Journal of Mines, Metals and Fuels, *71(12): 2616-2623; 2023. DOI: 10.18311/jmmf/2023/40599*

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: *www.informaticsjournals.com/index.php/jmmf*

Parametric Optimization in Turning Process of Galvanized Iron Metal using Taguchi Based Six Sigma Technique

P. Muraleedharan[1], V. R. Muruganantham[2], A. G. Karthikeyan[3]*, P. Muruganandhan[4], M. Mani[5] and Beporam Iftekhar Hussain[6]

[1]*Department of Mechanical Engineering, Karpagam College of Engineering, Coimbatore - 641032, Tamil Nadu, India*

[2]*Department of Mechanical Engineering, Kumaraguru College of Technology, Coimbatore - 641049, Tamil Nadu, India*

[3]*Department of Mechatronics Engineering, School of Mechanical Engineering, REVA University, Bengaluru - 560064, Karnataka, India; karthikeyanyasi@gmail.com*

[4]*Department of Mechanical Engineering, Mahendra Institute of Technology, Namakkal - 637503, Tamil Nadu, India*

[5]*Department of Mechanical Engineering, Sri Ranganathar Institute of Engineering and Technology, Coimbatore - 641110, Tamil Nadu, India*

[6]*Associate Professor, Department of Mechanical Engineering, Bapatla Engineering College, Bapatla - 522102, Andhra Pradesh, India*

Abstract

The Six Sigma approach is utilized in this research to improve the quality of process outputs while machining Galvanized Iron in turning process. The main objective of the present work is to improve the output characterization of MRR (Material Removal Rate) by optimizing the turning process parameters. Taguchi's parameter design is a method for optimizing control settings in Design of Experiments (DOE) to achieve the best results. An orthogonal array offers a framework of equal minimal experiments for prediction and diagnosis of optimal outcomes. The Material Removal Rate (MRR) is evaluated for each experiment. The response fluctuation was investigated using the Signal to Noise (S/N) ratio. In Miniutab 19 software, Taguchi technique reduces quality characteristic variation owing to uncontrollable parameters. Furthermore, statistical analysis reveals that the standard deviation and mean value of confirmatory trial results were lower than it was before Taguchi design run data.

Keywords: *Galvanized Iron, Material Removal Rate, Process Parameters, Six Sigma Method, Signal to Noise Ratio, Taguchi Method*

1.0 Introduction

In conventional lathe machine, many factors influence productivity, including materials of tool and work piece, working circumstances, cutting fluid utilized, tool shape, and so on[1]. Finding a set of metrics that produce the best outcomes is a challenging process. Six Sigma is a multi-stage approach to quality improvement[2]. In

*Author for correspondence

turning process, there are several parameters that have to be considered according to the material of the work piece, the material of the tool, the size of the tool. Few things that disturb the progression are speed of the spindle, Cutting Speed, cutting depth[3]. When it comes to customized machining, it's especially important to keep the method for determining the dimensions as brief as possible. Optimum cutting parameters, otherwise, the expense of analysis will skyrocket may be greater than the economic efficiency that could be If you labour under ideal conditions, you'll be able to achieve your goals[4]. As a result, lowering fluid consumption decrease, if not elimination, is critical from a cost and safety standpoint[5]. The Taguchi approach is a versatile method that may help solve a variety of issues, as well as mechanical engineering difficulties such as high-pressure jet optimization in turning process[6,7]. The S/N ratio and orthogonal array are two of the most important tools in this procedure. The properties of the S/N ratio could be split into three groupings: nominal is best, smaller is better, and higher is better[8,9,10]. The DMAIC approach includes the overall manufacturing process from the start, rather than just the finale result, and recognizes the entire activity from beginning to the last step[3,11]. The multi objective optimization methods were implemented to obtain the better output characteristics in turning process with irrespective of metals concern[12-14].

Hence from the various literatures, it is found that very few studies were carried out in cutting performance of Galvanized Iron in turning process. In this present study, Taguchi based six sigma technique is implemented to find the better optimized parameters levels in Turning process. The better production cost occurred using this technique to obtain the better-quality Galvanized Iron metals of machine parts and tools for mining industry applications.

