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Analysis and Optimization of Hard Turning Parameters for AISI 4340 Steel using Grey Relational Analysis

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ABSTRACT

AISI 4340 is a heat treatable, low alloy steel containing nickel, chromium and molybdenum. It is known for its toughness and capability of developing high strength in the heat treated condition while retaining good fatigue strength. Typical applications are for structural use, such as aircraft landing gear, power transmission gears and shafts and other structural parts. During the Project DoE will be carried for machining of AISI 4340 steel. Machining trials will be carried out according to DoE. Measurement of Surface roughness and Tool wear will be carried by suitable measuring instruments. Analysis will be done using ANOVA and Multiobjective optimization will be carried out using GRA.

Keywords: AISI4340 Steel,Cutting Speed, Feed rate, Depth of Cut, Surface Roughness,Tool Wear, Taguchi Methodology,

I. INTRODUCTION

Recently cutting of hardened steels is a topic of immense importance for today's industrial production and scientific research. Hardened steels have numerous applications in the automotive, gear, bearing, tool and die industry. Traditionally hardened steels have been machined by the grinding process. On other hand grinding process is time consuming and it is applicable to limited range of geometries. Consequently, improved technologies are needed for the machining of hardened steels that will provide high material removal rates (MRR) and also to increase flexibility in terms of part geometry. Due to the recent developments of advanced cutting tool materials the interest in cutting hardened steels has increased significantly.

AISI 4340 is a heat treatable, low alloy steel containing nickel, chromium and molybdenum. It is known for its toughness and capability of developing high strength in the heat treated condition while retaining good fatigue strength. Typical applications are for structural use, such as aircraft landing gear, power transmission gears and shafts and other structural parts. Grey relational analysis is very useful technique to optimize a process with multi response characteristics. Grey relational analysis to solve engineering problems. In GRA grey relational grade is calculated which can provide knowledge of the factors affecting response variables.Machining considered as complex process in which the relationship between various factors is unclear. Such systems is often are called grey that give poor, incomplete and uncertain information. To solve such kind of problem, grey relational analysis (GRA) is very useful. In grey relational analysis, black represents having no information and white represents having all information. A grey system has a level of information between black and white**.** Through the grey relational analysis, a grey relational grade is obtained to evaluate the multiple performance

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characteristics. As a result, optimization of the complicated multiple performance characteristics can be converted into optimization of a single grey relational grade. During this investigation Hard Turning of AISI 4340 steel will be performed. Machining trials will be carried out according to DoE. Measurement of Surface roughness and Tool wear will be carried by suitable measuring instruments. Analysis will be done using ANOVA and optimization will be carried out using Grey Relational Analysis.

II. LITERATURE REVIEW

Bailey attempted machining of AISI 4340 steel to study the effect of cutting speed and wear land length on the surface damage produced during machining of quenched and tempered AISI 4340 steel under dry, orthogonal conditions was determined. Machined test pieces were examined with a scanning electron and optical microscope. Surface roughness was determined with profilometer.The results of the investigation show that during machining considerable surface damage is produced; the intensity of which decreases with an increase in cutting speed and wear land length. It was found that the surface damage existed in a wide variety of forms which included chatter marks perpendicular to the direction of relative work-tool motion, long straight grooves parallel to the direction of work tool motion, large cavities, work piece debris, tool debris, plastic deformation, cracks, micro cracks and voids.

Khrais and Lin studied machining of 4140 steel with TiAlN PVD coated inserts .They investigated the tribological influences of PVD-applied TiAlN coatings on the wear of cemented carbide inserts and the microstructure wear behaviors of the coated tools under dry and wet machining. The turning test was conducted with variable high cutting speeds ranging from 210 to 410 m/min. The analyses based on the experimental results lead to strong evidences that conventional coolant has a retarded effect on TiAlNcoatings under high-speed machining. Micro-wear mechanisms identified in the tests through SEM micrographs include edge chipping, micro abrasion, micro-fatigue, micro-thermal, and micro-attrition. These micro-structural variations of coatings provide structure-physical alterations asthe measures for wear alert of TiAlN coated tool inserts under high speed machining of steels.

