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Effect of Heat Treatment Of Steel AISI X 210 Cr 12 on Surface Roughness Quality During Turning Operation.

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Abstract. This paper represents the effect of work piece hardness obtained of different heat treatments of steel (AISI X 210 Cr 12) on surface roughness quality during turning operation. Three different levels of hardness for specimen's material, typically (18, 48 and 59 HRC). Taguchi′s L27 orthogonal array design was used (3-levels and 4-factors) to study the analysis of variance (ANOVA) and signal to noise ratio. In this study, cutting speed, feed rate, depth of cut and hardness of work piece material were selected as process parameters, while surface roughness (Ra), metal removal rate (MRR) and roundness error were selected as quality responses. The results obtained from the S/N and (ANOVA) indicated that feed rate was the most significant parameter on surface roughness followed by cutting speed. Cutting speed was the most significant parameter on roundness followed by hardness while the most significant parameter on MRR was cutting speed followed by depth of cut. The increase in hardness improves surface roughness and increase roundness error.

Keywords : ANOVA, Taguchi, Surface roughness, Roundness error, MRR.

1. INTRODUCTION

Turning is the machining operation which widely used in industries for machining. The turning operation is controlled by cutting such as cutting speed, feed rate, depth of cut, the cutting tool material and geometry, hardness of the machined material and many other uncontrolled parameters. Therefore, the efforts of research workers diverted to optimize the cutting parameters in machining operations. Kaladharet.al.[1] applied Taguchi method and ANOVA to optimize the cutting parameters during turning of austenitic stainless steels to minimize surface roughness. They concluded that nose radius was the most significant parameter on surface roughness, followed by cutting speed, depth of cut and feed rate respectively. The same results were also obtained by Nalbant, etal [2]. Özel et al. [3] studied the effects of cutting-edge geometry, workpiece hardness, feed rate and cutting speed on surface roughness and forces in finish turning of hardened AISI H13 steel. They found that cutting edge geometry is the most significant factor on surface roughness and workpiece hardness is the most significant factor on forces, followed by cutting speed. Edwinet at al. [4] studied the machining parameter setting-for facing EN8 steel with-TNMG Insert by using Taguchi method. They found that the cutting speed was the most influence parameter on surface roughness, followed by feed rate. Kaladhar, et.al [5] carried out experiments for optimization of process parameters in turning of AISI 202 austenitic stainless steel with the aid of Taguchi method. They found that cutting speed was the most influence condition on surface roughness, followed by nose radius. A similar result was obtained in references [6,7] .Ranganath [8] studied the effect of rake angle on surface roughness in CNC turning by using Taguchi method and ANOVA. The input parameters were rake angle and nose radius and the surface roughness was the output parameter. They found that rake angle is the most significant parameter on surface roughness, followed by nose radius. Ranganath. et.al [9] carried out experimental analysis of surface roughness using response surface methodology (RSM). They found that depth of cut the most significant parameter on surface roughness, followed by depth of cut.

The machining parameters have different effects of surface quality of the produced workpiece specimen. The aim of this research is to study the optimization of the machining parameters which produce better workpiece surface quality and material removal rate in turning operation.

2. Experimental work

2.1 Workpiece material

In this work a BOOHLER K100 (AISI X 210 Cr12) is selected as a work piece material based on the good properties of this material. It has very good wear resistance and good in compressive and toughness. Moreover, it is a dimensional stable, therefore, this material has wide applications such as in components for recycling industry, fine blanking and stamping and wear parts. Workpiece was in a form of cylinder with dimensions of 25 mm diameter and 100 mm length, The chemical compositions of this is work piece material is shown in table 1.

