Sr. no | Insert type | Speed | Feed | Depth of Cut | Nose Radius | Material removal rate |
|---|---|---|---|---|---|---|
| 1 | **C type** | **145** | **0.32** | **1.1** | **1.2** | **51064** |
| 2 | W type | 125 | 0.32 | 1.1 | 1.2 | 43969 |
| 3 | D type | 160 | 0.28 | 0.5 | 1.2 | 22394 |
| 4 | T type | 170 | 0.28 | 0.5 | 1.2 | 23739 |

1) Summery of minimum surface roughness for C,W, D, and T type insert

**TABLE 8** Summery of minimum surface roughness for C,W, D, and T type insert

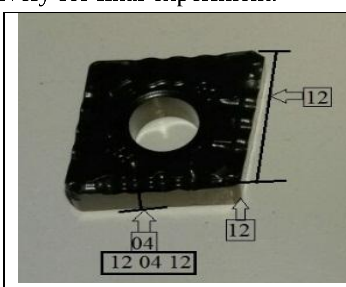
| Sr. no | Insert type | Speed | Feed | Depth of Cut | Nose Radius | Surface Roughness |
|---|---|---|---|---|---|---|
| 1 | C type | 180 | 0.18 | 1 | 0.4 | 1.132 |
| 2 | W type | 145 | 0.18 | 1 | 0.4 | 1.295 |
| 3 | D type | 180 | 0.08 | 0.5 | 0.4 | 0.852 |
| 4 | **T type** | **190** | **0.08** | **0.5** | **0.4** | **0.792** |

In the Table 7 and 8 shows that the C type insert get maximum material removal rate and T type insert get the minimum surface roughness so we selected the C and T type insert for material removal rate and surface roughness respectively for final experiment.

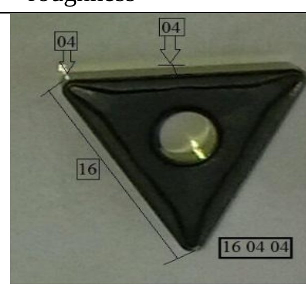
**3.5 Experimental setup and final experiment**

3.5.1. Cutting insert

Base on the pilot experiment C type and T type insert is selected for the material removal rate and surface roughness



C TYPE (12 04 12)



T TYPE (16 04 04)

Fig 11 Cutting insert

3.5.2. Cutting parameter

**TABLE 9** Cutting parameter

| Insert type | Speed | Feed | Depth of cut | Nose radius |
|---|---|---|---|---|
| C type | 145, 180 | 0.18, 0.32 | 0.5, 1.5 | 1.2 |
| T type | 170, 190 | 0.08, 0.28 | 0.5, 1.5 | 0.4 |

### 3.6 Design of experiment and Final experiment

In the design of experiment the Taguchi $L_8$ orthogonal array is used. And the taguchi $L_8$ orthogonal table is generated in the base of selected Cutting parameter

1) Proposed DOE Table for C type (CNGA 120412) Insert

**Table 10** Proposed DOE Table for C type (CNGA 120412) Insert

| Sr. no. | Speed (m/min) | Feed (mm/rev) | Depth of cut (mm) | Nose radius (mm) |
|---|---|---|---|---|
| 1 | 145 | 0.18 | 0.5 | 0.8 |
| 2 | 145 | 0.18 | 1.5 | 1.2 |
| 3 | 145 | 0.32 | 0.5 | 1.2 |
| 4 | 145 | 0.32 | 1.5 | 0.8 |
| 5 | 180 | 0.18 | 0.5 | 1.2 |
| 6 | 180 | 0.18 | 1.5 | 0.8 |
| 7 | 180 | 0.32 | 0.5 | 0.8 |
| 8 | 180 | 0.32 | 1.5 | 1.2 |

## IV. RESULT AND DISCUSSION

The optimum result for output surface roughness and material removal rate in terms of machining parameter of speed, feed, depth of cut and nose radius for material high chrome steel in on CNC turning machine have been obtained.

Base on the experimental result the C type insert gives the highest material removal rate and T type insert gives the highest surface finish.

In the C type insert the cutting parameter of 145 and 180 m/min, feed is 0.18 and 0.32 mm/rev, depth of cut is 0.5 and 1.5mm, and the nose radius is constant 1.2. now apply this cutting parameter the optimum value of the material removal rate is 86406.46 $mm^3$/min at speed is 180m/min, feed is 0.32 mm/rev, depth of cut 1.5 mm.

In the T type insert the cutting parameter of 170 and 190 m/min, feed is 0.08 and 0.28 mm/rev, depth of cut is 0.5 and 1.5mm, and the nose radius is constant 0.4. now apply this cutting parameter the optimum value of surface roughness is 0.7925 µm at speed is 190m/min, feed is 0.08 mm/rev, depth of cut 0.5 mm.

In the Design of experiment we use the taguchi method in this taguchi method there are different types of orthogonal array L4, L8, L9, L12, L16, L25, L27, and L32. In this orthogonal array the L8 orthogonal array is selected because of thus array the experimental run is lower and gets the optimum value of material removal rate and surface roughness.

## V. CONCLUSIONS

The conclusions have been made on the basis of experiment results. The current study was done to study the effect of cutting parameters on the surface Roughness, and material removal rate. The following conclusions are drawn from the study:

- C type insert gives the higher material removal rate.
- T type insert gives the higher surface roughness.
- The Better results have been obtained in terms of DOE techniques such as Taguchi and ANOVA using MINITAB software.
- In the Material removal rate the main affecting factor is Depth of cut and feed also the surface roughness the main affecting factor is Depth of cut and feed.
- ANOVA reveal that the Depth of cut and feed is the most affection process parameter followed by other parameters for Material removal rate and surface roughness.

## VI. FUTURE SCOPES

The machining was done on High Chrome Steel material to study the effect on process parameters like (speed, Feed. Depth of cut and Nose radius) on output parameter like (Surface roughness and material removal rate). Performance evaluation was done on surface roughness and material removal rate. Performance characteristic was analyzed by using Taguchi's Technique and regression analysis.

• The future scope of this deep study can be explore with advance work material have above 66HRc

• The material of cutting tool is used in this project was CBN 7025 with the shape of C, D, t and W type and nose radius is 0.4,0.8,1.2.. The experiment can be performed with different cutting insert on CNC turning machine. The future scope of this project with different nose radius of cutting inserts and the Round shape of cutting insert with positive and negative side cutting insert.

• The future scope of this project to find out the tool wear, tool life, and material removal rate with dry and wet condition.

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