

INVESTIGATION OF EFFECTS OF PROCESS CNC PARAMETERS AND INSERT GEOMETRY ON HARD TURNING OF STEELS

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ABSTRACT

This paper is present study has been done to study the effect of different input parameters on the desired responses on hard turning of different materials. The effect of hardness, material, depth of cut, nose radius, feed and cutting velocity has been evaluated on the machining force, the surface roughness and dimensional deviation. All this has lead to elimination of grinding process which had longer setup times and hard part turning is the upcoming trend which is much fast and précised. This paper is Turning of materials having hardness above 50 HRC (Rockwell scale) is known as hard part turning. Due to technological developments in the area of computerized numerically control machines, it very easy to machine precise components. The development of new tool materials is being used to turn the hard materials at high speeds

Taguchi's orthogonal array was used to design the experiment. The effect of all the input parameters on the output responses have been analyzed using the analysis of variance. White layer formation, phase analysis and micro strain developed were also studied. Grey relational analysis and Genetic Algorithms were used to determine the optimum combination of input parameters to get the best result.

Keywords: *Rockwell Scale, CNC Parameters.*

I. INTRODUCTION

1.1 MANUFACTURING

Manufacturing means transformation of raw materials into finished goods for the satisfaction of human needs. To transform the raw material different manufacturing processes are applied because of which the shape, size and physical properties of given material are altered.

Different types of manufacturing process for metals are: -

1. **Metal casting:** - Casting is a manufacturing process where a solid is melted and heated to certain temperature, then poured into a cavity or mould, the molten metal solidifies in the mould and the desired shape is formed.
2. **Metal forming and shaping:** - A simple metallic geometry is transformed into a complex one through plastic deformation. Tools or dies impart pressure on the material to transfer the desired geometry through the tool/material interface. It includes rolling, forging, extrusion, drawing, sheet forming, powder metallurgy, molding etc.

3. **Joining:** - Temporary or permanent joining of same or different materials. It includes welding, brazing, soldering, diffusion bonding, adhesive bonding, mechanical joining etc.
4. **Machining:** - It is the metal removing process. It includes turning, boring, drilling, milling, planing, shaping, broaching, grinding etc
5. **Finishing operations:** - It means improving the surface finish of the material. This includes honing, lapping, polishing, burnishing, deburring, coating, plating processes etc.
6. **Material property modification process:** - This process involves changing the property of materials to achieve desirable characteristics. This includes hardening, quenching, annealing, case carburizing etc.
7. **Advanced manufacturing processes:** - It comprises of nontraditional machining. It includes ultrasonic machining, abrasive jet machining, chemical, electric discharge machining, electrochemical machining, high-energy beam machining etc.

1.2 HARD TURNING

Turning of hard materials above 45 HRC is known as hard turning but usually the metals which are hard turned are in the range of 58-62 HRC. It must be noted that hard doesn't mean difficult but it stands for high hardness materials. The cutting tools used for hard turning are mainly made of Cubic Boron Nitride (CBN), Ceramic and Cermet. The use of tool depends upon the type of requirement like production quantity and type of surface finish required. Ceramic tool inserts can be used when batch production is to be done but CBN tool inserts are used when mass production is to be done. The selection of the tool depends upon the type of application, if intermittent cutting is to be done a low content CBN tool will not work

well because of low toughness. So a proper insert should be used as per the required application.

A typical hard turned part which is processed on a correctly configured machine, can have surface finishes below .0003 mm, roundness values of .00025 mm and size control as good as .005 mm. Not all machines are suitable for hard part turning. The machines used should have rigidity, power, efficient chip disposal methods and cooling solutions. Such characteristics cannot be achieved on a normal lathe. So as the technology advances CNC turning centers are being used for hard part turning purposes because they are much convenient and easier to use.

Table 1: Showing comparative difference between grinding and hard turning process

Grinding	Hard turning
Requires longer set up times	Short set up times
Investment is high	Low investment required
Cycle time is long	Cycle time is short
Multiple clamping operations are done	Single clamping of the work piece in chuck is done.
Low chip volume	High chip volume
Dressing of wheel is done so time is wasted	No dressing is done. Time is Effectively utilized.
Not Environmentally friendly because grinding sludge is formed	Environmentally friendly , it's a clean process
Profile grinding wheel is required	Single point cutting tool is required.

