International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 04 | Apr 2020 www.irjet.net p-ISSN: 2395-0072

AN OPTIMIZATION OF DRILLING PARAMETERS ON SS304 USING VARIOUS DRILL BITS

Sushil Sabari. R[1], Thiruvenkataselvam. K[2], Vanjinathan. S[3], Sathish. R[4]

[1,2,3,4]*Department of Mechanical Engineering, CARE Group of Institutions, Tamil Nadu, India*

---***---

Abstract - *Drilling operation is widely used in the aviation and automotive industries, although modern metal cutting methods have improved in the manufacturing industries, but conventional drilling still remains one of the most common machining. In this study, focuses on the optimization of drilling parameters using the Taguchi technique to obtain minimum surface roughness (Ra) and Hole diameter, Cylindricity & Machining Time. A number of drilling experiments were conducted using the L9 orthogonal array on Vertical Machining Center. The experiments were performed on SS304 using High Speed Steel (HSS), CRYO treated HSS and M42 twist drills under wet cutting conditions with various speed and feed. By the Taguchi experimental trials, data was collected and analyzed using commercial software MINITAB17.*

Key Words: **Drilling, Taguchi method, ANOVA, SS304, MINITAB17**

1. INTRODUCTION

1.1 Drilling

Drilling is a process of producing round holes in a solid material or enlarging existing holes with the use of multi-point cutting tools called drills or drill bits. Drilling is a continuous machining process. Various cutting tools are available for drilling, but the most common is the twist drill. Wide variety of drill processes are available to serve different purposes (core drilling, step drilling, counter boring, counter sinking, reaming, centre drilling, gun drilling etc.). With the rapidly growing technologies quality and productivity are the major concern. Productivity is concerned with the speed and feed during machining operation and quality refers to the product characteristics. So, the quality and productivity can be improved through parameters optimization. There are number of research works related to various drilling parameters optimization for achieving the performance responses. Among them surface roughness on drill bit is the major performance responses.

1.2 Minitab

MINITAB is the leading global provider of software and services for quality improvement, data analysis and statistics. MINITAB is a popular & powerful statistical software package that provides a wide range of data analysis capabilities. Most of the companies use MINITAB Statistical Software, the company's flagship product, and more student worldwide use MINITAB to learn statistics than any other package. From Statistical Process Control to Design of Experiments, MINITAB offers you the methods you need to implement every phase of your quality project. MINITAB provides a quick, effective solution for the level of analysis required in most Six Sigma projects.

1.3 Drilling Parameters

The Drilling parameters that we considered are speed, feed and material of the drill bit. The above mentioned are the key parameters which affects the machining of the workpieces. Input parameters that were considered are Different types of tools, Speed, Feed. Output parameters that were calculated are Surface Roughness, Machining Time, Circular Diameter, and Cylindrical Error.

Table -1: Process Parameters and Their Levels

Factors	Levels	Level 1	Level 2	Level 3
Tool Material (A)	3	HSS	M42	CRYO Treated HSS
Speed of Spindle (RPM) (B)	3	700	800	900
Feed Rate (mm/rev) (C)	3	0.2	0.4	0.6

2. METHODOLOGY

2.1 Design of Experiment (DOE)

Design of Experiment is a powerful approach to improve product design or improve process performance where it can be used to reduce cycle time required to develop new product or processes. Design experiment is a test or series of test that the input variable (parameter) of a process is change so that observation and identifying corresponding changes in the output response can be verify. The result of the process is analyzed to find the optimum value or parameters that have a most significant effect to the process.

2.2 Analysis of Variance (ANOVA)

The Analysis of Variance (ANOVA) is a powerful and common statistical procedure in the social sciences. It is the application to identify the effect of individual factors. In statistics, ANOVA is a collection of statistical models, and their associated procedures, in which the observed variance is partitioned into components due to different explanatory variables. In its simplest form ANOVA gives a statistical test of whether the means of several groups are all equal, and therefore generalizes.