Table 1 Chemical compositions of workpiece material

GRADE	C	Mn	Si	Cr
K100	2.00	0.35	0.25	11.5

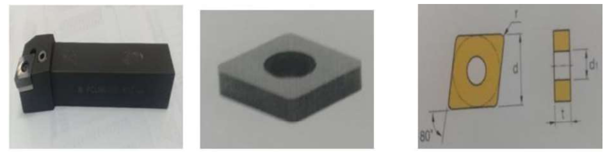
2.2 Heat treatment:

In this study, the effect of workpiece hardness in surface quality is investigated. Therefore two types of heat treatments are carried out to obtain two additional hardness to the hardness of the original material of (18 HRC). The heat treatment process is carried out on two stages, namely hardening stage, followed by tempering stage. The difference in hardness value of workpieces obtained in tempering stage, where, the first group of work pieces, tempering stage at 600 ºC followed by cooling in air to reach a hardness value of 48 HRC. The second group work pieces, tempering stage at 200 ºC, followed by cooling in air to reach a hardness value of 59 HRC.

So, three Different Hardness for Work Piece Material, are typically,(18, 48 and 59 HRC).

2.3Turning Process:

Cutting experiments were carried out using a conventional center lathe machine(length between chuck center to dead center 750 mm, maximum Diameter 420 mm, power 5 HP, speed up to 1250 rpm, feed motion Range (up to 1.30 mm). Uncoated carbide tip insert of ISO designation of CGNA 120408-cat 30 shown in Fig.1, is mounted on a tool holder of MCLNR2525M12 giving approach angle of 95º, Tool used for turning and its specification shown in Tables 2 and 3.



(a) Tool holder (b) Carbide inserts (c) The dimensions of carbide insert (dim. in mm)

Fig.1

Table 2 Tool General Specification:

ISO catalog number	Tip	Grade	dimension			
			d	t	Re	d1
CGNA 120408	Ceramic	CAT30	12.70	4.76	0.8	5.16

Table. 3Tool Material Specification:

Composition	Color	Density (g/cm³)	Hardness	Toughness (MPa.m)	Thermal Conductivity
Al_2O_3+TICN	Black	4.40	2,150	4.50	0.08

2.4 Measurement Devices:

The surface roughness parameter (R_a) of the workpiec after machining was measured with Surftest SJ-310 instrument shown in fig.2, while the roundness tester Talyrond 73- taylor hobson, S/no. 112/2802-0123, L.R = 0.01 µm shown in fig.3.
The uncertainty evaluation is carried out in accordance with the JCGM 100:2008. U is the expanded uncertainty using a coverage factor K = 2, providing a level of confidence of approximately 95 %. (U = $\pm$ 2.0 µm.).

All equipment used for measurement are traceable to gauge blocks which were calibrated by optical interferometer at KRISS traceable to SI units, certificate No: 05-03031-001

Fig.2 surftest instrument

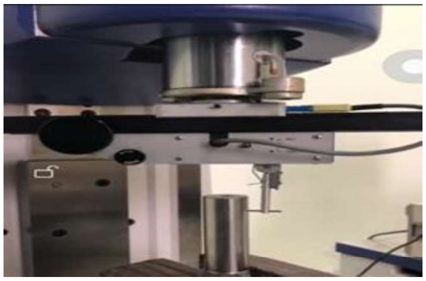


Fig.3 the roundness tester

2.5 Design of experiment

In this work selected parameters for turning experimentsare cutting speed, feed ,depth of cut and hardness of workpiece material (input variables). While the experimental responses are surface roughness, roundness error and MRR (outputs).

Taguchi designs experiments were performed using especially constructed tables known as "orthogonal arrays" (OA). The use of these tables makes the design of experiments very easy and consistent. Taguchi method with MINITAB-17 software was applied to plan and analyse the experiments and the results of this investigation.

In this work, four variables were selected with three levels for each and an OA L27 is selected. Each experiment was repeated three times to reduce the signal noise effect. The process parameters, levels and units are shown in the Table (4).

Table.4 Process Parameters and Levels.

Par. / Levels	Cutting Speed (mm/sec) (A)	Hardness (HRC) (B)	Feed Rate (mm/rev) (C)	Depth of Cut(mm) (D)
1	589	18	0.09	0.50
2	825	48	0.12	0.75
3	1178	59	0.16	1.00

3. Results and discussion :

The L_{27} experiments have been carried out according to the experiments according to design of experiment. After completing the experiments, a statistical analysis was done for the experimental data obtained which are shown in table 5.