II. LITERATURE REVIEW

Davim et al. Used Response Surface Methodology (RSM) to develop model for predicting the surface roughness,

specific cutting force, tool wear, power and machining force. The authors used AISI D2 as work material and used TiN based wiper tool. Selecting cutting speed, feed rate and machining time as parameters and keeping the depth of cut constant, the experiments performed showed that surface roughness value is proportional to feed rate. Flank and crater wear of the tool occurs at high cutting speed. The machining force and the power were more sensitive to feed rate as compared to cutting speed. With increase in machining time the specific cutting force increases as tool wears.

Singh and Rao [18] also developed a surface roughness prediction model by using Response Surface Methodology (RSM). The model developed considered cutting speed, feed and tool geometry (effective rake angle and nose radius) as the parameters. AISI 52100 material and mixed ceramic inserts were used for turning on a high power lathe. The model helped to select the tool geometry so that optimum results can be obtained during hard turning.

III. DESIGN OF STUDY

3.1 PHASES IN THE STUDY

The study can be divided into three phases

1. **PHASE 1** : Preliminary study

This phase aimed at detailed study of hard part machining. The effect of various process parameters on the performance of the process was studied and there working limits were identified.

2. **PHASE 2** : Experimental setup

In this phase the setup to mount the dynamometer on NC machine was developed with attached computer setup. To ensure desired hardness correct method of hardening was done on the material.

3. **PHASE 3**: Results and analysis

In this phase the forces and surface roughness were evaluated using ANOVA and the significant and insignificant

parameters were determined. The dimensional deviation was studied. Metallurgical analysis was completed to find the phases present in the material after hard turning. White layer formation and surface pattern was also studied. Grey relational analysis and Genetic algorithm were used to get optimum solutions.

3.2. EXPERIMENTAL DESIGN

Table 2: Degrees of freedom for various levels

Factors	Units	Degrees of freedom
Hardness	HRC	2
Material		2
Nose radius- Depth of cut	Mm	2
Speed	(m/min)	2
Feed	(mm/rev)	2
Total		10

Table 3: L₂₇ Experimental design

S.No.	Hardness (HRC)	Material	Nose Radius(mm)- depth of cut(mm)	Cutting speed (m/min)	Feed (mm/rev)
1	50	EN 31	0.4-0.075	75	0.03
2	50	EN 31	0.4-0.075	75	0.06
3	50	EN 31	0.4-0.075	75	0.1
4	50	SAE 8620	0.4-0.15	110	0.03
5	50	SAE 8620	0.4-0.15	110	0.06

6	50	SAE 8620	0.4-0.15	110	0.1
7	50	EN 9	0.8-0.15	150	0.03
8	50	EN 9	0.8-0.15	150	0.06
9	50	EN 9	0.8-0.15	150	0.1
10	55	EN 31	0.4-0.15	150	0.03
11	55	EN 31	0.4-0.15	150	0.06
12	55	EN 31	0.4-0.15	150	0.1
13	55	SAE 8620	0.8-0.15	75	0.03
14	55	SAE 8620	0.8-0.15	75	0.06
15	55	SAE 8620	0.8-0.15	75	0.1
16	55	EN 9	0.4-0.075	110	0.03
17	55	EN 9	0.4-0.075	110	0.06
18	55	EN 9	0.4-0.075	110	0.1
19	60	EN 31	0.8-0.15	110	0.03
20	60	EN 31	0.8-0.15	110	0.06
21	60	EN 31	0.8-0.15	110	0.1
22	60	SAE 8620	0.4-0.075	150	0.03
23	60	SAE 8620	0.4-0.075	150	0.06
24	60	SAE 8620	0.4-0.075	150	0.1
25	60	EN 9	0.4-0.15	75	0.03
26	60	EN 9	0.4-0.15	75	0.06
27	60	EN 9	0.4-0.15	75	0.1



Figure 1: ACE CNC jobber xl on which experiment was performed

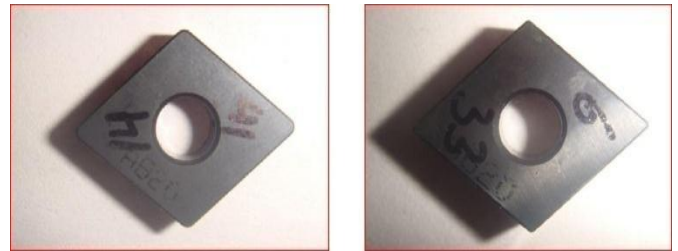


Figure 2: CNGA 0.8mm nose radius insert, CNGA 0.4 mm nose radius.

