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OPTIMIZATION OF TURNING PROCESS PARAMETER ON HARDENED STEEL FOR THREE COMBINED RESPONSES

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The present work concerned an experimental study of turning on chromium-molybdenum case hardening alloy steel of AISI 4140 grade. The purpose of this thesis is to study the effect of speed, feed, and depth of cut on material removal rate, metal surface and tool wear in machining AISI 4140 alloy steel using tungsten carbide tipped cutting tool. Experimental were conducted on CNC and the influence of turning parameter was considered using grey relation analysis based on accustomed approach. Based on the main effects plots obtained through Taguchi Analysis, a total of 16 tests were carried out, optimum level for MRR, Surface roughness and depth of cut were chosen from the four levels of cutting parameters considered. After taking the responses grey relation analysis apply on all experiment to optimize the input parameter for optimum response.

1. Introduction:

Turning is an important machining process within which a single point cutting tool removes unwanted material from the surface of a rotating cylindrical work piece. Turning is employed to reduce the diameter of the work piece, typically to a nominative dimension, and to produce a smooth finish on the metal. Coated hard metals have brought about tremendous increase in productivity since their introduction. Since then coatings have also been applied to high speed steel and especially to HSS drills. Coatings are diffusion barriers, they prevent the interaction between chip formed during the machining and the cutting material itself. The compounds which make up the coatings used are extremely hard and so they are very abrasion resistant. Over the years the demands of economic competition have motivated a lot of research in the field of metal cutting leading to the evolution of new tool materials of remarkable performance and vast potential for an impressive increase in productivity. An area of research interest in metal cutting is the analysis of cutting force, as minimum power consumption is a never ending endeavor. Among the Cutting force, Thrust force and Feed force the former prominently influences power consumption and the most common equation available for the estimation of Cutting force parameter of research interest is Material removal rate of the work piece produced.

High speed machining is not associated with increased productivity and better surface finish rather associated with a great amount of heat generation. Also the power requirement rises since amount of cutting force is involved. The range of materials which one can use for cutting has been in a continuous state of development

2. Background

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. The user of the machine tool must know how to choose cutting parameters in order to minimize cutting time, cutting force and produce better surface finish under stable conditions. Anixter et al. [1] in turning process, they proposed a methodology of evaluating those uncertainty components of a single cutting force measurement that are related to the contributions of the dynamometer calibration and the cutting process itself. On the basis of empirical model including errors from both the sources, the uncertainty for a single measurement of cutting force, and expressions for the uncertainty vs. cutting parameters are presented. Fang and Jawahir [2] predicted three important machining parameters, i.e. the cutting force ratio, chip thickness, and chip back-flow angle, on the basis of: the universal slip-line model, a maximum value principle in order to determine the state of stresses in the plastic region in restricted contact machining, Dewhurst and Collins' matrix technique and Powell's algorithm for non-linear optimizations and by correct implementation of these techniques it is found that the parameters cutting force, chip thickness, chip back-flow angle can easily be determined. Shet and Deng [3] presented a finite element method to simulate and to analyze the orthogonal metal cutting process under plane strain conditions, with main attention on the residual stress and strain fields in the finished work piece. Various modeling options have been employed. Yen et al. [4] focused the effects of edge preparation of the cutting tool (round and chamfer edge) on chip formation, cutting forces, and process variables like temperature, stress, and strain etc. in orthogonal cutting. With finite element method (FEM) simulations a fundamental understanding of the process mechanics with realistic cutting tool edges were provided, also it is possible to estimate the values of process variables that are very difficult to measure by experiment not measurable for cutting. Majumdar et al. [5] focused on the influences of the heat generation during metal cutting processes and its effects on cutting forces and tool wear. Results shows that as cutting speed increases from 29.6 m/min to 155.4 m/min maximum temperature in the tool will also increase from 709.36 K to 1320 K. The model also describes significant effect of conduction and convection losses in heat dissipation and temperature rise in the tool. From the available literature, it can be seen that though some work has been reported on influence of turning parameters on material removal rate , surface roughness measurement of the machined surface and Tool wear measurement, no attempt has so far been made to systematically to optimize the process variables with a view to obtain favorable responses.