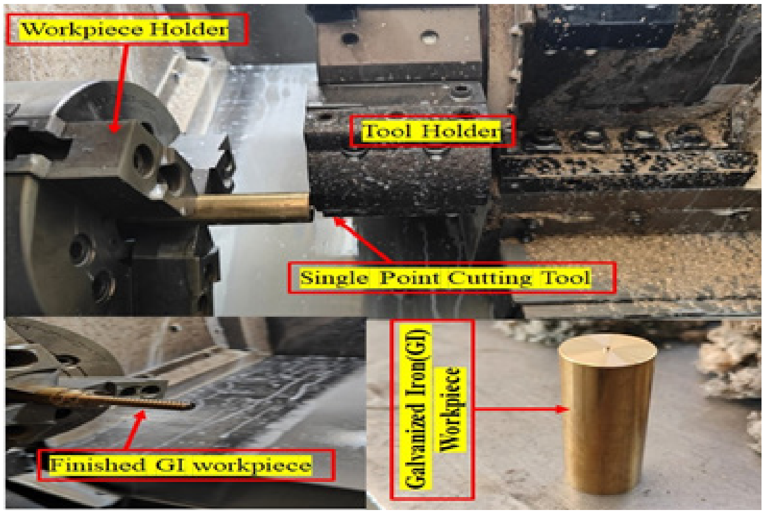

Figure 1. CNC turning process and GI setup with finished GI.

Table 1. Structure of Galvanized Iron (GI)

Sl. No.	Metals	Iron Variation
1	Graphite	Less than 0.25%
2	Silicon	Less than 0.04%
3	Manganese	Less than 1.35%
4	Sulphur	0.040%
5	Phosphorous	Less than 0.04%

2.0 Material and Method

Single Point Turning Tool (SPTT) is used as a tool material in the Turning Process. The number trails were considered based on the selected parameters and their levels. The image of the CNC lathe turning process is shown in Figure 1. The workpiece is clamped in the tool head and the raw material is shown in Figure 1. All the trials to be carried out with the same selected tool to find the output characteristics. The work materials for this project are galvanized iron for completing the experimentation to improve the MRR. The work material is assumed to be Galvanized Iron (GI), with the variation of metals composition is listed in Table 1. The finished Galvanized workpiece image is shown in Figure 1.

2.1 Measure- Data Collection

For each set of experiments, MRR is determined. MINITAB 19 software is deployed to find the Signal to Noise (S/N) ratio. Table 2 illustrates the process parameters of various levels. The MRR is determined using the formula.

MRR = (Initial Weight – Final Weight) / Time Taken (1)

3.0 Results and Discussion

To improve the quality of the process outputs, a Six Sigma technique is used. All flaws that can occur throughout the operation, with respect to men, machine, method, material, and atmosphere perceptions. As a result: speed

Table 2. Process parameters for the various levels

Input Parameters	Symbol	Levels			
		1	2	3	4
Speed of the Spindle (rpm)	A	95	150	230	390
Cutting Speed (mm/rev)	B	0.2	0.45	0.5	0.8
Cutting Depth (mm)	C	0.5	0.7	0.9	1.2

Table 3. Experimental data of Trial-I

Speed of the Spindle (rpm)	Cutting Speed (mm/rev)	Cutting Depth (mm)	Time (s)	Diff. in weights (gm)	MRR 1 (gm/sec)
95	0.2	0.5	36	7.32	0.235
95	0.45	0.7	20	3.65	0.198
95	0.5	0.9	15.8	3.45	0.203
95	0.8	1.2	9.58	1.56	0.145
150	0.2	0.7	30.5	5.23	0.186
150	0.45	0.5	13	2.45	0.231
150	0.5	0.9	11.5	2.85	0.241
150	0.8	1.2	9.2	1.45	0.178
230	0.2	0.9	27.56	5.62	0.223

Table 3 Continued

230	0.45	1.2	11.54	2.47	0.201
230	0.5	0.5	9.25	1.13	0.174
230	0.8	0.7	8.22	2.78	0.276
390	0.2	1.2	35.56	7.41	0.238
390	0.45	0.9	22.56	3.65	0.189
390	0.5	0.7	11.26	2.21	0.223
390	0.8	0.5	9.46	1.18	0.198

Table 4. Experimental data of Trial-II

Speed of the Spindle (rpm)	Cutting Speed (mm/rev)	Cutting Depth (mm)	Time (s)	Diff. in weights (gm)	MRR 2 (gm/sec)
95	0.2	0.5	35.2	7.52	0.298
95	0.45	0.7	21	3.78	0.114
95	0.5	0.9	17.78	3.45	0.245
95	0.8	1.2	11.18	1.45	0.185
150	0.2	0.7	31.25	5.41	0.176
150	0.45	0.5	15	2.49	0.239
150	0.5	0.9	12.5	3.21	0.248
150	0.8	1.2	10.2	1.45	0.187
230	0.2	0.9	26	5.75	0.261
230	0.45	1.2	12.44	2.41	0.227
230	0.5	0.5	9.29	1.36	0.116
230	0.8	0.7	8.56	2.59	0.234
390	0.2	1.2	35.56	8.14	0.216
390	0.45	0.9	22.96	3.98	0.179
390	0.5	0.7	11.46	2.27	0.244
390	0.8	0.5	8.78	1.36	0.192

of the spindle, Cutting Speed, cutting depth is chosen as the three constraints. Taguchi trial run built through the same range for all governable parameters using three controllable factors. Three runs were done for each parameter combination setting, and the averages are presented in Table 3, Tables 4 and 5 show the results. There