IV. RESULTS AND ANALYSIS

Table 4: Table for machining forces

Hardness HRC	Material	Nose radius - depth of cut(mm)	Cutting speed (m/min)	Feed (mm/rev)	Radial force(N)	Tangential force(N)	Feed force(N)	Machining Force(N)
50	EN 31	0.4-0.075	75	0.03	17.317	8.291	2.327	19.339
50	EN 31	0.4-0.075	75	0.06	23.128	9.8856	2.358	25.262
50	EN 31	0.4-0.075	75	0.1	40	17.1	5.641	43.866

50	SAE86 20	0.4- 0.15	110	0.03	8.158	6.144	0.362	10.219
50	SAE86 20	0.4- 0.15	110	0.06	15.62 3	5.797	0.440 9	16.669
50	SAE86 20	0.4- 0.15	110	0.1	50.36 7	22.93	5.705	55.634
50	EN 9	0.8- 0.15	150	0.03	6.649	3.3	1.378	7.549
50	EN 9	0.8- 0.15	150	0.06	50.29 4	23.25	4.614	55.599
50	EN 9	0.8- 0.15	150	0.1	21.65	1	2.172	21.781
55	EN 31	0.4- 0.15	150	0.03	18.44	6.573	2.016 5	19.680
55	EN 31	0.4- 0.15	150	0.06	20.06 3	10.3279	1.65	22.623
55	EN 31	0.4- 0.15	150	0.1	65.96 6	20.209	12.8	70.170
55	SAE86 20	0.8- 0.15	75	0.03	54.77 4	26.531	5.506	61.110
55	SAE86 20	0.8- 0.15	75	0.06	45.3	20.859	5.93	50.223
55	SAE86 20	0.8- 0.15	75	0.1	48.80 6	21.279	2.837 5	53.318
55	EN 9	0.4- 0.075	110	0.03	5.011	3.769	0.8	6.321
55	EN 9	0.4- 0.075	110	0.06	10.18 4	5.011	1.653 6	11.469
55	EN 9	0.4- 0.075	110	0.1	20.37 9	7.4784	2.762 5	21.882
60	EN 31	0.8- 0.15	110	0.03	20.94	8.5315	2.074 6	22.706
60	EN 31	0.8- 0.15	110	0.06	54.83 6	25.392	4.633	60.607
60	EN 31	0.8- 0.15	110	0.1	80.23	5.567	9.132	80.939
60	SAE86 20	0.4- 0.075	150	0.03	25.01 9	10.383	3.678	27.336

60	SAE86 20	0.4- 0.075	150	0.06	21.93 7	5.495	1.495 5	22.664
60	SAE86 20	0.4- 0.075	150	0.1	34.24	15.22	3.058	37.594
60	EN 9	0.4- 0.15	75	0.03	45.6	23.338	4.5	51.422
60	EN 9	0.4- 0.15	75	0.06	63.67 7	28.018	6.56	69.877
60	EN 9	0.4- 0.15	75	0.1	85.30 2	38.375	9.454	94.012

Table 5: Analysis of variance for means of Forces

Source	Degree of freedom	Sum of squares	Variance	F value	Significance
Hardness	2	2627.3	1313.66	5.63	Significant
Material	2	58.9	29.46	0.13	Not-Significant
Nose radius- depth of cut	2	2856.1	1428.03	6.12	Significant
Cutting speed	2	2472.9	1236.44	5.30	Significant
Feed	2	3593.1	1796.55	7.70	Significant
Residual error	16	3731.2	233.20		
Total	26	15339.5			

Table 6: Response table for means for forces

Level	Hardness	Material	Depth of cut- Nose radius	Cutting speed	Feed
1	28.44	40.58	23.97	52.05	25.08

