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"TO FIND OUT OPTIMUM CHARACTERISTICS FOR THE HIGH BREAKING STRENGTH IN WELDING OPERATION ANALYSIS PERFORMED BY USING THE TAGUCHI METHOD"

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ABSTRACT

Welding is utilized as a manufacture cycle in industry huge or little. It is a chief method for manufacturing and fixing metal items. The cycle is proficient, conservative and reliable for the purpose of joining metals. This is the main cycle which has attempted in the space. The cycle tracks down its applications in air, submerged and space. This paper has discussed an application of the Taguchi method for optimizing the welding factors in Welding operation and indicated that the Taguchi design of experiment is an effective way of determining the optimal welding factors for Breaking Strength. The Welding Strength achievement from the confirmation runs under the optimal welding factors identified through Taguchi design of experiment that is accomplished with a relatively small number of experimental runs However, the research work can be extended as future scope by taking various other factors and level combinations which affects the welding strength like skill of the worker, heating before welding, quality of electrode and speed of the welding operation etc. with other noise factors.

Keyword: *welding, electrode, noise factor, cycle, submerged.*

I. INTRODUCTION

WELDING

Welding is a process in which weld two metal with the help of the heat and with and without help of the pressure and fitter materials. Welding is the important and widely used process to join metals. Metals may be similar or dissimilar. Welding preferred over other joining process like riveting, casting and nut bolting because it is faster, quieter and many more advantageous over other joining techniques. Now a day, welding is extensively used in fabrications of automobiles, aircrafts, ships, electronic equipment, machinery, home applications etc. as an alternative of casting or as a replacement of riveted or bolted joints. Welding of similar metals without filler material is known as autogeneous welding while with filler material is called homogeneous welding. On the other hand, welding of dissimilar metals with filler material rod is called heterogeneous welding.

IMPORTANCE OF WELDING

Welding is used as a fabrication process in industry large or small. It is a principal means of fabricating and repairing metal products. The process is efficient, economical and dependable as a means of joining metals. This is the only process which has tried in the space. The process finds its applications in air, underwater and space.
Welding offers many advantages over bolting and riveting. In welding the weight of the joint is minimum In the case of tension members the absence of holes improves the efficiency of the section. It involves less fabrication cost compared

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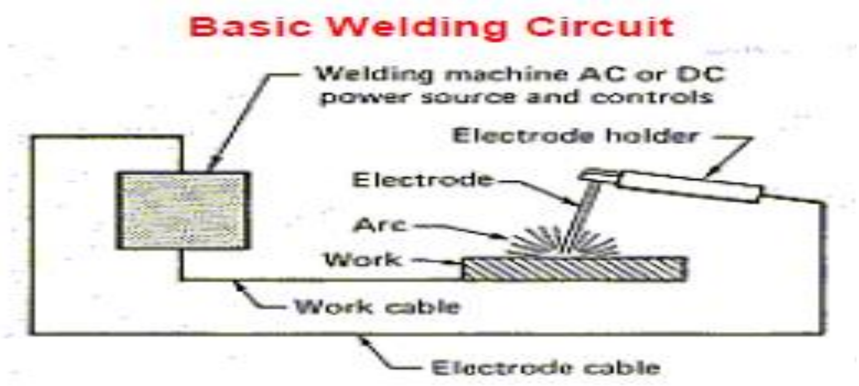
SJIF Impact Factor : 6.008

to other methods due to handling of fewer parts and elimination of operations like drilling, punching etc. and consequently less labor leading to economy. Welding offers air tight and water tight joining and hence is ideal for oil storage tanks, ships etc. Welded structures also have a neat appearance and enable the connection of complicated shapes. Welded structures are more rigid compared to structures with riveted and bolted connections.

COMMON ELECTRIC ARC WELDING PROCESSES

There are two principal sorts of bend welding processes. They are safeguarded metal bend welding and gas protected curve welding.

