OPTIMIZATION OF PROCESS PARAMETERS ON HONING AND VMC MACHINE FOR SAE8620 (FORK) MATERIAL USING TAGUCHI METHOD

Tornekar C. A.[1], Jadhav M.L.[2]

[1]Post Graduate Student, Department of Mechanical Engineering, Deogiri College of Engineering and Management Studies, Aurangabad, Maharashtra, India
[2]Professor, Department of Mechanical Engineering, Deogiri College of Engineering and Management Studies, Aurangabad, Maharashtra, India

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Abstract - *The present study is carried for the optimization of the process parameters in order to reduce the monthly In House Rejection Rate and for quality and enhancement of production thereby minimizing the consumer complaints. For the enhancement of the final product correlation of the effect of process parameters on SAE8620 was carried out. Taguchi methodology was adopted for the optimization. Analysis was repeated thrice for three different output parameters namely, surface roughness, internal diameter shift and internal diameter oversize. From the output cutting speed is observed as the major input parameter as compared to the other two parameters i.e. feed and depth of cut. In case of internal diameter shift number of passes had major contribution whereas in case of internal diameter oversize feed is the dominant parameter. The optimum levels were independently determined with reference to the output parameters.*

Key Words: SAE8620, Optimization, In house rejection, Honing, Milling, Taguchi Method.

1. INTRODUCTION

In the world of manufacturing industries, production plays a major role forming it as one of the key measures of success. Secondly, efficiency is one of the factors which come into account for maximizing output from optimum input. However, for finding a balance between production and efficiency investigation in the improvement of process parameters of any material may lead to gain higher profit with successful outcome for the industries. Also, there is a need for selection of appropriate tools along with optimal machining conditions for dimensional accuracy and surface finish of the material. In order to reduce the rejection rate of the material various machining operations can be done. Statistical experimentation can be done for the validation of the results.

1.1 Literature Survey:

In the study of Rajender Kumar et al [1] adoption of Taguchi Method for rejection cost of flexible hose assembly. ANOVA technique was used to analyze the results of orthogonal array experiment for determination of major influencing factor. The contribution of all the factors related for characterization of general trends was obtained. It concluded that improved quality with cost reduction can be obtained from Taguchi Method. S. Tariq et al [2] high pressure dia casting production process of an automotive industry with 7AI was carried out for optimum combination of process parameters in order to maximize productivity of the process and minimize casting defects. Design of Experiment (DOE) approach was carried out which helped in cost saving. R. Nivedha et al [3] six sigma DMAIC phases technique was adopted for experimentation on wheel cylinder to improve the rejection rate of manufacturing industry. With the Process flow, Pareto diagram and Fish bone diagram the determination of critical factors required for controlling and improving the expected zero rate rejection was done. Pimpalgaonkar et al [4] optimization of process parameters on honing machine was carried out by using Taguchi Method for optimization. The output reveled that stroke pressure has greatest effect on Material Removal Rate (MRR) whereas feed pressure has greatest effect on surface roughness. Shahadat hasan et al [5] Optimization of process parameters on EN8 steel was carried out with the help of milling machine operation. The output reveled that S/N ratio is useful in deriving optimum conditions and ANOVA technique is useful for defining the level of importance of various parameters on material removal rate and surface roughness.

2 EXPERIMENTAL SETUP

SAE8620 (FORK)- SAE8620 is a low carbon alloy steel having hardenability, toughness and were resistance surface rendering it extensively useful for all industrial sectors having automotive parts namely, shafts, crankshafts, gears and gearings.

Honing Machine - Honing is a method of internal grinding used to achieve precise geometry and surface finish for a particular metal work piece.

Milling Machine - Milling is a method of machining which uses rotary cutters for the removal of material by advancing cutter into a work piece.

Hole Mill Cutter - A Hole-mill is normally an undersized reamer with a boring geometry i.e. the size of the hole-mill is normally 0.2-0.6mm more than the size of the drill so that there are no drill marks on the hole plus the hole axis is corrected for subsequent reaming operation.