Table 5. Experimental data of Trial-III

Speed of the Spindle (rpm)	Cutting Speed (mm/rev)	Cutting Depth (mm)	Time (s)	Diff. in weights (gm)	MRR 3 (gm/sec)
95	0.2	0.5	35.45	7.53	0.274
95	0.45	0.7	21.14	3.14	0.165
95	0.5	0.9	17.56	3.36	0.288
95	0.8	1.2	12.54	1.74	0.181
150	0.2	0.7	31.46	5.36	0.163
150	0.45	0.5	15.78	2.84	0.221
150	0.5	0.9	12.47	3.61	0.282
150	0.8	1.2	10.2	1.27	0.171
230	0.2	0.9	26	5.36	0.265
230	0.45	1.2	12.447	2.98	0.237
230	0.5	0.5	9.65	1.36	0.126
230	0.8	0.7	8.47	2.41	0.247
390	0.2	1.2	35.76	8.52	0.231
390	0.45	0.9	22.66	3.88	0.196
390	0.5	0.7	11.26	2.36	0.212
390	0.8	0.5	8.71	1.29	0.130

Table 6. Trial outcomes, resultant σ, σ^2, S/N ratio

RUN	A	B	C	MRR1	MRR2	MRR3	Average	σ	σ^2	S/N ratio
1	1	1	1	0.235	0.298	0.274	0.269	0.07958	0.00635	-12.418
2	1	2	2	0.198	0.114	0.165	0.159	0.07104	0.00567	-13.548
3	1	3	3	0.203	0.245	0.288	0.245	0.07465	0.00596	-12.479
4	1	4	4	0.145	0.185	0.181	0.170	0.06214	0.00496	-14.248
5	2	1	2	0.186	0.176	0.163	0.175	0.02145	0.00171	-13.148

Table 6 Continued

6	2	2	1	0.231	0.239	0.221	0.230	0.03647	0.00291	-13.148
7	2	3	4	0.241	0.248	0.282	0.257	0.01745	0.00134	-12.355
8	2	4	3	0.178	0.187	0.171	0.179	0.01674	0.00134	-14.166
9	3	1	3	0.223	0.261	0.265	0.250	0.01245	0.00100	-13.165
10	3	2	4	0.201	0.227	0.237	0.222	0.01256	0.00100	-14.864
11	3	3	1	0.174	0.116	0.126	0.139	0.04157	0.00332	-11.761
12	3	4	2	0.276	0.234	0.247	0.252	0.04125	0.00329	-14.642
13	4	1	4	0.238	0.216	0.231	0.228	0.04365	0.00348	-13.986
14	4	2	3	0.189	0.179	0.196	0.188	0.01947	0.00155	-11.936
15	4	3	2	0.223	0.244	0.212	0.226	0.01746	0.00139	-14.146
16	4	4	1	0.198	0.192	0.13	0.173	0.09246	0.00738	-13.575

is a total of Forty-Eight investigational runs. The three runs average value, standard deviation, variance, and S/N ratio were calculated. Tables 3 to 5 presents investigational data of Material Removal Rate using Taguchi analysis. Table 6 shows the effects total parameters on Material Removal Rate and Signal to Noise ratio. Here, the higher the aspect of the quality, the better the method. Table 7 provides the mean response of variables from all factors in the MRR response table. Taguchi analysis design at every level has one more than three levels of factors for each level of factors. Table 6 shows the response values, which are determined by averaging all four responses. Table 8 shows the result for the S/N ratio of the response MRR. By using S/N response values are used to determine the optimal ratio and response value. Required features combination that yields the necessary Material Removal Rate (MRR).