Safeguarded Metal Arc Welding (SMAW) - Shielded metal curve welding (fig. Figure beneath) is performed by striking a bend between a covered metal terminal and the base metal. When the bend has been laid out, the liquid metal from the tip of the anode streams along with the liquid metal from the edges of the base metal to forma sound joint. This interaction is known as combination. The covering from the terminal structures a covering over the weld store, protecting it from pollution; in this manner the cycle is called safeguarded metal curve welding. The primary benefits of safeguarded metal circular segment welding are that great welds are made quickly for a minimal price. Safeguarded Metal Arc Welding, otherwise called manual metal curve welding, stick welding, or electric circular segment welding, is the most generally utilized of the different bend welding processes. Welding is performed with the intensity of an electric curve that is kept up with between the finish of a covered metal cathode and the work piece (See Figure underneath).



. Fig 1 Basic welding circuit

ELECTRIC ARC WELDING

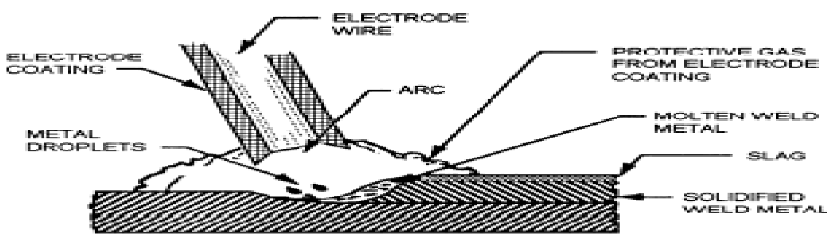


Fig. 2 Electric arc welding.

II. TAGUCHI METHODOLOGY

This chapter introduces Taguchi's Method in which multiple variables can be changed simultaneously without losing control of the experiment. The complete methodology, design and analysis procedure is discussed.

TAGUCHI TECHNIQUE

In early 1950's, Dr. Genichi Taguchi, "The Father of Quality Engineering," introduced the concept of off-line quality control techniques known as Taguchi parameter design. Offline quality control are those activities which were performed during the Product (or Process) Design and Development phase. Genichi Taguchi is a Japanese engineer, who has been active in the improvement of Japan's products and processes since the late 1940's. He has developed

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SJIF Impact Factor : 6.008

both a philosophy and methodology for the process of product quality improvement that depends heavily on statistical concepts and tools, especially statistically designed experiments. Many Japanese firms have achieved great success by applying his methods. It has been reported that thousand of engineers have performed tens of thousands of experiment based on his teaching. The Taguchi method is statistical tool, adopted experimentally to investigate influence of weld joint strength by welding parameters such as Hardness, Electrode Diameter and Weld Design. The Taguchi process helps The term Taguchi method refers to parameter design, tolerance design, the quality loss function, design of experiments, using orthogonal arrays and methodology applied to evaluate measuring system.