In the present study, the major input (process) parameters namely work speed, feed rate, depth of cut and number of passes influence the output (response) parameters namely surface roughness, internal diameter shift, internal diameter oversize of a work piece are considered.

3. METHODOLOGY

To conduct this research, an automotive company was selected which has been manufacturing various automotive parts from last 25 years. The company was consistently facing problem of part rejection at machining stage of their production line. To identify the problem cause effect study was done and from the observations it was identified that internal diameter shift, internal diameter oversize and surface roughness were the major cause of part rejection. To propose a solution for the same statistical analysis using Taguchi method has been carried out.

Taguchi Method - Taguchi Method of quality control is an optimistic approach that emphasizes the role of research and development in design and process parameters resulting in reduction of defects and failures in manufactured goods. Steps performed are as follows:

1. Selection of response (variables) parameters.
2. Identification and selection of input (variables) parameters.
3. Assigning of levels for the factors. Conduction of experiment.
4. Analyzing the data for S/N ratio and ANOVA.
5. Define optimum levels of process parameters.
6. Validation of results.

4. PERFORMANCE ANALYSIS

4.1) Surface Roughness:

Input parameters and their levels

Process Parameter's	LEVEL 1	LEVEL 2	LEVEL 3
Cutting Speed (Rpm)	350	650	950
Feed Rate (mm/rev)	50	80	120
Depth of Cut (mm)	0.25	0.50	1.0

Table 1.1: Experiment Process Parameters

Design of experiments (DOE) for selected input parameters experiments are designed using Taguchi L9 orthogonal standard array. For this purpose software Minitab 17 is used

Sr.No	Speed (Rpm)	Feed (mm/Rev)	Depth of Cut (mm)
1	350	50	0.25
2	350	80	0.5
3	350	120	1
4	650	50	0.25
5	650	80	0.5
6	650	120	1
7	950	50	0.25
8	950	80	0.5
9	950	120	1

Table 1.2: Experiment Process Parameters

4.1.1: Experimentation

After design of experiment, 9 experiments are carried out in vertical milling Machine. After each experiment surface roughness is calculated. A quality characteristic for surface roughness is "Smaller is the better".

Job No	Speed (Rpm)	Feed (mm/Rev)	Depth of Cut (mm)	Surface Finish (Ra)
1	350	50	0.25	1.25
2	350	80	0.5	1.53
3	350	120	1	1.96
4	650	50	0.25	2.62
5	650	80	0.5	2.34
6	650	120	1	3.26
7	950	50	0.25	4.02
8	950	80	0.5	3.54
9	950	120	1	4.35

Table 1.3: Surface Finish (Ra) Values against Input Parameters

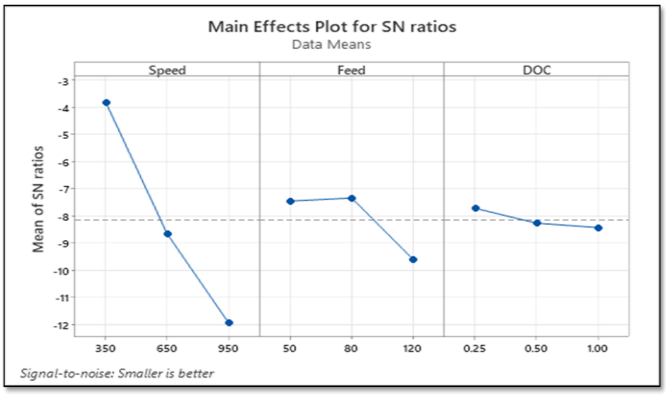
4.1.2: Results & Discussion

Signal-to-Noise Ratio

The Taguchi method can be used to determine the experimental condition having the least variability as the optimal condition. This variability can be expressed by signal-to-noise ratio (S/N ratio, denoted by η). The experimental condition that has the maximum S/N ratio is considered as the optimal condition because the variability of the characteristics is inversely proportional to S/N ratio [6]. The experiments were conducted at random as per the principles of design of experiments. The objective function described in this investigation is finding of smaller Surface Finish Values. So, the S/N ratios were calculated using the "Smaller the better" approach.

