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Experimental Investigation on Surface Roughness and Chip Morphology during CNC Turning of Aluminium (6063-T6)

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Abstract: ***The surface roughness is an important measure of product quality since it greatly affects the performance of mechanical parts as well as production cost. In this research work numbers of the experiment are carried out to investigate the evolution of chip morphology and its effect on surface roughness during CNC turning of aluminium 6063-T6 using different cutting tool inserts. Further, it is also present an effect of various cutting parameters and cutting tool geometry on surface roughness. After conducting experiment various chips are examined under a microscope for chip morphology and the effect of various types of chips on the surface finish is studied.***

Keywords: CNC Turning, surface roughness, chip morphology, Taguchi, ANOVA

I. INTRODUCTION

In modern machining industry, product quality is an important factor to keep in mind in order to achieve higher productivity. The turning process on a CNC is programmed by speed, feed rate, and cutting depth according to job characteristics which are frequently determined based on the job shop experiences. However, these cutting conditions are not guaranteed to be acceptable. Therefore, the optimum turning conditions have to be accomplished. This paper investigates the cutting parameters of Aluminum alloy 6063 in CNC turning machine and optimize these cutting parameters like depth of cut, speed, and feed. The cutting inserts used are CNMG, DNMG, and TNMG with appropriate shim material. After measuring surface roughness of machined part these results are related with chip morphology study. From an experimental result, an optimum cutting condition is being obtained.

A. Turning Process

Turning is the most common machining operation carried out in any machine shop. Turning is a form of metal removal process which is used to modify the shape, dimension, and surface roughness of a workpiece by removing the unwanted material in the form of chips. Turning is largely used to mate one part with other parts in the die, aerospace, automotive and machinery design also in manufacturing industries. To perform turning operation, relative motion is achieved between primary motion, called the cutting speed, and the secondary motion, called the cutting feed. In turning operation primary motion is provided to the workpiece while secondary motion is provided to the cutting tool. By using a combination of these motions, the desired shape of the machined surface can be obtained.

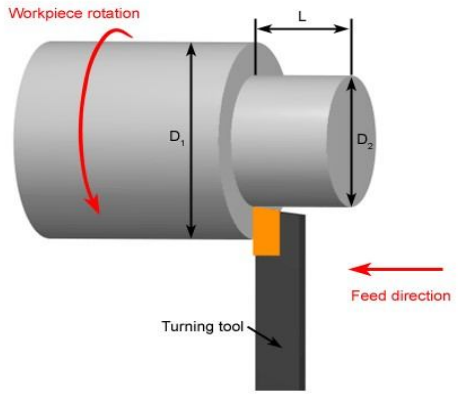


Fig. 1 Turning process

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B. What is Surface Roughness?

Surface roughness is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Quantitatively, surface roughness is evaluated by means of one or more of the following main parameters: the arithmetical average deviation of the surface profile (Ra), the height of irregularities at ten points (Rz), the maximum height of irregularities (Rmax), the average spacing of irregularities (Sm), the average peak spacing of irregularities (S), and the sampling length of the profile (tp).

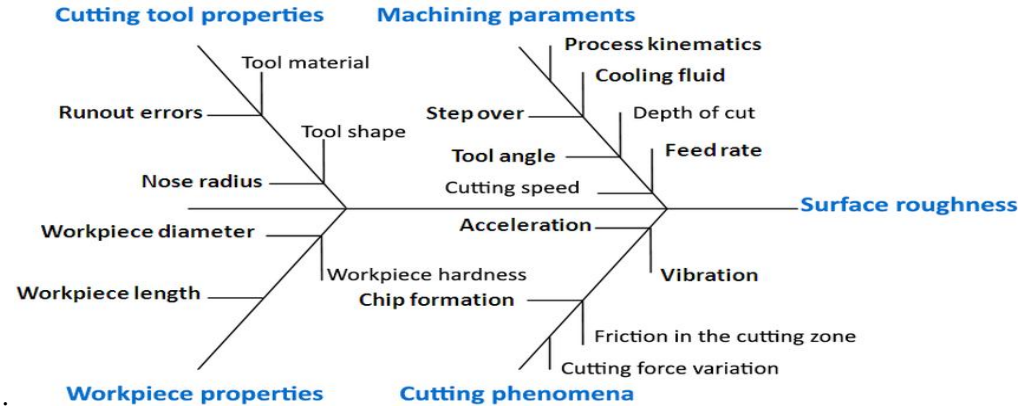


Fig.2 Factors affecting surface finish

II. LITERATURE REVIEW

Daochun Xu et al. (2014) [1] had investigated the chip formation process of aluminium alloy 6061-T6 by performing a series of operation on a wide range of cutting speed and feed. By doing so, there are seven types of chips were obtained in the operation. In this experiment, the chips mainly appear to be a continuous chip, discontinuous chip, and curling chip. By increasing cutting speed, friction angle, chip thickness, length and width of the first shear zone decreases and there is an increase in shear slide distance and shear angle by increasing cutting speed.