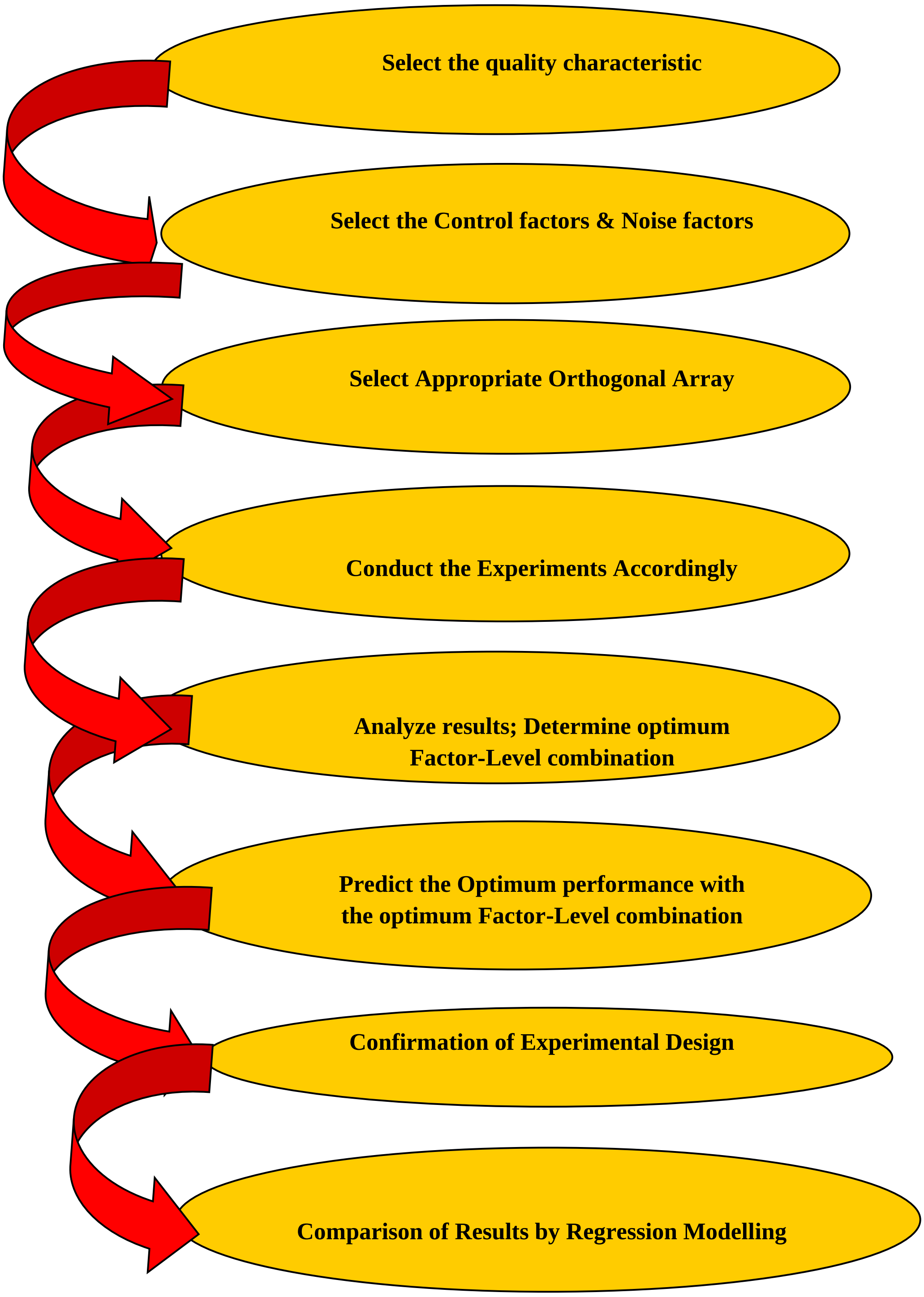

Fig. 3 Procedure & Steps of Taguchi Parameter Design

ISSN : 2455-9679
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III. EXPERIMENTAL SET UP

SELECTION OF RANGES & LEVELS OF PROCESS VARIABLES

As the literature suggested, the experimental setup is constructed for the material and the various factors and their levels are chosen, which are dependent on the following properties of the material under welding:

- Structure of the material
- Hardness of the material
- Tensile Strength of the material
- Weld Design

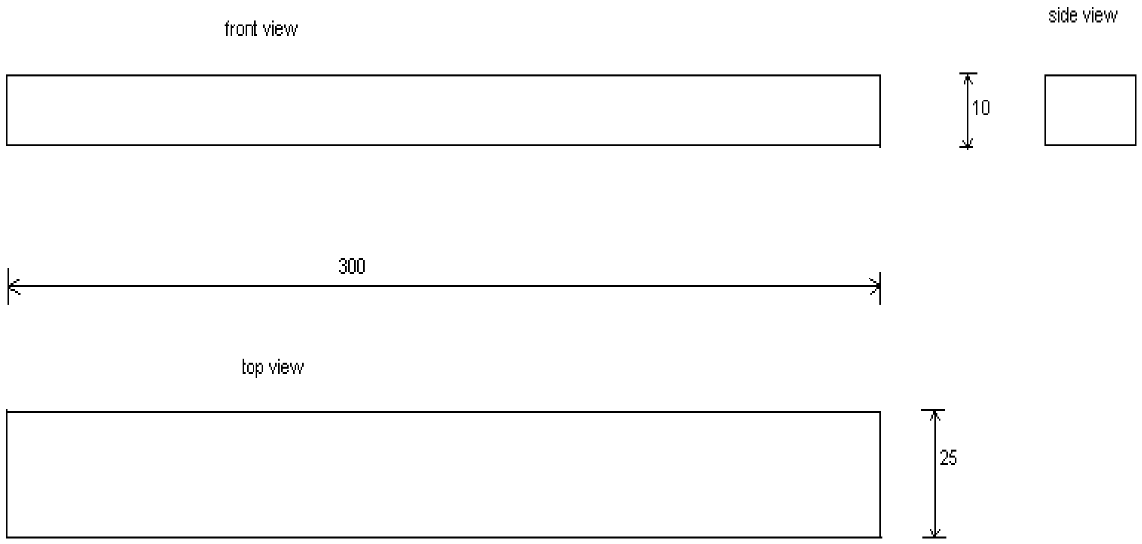
The factor that considerably contributes to the quality of weld in welding operation is selected.