Table.5 Experimental Results According to Taguchi DOE

Run	CUTTING SPEED (mm/s)	HARDNESS (HRC)	FEED RATE (mm/rev)	D-OF CUT (mm)	MRR (mm^3/s)	MEAN Ra (µm)	MEAN ROUND ROUNDNESS ERROR(µm)
1	589	18	0.09	0.50	26.505	1.105	9.53
2	589	18	0.09	0.50	26.505	1.465	9.93
3	589	18	0.09	0.50	26.505	1.607	10.15
4	589	48	0.12	0.75	53.010	1.252	10.25
5	589	48	0.12	0.75	53.010	1.894	11.13
6	589	48	0.12	0.75	53.010	1.857	5.79
7	589	59	0.16	1.00	94.240	2.039	9.21
8	589	59	0.16	1.00	94.240	1.690	6.70
9	589	59	0.16	1.00	94.240	2.105	12.90
10	825	18	0.12	1.00	99.000	1.553	13.13
11	825	18	0.12	1.00	99.000	2.199	12.95
12	825	18	0.12	1.00	99.000	1.831	12.56
13	825	48	0.16	0.50	66.000	2.075	12.30
14	825	48	0.16	0.50	66.000	2.216	12.14
15	825	48	0.16	0.50	66.000	2.185	8.05
16	825	59	0.09	0.75	55.688	1.530	9.75
17	825	59	0.09	0.75	55.688	1.301	9.36
18	825	59	0.09	0.75	55.688	1.391	15.55
19	1178	18	0.16	0.75	141.360	1.413	13.16
20	1178	18	0.16	0.75	141.360	1.650	12.91
21	1178	18	0.16	0.75	141.360	1.815	12.36
22	1178	48	0.09	1.00	106.020	1.190	9.13
23	1178	48	0.09	1.00	106.020	0.963	9.83
24	1178	48	0.09	1.00	106.020	1.195	9.53
25	1178	59	0.12	0.50	70.680	1.241	9.90
26	1178	59	0.12	0.50	70.680	1.526	8.53
27	1178	59	0.12	0.50	70.680	1.515	12.07

3.1. The effect of process parameters on surface roughness:

The average performance and S/N ratio were calculated for different responses. The main effects plot of S/N ratios is shown in Fig.4. It describes the variation of individual response of four parameters i.e. hardness, speed, feed and depth of cut and surface roughness.

The main effect plots are used to determine the optimal design conditions to obtain the minimum surface roughness. It is evident from Fig.4 and that Ra is minimum at level 3 of speed, the level 3 of hardness, level 1 of feed rate, and level 2 of depth of cut. Also, table 6 indicates that, the feed rate is the most significant on surface roughness, followed by cutting speed, followed by depth of cut and finally the hardness of workpiece material.