Fuda Ning et al. (2014) [2] studied chip morphology and its effect on surface roughness during milling of Inconel 718 alloy. They found that when cutting speed increases from 25 to 200 m/min, the chip burrs value decreases first and then increases. Both height and pitch of chip burrs reach the lowest value at a cutting speed of 75 m/min and serrated chip begin to appears. That cutting speed is called critical cutting speed and the surface roughness R_a is also minimum at that point.

Vickey Nandal et al. (2015) [3] concluded that during machining of AISI 4140 (410 HV) steel, the formation of Continuous and saw tooth chips take place at relatively low cutting speeds and different feed rate has been examined. All cutting tests were performed by using Cubic boron nitride (CBN) tool inserts on specific cutting speeds from 75 m/min to 150 m/mi. This study investigated that both cutting speed and feed rate are found to have an influence on the chip thickness.

Basim A. Khidhir et al. (2010) [4] has done a study on turning operation of nickel-based Hastelloy C-276 using different types of inserts using CNC machine at different stages of cutting speed. By using different types of inserts chip transition is taking place from thick continuous chip to wider discontinuous chip. The burrs disappear for the coated insert tips when the speed changed to 150m/min and also surface roughness is improved.

Mohamed Baccar Mhamdi et al. (2013) [5] has performed an operation on AISI-D2 steel at different cutting conditions and observed their chip formation mechanism to obtain optimum cutting condition. During machining, process chips are collected for microscope examination and from the study of chip morphology it is found that the chip formation mechanism is affected by cutting conditions.

Walid Mahmoud Shewakh (2013) [6] investigated the influence of shim materials on the surface quality during hard turning of bearing steel. Using shims made of natural and composite materials to enhance the damping properties of the ceramic inserts holding systems, the surface roughness is being evaluated. The experimental results show that the chlorites and sandstones have the minimal acoustic activity, the sandstones shim has the minimal vibration within high frequencies: within the low frequencies, the chlorites shims have shown advanced priority against the other shims.

Basil M. Eldhose et al. (2014) [7] investigates the effects of various parameters such as depth of cut, speed and feed on the material removal rate and surface roughness of the SS304 in a CNC turning machine. There are three factors cutting speed, feed, and depth of cut at three different levels are taken for experiment and their degree of influence is studied. Taguchi method is adopted in the

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design of the experiment to reduce numbers of the experiment. In this analysis, they concluded that speed is the most influencing parameter followed by the depth of cut and feed.

Nachimuthu A. K. (2013) [8] Taguchi method for minimization of surface roughness in turning operation. During operation, we have to select various cutting parameter combinations of speed, feed, and depth of cut which is always not acceptable. So, by using Taguchi method these parameters combination can be predicted and according to control level numbers of experiments are carried out. At a speed of 4000rpm, the feed of 0.2m/min, and using aluminium shim material, surface roughness reduced to its minimum value. ANOVA analysis is used to find cutting parameters effect on surface roughness.

III.EXPERIMENTAL SETUP

A. Material

The material studied here is aluminium 6063-T6. The length and diameter of the workpiece are 100mm and 50mm respectively.

TABLE I
Chemical composition of aisi d2 steel, WT %.

Component	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Other
Wt. %	Max 97.5	0.0-0.10	0.0-0.10	0.0-0.35	0.45-0.90	0.0-0.10	0.20-0.60	0.0-0.10	0.0-0.10	0.0-0.05

B. Test conditions

1) CNC Machine: The turn master GF 165-A CNC lathe machine is used for performing experiments.