Fig. 4 V – joint

Fig.5 J – joint

Fig.6 Bevel joint

EXPERIMENTAL LAYOUT



All dimensions are in mm.

Fig.7 Three views of Mild Steel Work-Piece

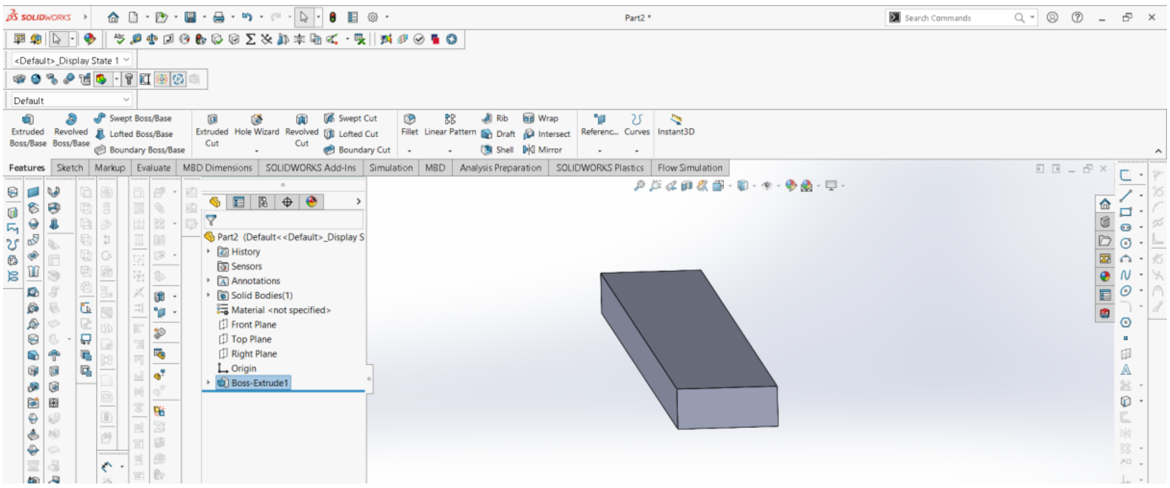


Fig. 8 3-D View of Mild Steel Work-Piece

Measurement of Breaking Strength

The tensile test on the universal test machine is carried out by gripping the two ends of the specimen and applying an increasing pull on the specimen till it fractures. During the test, the tensile load as well as elongation of the previously marked gauge length in the specimen is measured with the help of load dial of the machine and extensometer respectively.

ASSIGNMENT OF FACTORS AND INTERACTIONS

Total Degree of freedom (D.O.F): Each of the three factors is to be studied at three levels; therefore each factor has D.O.F. of 2.

ISSN : 2455-9679
SJIF Impact Factor : 6.008

Since, D.O.F. = number of levels -1.

The degree of freedom for the interaction is computed by multiplying the D.O.F. of each of interacting factors. Thus;

D.O.F. for A is 2
D.O.F. for B is 2
D.O.F. for C is 2

Therefore, the total D.O.F.,

$$(D.O.F._T) = 6 \quad \text{----(vi)}$$

Selection of Orthogonal Array

The OA (Orthogonal Array) to be selected must satisfy the following conditions:

Since, D.O.F. of O.A. selected $\geq$ D.O.F. required.

The experiment under consideration has 6 D.O.F. and therefore requires an O.A with 9 or more D.O.F., Hence an O.A. with at least 9 experiments is to be selected to estimate the effect of each factor and the desired interaction.

Taguchi has tabulated 9 basic orthogonal arrays which are called standard orthogonal arrays. An arrays name indicates the number of rows, number of columns and number of levels in each of the columns. As per Taguchi philosophy; usually it is expensive to conduct various experiments therefore, the optimum possible OA must be selected.