Tool wear is an inherent occurrence in any machining process. Wear affects tool life and product quality. Hence, improvements have to be made in order to increase tool life. Surface finish is also an important aspect of a machined product. To study the influence/effect of machining parameters viz. speed, feed and depth of cut, on the tool wear of a cutting tool. To study the influence/effect of machining parameters viz. speed, feed and depth of cut, on the surface roughness of machined material. To determine optimum machining parameter settings for the chosen tool/work combination so as to minimize the tool wears and surface roughness using grey analysis Method. The influence of cutting parameters (speed, feed, and depth of cut) on MRR, surface finish and Tool wear has been analyzed. Under the different cutting conditions 16 experiment based mixed level design was used to study Material removal Rate (MRR), Surface Roughness (SR) & Tool Wear (TW) of turning on alloy tool steel grade AISI 4140 work-piece.

3. Methodology

The workpiece material used for the experiments is Alloy steel 4140 of standard dimensions was used for machining with 40 mm diameter, 100 mm long (6 sample). The work piece used for the concluded experiment was AISI 4140 alloy steel. There are two series of alloy steels – 4140-series and 8620-series. AISI 4140 series steels find most wide use around the world .AISI 4140 is a chromium – molybdenum case – hardening steel that displays good strength, hardenability and toughness. Tool steels are high carbon steels (either carbon or alloy) possessing high hardness, strength and wear resistance. Tool steels are heat treatable. In order to increase hardness and wear resistance of tool steels, alloying elements forming hard and stable carbides (chromium, tungsten, vanadium, manganese, molybdenum) are added to the composition.

Table 1 AISI 4140 Alloy Steel

Category	Steel
Class	Alloy Steel
Type	Standard
Common Name	Chromium Molybdenum Steel

Cutting Tool Material use Tungsten carbide (chemical formula: WC) is a chemical compound (specifically, a carbide) containing equal parts of tungsten and carbon atoms. In its most basic form, tungsten carbide is a fine gray powder, but it can be pressed and formed into shapes for use in cutting tools etc. Tungsten carbide is approximately two times stiffer than steel, with a Young's modulus of approximately 530–700 GPa and is double the density of steel—nearly midway between that of lead and gold. It is comparable with corundum (α-Al_2O_3}) in hardness and can only be polished and finished with abrasives of superior hardness such as cubic boron nitride and diamond powder, wheels, and compounds.

Process parameters

The following table (Table 2) shows the levels of the cutting parameters chosen.

Table 2 Process Parameter of Turning Operation

Parameter	Level 1	Level 2	Level 3	Level 4
Cutting Speed (m/min)	120	160	200	240
Feed mm/rev	0.08	0.10	0.12	0.14
Depth of Cut (mm)	4	6	8	10

Design of experiments in MINITAB:

Dr. Genichi Taguchi is regarded as the foremost proponent of robust parameter design, which is an engineering method for product or process design that focuses on minimizing variation and/or sensitivity to noise. When used properly, Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. In robust parameter design, the primary goal is to find factor settings that minimize response variation, while adjusting (or keeping) the process on target. CNC Machining is used in the production of many complex three-dimensional shapes. It is because of these qualities that CNC Machining is used in jobs that need a high level of precision or very repetitive task.