2	35.20	37.20	45.59	31.83	37.22
3	51.91	37.77	45.98	31.67	53.24
Delta	23.47	3.38	22.01	20.38	28.17
Rank	2	5	3	4	1

Smaller is better

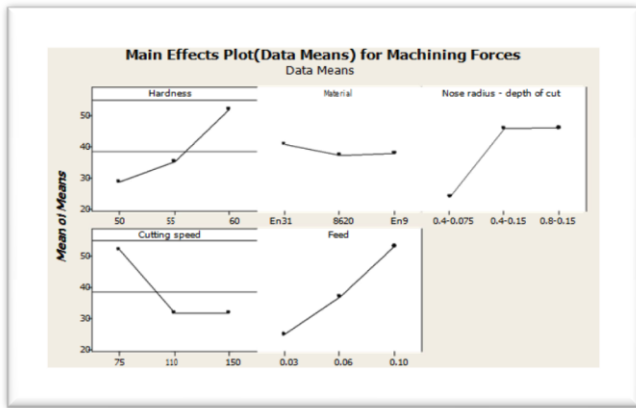


Figure 3: Main effects plot for means for machining forces.

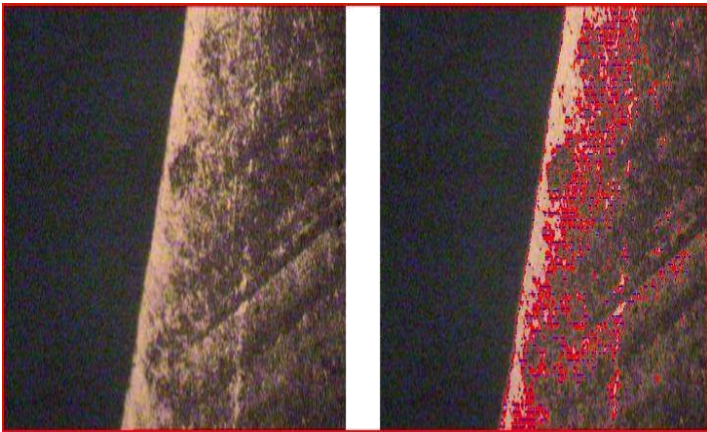


Figure 4: Peaks obtained for virgin sample EN 31

4.1. METALLURGICAL ANALYSIS

Sample EN 31: Virgin sample turned without hardening

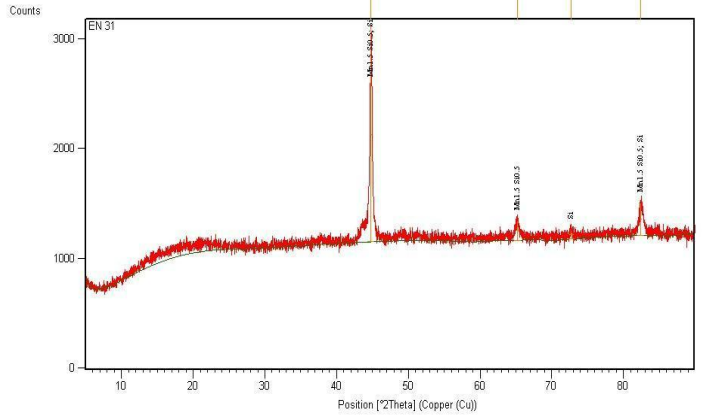


Figure 5: SEM image at 200 X for sample number 34

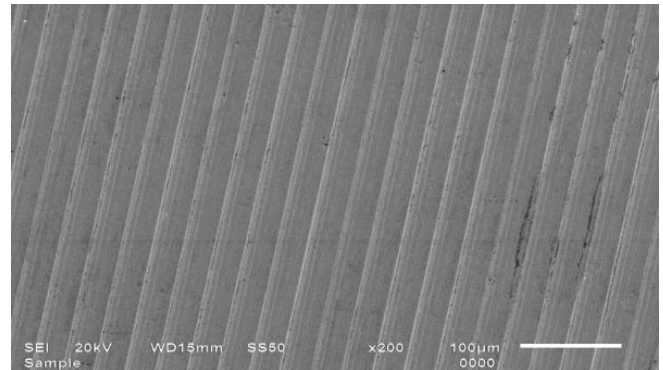


Figure 6: MIAS image for Sample number 34 at 400 X

4.2. COMPARISON BETWEEN HARD TURNED SURFACE AND GRINDING

FINISH SURFACE

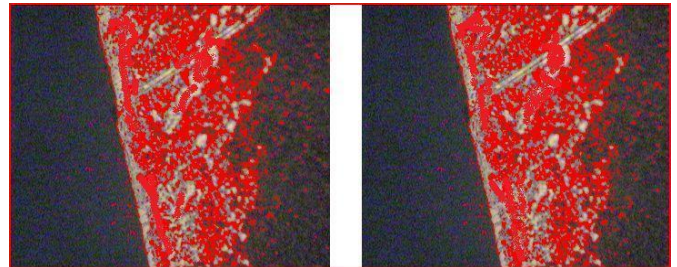


Figure 7: MIAS image for Sample number 37 at 400 X

Table 7: Thickness of white layer obtained from MIAS

Sample number	Thickness of the white layer in microns
34	9.56
37	9.12
46	7.4

V. RESULTS AND CONCLUSIONS

5.1. RESULTS FOR FORCES AND SURFACE FINISH.

In the experiment Taguchi's L_{27} design was used to study the effect of hardness, material type, feed, cutting speed and the combined effect of nose radius and depth of cut on the machining forces, surface roughness, dimensional deviation, white layer formation and phase study. ANOVA was used to study the significance of various parameters. Grey relational analysis and Genetic Algorithm was used to design the optimum condition. From the experiment following results were obtained.

5.2. MACHINING FORCES

- The dynamometer readings showed that the main dominating force was radial force, tangential force was less than the radial force and feed force was the least. Upon this basis the machining force was mainly influenced by radial component of force.
- At feed rate of 0.03 mm/rev, forces were least. As the feed increased the forces also increased.
- The cutting velocity of 75 m /min it was observed that maximum force was applied there. As the working range of ceramic inserts was between 100 – 200 m /min. So ceramic inserts should be used in this specified range to get the best possible result.
- From 110 m /min to 150 m /min there was no considerable increase in the forces.

- Hardness played an important role in increase in the forces. The material type had no significant effect on machining forces.