Here, the selected O.A. is L_9 from the book of standard orthogonal Arrays (Table 3.1). The factors & their chosen levels are listed in Table 4.1. The starting levels before conduction the matrix experiments for the 3 factors, identified by Hardness, Electrode Diameter and Weld Design (Edge Preparation).

Our goal for this project is to determine the best setting for each parameter so that the breaking strength is maximized. Therefore the matrix experiment selected for this project is given in Table 5.1. It consists of 9 individual experiments; corresponding to 9 rows. The 3 (three) columns of the matrix represent the 3 factors as indicated in Table 4.1; the entries in the matrix represent the level of factors.

Thus experiment 1 is conducted with each factor at the first level. Referring Table 5.1; the factor levels for experiment are:

- Hardness
- Electrode Diameter
- Weld Design (Edge Preparation)

Taguchi Techniques for Quality Engineering, Philip J Ross[13], Tata McGraw-Hill Publishing Company limited. Here the columns of the array are mutually Orthogonal i.e. for any pair of columns, if all the combinations of factor levels occur and they occur an equal number of times then this is called the balancing property and since in this matrix, for each pair of columns, there exist 9 possible combinations of factor levels and each combination occurs precisely once, therefore it implies orthogonality.

IV. EXPERIMENTATION, ANALYSIS, REGRESSION MODELLING AND RESULTS

According to the scheme of experimentation outlined in Table 5.1, the experiments were carried out to yield the desired welding operation of the specified material (Mild steel).

ISSN : 2455-9679
SJIF Impact Factor : 6.008

Fig.9 Lab Muffle Furnace

First of all some work pieces are put into the muffle furnace and set a temperature of about 910-920º C and once this temperature is reached then the furnace is put off and allow it to cool at room temperature. This process might take 20-24 hours then the work pieces taken out. This is the annealing process to obtain soft work pieces.

Fig.10 Hardening Process of Mild Steel in Open Hearth Furnace

After that some work pieces are put into the open hearth furnace and heat the pieces till they become red hot at a temperature of about 1300º -1400º C and once this temperature is reached then the work pieces are taken out and suddenly dipping the pieces into the brine solution as salt (as shown in Figure 5.3). This is our quenching process to obtain hard work pieces.

Fig.11 Photograph of the Welded M.S. Work Pieces

CONDENSED EXPEREMENTAL RESULTS

With reference to Table 4.1 and Table 3.1; the results are collected for the design of experiment or matrix experiment (Table 5.1) as discussed earlier.

 ISSN : 2455-9679
SJIF Impact Factor : 6.008

Average Mean Breaking Strength (Y) = 286.18 N/mm²

Table.1 Consolidated Design of Experiment Table

S.N.	Exp. No.	Hardness (A)	Electrode Diameter (mm) (B)	Weld Design (C)	Breaking Strength (N/mm²) (I)	Breaking Strength (N/mm²) (II)	Mean Breaking Strength (I + II)/2 (N/mm²)
1	1	S	D1=3.70	V	197.51	206.69	202.10
2	2	S	D2=4.70	BEVEL	220.65	220.65	220.65
3	3	S	D3=5.70	J	298.89	290.44	294.66
4	4	M	D1=3.70	J	240.97	230.08	235.52
5	5	M	D2=4.70	V	325.10	331.83	328.46
6	6	M	D3=5.70	BEVEL	375.40	369.35	372.37
7	7	H	D1=3.70	BEVEL	228.97	228.97	228.97
8	8	H	D2=4.70	J	345.55	330.30	337.92
9	9	H	D3=5.70	V	350.75	359.32	355.03

In this research work, the controllable factors taken are Hardness (A), Electrode Diameter (B) and Weld Design (C). Since they affect weld strength in welding operations, and since these factors are controllable in the welding process, they are considered as controllable factors.

Further, as per the Taguchi parameter design an important attribute is uncontrollable factors for the analysis. In this research work, the change in length of the work piece during tensile test on U.T.M is uncontrollable factor.