Paulet attempted optimization of Cutting Parameters in Hard Turning of AISI 4340 Steel. They investigated the effect on surface finish and tool wear in a continuous dry turning of hardened steel when using a ceramic wiper tools. This report describes about the hard turning of AISI 4340 alloy steel by varying various parameters. The hard turning parameters are: Cutting speed, Feed and Depth of cut. The main objectives of this project, study the effect of parameters such as cutting speed, feed, depth of cut on surface roughness, tool wear and cutting force during the hard turning of AISI 4340alloy steel using ceramic wiper tool and the effect of various process parameters on hard tuning and optimize the cutting parameters. They found that it is found that the surface roughness is significantly influenced by feed and cutting speed; however depth of cut has very less effect during hard turning of AISI 4340 alloy steel. Also they found that for tool wear during hard turning of AISI 4340 alloy steel, feed has significant influence and depth of cut is the least influential of all.

Ram and Yadav attempted optimization of machining parameters in turning of EN-31 alloy steel using response surface methodology.In this attempt a detail study was performed on the CNC lathe machine for turning of the EN-31 alloy steel. Response surface methodology (RSM) is used for design of experiments which is based on

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second order face centred central composite design (CCD). The effect of process parameters viz. Spindle speed, feed rate and depth of cut on the surface roughness and material removal rate is carried out and optimize the response variables (for maximum material removal rate and minimum surface roughness). They found that forsurface roughness spindle speed seems to be the most significant and influential parameter followed by depth of cut. The feed rate has the least effect on the surface roughness.For material removal rate (MRR) out of three process parameters depth of cut seems to be the most significant and influential parameter followed by spindle speed.

V. Bhemunietstudied the effect of machining parameters on tool wear and nodal temperature in hard Turning of AISI D3 Steel. In this work, an attempthas been made to develop a model and predict the tool wear and nodal temperature of hard turned AISI D3 hardened steel using Response Surface Methodology (RSM). The combined effects ofcutting speed, feed rate and depth of cut are investigated using contour plots. RSM based CentralComposite Design (CCD) is applied as an experimental design. Al2O3/TiC mixed ceramic tool with a corner radius of 0.8 mm is employed to accomplish 20 tests with six center points. The adequacy of the developed models is checked using Analysis of Variance (ANOVA). Main and interaction plots are drawn to study the effect of process parameters on output responses.

Gupta and Sood attempted Optimization of multi characteristics during machining of AISI 4340 Steel using Taguchi's approach and utility concept. In this experimental studies in machining were carried out under varying conditions of process parameters, such as cutting speed (v), feed (f) and different cooling conditions (i.e. dry, wet and cryogenic in which liquid nitrogen used as a coolant) by using uncoated tungsten carbide insert tool. Experiments were carried out as per Taguchi's L9 orthogonal array with the utility concept and multi response optimization were performed for minimization of specific cutting force (KS) and surface roughness (Ra). Further statistical analysis of variation (ANOVA) and analysis of mean (ANOM) were used to determine the effect of process parameters on responses KS and Ra based on their P value and F value at 95 % confidence level. The optimization results proved that, cutting speed 57 m/min, feed 0.248 mm/min and cryogenic cooling is required for minimizes KS and Ra.