Fig. 3 CNC Machine

TABLE II
Machine Specifications

Sr. No.	Specifications	Units
1	Maximum Turning Diameter	200mm
2	Maximum Turning length	300mm
3	Distance between center	550mm
4	Spindle motor	5HP
5	Chuck Size	165mm
6	Positioning Accuracy	0.008mm
7	Motor power	0.18KW

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2) Surface Roughness Tester: The Mitutoyo Sj-210 surface roughness tester used for measuring surface roughness of workpiece after machining



Fig.4 Surface roughness tester

3) Tool Material: Tool Holder: DCLNR 20412CQ

Cutting insert: (Nose radius=0.81, Grade = CA 225)

1) CNMG-12 04 08 2) DNMG-15 04 08 3) TNMG -22 04 08





IV. RESULT AND DISCUSSION

A. Selection Of Parameters And Levels

The process parameters which are to be optimized were set in levels in the machine range. Each parameter had 3 levels. The effects of these parameters were considered for evaluation of effective response. The process parameters with their respective level are shown in table 3.

TABLE III
Parameters And Levels

No.	Parameters	Level 1	Level 2	Level 3
1	Speed(m/min)	200	250	300
2	Depth of cut(mm)	0.5	1	2
3	Cutting Insert	CNMG	TNMG	DNMG

B. Selection of Orthogonal Array

Experiments were planned according to Taguchi's L27 orthogonal array, which has 27 rows corresponding to the number of experiments (27degrees of freedom) with 3 columns at three different levels as shown in table 3

C. Experiment Procedure

Taguchi analysis is performed according to the selected design of the experiment table. The minimum surface roughness developed in each set of the combination is noted and tabulated in the table. For each experiment, the orthogonal array, signal to noise ratio(S/N) are calculated. The quality response is mainly divided into three categories; the smaller is better, larger is better and nominal is better.

Smaller-the-better' S/N = -10*log (Σ (Y2)/n) (1)
Larger-the-better' S/N = -10*log (Σ (1/Y2)/n) (2)
Nominal-the-better' S/N= -10*log (S2) (3)

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Where y is the measured data y is the average data s is the variance of y and n is the number of samples. For each type of the characteristic with the above S/N ratio transformation the higher the S/N ratio the better is the result. Minitab 18 statistical software used to calculate S/N ratios for each factor are shown in table 4.

D. Surface Roughness Measurement

TABLE IV
Experiment Results For Surface Roughness Corresponding S/N Ratio Of Cutting Parameters

No.	Cutting Insert	Speed(m/min)	Depth of Cut(mm)	Surface Roughness(μm)	S/N Ratio
1	CNMG	200	2	0.438	7.1705
2		200	1	0.371	8.6125
3		200	0.5	0.292	10.6923
4		250	2	0.572	4.8520
5		250	1	0.475	6.4661
6		250	05	0.275	11.2133
7		300	2	0.395	8.0680
8		300	1	0.272	11.3086
9		300	0.5	0.257	11.8013
10	DNMG	200	2	0.995	0.0435
11		200	1	0.907	0.8478
12		200	0.5	0.884	1.0709
13		250	2	0.813	1.7981
14		250	1	0.793	2.0145
15		250	0.5	0.768	2.2927
16		300	2	0.785	2.1026
17		300	1	0.765	2.3267
18		300	0.5	0.743	2.5802
19	TNMG	200	2	1.423	-3.0641
20		200	1	1.085	-0.7085
21		200	0.5	0.952	0.4272
22		250	2	1.110	-0.9064
23		250	1	1.061	-0.5143
24		250	0.5	0.982	0.1577
25		300	2	0.915	0.7715
26		300	1	0.985	0.1312
27		300	0.5	0.951	0.4363

TABLE V
Response Table For Signal To Noise Ratio (Smaller Is Better)

Level	Cutting Insert	Cutting Speed	Depth of Cut
1	8.9094	2.7880	4.5192
2	1.6753	3.0416	3.3872
3	-0.3632	4.3919	2.3151
Delta	9.2727	1.6038	2.2040
Rank	1	3	2

From table 5 delta values, it assigns the rank to each which is having more influence on the mean of surface roughness. From the results S/N ratio also it is observed that Cutting Insert is the dominant factor for surface roughness.

