Analysis and Improvement of Testing Parameters for Mild Steel and Stainless Steel using Taguchi and ANOVA Method

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Abstract— The objective of this paper is to perform an analysis by conducting the mechanical testing of mild steel and stainless steel rods of various diameters on universal testing machine to evaluate the vertical deformation, normal stress, tensile stress and stain there by designing the experiments (DOE) for Taguchi analysis to know the key parameters in this work. For conducting this experiment the input parameters taken are diameter of shaft, length of the shaft, time of loading and weight of the shaft. After performing the Taguchi analysis the key parameters were found. Then the work is further carried out to ANOVA analysis of variance method to optimize the values for the parameters. A total of 9 rods for each material were taken and of different lengths. The assumptions considered for the above work are listed in the document.

Keywords: Testing Parameters, Design of Experiments, Taguchi, ANOVA Methods

I. INTRODUCTION

The testing parameters considered in these experiments are listed below. A sum of 9 rods has been taken for each material to undergo testing and analysis. They are 13mm, 19mm, 21mm, 25mm, 32mm, 48mm, 64mm, 90mm and 114mm. all the shafts are of circular cross section.

S No	Input	Output
1	Length	Vertical deformation
2	Diameter	Normal stress
3	Testing time	Shear stress
4	Weight	Strain

Level	Length (mm) (A)	Diameter (mm) (B)	Time (sec) (C)	Weight
1	60	13	112	0.578
2	62	19	123	1.379
3	65	21	131	1.767
4	61	25	142	2.35
5	64	32	149	4.04
6	66	48	156	9.375
7	67	64	164	16.9
8	61	90	172	30.46
9	62	114	189	24.83

Table 1: Input parameters with their respective levels for mild steel rods

Level	Length (mm) (A)	Diameter (mm) (B)	Time (sec) (C)	Weight or force (N) (D)
1	65	13	116	0.262
2	61	19	125	0.525
3	64	21	134	0.673
4	60	25	147	0.895
5	62	32	153	1.515
6	68	48	159	3.740
7	70	64	167	6.845
8	66	90	176	12.76
9	67	114	194	20.78

Table 2: Input parameters with their respective levels for stainless steel rods

II. ANALYSIS BASED ON TAGUCHI METHOD

Analysis of signal-to-noise ratio(S/N) & analysis of variance (ANOVA) are given as follow.

A. Analysis of (S/N) ratio

It is the ratio is the ratio of signal-to-noise. Signal indicates the output desirable value i.e. mean of output characteristics & noise indicates undesirable value i.e. squared deviation of output characteristics. (S/N) ratio measures quality characteristics. (S/N) ratio is denoted by η & its unit is db. Quality characteristics are defined as higher the best (HB) & lower the best (LB). For maximizing tensile shear strength higher the best value is desirable & also for nugget diameter. Strain and deformation will be preferred as lower the best value (LB).

The equation for η for higher the best is (1) & for lower the best is (2) is given as follow.

1) Case 1

It involves the shafts of mild steel of diameters 13mm, 19mm and 21mm. These shafts have been taken in to experiment to find the outcomes such as vertical deformation, normal stress, shear stress and strain. As mentioned above the input parameters for this experiment are length, diameter, thickness and weight or load or pressure.

S No	Length (mm)	Diameter (mm)	Time (sec)	Weight (N)	Average Tensile shear strength	Force (N)
	(A)	(B)	(C)	(D)	kN	
1	1	1	1	1	2.1	65.9
2	1	1	2	2	2.0	60.6
3	1	1	3	3	2.4	77.4
4	1	2	1	2	2.4	75.8
5	1	2	2	3	2.3	73.8
6	1	2	3	1	2.9	92.8
7	1	3	1	3	2.5	80.1
8	1	3	2	1	2.0	61.1
9	1	3	3	2	3.4	106.4
10	2	1	1	1	3.4	107.1
11	2	1	2	2	3.9	119.5
12	2	1	3	3	4.1	123.1
13	2	2	1	2	3.5	109.5

14	2	2	2	3	3.5	107.9
15	2	2	3	1	4.2	125.9
16	2	3	1	3	3.3	104.9
17	2	3	2	1	3.4	106.2
18	2	3	3	2	3.9	117.4
19	3	1	1	1	3.6	116.5
20	3	1	2	2	3.4	105.1
21	3	1	3	3	4.0	120.7
22	3	2	1	2	4.4	129.4
23	3	2	2	3	4.2	124.8
24	3	2	3	1	4.5	130.4
25	3	3	1	3	4.2	125.5
26	3	3	2	1	4.3	126.5
27	3	3	3	2	4.4	129.1

B. Taguchi & Analysis of variance (ANOVA)

ANOVA is a statistical analysis tool for data analysis. It includes design parameters that affect significantly output characteristics. In ANOVA method, sum of square (SS), mean square (MS) & F-test values are calculated for deciding significant factors which affecting the process & also percentage contribution contributed by parameters are calculated. ANOVA table for tensile shear strength are described in "TABLE-3", average effect response table for tensile shear strength as shown in "TABLE-4" & S/N ratio analysis of rank wise parameters are described in "TABLE-5".