J.G. Lima carried out hard turning of AISI 4340 high strength low alloy steel and AISI D2 cold work tool steel. They evaluated the machinability of hardened steels at different levels of hardness and using a range of cutting tool materials. More specifically, the work was focused on the machinability of hardened AISI 4340 high strength low alloy steel and AISI D2 cold work tool steel. The tests involving the AISI 4340 steel were performed using two hardness values: 42 and 48 HRC; in the former, a coated carbide insert was used as cutting tool, whereas in the latter a polycrystalline cubic boron nitride insert was employed. The machining tests on the AISI D2 steel hardened to 58 HRC were conducted using a mixed alumina-cutting tool. Machining forces, surface roughness, tool life and wear mechanisms were assessed. The results indicated that when turning AISI 4340 steel using low feed rates and depths of cut, the forces were higher when machining the softer steel and that surface roughness of the machined part was improved as cutting speed was elevated and deteriorated with feed rate. Abrasion was the principal wear mechanism acting when turning the 42 HRC steel, whereas diffusion was present when machining the 50 HRC steel. Turning AISI D2 steel (58 HRC) with mixed alumina inserts allowed a surface finish as good as that produced by cylindrical grinding. The flank wear of the mixed alumina

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tool increased with cutting speed and depth of cut, presenting a considerably higher tool wear rate when using at a cutting speed of 220 m/min and feed rate of 0.15 mm/rev, which resulted in tool failure by spelling.

III. PROBLEM STATEMENT

From literature it can be observed that analysis of AISI steel has been done by using conventional tools like ANOVA, Taguchi etc. Also very few researchers have worked on optimization of AISI 4340 using advanced optimization techniques so we selected this area to carry out analysis and optimization of hard turning parameters for AISI 4340 Steel using Grey Relational Analysis.

3.1Objectives

1.1.1 To carry out "Analysis of effect of cutting parameters on surface finish and tool wear using ANOVA and Taguchi"

2.2.2 To carry out "Multi-Objective optimisation of cutting parameters for hard turning of AISI 4340 steel using Grey Relational Analysis"

IV. METHODOLOGY

4.1 Review of literature to study existing work done in the area of Hard Turning of AISI 4340.

4.2 Selection of tool material, tool geometry and cutting parameters – cutting speed(v), depth of cut (d) and feed rate (f) with respect to work material.

4.3 Formation of design of experiments using Taguchi Methodology.

4.4 Experimentation by varying cutting parameters (v, d, f).

4.5 The cutting tool and work piece surface will be then examined by appropriate measuring instrument like Surface Roughness Tester, Tool Maker's Microscope/Profile Projector and High Resolution Photography

4.6 Results of experiments will be analysed.

4.7 Multi-objective optimisation of cutting parameters for hard turning Grey Relational Analysis (GRA)

4.8 Interpretation of results.

4.9 Conclusion and documentation.

V. SURFACE ROUGHNESS

Surface roughness is a measure of the surface finish of a product and anindex of the product quality. Surface roughness is a measurement of the small scale variations in the height of a physical surface. It is expressed in various ways and methods, like arithmetic mean or centre-line average (Ra), Root-mean square average (Rq), maximum peak (Ry), ten-point mean roughness (Rz), maximum valley depth (Rv), maximum height of profile (Rt = Rp – Rv) etc. Out of all these, the most commonly used indicator for surface roughness is Ra.

Ra, or the arithmetic mean value, previously known as AA (Arithmetic Average) or CLA (Centre-Line Average) is the arithmetic mean of deviations of a series of points from the centre line or datum line. The datum line is such that sum of the areas under the profile above the datum will be equal to the sum of areas below the datum. Generally, surface roughness is expressed in microns (μm).and the See equation no.1

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$$\mathrm{Ra} = \frac{a+b+c+d+e+f+\cdots}{n}$$ ....Equation 1

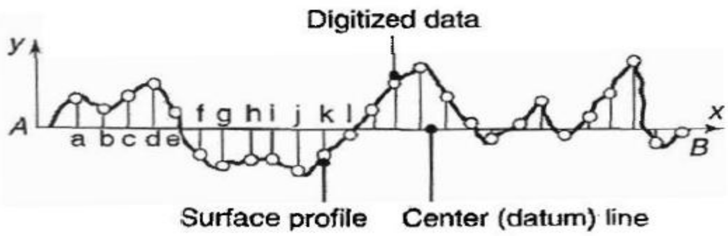

Fig.1. Surface roughness nomenclature

Studies by Sahin Y. and Motorcu A.R. have shown that surface roughness is mostly dependent on feed rate which is the dominating factor.