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The influence of control factor can be more clearly presented with the response graph as shown in figure 5

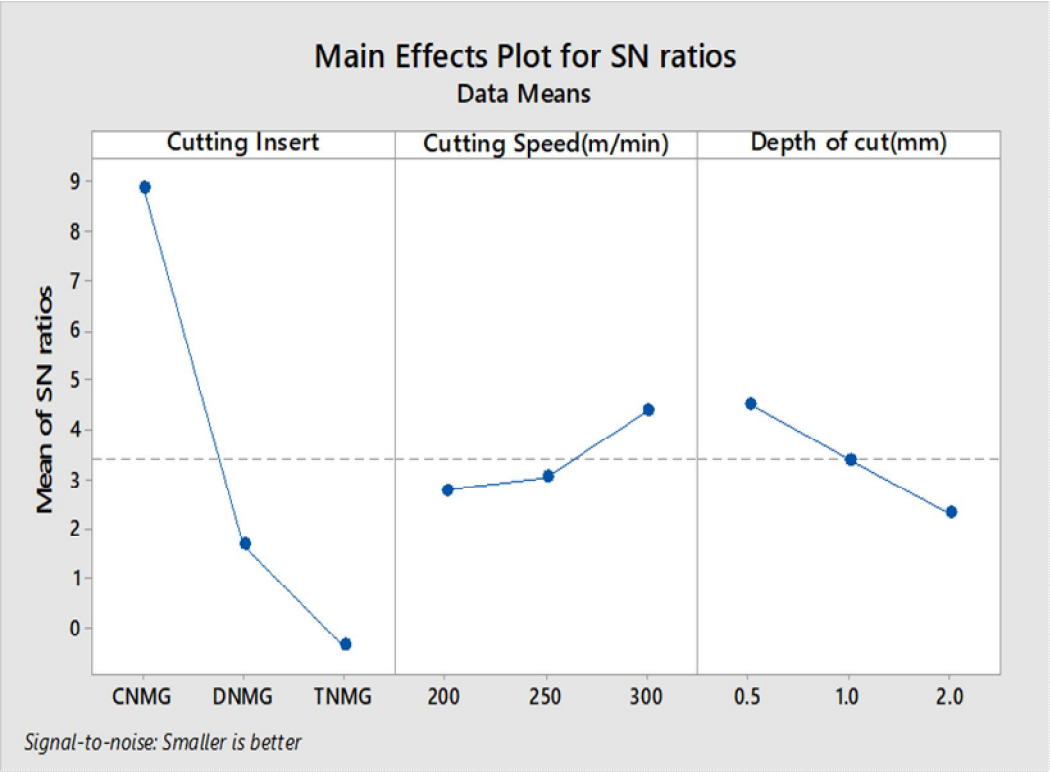


Fig.5 Main effect plots for S/N ratio for surface roughness

From the above graph, the optimum values for the surface roughness are (a) Cutting insert= CNMG (b) Spindle speed =300 m/min (c) Depth of cut = 0.5 mm.

E. Analysis of variance (ANOVA) for Surface Roughness

Minitab 18 statistical software used to obtain ANOVA table for surface roughness. In ANOVA table P value is set in terms of (Alpha = 0.05). If the P value is below 0.05 then parameters are significant level and ANOVA also define as contribution factor for each parameter. It is clear from table 6 that cutting insert is the most significant parameter for surface roughness with a contribution of 88.27% followed by the depth of cut (4.46%) and cutting speed (2.68).

TABLE VI
Analysis Of Variance For Transformed Response

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Cutting insert	2	0.85912	88.27%	0.85912	0.429561	192.14	0.000
Cutting Speed(m/min)	2	0.02605	2.68%	0.02605	0.013025	5.83	0.010
Depth of cut(mm)	2	0.04345	4.46%	0.04345	0.021727	9.72	0.001
Error	20	0.04471	4.59%	0.04471	0.002236		
Total	26	0.97334	100.00%				

F. Chip morphology

Chip morphology is a study of chip geometry which is produced during various operation like turning, milling etc. An understanding of the theory is an important part of the development of such machines and their cutting tools. Types of chips depend on various cutting conditions like speed, feed and depth of cut, work material, tool geometry etc.

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1. Cutting insert: CNMG Speed: 200m/min Depth of cut: 1mm Chip type: Long tubular helical	
2. Cutting insert: CNMG Speed: 300m/min Depth of cut: 2mm Chip type: long tubular	
3. Cutting insert: CNMG Speed: 250m/min Depth of cut: 0.5mm Chip type: washer type helical	
4. Cutting insert: DNMG Speed: 300m/min Depth of cut: 1mm Chip type: loose arc chip	
5. Cutting insert: DNMG Speed: 200m/min Depth of cut: 2mm Chip type: short washer helical	
6. Cutting insert: TNMG Speed: 200m/min Depth of cut: 2mm Chip type: long Snarled ribbon	