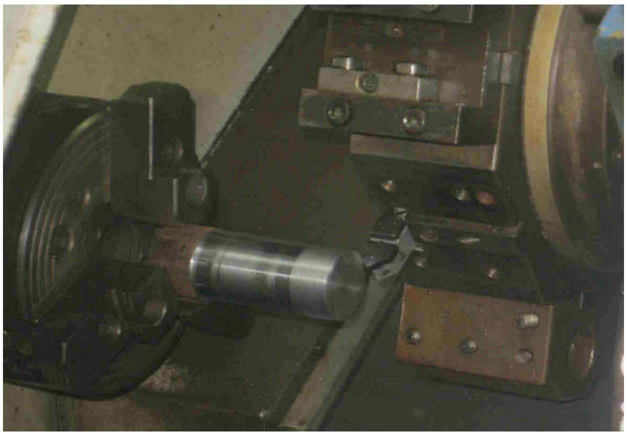

Fig 1 Mounting of tool and work piece

In grey relational analysis, the data pre-processing is the first step performed to normalize the random grey data with different measurement units to transform them to dimensionless parameters [8]. Experimental data i.e. measured features of quality characteristics of the product are first normalized ranging from zero to one by lower the better relation because in this work need to reduce surface roughness and chemical wear, so the responses value should be low to reducing the defects. This process is known as grey relational generation. For lower-the-better criterion follow eq 1 and for higher the better criteria follow eq 2, the normalized data can be expressed by equation (1)

$$X_i = \frac{max(y)_i - (y)_i}{\max(y)_i - \min(y)_i} \qquad \ldots..(1)$$

$$X_i = \frac{(y)_i - min(y)_i}{\max(y)_i - \min(y)_i} \qquad \ldots..(2)$$

$$where\ i = 1,2 \ldots..n$$

Based on normalized responses data, grey relational coefficient is calculated to signify the correlation between the desired and actual experimental data. Then overall grey relational grade is determined by averaging the grey relational coefficient corresponding to selected responses. The overall performance distinctive of the multiple response process depends on the calculated grey relational grade. This approach converts a multiple-response process optimization problem into a single response optimization situation; the single objective function is the overall grey relational grade. The optimal parametric combination is then evaluated by maximizing the overall grey relational grade.

The calculation of the grey relational coefficient and the weight of each quality characteristic is determined by equation (3):

$$G_i = \frac{L_{min} + \varepsilon L_{max}}{L_i(k) + \varepsilon L_{max}} \qquad \ldots\ldots..(3)$$

Where, L_{min} is the global minimum, L_{max} is the global maximum and ε is distinguish coefficient which is taken in between 0 to 1 in this case 0.5 weight is taken. Grey relation grade can be calculated by equation (4)

$$Grg_i = \frac{1}{n}\sum_{j=1}^{n} G_i(j) \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where n is the number of process responses

The lower value of the grey relational grade represents the reference sequence Grg_i. As mentioned before, the reference sequence Grg_i is the best process response in the experimental layout is taken whose grey relation grade is maximum.

4. Results

The responses results are obtain pass the machining and other measurement apparatus their reading and results are tabulated as per the experimental work are shown in the Table 5.1.

Table 5.1: Results Obtained

S. No.	Speed S (m/min)	Feed f (mm/rev)	DOC d (mm)	*MRR* (cm^3)	SR (µm)	Flank W. (mm)
1	120	0.08	4	3.34	4.63	0.543
2	120	0.10	6	3.65	4.25	0.585
3	120	0.12	8	3.01	4.34	0.552
4	120	0.14	10	5.44	3.65	0.755
5	160	0.08	6	3.11	6.59	0.464
6	160	0.10	4	3.89	6.65	0.500
7	160	0.12	10	5.87	6.88	0.674
8	160	0.14	8	6.92	6.93	0.400
9	200	0.08	8	4.87	5.16	0.435
10	200	0.10	10	3.34	6.30	0.590
11	200	0.12	4	3.41	6.40	0.522
12	200	0.14	6	7.01	6.63	0.702
13	240	0.08	10	3.87	6.93	0.621
14	240	0.10	8	4.02	7.02	0.384
15	240	0.12	6	4.98	6.67	0.560
16	240	0.14	4	5.74	5.49	0.585

Analysis of Results and Plots

The results obtained from the experiment were fed into MINITAB ® 16 for further analysis. Residual stress plot of three responses are shown in fig 2 to fig 4. The model is adequate as represented by the points falling on a straight line in the normal probability plot. It denotes that the errors are normally distributed. Also, the plot of the residuals versus the predicted response is structure less i.e. containing no obvious pattern. Again, the model is adequate as represented by the points falling on a straight line in the normal probability plot. It is an indication that the errors are normally distributed which should be the case for a good-fit model. The histogram also shows a nearly bell-shaped normal distribution. Also, the plot of the residuals versus the predicted tool wear is structure less i.e. containing no obvious pattern.