Source	DOF	SS	MS	F-value	% C
A	2	44.37	22.18	312.39	79.917
B	2	1.57	0.78	10.98	2.827
C	2	4.26	2.13	30	7.672
D	2	0.16	0.08	1.12	0.288
Error	72	5.16	0.07		9.293
Total	80	55.52			100

Table 3: ANOVA table for experimental data

Level	A	B	C	D
1	2.4	3.2	3.3	3.3
2	3.7	3.6	3.2	3.5
3	4.1	3.5	3.8	3.4
Delta	1.7	0.4	0.6	0.2
Rank	1	3	2	4

Table 4: Average effect response table for tensile shear strength

Level	A	B	C	D
1	7.71	9.95	10.16	10.36
2	11.35	10.78	9.83	10.58
3	12.31	10.63	11.36	10.42
Delta	4.6	0.83	1.53	0.22
Rank	1	3	2	4

Table 5: S/N ratio for tensile shear strength

From the above table it is understood that length of the rod is more influencing among all other parameters, the tensile shear stress. And next to that the time of operation is influencing more and then the diameter of the rod and at the end the weight of the shaft.

Level	A	B	C	D
1	7.821	9.85	10.23	10.76
2	11.25	10.38	9.18	10.28
3	12.51	10.23	11.76	10.82
Delta	4.68	0.53	2.58	0.54
Rank	1	4	2	3

Table 6: S/N ratio for Normal stress

From the above table it is understood that length of the rod is more influencing among all other parameters, the normal stress. And next to that the time of operation is influencing more and then the weight of the shaft and at the end the diameter of the rod.

Level	A	B	C	D
1	6.74	10.15	10.76	9.36
2	9.23	10.28	9.21	10.18
3	8.75	10.93	11.76	10.32
Delta	2.49	0.78	2.55	0.96
Rank	1	4	2	3

Table 7: S/N ratio for Vertical deformation

From the above table it is understood that length of the rod is more influencing among all other parameters, the vertical deformation. And next to that the time of operation is influencing more and then the weight of the shaft and at the end the diameter of the rod.

Larger value of S/N ratio represents better quality characteristics for tensile shear strength. According to S/N ratio graph the levels of parameters to be set for determine optimum value of tensile shear strength is A3B2C3D2.

Most significant parameter according to ANOVA table is length which affects the performance of tensile shear strength. After length the significant parameter are diameter, time, and weight. Time and weight are less effective parameters compare with others. The percentage contributed by length, diameter, time and weight are 79.917%, 7.672%, 2.827%, & 0.288%.

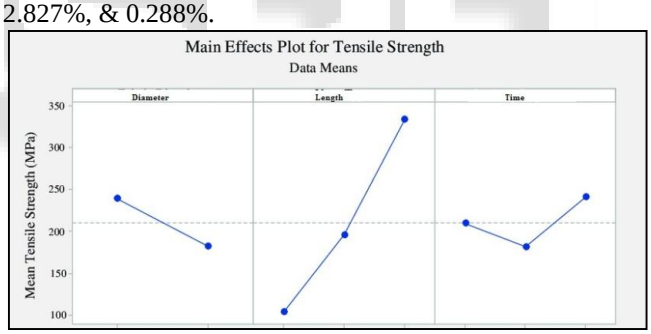

Fig. 3: Effects of parameters and data means

III. CONFIRMATION TEST

Confirmation test is very important in design of parameters. The aim of confirmation test is to validate the optimal value during analysis is $A_3B_2C_3D_2$. The confirmation test is done by the specific combination of parameters with their levels which were predicted as $A_3B_2C_3D2$. In this experimental procedure the optimal value has been predicted & new experiment is designed to conducting new experiments to get best weld performance of tensile shear strength. The predictions for optimum tensile shear strength are.

Predicted mean = A3+B2+C3+D2 4.8 µm.

Similarly S/N ratio mean = 13.68 db.

Comparison result of predicted tensile shear strength of optimum parameters with actual tensile strength using the optimal parameter are as given in "TABLE -6". The improvement in tensile shear strength is 4.08% & in S/N ratio is 2.54%. So tensile shear strength can be increase by Taguchi method.