Cutting Speed	Feed Rate	DOC	Surface Finish	SNRA	MEAN
350	50	0.25	1.25	-1.938	1.25
350	80	0.5	1.53	-3.694	1.53
350	120	1	1.96	-5.845	1.96
650	50	0.5	2.62	-8.366	2.62
650	80	1	2.34	-7.384	2.34
650	120	0.25	3.26	-10.264	3.26
950	50	1	4.02	-12.085	4.02
950	80	0.25	3.54	-10.980	3.54
950	120	0.5	4.35	-12.770	4.35

Table 1.4: Results Table of Surface Finish



Graph1.1: Effect of Signal to Noise Ratio

Level	Speed	Feed	DOC
1	-3.826	-7.463	-7.728
2	-8.672	-7.353	-8.277
3	-11.945	-9.626	-8.438

Table 1.5: Response Table of Signal to Noise Ratios

To get better Surface finish the optimal parameters are Spindle Speed at 350 rpm, feed at 80 mm/rev & depth of cut at 0.25

4.1.3 Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) gives a clear picture of the extent to which a particular process parameter affects the response. Hence ANOVA was used to statistically distinguish the significant factors from insignificant ones. The ANOVA for means of surface Roughness and are shown in Table

Source	DOF	SS	MS	F	P	% Contribution
Speed	2	8.5706	4.2853	60.96	0.016	89.24919296
Feed	2	0.8576	0.4288	6.1	0.141	8.930542539
DOC	2	0.0342	0.0171	0.24	0.804	0.356138707
Residual Error	2	0.1406	0.0703			
Total	8	9.603				

Table 1.6: ANNOVA Table for Means of (Ra Values)

F- Test was carried out for checking the significance of the process parameters. It was found out that Speed having contribution of 89.29% was the most significant parameters. While other two factors were insignificant.

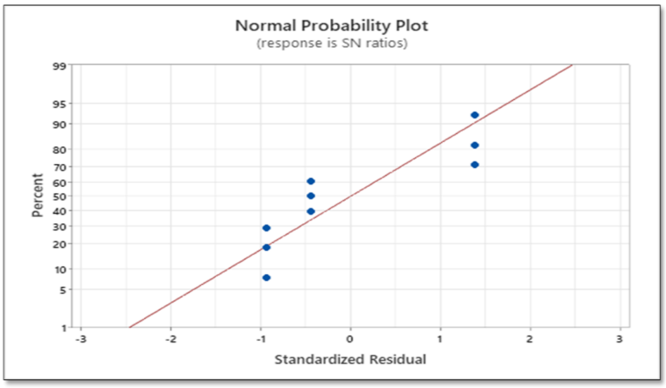
After doing the ANOVA in Minitab 15 the value of R2 & R2 (Adj) are obtained, they are as follows,

S = 0.2651, R2 = 98.54.0%, R2 (Adj) = 94.14%

In addition, a numerical model by design expert has been developed and the analysis of variance (ANOVA) by design expert is presented in Table. The R2 coefficient indicates the goodness of fit for the model. In this case, the value of the coefficient (R2 = 0.99854) indicates that 98.54% of the total variability is explained by the model after considering the significant factors. . The difference between R2 & R2 (Adj) was 3.2 % and it shows that presence of less number of insignificant factors in the model. Effects with the value of P is less than 0.05 so that are significant 95%.

4.1.4 Validation of the Models: Graphical Tools

Graphical tools can be used for validation of the models. The graphical method characterizes the nature of residuals of the models. Graph 1.2 shows the residual plots for Ra. In the normal probability plot of the residuals shown in graph 1.2 the data were plotted against a theoretical normal distribution in such a way that the points should form an approximate straight line, and a departure from this straight line would indicate a departure from a normal distribution, which was used to check the normality distribution of the residuals. In graph 1.2 the first residual plot is Normal Probability plot, it shows all the points are close to the straight line which means residuals are normally distributed.