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V. CONCLUSIONS

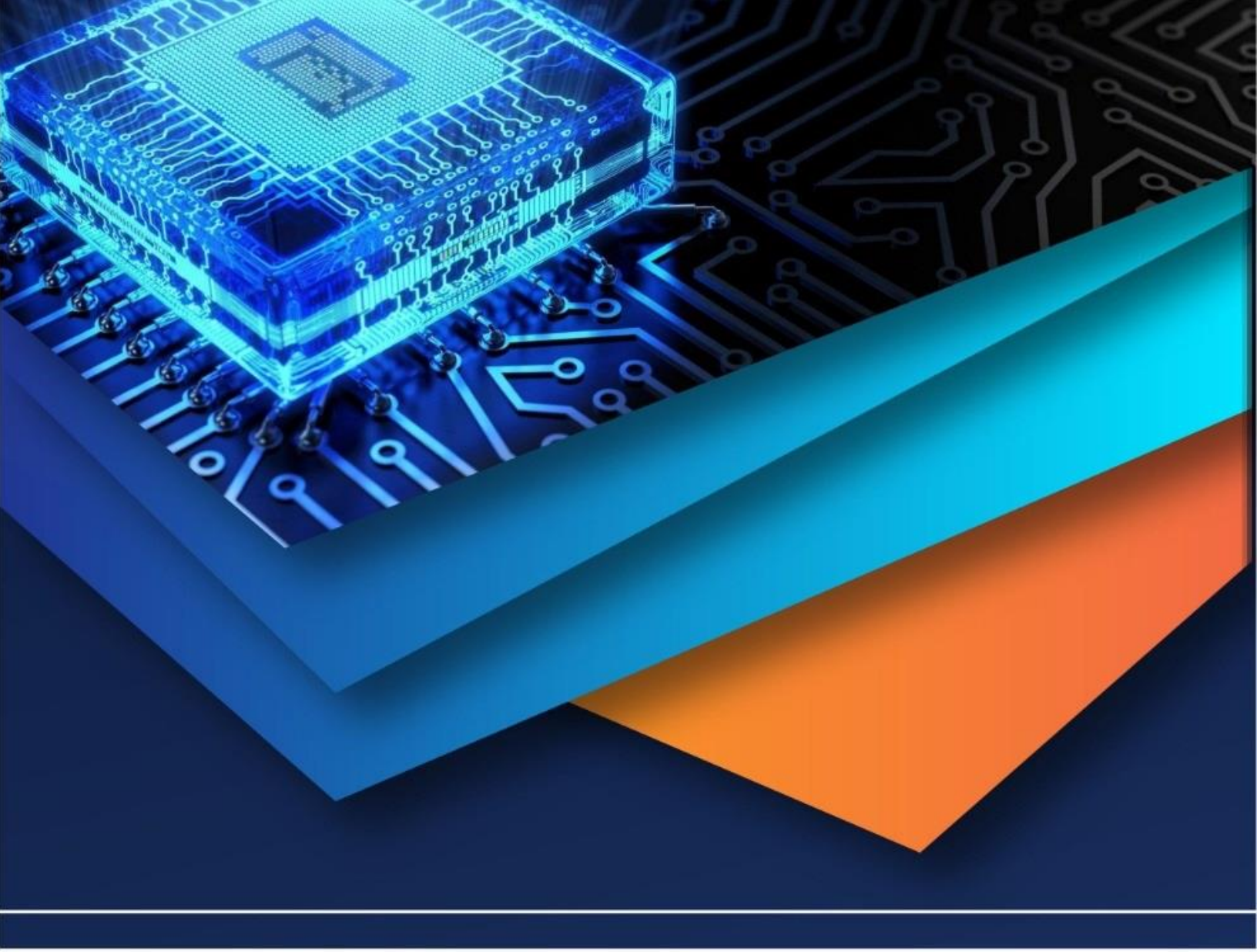
The following conclusions are drawn based on the experimental results of this study:

A. The experimental results show that Cutting insert is the major influencing parameters among the three controllable factors (Spindle speed, depth of cut) on surface roughness.
B. Minimum surface roughness obtained at an optimum level cutting speed 300 m/min, feed 0.15 mm/rev and depth of cut 0.5mm using CNMG insert.
C. Whenever increases in speed it reduces the surface roughness and increase in depth of cut, increases the surface roughness.
D. CNMG gives the least surface roughness compares to TNMG and TNMG.
E. By studying chip formation characteristics, we can get information about a cutting condition which is helpful in improving product quality

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