"Optimization of Surface Roughness in Turning of Hardened AISI D2 Steel"

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***Abstract* : Hard turning is a developing technology that offers many potential benefits compared to grinding, which remains the standard finishing process for critical hardened surfaces. To increase the implementation of this technology, questions about the ability of this process to produce surfaces that meet surface finish and integrity requirements must be answered. Additionally, the economics of the process must be justified, which requires a better understanding of tool wear patterns, life predictions, cause and effects of defects, also to formulate effective measures to counter the same.**

AISI D2 (high carbon high chromium) is one of the most difficult material to machine because of their high hardness, affinity to react with tool materials. Because of its excellent mechanical properties and high wear resistance, it plays an important role in recent years in blanking, moulding, forming, thread rolling and drawing dies, shear blades, gauges and burnishing rolls. In order to perform the turning operation a ceramic insert tool is used

***Keywords*— hard turning, D2, Surface Roughness, AISI**

I. INTRODUCTION

Producers of machined components and manufactured goods are continually challenged to reduce cost, improve quality and minimize setup times in order to remain competitive. Frequently the answer is found with new technology solutions. Such is the case with grinding where the traditional operations involve expensive machinery and generally have long manufacturing cycles, costly support equipment, and lengthy setup times. However, the grinding process itself may require several machine tools and several setups to finish all component surfaces. Because grinding can be a slow process with low material-removal rates, there has been a determined search for replacement processes

The newer solution is a hard turning process, which is best performed with appropriately configured turning centres or lathes. Hard turning really started to develop at the beginning of the nineties. The reason for this was the availability of new tool materials and the capability of designing a turning machine that was rigid, stable and accurate enough to successfully finish hard turn. The result of these developments have made finish hard turning a viable alternative to grinding, as an accurate finishing operation.

Hard turning differs from conventional turning because of the work piece material, the cutting tools required, the cutting conditions applied and the chip formation mechanism.

II. PROBLEM IDENTIFICATION

Problem Statement:

The development of more wear-resistant tool materials such as Cubic Boron Nitride (CBN) have made hard turning a potential alternative to grinding operations in the finishing of hard materials. Setting up the Cutting Parameters i.e. Cutting Speed, Feed, Depth of Cut for hard turning of AISI D2 (High Carbon High Chromium) Cold worked Tool Steel

Objective:

- Conduct the experimentation on Aisi D2 (High Carbon High Chromium) Cold worked Tool Steel.
- Use Cubic Boron Nitride as a tool.
- Conduct screening experiments to decide the levels of Cutting speed, feed & Depth of cut.
- Prepare Design of Experiment plan for multiple levels.
- Optimization of process parameters like Cutting force, Surface roughness & Residual Stresses.
- Analysis of experimental results by Statistical method.

Methodology:

Methodology is the systematic, theoretical analysis of the methods applied to a field of study, or the theoretical analysis of the body of methods and principles associated with a branch of knowledge. It, typically, encompasses concepts such as paradigm, theoretical model, phases and quantitative or qualitative techniques.

A Methodology does not set out to provide solutions but offers the theoretical underpinning for understanding which method, set of methods or so called "best practices" can be applied to a specific case.[48]

Design of Experiment:

Design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is present, whether under the full control of the experimenter or not. However, in statistics, these terms are usually used for controlled experiments. Formal planned experimentation is often used in evaluating physical objects, chemical formulations, structures, components, and materials.

A methodology for designing experiments was proposed by Ronald A. Fisher, in his innovative books: Much of his pioneering work dealt with agricultural applications of statistical methods. As a mundane example, he described how to test the hypothesis that a certain lady could distinguish by flavour alone whether the milk or the tea was first placed in the cup. These methods have been broadly adapted in the physical and social sciences, and are still used in agricultural engineering.

Design Variables

The design variables are described into two groups:

- Response Parameters: Cutting force, Residual Stresses, Surface Roughness
- Machining Parameters: Cutting Speed, Feed, Depth of Cut.