2.3 Taguchi Method

The Taguchi technique is a methodology for finding the optimum setting of the control factors to make the product or process insensitive to the noise factors. Taguchi's techniques have been used widely in engineering design, and can be applied to many aspects such as optimization, experimental design, sensitivity analysis, parameter estimation, model prediction, etc. The distinct idea of Taguchi's robust design that differs from the conventional experimental design is that of designing for the simultaneous modelling of both mean and variability. Taguchi based optimization technique has produced a unique and powerful optimization discipline that differs from traditional practices. While, traditional experimental design methods are sometimes too complex and time consuming, Taguchi methodology is a relatively simple method. Taguchi method uses a special highly fractionated factorial designs and other types of fractional designs obtained from orthogonal arrays (OA) to study the entire experimental region of interest for experimenter with a small number of experiments. This reduces the time and costs of experiments, and additionally allows for an optimization of the process to be performed. The columns of an OA represent the experimental parameters to be optimized and the rows represent the individual trials (combinations of levels). Traditionally, data from experiments is used to analyze the mean response. However, in Taguchi method the mean and the variance of the response (experimental result) at each setting of parameters in OA are combined into a single performance measure known as the signal-to-noise (S/N) ratio. Depending on the criterion for the quality characteristic to be optimized, different S/N ratios can be chosen:

- Smaller-The-Better
- Larger-The-Better
- Nominal-The-Best

2.4 SMALLER IS BETTER

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the smaller-is-better S/N ratio using base 10 log is:

$$S/N = -10*\log(S(Y2)/n)$$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

2.5 LARGER IS BETTER

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the larger-is-better S/N ratio using base 10 log is:

$$S/N = -10*\log(S(1/Y2)/n)$$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

2.6 NOMINAL IS BEST

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the nominal-is-best I S/N ratio using base 10 log is:

$$S/N = -10*\log(s2)$$

Where s = standard deviation of the responses for all noise factors for the given factor level combination.

3. EXPERIMENTAL WORK

3.1 Workpiece Material Details

The work material is cut as required sizes of 32×32×18 mm3, from AISI 304 Stainless Steel with help of power hacksaw to perform drilling operation on them. The chemical composition of work materials is shown in Table 2.

Table -2: Chemical Properties of AISI 304

S.no	Component	Composition in Weight %	
		Min.	Max.
1	Carbon, c	0	0.08
2	Chromium, Cr	18	20
3	Iron, Fe	66.345	74
4	Manganese, Mn	0	2
5	Nickel, Ni	8	10.5
6	Phosphorus, P	0	0.045
7	Sulphur, S	0	0.03
8	Silicon, Si	0	1

3.2 TOOL MATERIAL SETUP

3.2.1 High Speed Steel (HSS) Drill Bit

Advent of HSS in around 1905 made a break through at that time in the history of cutting tool materials though got later suspended by many other novel tool materials like cemented carbides and ceramics.

Table -3: Composition of HSS

Element	Composition (%)
Tungsten, W	18
Chromium, Cr	4
Vanadium, V	1
Carbon, C	0.7
Iron, Fe	rest

3.2.2 M42 Drill Bit

M42 super high-speed steel is a premium cobalt high speed steel with a chemical composition designed for high hardness and superior hot hardness.

Table -4: Composition of M42

Carbon	Silicon	Chromium	Tungsten	Molybdenum	Vanadium	Cobalt
1.08	0.45	3.85	1.50	9.50	1.20	8.00

New cobalt drill bits are a dull gold color, making them distinctive on the shelf (or in your toolbox). The color occurs when the drill bits are baked in the process of production; it's not a paint or plating cobalt drill bits are cobalt alloy through and through. For this reason, they can be sharpened relatively easily with cutting fluid while retaining their strength and durability.

3.2.3 CRYO treated HSS Drill bit

The deep cryogenic treatment was carried out as per the following process parameters.

Table -5: Process parameter for Cryogenic

Soak temperature	-185°C
Soak period	36 hours
Cooling rate	1°C per min
Heating rate	1°C per min
Tempering temperature	200°C
Tempering period	1 hr.
Tempering cycle	1
Total cycle time	34 hrs.