Graph No. 1.2: Residual Plots for Ra Value

4.2) I.D Shift:

Input parameters and their levels

Process Parameter's	LEVEL 1	LEVEL 2	LEVEL 3
Cutting Speed (Rpm)	350	650	950
Feed Rate (mm/rev)	50	80	120
No of Passes	1	2	3

Table 2.1: Experiment Process Parameters

Design of experiments (DOE) for selected input parameters experiments are designed using Taguchi L9 orthogonal standard array. For this purpose software Minitab 17 is used

Job No	Speed (Rpm)	Feed (mm/Rev)	Depth of Cut (mm)
1	350	50	1
2	350	80	2
3	350	120	3
4	650	50	2
5	650	80	3
6	650	120	1
7	950	50	3
8	950	80	1
9	950	120	2

Table 2.2: Experiment Process Parameters

4.2.1 Experimentation

After design of experiment, 9 experiments are carried out in vertical milling Machine. After each experiment I.D Shift is calculated. A quality characteristic for I.D Shift is "Smaller is the better".

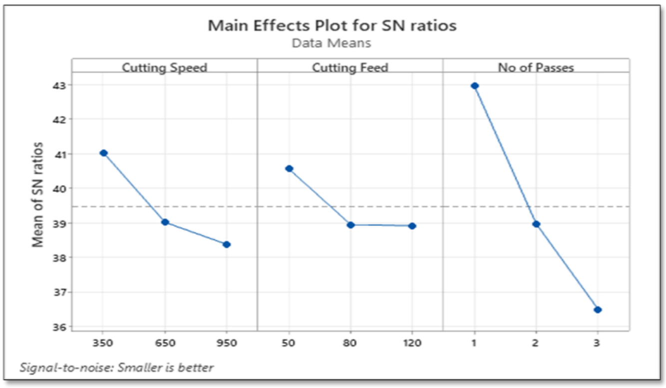
Job No	Speed (Rpm)	Feed (mm/Rev)	Depth of Cut (mm)	I.D Shift
1	350	50	1	0.005
2	350	80	2	0.010
3	350	120	3	0.014
4	650	50	2	0.011
5	650	80	3	0.016
6	650	120	1	0.008
7	950	50	3	0.015
8	950	80	1	0.009
9	950	120	2	0.013

Table 2.3: I.D Shift Values against Input process Parameter's

4.2.2 Results and Discussions

Cutting Speed	Feed Rate	No of Passes	I.D shift	SNRA1	MEAN 1
350	50	1	0.005	46.021	0.005
350	80	2	0.010	40.000	0.01
350	120	3	0.014	37.077	0.014
650	50	2	0.011	39.172	0.011
650	80	3	0.016	35.918	0.016
650	120	1	0.008	41.938	0.008
950	50	3	0.015	36.478	0.015
950	80	1	0.009	40.915	0.009
950	120	2	0.013	37.721	0.013

Table 2.4: Results Table of I.D Shift Values



Graph 2.1: Effect of Signal to Noise Ratio

Level	Speed	Feed	No of Passes
1	41.03	40.56	42.96
2	39.01	38.94	38.96
3	38.37	38.91	36.49
Delta	2.66	1.64	6.47
Rank	2	3	1

Table 2.5: Response Table of Signal to Noise Ratios

To get minimize I.D Shift the optimal parameters are Spindle Speed at 950 rpm, feed at 80 mm/rev & No of Pass 1.