Cutting parameters are shown in table below:

level / Parameters	1	2	3	4
Cutting Speed (m\min)	60	85	110	140
Feed rate (mm\rev)	0.04	0.08	0.12	0.16
Depth of cut (mm)	0.15	0.30	0.45	0.60

Table.2: Cutting Parameters and levels (Before conducting screening experiment)

Design of Experiment Plan by using, Plackett–Burman designs for screening experiments.

Level / Parameters	1	2	3	4
Cutting Speed (m\min)	60	70	80	90
Feed rate (mm\rev)	0.04	0.05	0.06	0.07
Depth of cut (mm)	0.10	0.15	0.20	0.25

Plackett–Burman designs plan for screening experiments (Before Screening Experiments)

StdOrder	RunOrder	Cutting speed (v) m/min	Feed rate (f) mm/rev	Depth of cut (ap)
6	1	140	0.16	0.6
4	2	140	0.04	0.6
8	3	60	0.04	0.6
12	4	60	0.04	0.15
11	5	60	0.16	0.15
5	6	140	0.16	0.15
9	7	60	0.04	0.15
2	8	140	0.16	0.15
3	9	60	0.16	0.6
1	10	140	0.04	0.6
10	11	140	0.04	0.15
7	12	60	0.16	0.6

Cutting Parameters and their levels (After conducting screening experiment on 50 HRc & 60 HRc materials)

Design of Experiment Plan by using, Plackett–Burman designs for screening experiments.

Plackett–Burman designs plan for screening experiments (After Screening Experiments)

Std Order	Run Order	Cutting speed (*Vc*) m/min	Feed rate (f) mm/rev	Depth of cut (ap) [Diametrically]
6	1	90	0.08	0.3
4	2	90	0.04	0.3
8	3	60	0.04	0.3
12	4	60	0.04	0.15
11	5	60	0.08	0.15
5	6	90	0.08	0.15
9	7	60	0.04	0.15
2	8	90	0.08	0.15
3	9	60	0.08	0.3
1	10	90	0.04	0.3
10	11	90	0.04	0.15
7	12	60	0.08	0.3

Time duration for hardning:

$45^{\pm}2$ or 50 HRC

$50^{\pm}2$ or 55 HRC

$55^{\pm}2$ or 60 HRC

Tool Material:

Selection of cutting tool:

The cutting edge preparation has a significant effect on the cutting forces in turn the output Parameters like residual tresses, surface roughness etc. The cutting edge preparation also has an effect on the metal removal rate and subsurface changes as reported by (Pawade R S, Suhas Joshi 2008) in machining Inconel 718 with chamfered and honed CBN tools.[49]

However the various authors have used only single value of hardness and the comparative study of lightly chamfered and honed and wiper geometry has not been done.

Cubic Boron Nitride (CBN):

Increased productivity can be achieved with CBN tools through:

- Higher cutting speeds.
- Higher feed rates.
- Longer tool life.
- Less machine downtime.
- More parts per machine means direct tool costs can be reduced.
- Very tight work piece surface finish tolerances can be achieved on difficult-to-machine materials. CBN can be used to machine ferrous materials in the hardened condition as an alternative to grinding, making it possible to substantially reduce component machining times.
- CBN offers environmental benefits — the generation of grinding sludge is eliminated and the chips can be recycled.
- Improved surface integrity of critical components.

III. RESULT ANALYSIS

The results of surface roughness in screening experiments conducted on 50 HRc and 60 Hrc

Experimental results of screening experiment

Table Plackett- Burman designs for 4 Levels and 3-Parameters for 50 HRC

d Order	Run Order	Cutting speed (*Vc*) m/min	Feed rate (f) mm/rev	Depth of cut (ap) [Diametrically]	Surface Roughness	Operation time (Min)	Tool Used
6	1	90	0.08	0.3	0.99		BMX 360 (3QP)
4	2	90	0.04	0.3	1.55	7	
8	3	60	0.04	0.3	1.2	8.3	
12	4	60	0.04	0.15	0.68	17	
11	5	60	0.08	0.15	0.83	3.3	BMX 330 (2QP)
5	6	90	0.08	0.15	0.86	3.15	
9	7	60	0.04	0.15	0.45	5	
2	8	90	0.08	0.15	0.74	2	
3	9	60	0.08	0.3	0.84	3.32	
1	10	90	0.04	0.3	0.65	2.37	
10	11	90	0.04	0.15	0.26	4.39	
7	12	60	0.08	0.3	0.549	3.3	