3.3 MACHINING SETUP

3.3.1 VERTICAL MACHINING CENTER

CNC vertical machining centres (VMCs) remain machine shop staples. These milling machines have vertically oriented spindles that approach work pieces mounted on their table from above and commonly perform 2.5- or 3-axis machining operations. They are less costly than horizontal machining centres (HMCs), which makes them attractive to small job shops as well as larger machining operations. In addition, the performance of these machines has increased over the years, leveraging technologies such as high-speed spindles and advanced CNC capabilities (including conversational control programming). Ancillary equipment is also available to increase the flexibility and capability of these machines, including spindle speeders, angle heads, tool- and part-probes, quick-change work holding devices, and rotary indexers to enable four- or five axis machining work.

Fig -1: VMC-SINUMERIC 828D BASIC

The work piece is holding on the worktable of the machine. The table movement controls the feed of work piece against the rotating cutter. The cutter is mounted on a spindle or Arbor and revolves at high speed. Except for rotation the cutter has no other motion. As the work piece advances, the cutter teeth remove the metal from the surface of work piece and the desired shape is produced as shown in Fig -2.

Fig -2: Work Piece after Drilling

3.3.2 Coordinate Measuring Machine

The typical CMM is composed of three axes, an X, Y and Z. These axes are orthogonal to each other in a typical three-dimensional coordinate system. Each axis has a scale system that indicates the location of that axis. The machine will read the input from the touch probe, as directed by the operator or programmer. The machine then uses the X, Y, Z coordinates of each of these points to determine size and position with micrometer precision typically. It is employed to calculate the cylindrical error and circular diameter.

3.3.3 Surface Roughness Measurement

Surface roughness tester TR-200 (Portable surface roughness tester) instrument is widely used to measure the shape or form of components. A profile measurement device is usually based on a tactile measurement principle. The surface is measured by moving a stylus across the surface. As the stylus moves up and down along the surface, a transducer converts these movements into a signal which is then transformed into a roughness number and usually a visually displayed profile. Multiple profiles can often be combined to form a surface representation.

Fig -3: Surface Roughness Tester TR-200

4. SURFACE ROUGHNESS

4.1 S/N RATIO

Table -6: Surface Roughness and S/N Ratios Values for the Experiments

Trial	Designation	Tool	Speed	Feed	Surface Roughness	SNRA1
1	$A_1B_1C_1$	HSS	700	0.02	1.822	-5.21097
2	$A_1B_2C_2$	HSS	800	0.04	1.372	-2.74708
3	$A_1B_3C_3$	HSS	900	0.06	2.427	-7.70140
4	$A_2B_1C_2$	M42	700	0.04	1.306	-2.31886
5	$A_2B_2C_3$	M42	800	0.06	1.876	-5.46466
6	$A_2B_3C_1$	M42	900	0.02	2.092	-6.41123
7	$A_3B_1C_3$	CRYO	700	0.06	1.972	-5.89814
8	$A_3B_2C_1$	CRYO	800	0.02	2.360	-7.45824
9	$A_3B_3C_2$	CRYO	900	0.04	2.351	-7.42505

4.2 Roughness Response for Each Level of The Process Parameter

Table -7: Response Table for Signal to Noise Ratios-Smaller is better

Level	Tool	Speed	Feed
1	-6.927	-4.476	-6.360
2	-5.220	-5.223	-4.164
3	-4.732	-7.179	-6.355
Delta	2.196	2.703	2.196
Rank	3	1	2

4.3 General Linear Model: RA versus TOOL, SPEED, FEED

Table -8: Factor Information

Factor	Type	Levels	Values
Tool	Fixed	3	HSS, M42, CRYO
Speed	Fixed	3	700, 800, 900
Feed	Fixed	3	0.02, 0.04, 0.06

4.4 ANOVA

Table -9: Analysis of Variance for RA

Source	DF	SEQ SS	ADJ MS	F	P	% of contribution
Tool	2	0.35928	0.17964	4.00	0.200	27
Speed	2	0.55373	0.27687	6.16	0.140	41
Feed	2	0.34473	0.17236	3.83	0.207	26
Error	2	0.08993	0.04496	-	-	6
Total	8	1.34767	-	-	-	100