The surface roughness is usually measured in a direct way by the use of devices called Profilometer. The Profilometer is a stylus probe instrument in which the stylus mounted in the pick-up unit traverses across the machined surface by means of a motor drive. The pick-up receives ad rectifies the output which is further amplified and the average height of the roughness is reported digitally. One of the common types of Profilometer available is the Taylor-Hobson Talysurf. It works on the principle of carrier modulation.

VI. CUTTING TOOL INSERT

The term „Insert‟ refers to the condition when a cutting tool is screwed or clamped to a holder which is in turn fixed to the tool post. Inserts are clamped through various locking mechanisms. The advantage of inserts is that when one particular edge is worn out, it can be rotated to present a new cutting edge. In certain cases, if the geometry allows, after all such edges have been used up; the insert can be removed, turned upside down and clamped again to reveal a fresh array of cutting edges. There is a large variety of cutting tool materials that are available, each having its own specific properties and performance abilities. Examples of insert materials are Carbides, HSS, CBN, Diamond, Carbon speed steels etc. Carbide tools find common use in the metal cutting industry due to their ability to machine at elevated temperatures and higher speeds.

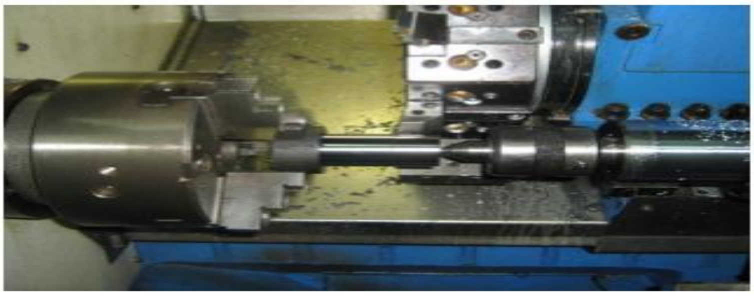

Fig.2 Turning Process in CNC Lathe Machine

VII. EXPERIMENTAL OBSERVATION & ANALYSIS

According to Taguchi’s orthogonal array theory L9 orthogonal array is adopted for the whole experimentation for turning operation of AISI 4340 graded steel. In L9 orthogonal array, 9 experimental runs are conducted and

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the corresponding out puts is evaluated by Taguchi optimization technique. Here, Tool wears and means of surface roughness are measured by above said instruments and these values are taken out put responses in Taguchi optimization method. Table 1 shows the standard structure of L9 orthogonal array which levels of each parameters are taken as 1, 2 and 3 respectively.

Table 1:Taguchi orthogonal array

Taguchi orthogonal array Sl. no.	Cutting speed	Feed	Depth of cut
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

Table 2: Machining parameters and Levels

Parameter	Units	Levels		
		1	2	3
Cutting Speed(V)	m/min	90	130	160
Feed (F)	mm/rev	0.06	0.10	0.15
Depth Of Cut(D)	mm	0.30	0.60	0.90

Here, the process variables are cutting speed, feed rate and depth of cut. These are the input parameters for the Taguchi optimization. So, nine experiments are carried out as per this orthogonal array and corresponding output data are recorded serially. The surface roughness was measured thrice times at different parts of the surface of work piece and then calculate the mean of those value. The full structure of experimentation is tabulated in Table 3 as per L9 orthogonal array.