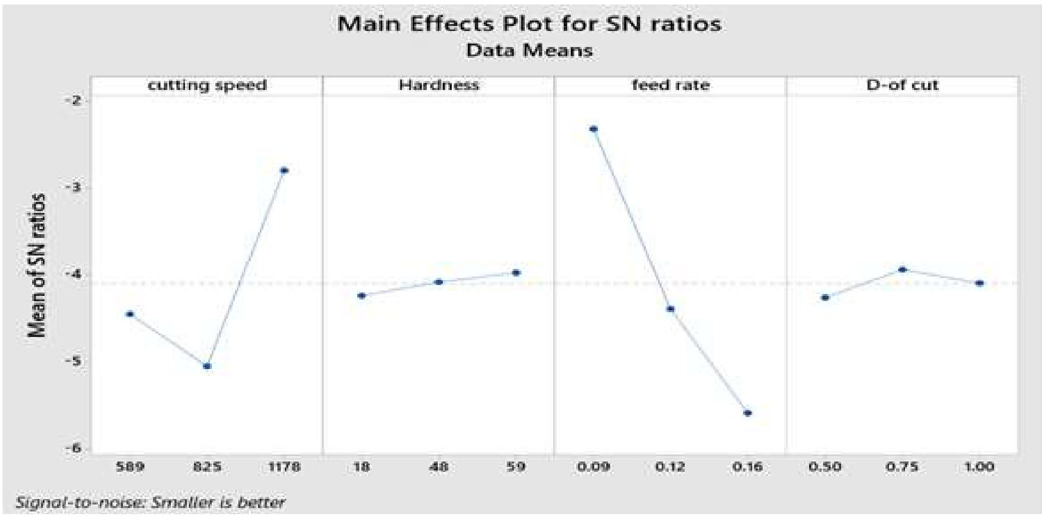


Fig.4 main effects plot of SN ratios for Ra

Table 6 Response for Signal to Noise Ratios for Ra

Smaller is better

Level	Cutting speed	Hardness	Feed rate	D-of cut
1	- 4.455	-4.241	-2.318	-4.263
2	-5.052	-4.085	-4.395	-3.943
3	-2.796	-3.977	-5.590	-4.097
Delta	2.256	0.264	3.271	0.320
Rank	2	4	1	3

3.2. The effect of process parameters on MRR:

The main effects plot of S/N ratios is shown in Fig.5. It is evident that MRR has maximum value at level 3 of cutting speed, level 3 of Feed and level 3 of depth of cut. The calculation of ranking of each input process parameter is indicated in table 7, the depth of cut is the most significant on MRR, followed by cutting speed. The hardness has no significant influence on the MRR.

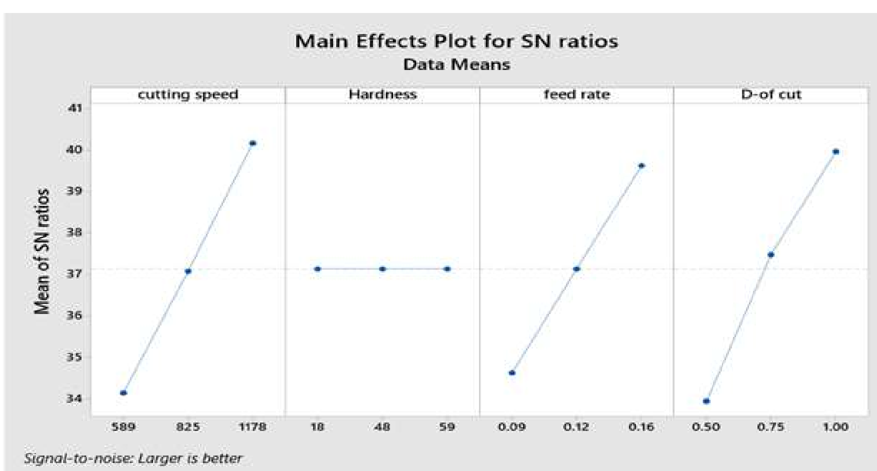


Fig.5 main effects plot of SN ratios for MRR

Table 7 Response for Signal to Noise Ratios for MRR

Larger is better

Level	Cutting speed	Hardness	Feed rate	D-of cut
1	34.15	37.13	34.63	33.95
2	37.07	37.13	37.13	37.47
3	40.17	37.13	39.63	39.97
Delta	6.02	0.00	5.00	6.02
Rank	2	4	3	1

3.3. The effect of process parameters on roundness error:

In the case of roundness, it is evident from Fig.6 that roundness has a minimum value at level 1 of cutting speed, level 2 of hardness, level 1 of feed, and level 1 of depth of cut. Table 8 indicates that, the cutting speed is the most significant on roundness, followed by the hardness of work piece material.