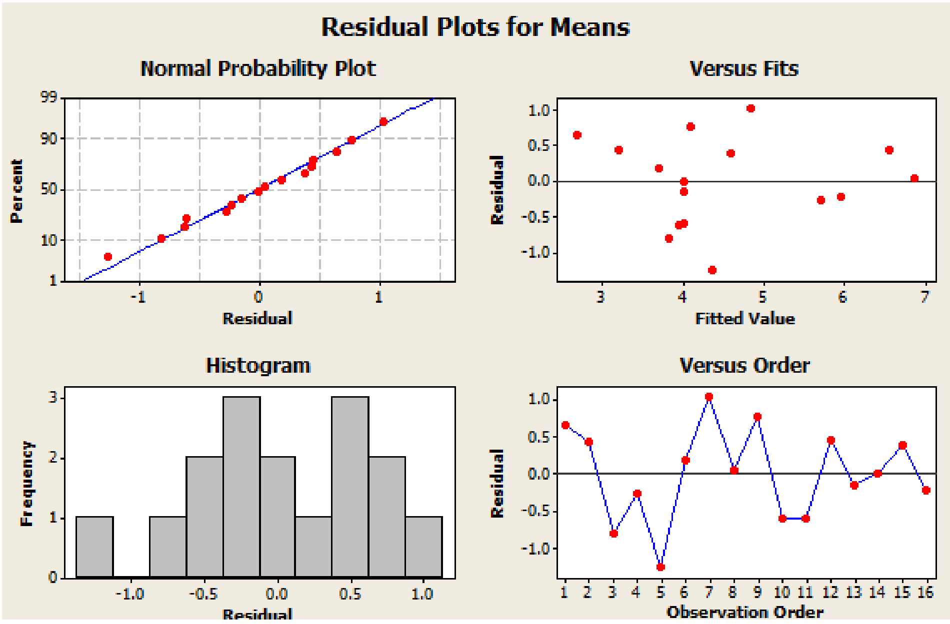

Fig 2 Four in one graph for MRR

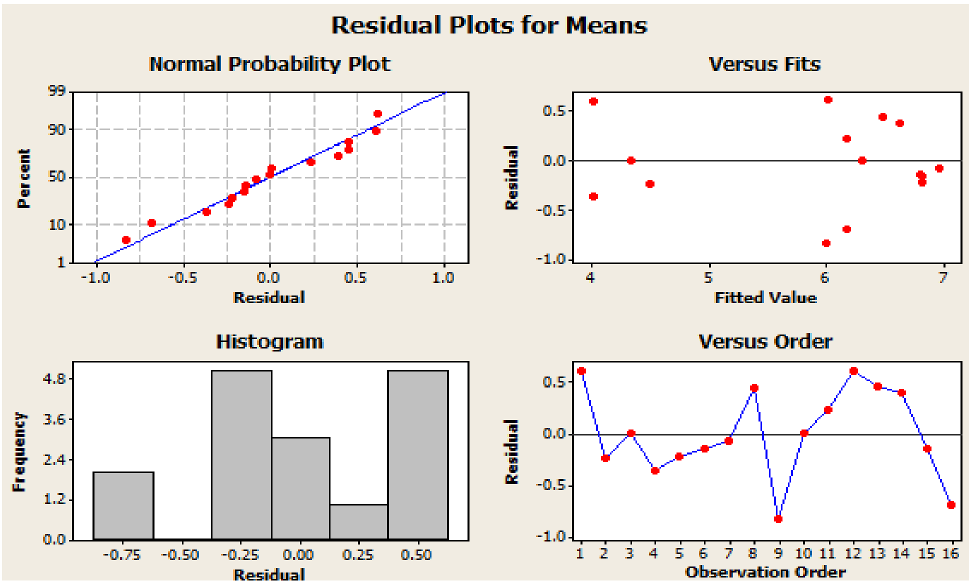

Fig 3 Four in one graph for SR

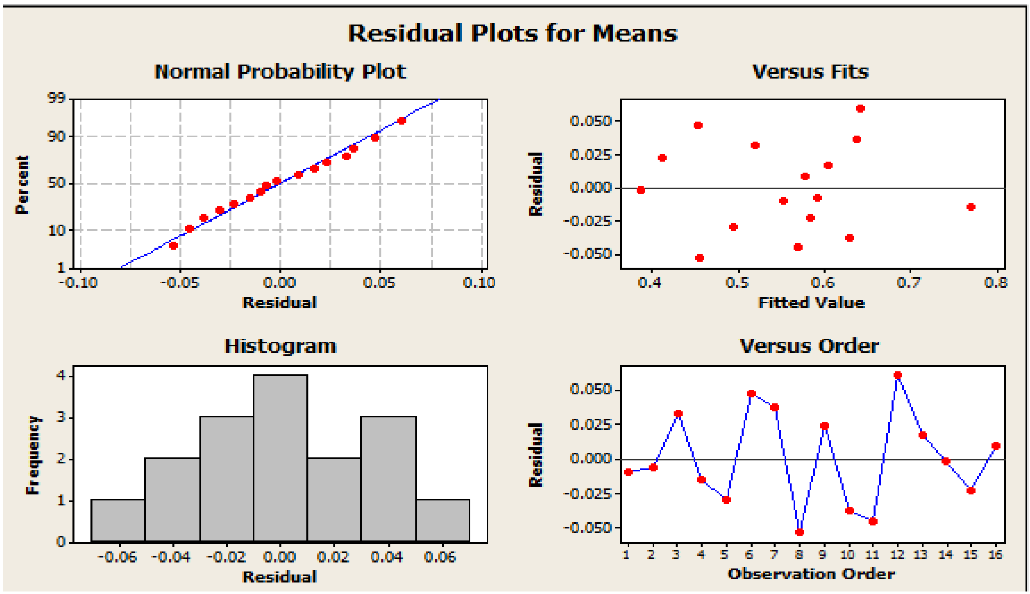

Fig 4 Four in one graph for MRR

5.3 Grey relation analysis

Grey relation analysis is applied on responses to obtain the optimum parameter are shown in table 3. The main effect plots are shown in fig 4 which gives the optimum responses.

Table 3 Observation table

S N.	Nij MRR	Nij SR	Nij FW	Gi MRR	Gi SR	Gi FW	GRG
1	0.085492	0.709199	0.552083	0.35348	0.63227	0.527473	0.504408
2	0.165803	0.821958	0.442708	0.374757	0.737418	0.472906	0.528361
3	0	0.795252	0.528646	0.333333	0.709474	0.514745	0.519184
4	0.629534	1	0	0.574405	1	0.333333	0.635913
5	0.284974	0.127596	0.757813	0.411514	0.364324	0.673684	0.483174
6	0.746114	0.109792	0.664063	0.66323	0.359658	0.598131	0.54034
7	0.740933	0.041543	0.210938	0.658703	0.342828	0.387879	0.463137
8	0.753886	0.026706	0.924479	0.670139	0.339376	0.868778	0.626098
9	**1**	**0.551929**	**0.833333**	**1**	**0.527387**	**0.75**	**0.759129**
10	0.085492	0.21365	0.429688	0.35348	0.388697	0.467153	0.40311
11	0.103627	0.183976	0.606771	0.358071	0.379932	0.559767	0.43259
12	0.259067	0.115727	0.138021	0.402923	0.3612	0.367113	0.377079
13	0.339378	0.026706	0.348958	0.430804	0.339376	0.434389	0.401523
14	0.365285	0	0.966146	0.440639	0.333333	0.936585	0.570186
15	0.510363	0.103858	0.507813	0.505236	0.35813	0.503937	0.455767
16	0.707254	0.454006	0.442708	0.630719	0.478014	0.472906	0.527213