Table 3: Observation table

Observation table Run	Speed (Vc)	Feed (f)	Doc (d)	Tool Wear (micron)	S. R. (1)	S. R. (2)	S. R. (3)	Average S. R.
1	90	0.06	0.3	0.860	1.94	1.65	1.88	1.82
2	90	0.10	0.6	1.061	1.29	1.10	1.29	1.24
3	90	0.15	0.9	1.006	1.49	1.52	1.61	1.54
4	130	0.06	0.6	1.201	2.40	2.61	2.24	2.41
5	130	0.10	0.9	1.127	2.21	2.66	2.33	2.40

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6	130	0.15	0.3	1.383	3.33	3.49	3.42	3.41
7	160	0.06	0.9	1.282	2.61	2.42	2.49	2.50
8	160	0.10	0.3	1.302	3.21	3.33	3.41	3.31
9	160	0.15	0.6	1.392	3.64	3.59	3.61	3.61

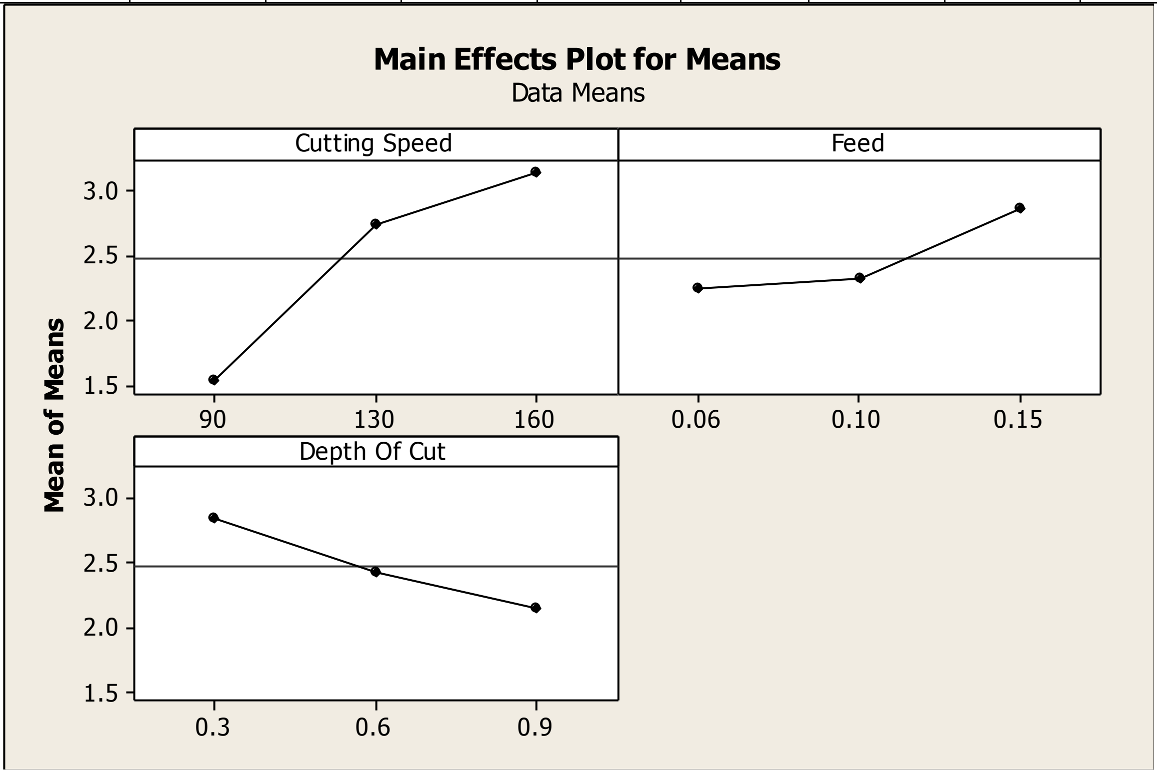

Table 4: Response table for means

Level	Cutting Speed	Feed	Depth Of Cut
1	1.533	2.243	2.847
2	2.740	2.317	2.420
3	3.140	2.853	2.147
Delta	1.607	0.610	0.700
Rank	1	3	2

VIII. RESULTS & ANALYSIS

These above data are analyzed by a power full statistical tool named Minitab software of latest version 17. First of all the input parameters are defined in the software as per their corresponding value and then give the responses data to optimize. Here, the main objective of the problem is to minimize the value of tool wear and surface roughness. So, the criterion of Smaller-The-Better is adopted for the optimization. The analysis of Means is carried out by the software. Then, ANOVA analysis of each parameter is done after simulation of optimization. And lastly the influences of residuals on parameters are carried out by plotting graph by main effects plots for means.