1) Case 2

Similar to the case 1 in this case it involves the shafts of mild steel of diameters 25mm, 32mm and 48mm. These shafts have been taken in to experiment to find the outcomes such as vertical deformation, normal stress, shear stress and strain. As mentioned above the input parameters for this experiment are length, diameter, thickness and weight or load or pressure.

B. Taguchi & Analysis of variance (ANOVA)

ANOVA is a statistical analysis tool for data analysis. It includes design parameters that affect significantly output characteristics. In ANOVA method, sum of square (SS), mean square (MS) & F-test values are calculated for deciding significant factors which affecting the process & also percentage contribution contributed by parameters are calculated. ANOVA table for tensile shear strength are described in "TABLE-3", average effect response table for tensile shear strength as shown in "TABLE-4" & S/N ratio analysis of rank wise parameters are described in "TABLE-5".

Source	DOF	SS	MS	F-value	% C
A	2	45.27	21.19	313.29	79.299
B	2	1.63	0.76	11.28	2.825
C	2	4.12	2.15	31	7.618
D	2	0.18	0.08	1.15	0.268
Error	72	4.97	0.68		9.974
Total	80	55.52			100

Table 3: ANOVA table for experimental data

Level	A	B	C	D
1	2.3	3.1	3.2	3.1
2	3.4	3.8	3.1	3.6
3	3.9	3.2	3.4	3.2
Delta	1.9	0.7	0.3	0.5
Rank	1	2	4	3

Table 4: S/N ratio for Normal stress

From the above table it is understood that length of the rod is more influencing among all other parameters, the tensile shear stress. And next to that the diameter of the rod is influencing more and then the weight of the shaft and at the end the time of operation.

Level	A	B	C	D
1	7.21	9.85	9.16	10.16
2	11.45	10.48	10.23	10.68
3	12.21	10.33	10.36	10.22
Delta	5	0.63	1.2	0.52
Rank	1	3	2	4

Table 5: S/N ratio for tensile shear strength

From the above table it is understood that length of the rod is more influencing among all other parameters, the tensile shear stress. And next to that the time of operation is influencing more and then the diameter of the rod and at the end the weight of the shaft.

Level	A	B	C	D
1	6.34	9.95	10.56	9.16
2	9.53	10.18	9.31	10.48
3	8.15	10.73	11.26	10.2
Delta	3.19	0.78	1.95	1.32
Rank	1	4	2	3

Table 5: S/N ratio for Vertical deformation

From the above table it is understood that length of the rod is more influencing among all other parameters, the vertical deformation. And next to that the time of operation is influencing more and then the weight of the shaft and at the end the diameter of the rod.

Larger value of S/N ratio represents better quality characteristics for tensile shear strength. According to S/N ratio graph the levels of parameters to be set for determine optimum value of tensile shear strength is A3B2C3D2.

Most significant parameter according to ANOVA table is length which affects the performance of tensile shear strength. After length the significant parameter are diameter, time, and weight. Time and weight are less effective parameters compare with others. The percentage contributed by length, diameter, time and weight are 78.216%, 8.132%, 2.625%, & 0.279%.

IV. CONFIRMATION TEST

Confirmation test is very important in design of parameters. The aim of confirmation test is to validate the optimal value during analysis is $A_3B_2C_3D_2$. The confirmation test is done by the specific combination of parameters with their levels which were predicted as $A_3B_2C_3D2$. In this experimental procedure the optimal value has been predicted & new experiment is designed to conducting new experiments to get best weld performance of tensile shear strength. The predictions for optimum tensile shear strength are.

Predicted mean = A3+B2+C3+D2 = 4.7 µm.

Similarly S/N ratio mean = 12.79 db.

Comparison result of predicted tensile shear strength of optimum parameters with actual tensile strength using the optimal parameter are as given in "TABLE -6". The improvement in tensile shear strength is 3.68% & in S/N ratio is 2.63%. So tensile shear strength can be increase by Taguchi method. Likewise Case 3, 4, 5 and 6 were analyzed and the results are listed below.

V. RESULTS

This paper deals with optimization & the affect of factors on stress and deformation of the mild steel and stainless steel. Taguchi method determines significant testing parameters on UTM. According to ANOVA table testing time highly affects tensile shear strength whereas shaft diameter and length are second higher parameter that affects tensile shear strength. Testing time and weight are less affective parameters. S/N ratio determines the optimum combination of parameters with their levels or maximizing tensile shear strength. By conducting confirmation test & its results it is possible to increase tensile shear strength by 4.08%. The experimental results validate Taguchi method for quality engineering to best performance & optimization of testing parameters on UTM using mild steel and stainless steel.

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