4.5 Regression Equation

RA = 1.9531 + 0.275 TOOL_CRYO - 0.079 TOOL_HSS - 0.195 TOOL_M42 - 0.253 SPEED_700 - 0.084 SPEED_800 + 0.337 SPEED_900 + 0.138 FEED_0.02 - 0.277 FEED_0.04 + 0.139 FEED_0.06

4.6 Main Effects Plot for SN ratios

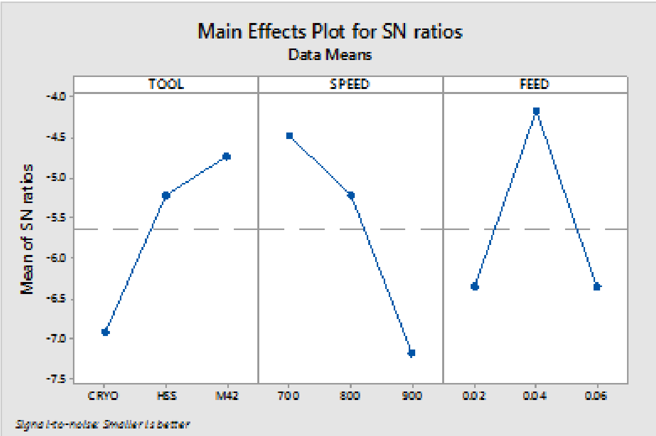

Chart -1: Main Effects Plot for SN Ratios

5. MACHINING TIME

5.1 S/N RATIO

Table -10: S/N Ratios Values for the Machining Time

Trial	Designation	Tool	Speed	Feed	Machining Time	SNRA1
1	$A_1B_1C_1$	HSS	700	0.02	1.32	-2.41148
2	$A_1B_1C_1$	HSS	800	0.04	1.28	-2.14420
3	$A_1B_1C_2$	HSS	900	0.06	1.02	-0.17200
4	$A_1B_1C_3$	M42	700	0.04	1.26	-2.00741
5	$A_1B_2C_1$	M42	800	0.06	1.24	-1.86843
6	$A_1B_2C_2$	M42	900	0.02	1.28	-2.14420
7	$A_1B_2C_3$	CRYO	700	0.06	1.30	-2.27887
8	$A_1B_3C_1$	CRYO	800	0.02	1.27	-2.07607
9	$A_1B_3C_2$	CRYO	900	0.04	1.26	-2.00741

5.2 Machining Time Response for Each Level of the Process Parameter

Table -11: Response Table for MT-smaller is better

Level	Tool	Speed	Feed
1	-2.121	-2.233	-2.211
2	-1.576	-2.030	-2.053
3	-2.007	-1.441	-1.440
Delta	0.545	0.791	0.771
Rank	3	1	2

5.3 General Linear Model: Machining Time versus Tool, Speed, Feed

Table -12: Factor Information

Factor	Type	Levels	Values
Tool	Fixed	3	HSS, M42, CRYO
Speed	Fixed	3	700, 800, 900
Feed	Fixed	3	0.02, 0.04, 0.06

5.4 ANOVA

Table -13: Analysis of Variance- Machining Time

Source	DF	Seq SS	Adj MS	F	P	% of Contribution
Tool	2	0.008022	0.004011	0.42	0.703	13
Speed	2	0.018156	0009078	0.96	0.511	29
Feed	2	0.017622	0.008811	0.93	0.518	28
Error	2	0.018956	0.009478	-	-	30
Total	8	0.062756	-	-	-	100

5.5 Regression Equation

MT = 1.2478 + 0.0289 TOOL_CRYO - 0.0411 TOOL_HSS + 0.0122 TOOL_M42+ 0.0456 SPEED_700+ 0.0156 SPEED_800-0.0611 SPEED_900+ 0.0422 FEED_0.0+ 0.0189 FEED_0.04-0.0611 FEED_0.06