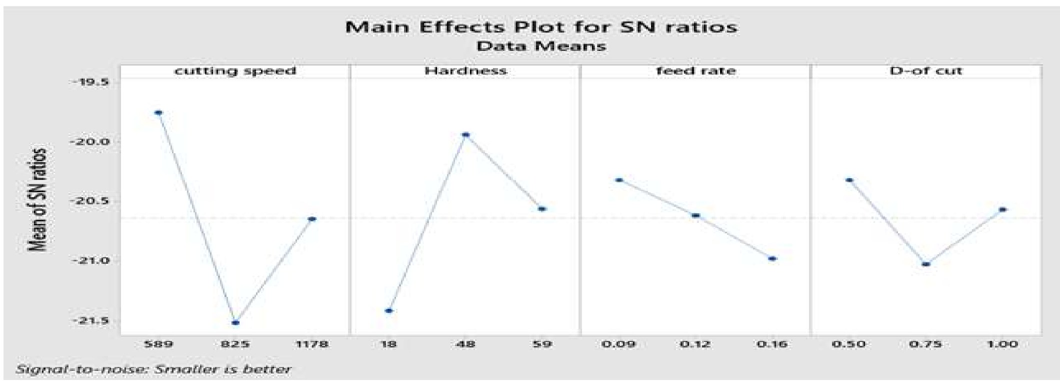


Fig.6 main effects plot of SN ratios for roundness error

Table 8 Response for Signal to Noise Ratios for Roundness error

Smaller is better

Level	Cutting speed	Hardness	Feed rate	D-of cut
1	- 19.75	- 21.41	- 20.32	- 20.32
2	- 21.51	- 19.94	- 20.62	- 21.03
3	- 20.65	- 20.56	- 20.98	- 20.57
Delta	1.76	1.48	0.66	0.71
Rank	1	2	4	3

4Analysis of Variance (ANOVA):

Analysis of variance (ANOVA) was performed to determine the most significant input parameter and to quantify their effects on each output. The results are presented in Tables 8, 9 and 10.

From Table (9), it is clear that cutting speed has the highest Contribution % of 17.95% on roundness error, followed by hardness with 15.61%.

In Table (10), the feed rate has the highest contribution on surface roughness with contribution of 48.13%, followed by cutting speed with contribution of 23.80%

The contribution of each input parameter on MRR is indicated in Table 11, the highest Contribution wae assigmned fo cutiing speed with contribution of 38.17% followed by depth of cut (33.44%) and finally feed rate (23.44%.).

Table.9 ANOVA for roundness error model

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution %
Cutting speed	2	42.907	21.454	2.62	0.101	27.95 %
Hardness	2	39.928	19.964	2.28	0.131	25.61 %
Feed rate	2	22.694	11.482	0.31	0.739	12.13 %
D-of cut	2	13.274	6.637	0.37	0.693	12.56 %
Error	18	18.810	4.378	-	-	21.75 %
Total	26	127.613	-	-	-	100 %

Table.10 ANOVA for surface roughness model

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution %
Cutting speed	2	0.81932	0.409661	8.10	0.003	33.80 %
Hardness	2	0.01349	0.006747	0.13	0.876	00.39 %
Feed rate	2	1.65677	0.828383	16.39	0.000	48.13 %
D-of cut	2	0.04295	0.021476	0.42	0.660	6.24 %
Error	18	0.90988	0.050549	-	-	11.44 %
Total	26	3.44242	-	-	-	100 %

Table.11 ANOVA for metal removal rate model

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution %
Cutting speed	2	10836.0	5418.00	-	-	38.17 %
Hardness	2	1303.2	651.58	-	-	04.60 %
Feed rate	2	6757.4	3378.70	-	-	23.80 %
D-of cut	2	9494.7	4747.35	-	-	33.44 %
Error	18	0.0	0.00	-	-	0 %
Total	26	28391.3	-	-	-	100 %

Conclusions:

In this investigation, Taguchi and ANOVA techniques have been applied to analyze the effect of the hardness of workpiece material and different cutting parameters on surface quality and MRR. The following conclusions are drawn as listed below:

(1) The cutting speed has the most significant effect on roundness with 27.85 % contribution followed by hardness of work piece material with 25.61 %.
(2) The feed rate has the most significant effect on surface roughness with 48.13 % contribution followed by cutting speed with 33.80 %
(3) The cutting speed has the most significant effect on material removal rate with 38.17 % contribution followed by depth of cut with 33.44% and finally the feed rate with 23.80 %.
(4) For minimum surface roughness, the optimal parametric combination is $A_3B_3C_1D_2$, for maximum material removal rate is at the parametric combination is $A_3B_1C_3D_3$ and finally for minimum roundness error, the optimal parametric combination is $A_1B_2C_1D_1$.

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