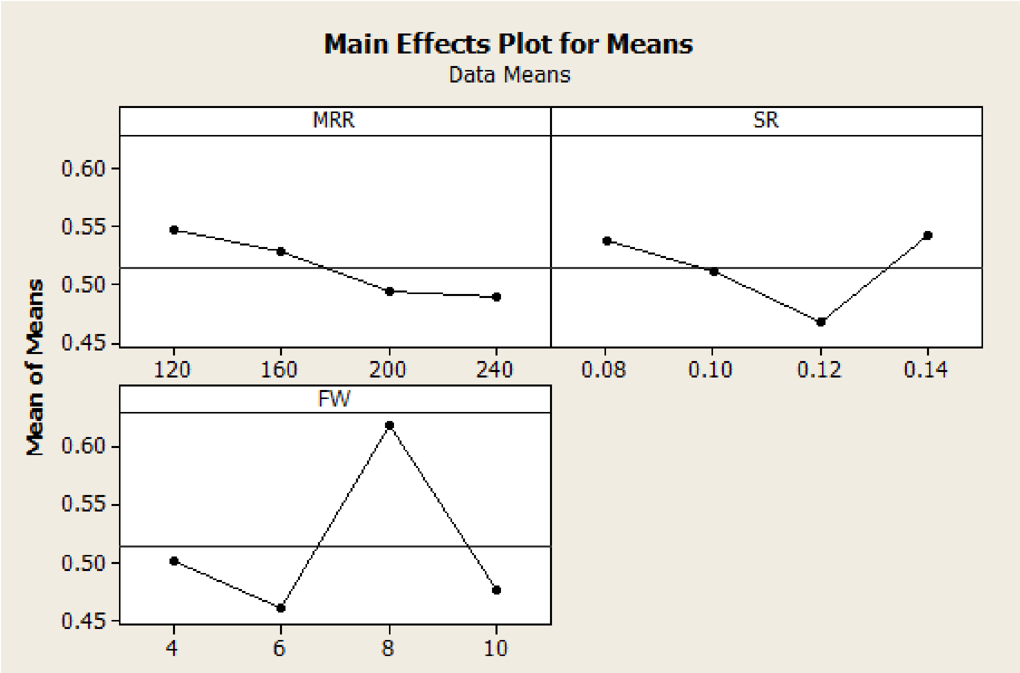

Fig 4 Mean Effect Plot for GRG

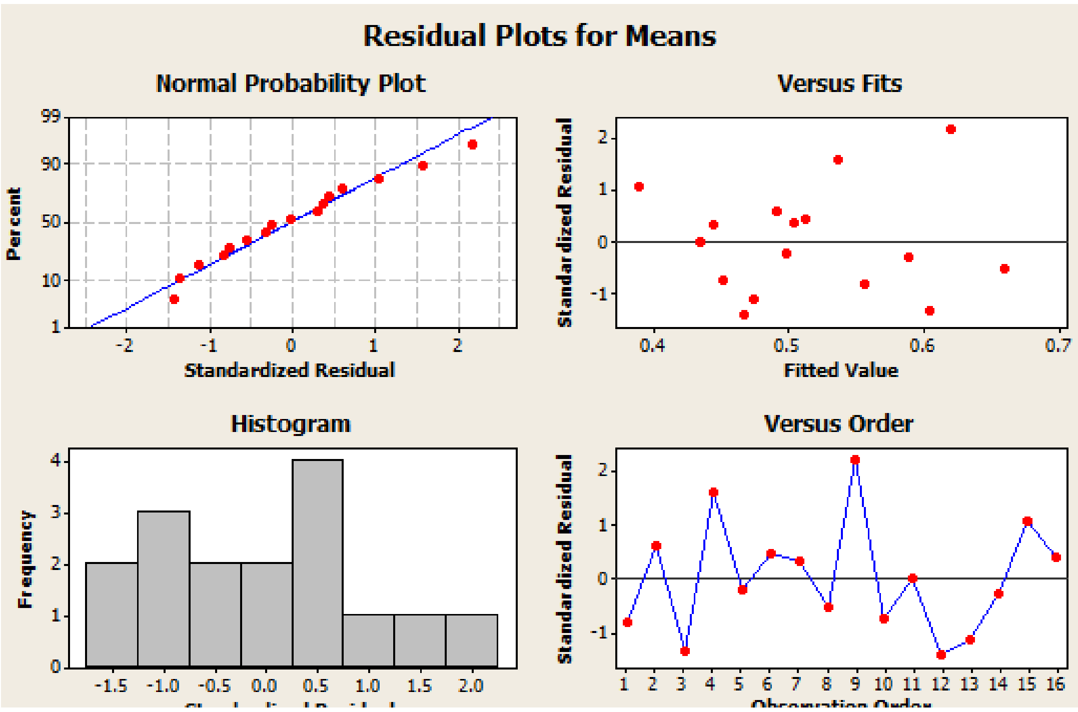

Fig 5 Regression Graph for GRG

5. Conclusion

- The important factor affecting the MRR (Material Removal Rate) is cutting speed then depth of cut then feed rate. The optimum condition for best MRR is f=0.14rev/min, S=200 m/min and d=6 mm.

- For Surface roughness (SR) the most important factor are as follows: Cutting Speed, feed rate and depth of cut. The optimum condition for best SR is f=0.08rev/min, S=240 m/min and d=14 mm.
- Observation of Tool wear (TW) during experiment we find that the most affecting factors are Cutting Speed closely followed by feed rate then depth of cut. The optimum condition for best Tool wear is f=0.08 rev/min, S=240 m/min and d=2 mm. Grey relation analysis was adopted to optimize the Turning process with multiple performance characteristics i.e. material removal rate, surface roughness and flank wear. The optimal turning parameter setting were found to be setting cutting speed 200 m/min, feed 0.08 rev/min. and dept. of cut 8 mm for maximum material removal rate and for minimum surface roughness and flank wear cutting speed would be 130 m/min, feed 0.08 m/rev at the depth of cut of 8 mm.

References:

[1]. D.A. Axinte, W. Belluco, L. De Chiffre ,"Evaluation of cutting force uncertainty components in Turning" International Journal of Machine Tools & Manufacture 41,pp. 719–730, 2001.