5.6 Main Effects Plot for SN Ratio

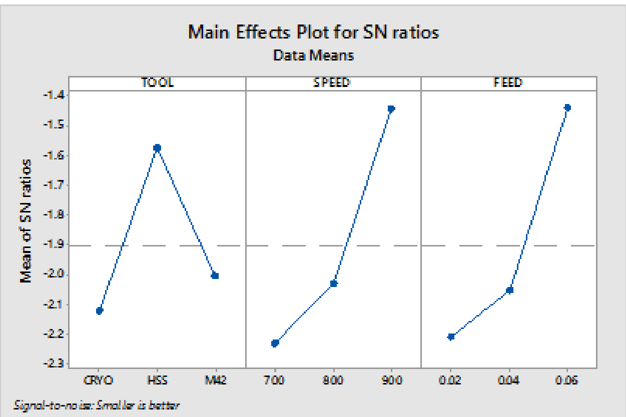

Chart -2: Main Effects Plot for SN Ratios

6. CIRULAR DIAMETER

6.1 S/N Ratio

Table -14: S/N Ratio for Circular Diameter

Trial	Designation	Tool	Speed	Feed	Diameter	SNRA1
1	$A_1B_1C_1$	HSS	700	0.02	10.068	-20.0589
2	$A_1B_1C_1$	HSS	800	0.04	10.107	-20.0924
3	$A_1B_1C_2$	HSS	900	0.06	10.098	-20.0847
4	$A_1B_1C_3$	M42	700	0.04	10.107	-20.0924
5	$A_1B_2C_1$	M42	800	0.06	10.091	-20.0787
6	$A_1B_2C_2$	M42	900	0.02	10.093	-20.0804
7	$A_1B_2C_3$	CRYO	700	0.06	10.115	-20.0993
8	$A_1B_3C_1$	CRYO	800	0.02	10.122	-20.1053
9	$A_1B_3C_2$	CRYO	900	0.04	10.089	-20.0770

6.2 Circle Diameter Response for Each Level of the Process Parameter

Table -15: Response Table for Signal to Noise Ratios-Smaller is better

Level	Tool	Speed	Feed
1	-20.09	-20.08	-20.08
2	-20.08	-20.09	-20.09
3	-2008	-20.08	-20.09
Delta	0.02	0.01	0.01
Rank	1	2	3

6.3 General Linear Model: Circle versus Tool, Speed, Feed

Table -16: Factor Information

Factor	Type	Levels	Values
Tool	Fixed	3	HSS, M42, Cryo
Speed	Fixed	3	700, 800, 900
Feed	Fixed	3	0.02, 0.04, 0.06

6.4 ANOVA

Table -17: Analysis of Variance of Circle Diameters

Source	DF	SEQ SS	ADJ MS	F	P	% of contribution
Tool	2	0.000484	0.000242	0.40	0.714	23
Speed	2	0.000289	0.000144	0.24	0.807	14
Feed	2	0.000094	0.000047	0.08	0.928	5
Error	2	0.001208	0.000604	-	-	58
Total	8	0.002075	-	-	-	100

6.5 Regression Equation

CIRCLE = 10.0989 + 0.0098 TOOL_CRYO – 0.0079 TOOL_HSS – 0.0019 TOOL_M42 – 0.0022 SPEED_700 + 0.0078 SPEED_800 – 0.0056 SPEED_900 – 0.0046 FEED_0.02 + 0.0021 FEED_0.04 + 0.0024 FEED_0.06