- Nose radius of 0.8 mm had very small increase in the forces. Only depth of cut influenced the machining forces. As the depth of cut increased the machining forces increased.

5.3. SURFACE ROUGHNESS

- The best surface finish was obtained on the feed of 0.3 mm/rev.
- It was found that on some parameter settings the surface generated was very rough.
- Smaller depth of cut had much better surface finish.
- In comparison at same depth of cut the nose radius of 0.8 mm showed better results.
- To get better results cutting speed should fall in the working range of inserts.

VI. CONCLUSIONS

6.1. FORCES AND SURFACE ROUGHNESS

It was found that to get the best results for hard part turning, to achieve best surface finish, and to minimise the machining forces it was necessary that the ceramic inserts used should be in there working range of 100 m /min to 200 m /min and the feed range of 0.03 to 1.5 mm/rev. 0.8 mm nose radius gave the best surface finish. Finishing cut along with less feed should be used to get the best surface finish. Roughing cuts can be given at high feed rate so that there is increase in production rate.

6.2. METALLURGICAL ANALYSIS.

XRD results showed that there was complete change in the phases. The main phase found was Chromium after hard turning of all materials. White layer does not get damaged by etching. The possible reason for the white layer formation was because of Heat affected zone (HAZ) or due to quenching. Distance between two crests was equal to the feed. Micro

strain developed on the surface was compressive in nature and the main reason for this can be because of the formation of white layer.

VII. SCOPE FOR FUTURE WORK

Further investigations are needed to develop the tool material inserts which should be comparatively cheap and last long. Apart from this, work should be done on development of cooling systems for the hard part turning process. So that white layer formation can be minimized. More study is to be done on metallurgical phase changes at different hardness for different materials after and before hard turning. Hard components having larger inner diameters gives roundness errors after hard turning, so work can be done to reduce the roundness errors of shafts by designing a special type chuck which imparts a uniform clamping force on the outer periphery.

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