[2]. N. Fang a, I.S. Jawahir, "Analytical predictions and experimental validation of cutting force ratio, chip thickness, and chip back-flow angle in restricted contact machining using the universal slip-line model" International Journal of Machine Tools & Manufacture 42,pp. 681–694, 2002.

[3]. C. Shet, X. Deng, "Residual stresses and strains in orthogonal metal cutting" International Journal of Machine Tools & Manufacture 43,pp. 573–587, 2003.

[4]. Yung-Chang Yen, Anurag Jain, Taylan Altan , "A finite element analysis of orthogonal machining using different tool edge geometries" Journal of Materials Processing Technology 146,pp. 72–81, 2004.

[5]. Pradip Majumdar, R. Jayaramachandran, S. Ganesan, "Finite element analysis of temperature rise in metal cutting Processes" Applied Thermal Engineering 25, pp. 2152–2168, 2005.

[6]. SeongMin Son, HanSeok Lima, JungHwan Ahn, "The effect of vibration cutting on minimum cutting thickness" International Journal of Machine Tools & Manufacture 46,pp. 2066–2072, 2006.

[7]. Akasawa, T., Sakurai, H., Nakamura, M., Tanaka, T., & Takano, K. (2003). Effects of free-cutting additives on the machinability of austenitic stainless steels. Journal of Materials Processing Technology, 143, 66-71

[8]. Sanchit Kumar Kharea & Sanjay Agarwal, Optimization of Machining Parameters in Turning of AISI 4340 Steel under Cryogenic Condition Using Taguchi Technique, The 50th CIRP Conference on Manufacturing Systems, Elsevier, 63 (2017) pp. 610 – 614.