Experimental results of screening experiment

Plackett- Burman designs for 4 Levels and 3-Parameters for 60 HRC

Std Order	Run Order	Cutting speed (v) m/min	Feed rate (f) mm/rev	Depth of cut (ap)	Surface Roughness	Cycle time (Min)	Operation time (Min)
6	1	90	0.07	0.25	0.88	1.54	23.27
4	2	90	0.04	0.25	0.55	3.41	6.09
8	3	60	0.04	0.25	0.26	5.48	6.58
12	4	60	0.04	0.1	0.19	5.48	8.08
11	5	60	0.07	0.1	0.34	3.16	4.46
5	6	90	0.07	0.1	0.42	2.09	2.44
9	7	60	0.04	0.1	0.17	5.38	7.05
2	8	90	0.07	0.1	0.31	2.09	3.15
3	9	60	0.07	0.25	0.35	3.16	4.38
1	10	90	0.04	0.25	0.19	3.41	4.53
10	11	90	0.05	0.15	0.22	2.58	5.05
7	12	60	0.07	0.3	0.27	1.25	3.28

Result analysis for 50 HRC & 60 HRC by using regression analysis.

- **Factorial Fit: 50 versus Cutting speed, Feed rate (f), Depth of cut**

Estimated Effects and Coefficients for 50 (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		0.799917	0.09903	8.08	0.000
Cutting speed (v) m/min	0.083500	0.041750	0.09903	0.42	0.684
Feed rate (f) mm/rev	0.003167	0.001583	0.09903	0.02	0.988
Depth of cut (ap)	0.326500	0.163250	0.09903	1.65	0.138

S = 0.343065   PRESS = 2.11848

R-Sq = 26.57%   R-Sq(pred) = 0.00%   R-Sq(adj) = 0.00%

Analysis of Variance for 50 (coded units)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effect	3	0.34075	0.340754	0.113585	0.97	0.455
Cutting speed (v) m/min	1	0.002092	0.002017	0.020917	0.18	0.684
Feed rate (f) mm/rev	1	0.00003	0.000030	0.000030	0.00	0.988
Depth of cut (ap)	1	0.31981	0.319807	0.319807	2.72	0.138
Residual Error	8	0.94155	0.941547	0.117693		
Lack of Fit	4	0.46056	0.460557	0.115139	0.96	0.516
Pure Error	4	0.48099	0.480990	0.120248		
Total	11	1.28230				