6.6 Main Effects Plot for SN Ratio

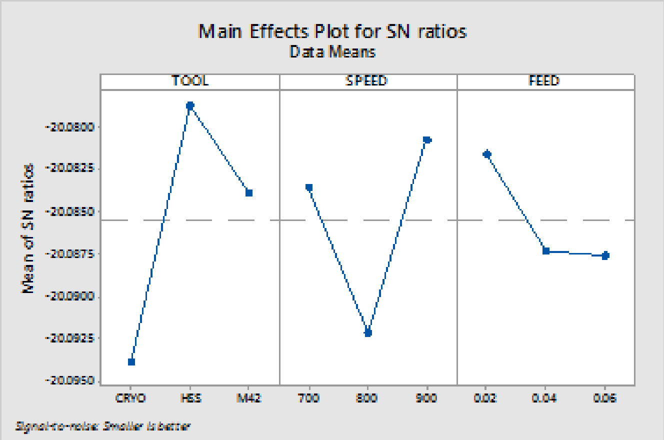

Chart -3: Main Effects Plot for SN Ratios

7. CYLINDRICAL ERROR

7.1 S/N Ratio

Table -18: Cylindrical Error S/N Values

Trial	Designation	Tool	Speed	Feed	Cylindrical Error	SNRA1
1	$A_1B_1C_1$	HSS	700	0.02	0.022	33.1515
2	$A_1B_1C_1$	HSS	800	0.04	0.033	29.6297
3	$A_1B_1C_2$	HSS	900	0.06	0.020	33.9794
4	$A_1B_1C_3$	M42	700	0.04	0.028	31.0568
5	$A_1B_2C_1$	M42	800	0.06	0.021	33.5556
6	$A_1B_2C_2$	M42	900	0.02	0.036	28.8739
7	$A_1B_2C_3$	CRYO	700	0.06	0.009	40.9151
8	$A_1B_3C_1$	CRYO	800	0.02	0.006	44.4370
9	$A_1B_3C_2$	CRYO	900	0.04	0.044	27.1309

7.2 Cylindrical Error Response for Each Level of the Process Parameter

Table -19: Response Table for Signal to Noise Ratios-Smaller is better

Level	Tool	Speed	Feed
1	37.49	35.04	35.49
2	32.25	35.87	29.27
3	31.16	29.99	36.15
DELTA	6.33	5.88	6.88
RANK	2	3	1

7.3 General Linear Model: Cylindrical Error versus Tool, Speed, Feed

Table -20: Factor Information

Factor	Type	Levels	Values
Tool	Fixed	3	HSS, M42, CRYO
Speed	Fixed	3	700,800,900
Feed	Fixed	3	0.02,0.04,0.06

7.4 ANOVA

Table -21: Analysis of Variance of Cylindrical Error

Source	DF	SEQ SS	ADJ MS	F	P	% of contribution
Tool	2	0.000115	0.000057	0.59	0.629	9
Speed	2	0.000365	0.000182	1.88	0.347	30
Feed	2	0.000545	0.000272	2.81	0.263	45
Error	2	0.000194	0.000097	-	-	16
Total	8	0.001218	-	-	-	100

7.5 Regression Equation

CYL.E = 0.02433 – 0.00467 TOOL_CRYO + 0.00067 TOOL_HSS + 0.00400 TOOL_M42 – 0.00467 SPEED_700 – 0.00433 SPEED_800 + 0.00900 SPEED_900 – 0.00300 FEED_0.02 + 0.01067 FEED_0.04 – 0.00767 FEED_0.06

7.6 Main Effects Plot for SN Ratio

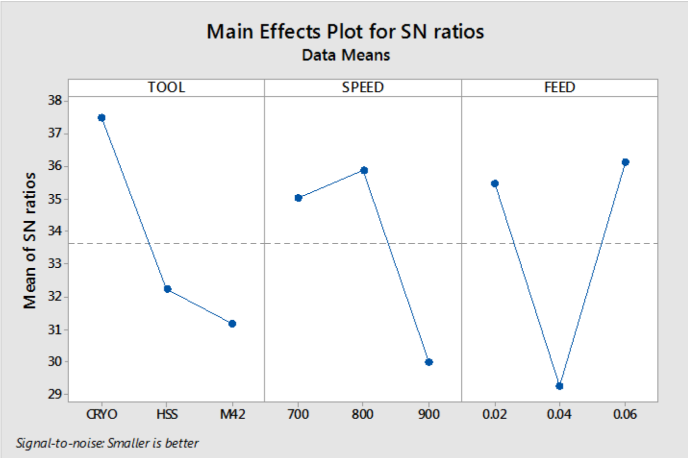

Chart -4: Main Effects Plot for SN Ratios

8. RESULTS AND DISCUSSIONS

8.1 L-9 Orthogonal Array

Through the Design of Experiments the desired input parameters have been calculated and analyzed as an orthogonal array. In this Trails, we have considered three factor and three levels. L9 Orthogonal array been created with the help of considered input and output parameters.