4.2.3Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) gives a clear picture of the extent to which a particular process parameter affects the response. Hence ANOVA was used to statistically distinguish the significant factors from insignificant ones. The ANOVA for means of surface Roughness and are shown in Table

Source	DOF	SS	MS	F	P	% Contribution
Speed	2	0.000012	0.000006	52	0.019	11.5384615
Feed	2	0.000004	0.000002	16	0.059	3.84615385
No of Passes	2	0.000088	0.000044	397	0.003	84.6153846
Residual Error	2	0	0			
Total	8	0.000104				

Table 2.6: ANOVA Table for Means of (I.D Shift)

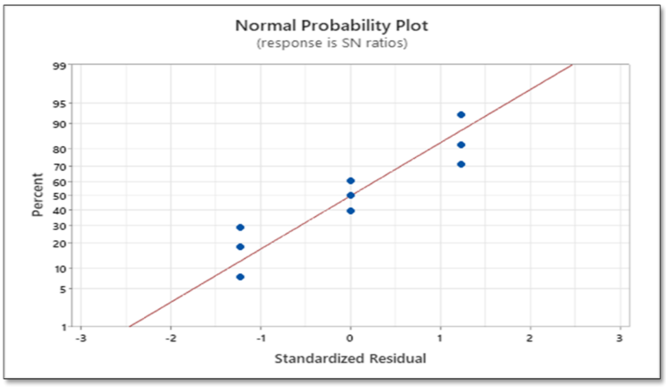
F- Test was carried out for checking the significance of the process parameters. It was found out that Speed having contribution of 894.64% was the most significant parameters. While other two factors were insignificant.

After doing the ANOVA in Minitab 15 the value of R2 & R2 (Adj) are obtained, they are as follows,

S = 0.7201, R2 = 98.73 %, R2 (Adj) = 94.93%

The difference between R2 & R2 (Adj) was 3.2 % and it shows that presence of less number of insignificant factors in the model. Effects with the value of P is less than 0.05 so that are significant 95%

4.2.4 Validation of the Models: Graphical Tools



Graph No. 2.2: Residual Plots for I.D Shift Value

In graph 2.2 the first residual plot is Normal Probability plot, it shows all the points are close to the straight line which means residuals are normally distributed.

4.3) I.D Over-Size:

Input parameters and their levels

Process Parameter's	LEVEL 1	LEVEL 2	LEVEL 3
Cutting Speed (Rpm)	350	650	950
Feed Rate (mm/rev)	50	80	120

Table 3.1: Experiment Process Parameters

Design of experiments (DOE) for selected input parameters experiments are designed using Taguchi L9 orthogonal standard array. For this purpose software Minitab 17 is used.

Job No	Speed (Rpm)	Feed (mm/Rev)
1	350	50
2	350	80
3	350	120
4	650	50

5	650	80
6	650	120
7	950	50
8	950	80
9	950	120

Table 3.2: Experiment Process Parameters

4.3.1Experimentation

After design of experiment, 9 experiments are carried out in vertical milling Machine. After each experiment I.D Over-Size is calculated. A quality characteristic for I.D Over-Size is "Smaller is the better".

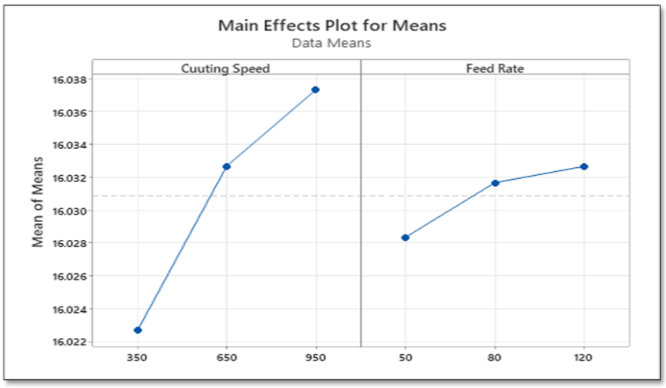
Job No	Speed (Rpm)	Feed (mm/Rev)	I.D Over-Size
1	350	50	16.020
2	350	80	16.025
3	350	120	16.023
4	650	50	16.028
5	650	80	16.034
6	650	120	16.036
7	950	50	16.037
8	950	80	16.036
9	950	120	16.039