Estimated Coefficients for 50 using data in uncoded units

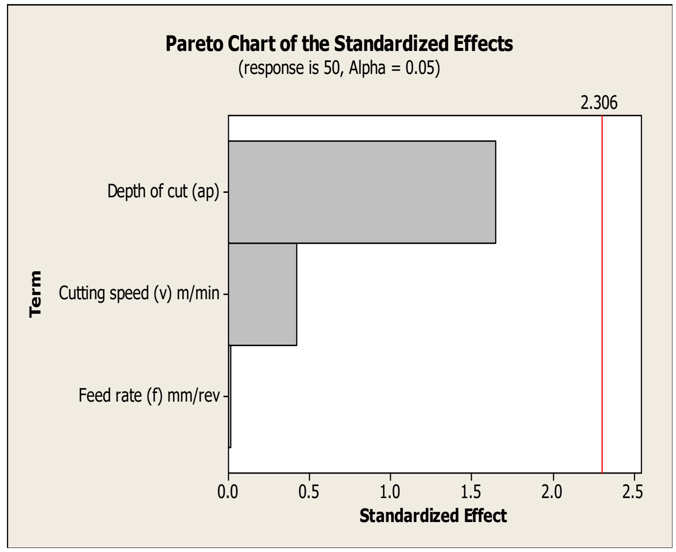
Term   Coef

Constant   0.420819

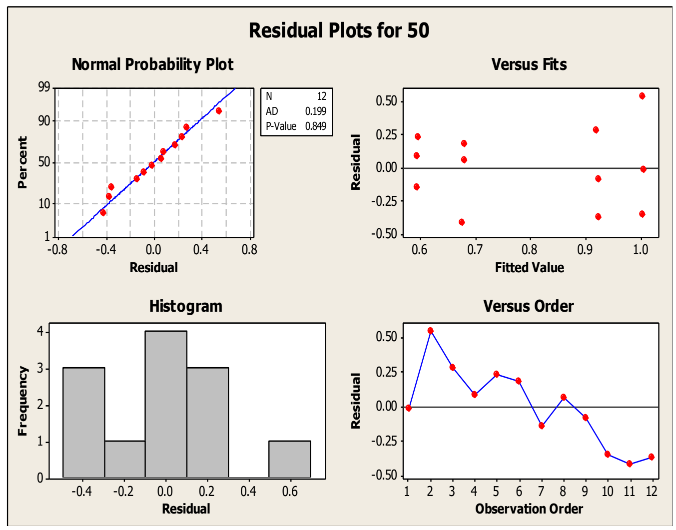
Cutting speed (v) m/min 0.00104375

Feed rate (f) mm/rev   0.02639

Depth of cut (ap)   0.725556

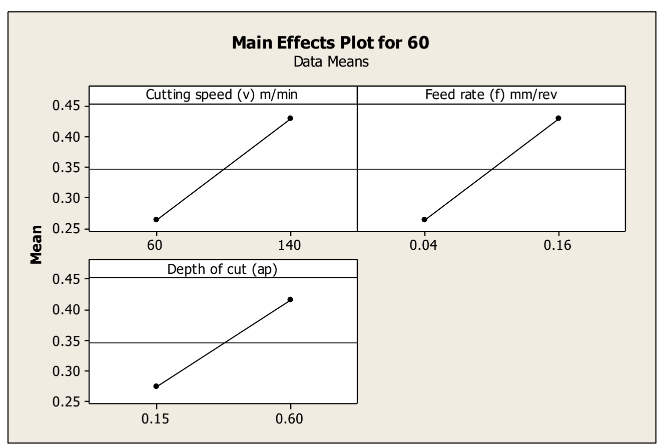


Pareto chart of the standardized effect



Residual Plots for 50 HRC

IV. EQUATIONS



V. CONCLUSION

After gone through different research papers it has been observed that, most of the researchers used Cubic Boron Nitride (CBN) or Polycrystalline Cubic Boron Nitride (PCBN) tool for hard turning operation. Most of the researchers conducted the hard turning operation on the range of 45 HRC to 62 HRC hardened material which help us to finalise the hardness levels. The experiment conducted by researchers also helps to identify the maximum and minimum levels of Cutting speed, Feed and Depth of Cut.

Review of research papers helps to finalize the geometry of cutting tool. Standard honed, Heavy honed, Light honed and Wiper geometry with nose radius 0.8 mm will be used for the final experimentation.

Palackett Burmen Method is carried out to conduct screening experiments. Screening experiments were carried out on AISI D2 (high carbon high chromium) tool steel with different hardness range by using CBN tool.

Screening experiments helps to reset the levels of Cutting Speed, Feed and Depth of Cut to conduct the final experimentation.

Better Surface roughness results are obtained in case of dry turning.

Final design of experiment plan is prepared by using D type Optimal Design method which is used for multiple levels input.

After reviewing the regression analysis for 50 HRC and 60 HRC, it has been observe that the regression square (Adj) values are showing the 0.00 percent error it is suppose to be more than 95 percent. The Pareto chart indicates that, the levels required to find out the significance of the factor does not meet the requirements it should more than the set alpha level. And the mean graph also indicates that the feed rate levels in case of 50 HRC are not obtaining upto the marks i.e. the mean line is exactly parallel to X-axis.

This result statistically indicates that the factor levels are failed to identify the error because of the less range between the maximum and the minimum values of output. Hence, to obtain the good statistical results the differences between the levels are increased.

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