Table 7. Controllable factors responses to the average MRR

	A	**B**	**C**	
Level 1	0.2345	0.2465	0.2265	**Optimum Combination smaller the better (A3-B2-C3)**
Level 2	0.2164	0.2065	0.2273	
Level 3	0.2143	0.2171	0.2196	
Level 4	0.2306	0.2236	0.2213	

Table 8. Controllable factors' responses to the S/N ratio

	A	B	C	
Level 1	-13.5478	-12.418	-12.355	**Optimum Combination smaller the better (A4-B1-C2)**
Level 2	-12.2478	-13.548	-14.166	
Level 3	-14.2478	-12.479	-13.165	
Level 4	-13.5746	-14.248	-14.864	

3.1 Improve and Control

The optimal turning process setting combination is A3-B2-C3, which translates to Rotational speed of 230 revolutions per minute, cutting rate of 0.45 millimeters per revolution, and cut penetration of 0.9 mm. The biggest value is used to calculate the S/N ratio. Then there's the S/N. A4-B1-C2 is the best setting combination for ratio response. The letters A4-B1-C2 stand for the spindle is spinning at 390 rpm, with a Cutting rate of 0.2 mm/rev, cut penetration of 0.7 mm.

4.0 Conclusion

From the successful conduction of the experiments which shown the shrink the sequence and cash spent on production process using Six Sigma process, hence the fundamental goal of all manufacturing firms. Taguchi optimization analysis was used to optimize the turning process parameter in this study. The number of experiment runs was lowered using Taguchi analysis. Overall, a total of 48 trial runs were carried out. The best grouping of settings A4-B1-C2 is the Taguchi analysis design, that is the speed of the spindle is 390 230 revolutions per minute. With a feed rate of 0.2 millimeters per revolution and a cut penetration of 0.7 mm, the existing feed rate is maintained. Efficiency is augmented, and superior product quality parts of GI parts for mining industry is suggested.

5.0 References

1. Schwartz M. Boca raton: encyclopedia and handbook of materials, Parts and Finishes. CRC Press, 3rd edition; 2016. https://doi.org/10.1201/b18998
2. Kwak YH, Anbari FT. Benefits, obstacles, and future of six sigma approach. Techno. 2006; 26:708-15. https://doi.org/10.1016/j.technovation.2004.10.003
3. Sekulić M, Kovac PP, Gostimirović M, Kramar D. Optimization of high-pressure jet assisted turning process by Taguchi method. Adv Prod Eng Manag. 2013; 8:5-12. https://doi.org/10.14743/apem2013.1.148
4. Thomas JJ, Vishnu Prasad VN. Multi objective optimization and comparison of process parameters in turning operation. Int J Eng Res Technol. 2017; 6:193-9. https://doi.org/10.17577/IJERTV6IS060138
5. Musavi SH, Davoodi B, Eskandari B. Evaluation of surface roughness and optimization of cutting parameters in turning of AA2024 alloy under different cooling-lubrication conditions using RSM method. J Cent South Univ. 2020; 27:1714-28. https://doi.org/10.1007/s11771-020-4402-2
6. Das PP, Das P, Ghadai RK, Manickam R, Kalita K. Optimization of turning process parameters by taguchi based six sigma. Mech Mech Eng. 2017; 21:649–56.
7. Muruganantham VR, Muraleedharan P, Devan PD, Eswar RM. Six sigma - DMAIC method for choice of material in natural fibers in polymer composite based wall brick. AIP Conf Proc. 2022; 2446:150002. https://doi.org/10.1063/5.0108188
8. Das MK, Kumar K, Barman TKR, Sahoo P. Optimisation of EDM process parameters using grey-Taguchi technique. Int J Mach Mach Mater. 2014; 15:235–62. https://doi.org/10.1504/IJMMM.2014.060553
9. Suhail AH, Ismail N, Wong SV, Abdul Jalil NA. Optimization of cutting parameters based on surface roughness and assistance of workpiece surface temperature in turning process. Am J Eng Appl Sci. 2010; 3:102-8. https://doi.org/10.3844/ajeassp.2010.102.108
10. Naik GM, Narendranath S. Optimization of wire-ED turning process parameters by taguchi-grey relational analysis. I-man J Mech Eng. 2018; 8:1-8.

11. Singh BJ, Sodhi HS. Parametric optimisation of CNC turning for Al-7020 with RSM. Int J Oper Res. 2014; 20:180-206. https://doi.org/10.1504/IJOR.2014.061769
12. Ketabforoush M, Aziz NA. The effect of taguchi-based six sigma method on variation reduction in a green construction material production process. IJST-T Civ Eng. 2021; 45:879–89. https://doi.org/10.1007/s40996-021-00583-1
13. Chen JC, Li Y, Cox RA. Taguchi-based Six Sigma approach to optimize plasma cutting process: an industrial case study. Int J Adv Manuf Technol. 2009; 4:760–9. https://doi.org/10.1007/s00170-008-1526-1
14. Li N, Chen Y-J, Kong D-D. Multi-response optimization of Ti-6Al-4V turning operations using Taguchi-based grey relational analysis coupled with kernel principal component analysis. Adv Manuf. 2019; 7:142–54. https://doi.org/10.1007/s40436-019-00251-8