Table 3.3: I.D O/S Values against Input process Parameter's

4.3.2 Results and Discussions

Cutting Speed	Feed Rate	Internal Dia oversize	SNRA	MEAN
350	50	16.02	-24.093	16.02
350	80	16.025	-24.096	16.025
350	120	16.023	-24.095	16.023
650	50	16.028	-24.098	16.028
650	80	16.034	-24.101	16.034
650	120	16.036	-24.102	16.036
950	50	16.037	-24.102	16.037
950	80	16.036	-24.102	16.036
950	120	16.039	-24.104	16.039

Table 3.4: Results Table of I.D over Size



Graph 3.1: Effect of Signal to Noise Ratio

Level	Speed	Feed
1	-24.09	-24.10
2	-24.10	-24.11
3	-24.10	-24.11
Delta	0.01	0
Rank	1	2

Table 3.5: Response Table of Signal to Noise Ratios

To get minimize I.D Over-Size the optimal parameters are Spindle Speed at 350 rpm, feed at 80 mm/rev.

4.3.3. Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) gives a clear picture of the extent to which a particular process parameter affects the response. Hence ANOVA was used to statistically distinguish the significant factors from insignificant ones. The ANOVA for means of surface Roughness and are shown in Table.

Source	DOF	SS	MS	F	P	% Contribution
Speed	2	0.000337	0.000168	31.92	0.003	86.6323907
Feed	2	0.000031	0.000015	2.93	0.165	7.96915167
Residual Error	4	0.000021	0.000005			
Total	8	0.000389				

Table 3.6: ANNOVA Table for Means of (I.D over Size)

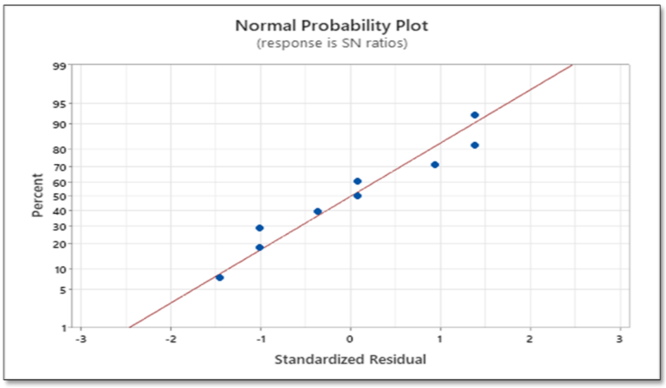
F- Test was carried out for checking the significance of the process parameters. It was found out that Speed having contribution of 86.63% was the most significant parameters. While other factors were insignificant.

After doing the ANOVA in Minitab 15 the value of R2 & R2 (Adj) are obtained, they are as follows,

S = 0.023, R2 = 94.75%, R2 (Adj) = 89.14%

The difference between R2 & R2 (Adj) was 5.61 % and it shows that presence of less number of insignificant factors in the model. Effects with the value of P is less than 0.05 so that are significant 95%

4.3.4 Validation of the Models: Graphical Tools



Graph No. 3.2: Residual Plots for I.D Shift Value

In graph 3.2 the first residual plot is Normal Probability plot, it shows all the points are close to the straight line which means residuals are normally distribute

5. CONCLUSIONS

1. The Levels of the parameters were optimized with Respect to Surface Finish, I.D Shift & I.D oversize.

2. ANOVA Predicted that the Cutting Speed contributes dominantly among other two factors towards surface Roughness (Ra). It was inferred from Taguchi Analysis that to get better Surface finish the optimal parameters are Spindle Speed at 350 rpm, feed at 80 mm/rev & depth of cut at 0.25.

3. In Case of I.D shift values, ANOVA Predicted that No. of Passes of Honing Tool contributed significantly compared to the other two parameters It was inferred from Taguchi Analysis that to get better Surface finish the optimal parameters are Spindle Speed at 950 rpm, feed at 80 mm/rev & No of Pass 1.

4. In Case of I.D Oversize values, ANOVA Predicted that Cutting Speed contributed significantly compared to the Feed.

5. These helped to minimize the customer Complaints, to minimize the defects, to maximize the productivity and for smooth process Flow.

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