Table -22: Experimental Data

Trial	Designation	Tool	Speed	Feed	Surface Roughness	Machining Timing	Circular Diameter	Cylindrical Error
1	$A_1B_1C_1$	HSS	700	0.02	1.822	1.32	10.068	0.022
2	$A_1B_2C_2$	HSS	800	0.04	1.372	1.28	10.107	0.033
3	$A_1B_3C_3$	HSS	900	0.06	2.427	1.02	10.098	0.020
4	$A_2B_1C_2$	M42	700	0.04	1.306	1.26	10.107	0.028
5	$A_2B_2C_3$	M42	800	0.06	1.876	1.24	10.091	0.021
6	$A_2B_3C_1$	M42	900	0.02	2.092	1.28	10.093	0.036
7	$A_3B_1C_3$	CRYO HSS	700	0.06	1.972	1.30	10.115	0.009
8	$A_3B_2C_1$	CRYO HSS	800	0.02	2.360	1.27	10.122	0.006
9	$A_3B_3C_2$	CRYO HSS	900	0.04	2.351	1.26	10.089	0.044

8.2 Optimal Control Factor

Surface Roughness -	A3 (CRYO Drill)
	B1 (700 rpm)
	C2 (Feed – 0.04mm/Rev)
Machining Time -	A3 (CRYO Drill)
	B1 (700 rpm)
	C2 (Feed – 0.04mm/Rev)
Circular Diameter -	A1 (HSS Drill)
	B2 (Speed-700)
	C3 (Feed-0.06mm/Rev)
Cylindrical Error -	A2 (M42 Drill)
	B3 (Speed-900)
	C1 (Feed-0.02mm/Rev)

9. CONCLUSION

In this study, the Taguchi technique and ANOVA were used to obtain optimal Drilling parameters in Drilling operation of SS304 under wet conditions. As a result of the Taguchi experimental trials, it was found that the type of speed was the most significant factor improving the surface roughness and Machining timing with contribution respectively. The optimum control factor for surface roughness and Machining Timing A3 (CRYO treated HSS Drill), B1 (Speed-700) and C2 (Feed –0.04mm/Rev). The optimum control factor for Circular Diameter were A1 (HSS Drill), B2 (Speed-700) and C3 (Feed –0.06mm/Rev) and Type of drill bit used were the most significant factor improving the diameter accuracy. The optimum control factor for Cylindrical Error were A2 (M42 Drill), B3 (Speed-900) and C1 (Feed –0.02mm/Rev) Feed were the most significant factor reducing the cylindrical error with contribution of 45%. In our Experiment Cryo treated HSS drill bit performed minimum cylindrical error during drilling operation in vertical milling machine and good dimensional accuracy were obtained with HSS drill bit.

REFERENCES

[1] A. Navanth1, T. Karthikeya Sharma, A study of Taguchi method-based optimization of drilling parameter in dry drilling of al 2014 alloy at low speeds, ISSN: 2231 – 6604 volume 6, issue 1, pp: 65-75 ©ijeset.

[2] J. Prasanna, L. Karuna Moorthy, M. Venkat Raman, Sai Prashanth, D. Raj Chordia, Optimization of process parameters of small hole dry drilling in Ti–6Al–4V using Taguchi and grey relational analysis, Measurement 48 (2014) 346–354.

[3] Ulla's Çayda¸s1, Ahmet Hasçalık1, Ömer Buytoz1, and Ahmet Meyveci2, Performance Evaluation of Different Twist Drills in Dry Drilling of AISI 304 Austenitic Stainless Steel, Materials and Manufacturing Processes, 26: 951–960, 2011.

[4] M. Balaji, B.S.N. Moorthy, N. Mohan Rao, Optimization of Cutting Parameters in Drilling of AISI 304 Stainless Steel Using Taguchi and ANOVA, Procedia Technology 25 (2016) 1106 – 1113.

[5] Gaurav Chaudharya Manoj Kumarb, Santosh Vermac Anupam Srivastavd, Optimization of drilling parameters of hybrid metal matrix composites using response surface methodology, Procedia Materials Science 6 (2014) 229 – 237.