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IX. CONCLUSION

1. Conclusion can be derived from the experimentation done using AISI 4340 graded steel and carbide cutting insert.
2. A set of levels of parameter is obtained in order to minimize surface roughness as well as tool wear.
3.It is found that cutting velocity affects more while calculating tool wear and where depth of cut affects more while experimentation of surface roughness.
4. A conformation test is done in order to get optimal setting, it is evidenced that A2 B3 C2 for measuring tool wear and it is found to be 0.860 micron and A1 B2 C1 for surface roughness, it is found to be 1.24 micron.

REFERENCES

[1]. Wear behavior of CBN tools while turning various hardened steels, Gérard Poulachon,B.P. Bandyopadhyay ,I.S. Jawahir, SébastienPheulpin and Emmanuel Seguin,

[2]. Adilson José de Oliveiraa, AnselmoEduardoDiniz and DaviJaniniUrsolino, Journal of Materials Processing Technology 209 (2009) 5262–5270.

[3]. State of the art in hard turning, GauravBartarya and S.K.Choudhury , International Journal of Machine Tools & Manufacture 53 (2012) 1–14.

[4]. J Deng (1989) "Introduction to grey system". Journal of Grey System 1(1) (1989) 1–24.

[5]. Munish Kumar Gupta, Pardeep Kumar Sood, "Optimizing Multi Characterstics in Machining of AISI 4340 Steel Using Taguchi's Approach and Utility Concept" , J. Inst. Eng. India Ser. C DOI 10.1007/s40032-015-0201-1.

[6]. RajuShrihariPawade&Suhas S. Joshi Multi-objective optimization of surface roughness and cutting forces in high-speed turning of Inconel 718 using Taguchi grey relational analysis (TGRA), Int J AdvManufTechnol (2011) 56:47–62.

[7]. UlasCaydas, AhmetHascalık,Use of the grey relational analysis to determine optimum laser cutting parameters with multi-performance characteristics, Optics & Laser Technology 40 (2008) 987–994.

[8]. J.L. Lin , C.L. Lin , The use of the orthogonal array with grey relational analysis to optimize the electrical discharge machining process with multiple performance characteristics, International Journal of Machine Tools & Manufacture 42 (2002) 237–244.

[9]. John a. bailey, On surface damage during machining of aisi 4340 steel, Wear 27 (1974) 161-173.

[10]. Samir K. Khrais, Y.J. Lin, "Wear mechanisms and tool performance of TiAlNPVDcoated inserts during machining of AISI 4140 steel" , Wear 262 (2007) 64–69.

[11]. Basil K Mathew Paul, TinaRaju, Dr. Biju B, "Optimization of Cutting Parameters in Hard Turning of AISI 4340 Steel" , International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Volume 1 Issue 8 (September 2014).

[12]. Varaprasad.Bh, Srinivasa Rao.Ch, P.V. Vinay, "Effect of Machining Parameters on Tool Wear in Hard Turning of AISI D3 Steel" , 12th Global congress on manufacturing and management, GCMM 2014.

[13]. Sonu Ram, Raj Kumar yadav, " Optimization of machining parameters in turning of en-31 alloy steel using response surface methodology" ,ICRISTME-16, ISBN: 978-81-931039-1-3.

[14]. VaraprasadBhemuni, SrinivasaRaoChelamalasetti, Siva Prasad Kondapalli, "Effect of Machining Parameters on Tool Wear and Nodal Temperature in Hard Turning of AISI D3 Steel".