ANALYSIS OF VARIANCE (ANOVA)

Analogy with Fourier analysis of the power of an electrical signal and ANOVA is displayed in Graph 5.1. The experiments are arranged along the horizontal axis like time. The overall mean is plotted as a straight line like a DC component. The effect of each factor is displayed as a harmonic. The level of factor A for experiments 1, 2 and 3 is sA. So the height of the wave for A is plotted as sA2 for these experiments. Similarly the height of the wave for the experiments 4, 5 and 6 is sB3 and the height of the wave for the experiments 7, 8 and 9 is sC1. By virtue of this analogy, the observed S/N ratio for any experiment is equal to the sum of the height of the overall mean and the deviation from mean caused by the levels of the three factors. By referring to the waves of the different factors (Graph 5.1). Orthogonal decomposition of the observed S/N ratio can be described as the sum of the overall mean, Effect of factor A, Effect of factor B, Effect of factor C. In order to determine the significant Breaking Strength affecting the quality characteristics (Welding Strength), ANOVA analysis of raw data is used and the result is shown in Table 5.5.

ISSN : 2455-9679
SJIF Impact Factor : 6.008

(i) Grand total sum of squares = $\sum_{i=1}^{n} \eta_i^2$ = 21547.94 dB^2

(ii) Overall mean of S/N ratio = m = 48.92 dB

(i) Sum of square due to mean = 9 * $(48.92)^2$

= 21538.49 dB^2

(iv) Sum of square due to factor A = $3(sA_1-m)^2 + 3(sA_2-m)^2 + 3(sA_3-m)^2$

= 9.75 dB^2

(v) Sum of square due to factor B = $3(sB_1-m)^2 + 3(sB_2-m)^2 + 3(sB_3-m)^2$

= 20.70 dB^2

(vi) Sum of square due to factor C = $3(sC_1-m)^2 + 3(sC_2-m)^2 + 3(sC_3-m)^2$

= 0.83 dB^2

(vii) Total sum of squares = $\sum_{i=1}^{n} (\eta_i - m)^2$

= 10.42 dB^2

From Table 5.5, it is apparent that the F- ratio values of factor A (Hardness) and factor B (Electrode Diameter) are all greater than $\mathbf{F_{0.05,\ 2,\ 20} = 3.49}$ (from Appendices). While factor C (Weld Design) is proved to be a least significant welding parameter affecting the Welding Strength and thus proven to be significant.

Table 2 ANOVA Table for S/N Ratio

Source of Variation	**Degree of Freedom**	**Sum of Square**	**Mean Square**	**F- Value**
Hardness	**2**	**9.75**	**4.875**	**4.674**
Electrode Diameter	**2**	**20.70**	**10.35**	**9.923**
Weld Design	**2**	**0.83**	**0.415**	**0.397**
Error	**20**	**-20.86**	**-1.043#**	_
Total	**26**	**10.42**	_	_

CONFIRMATION EXPERIMENT

To validate the optimum welding conditions (A2, B3, C1) that were suggested by the experiments (refer 5.3.2), so that it must corresponds with the predicted value by the Taguchi methodology the planning layout of the confirmation experiments, while considering noise factors (measured locations); the total of two experiments were conducted by

 ISSN : 2455-9679
SJIF Impact Factor : 6.008

using the combination of Medium Hardness (A2), Electrode diameter ((B3) and Weld design (edge preparation) as V-joint (C1), then the breaking strength was measured for the work pieces for this combination (as shown in Figure 5.6) and is tabulated in Table 5.6.

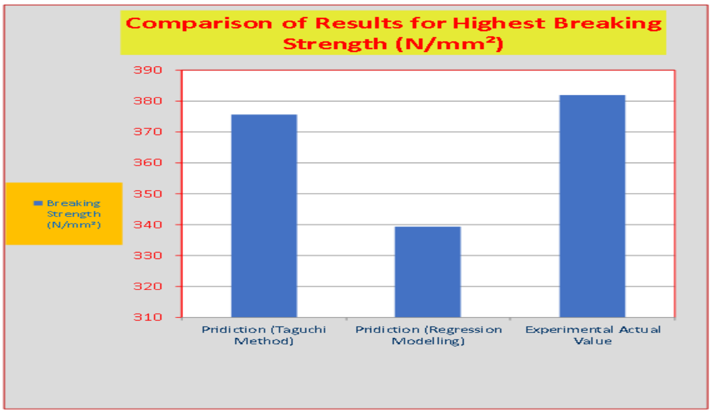


Fig. 12 Comparison of Results for Highest Breaking Strength

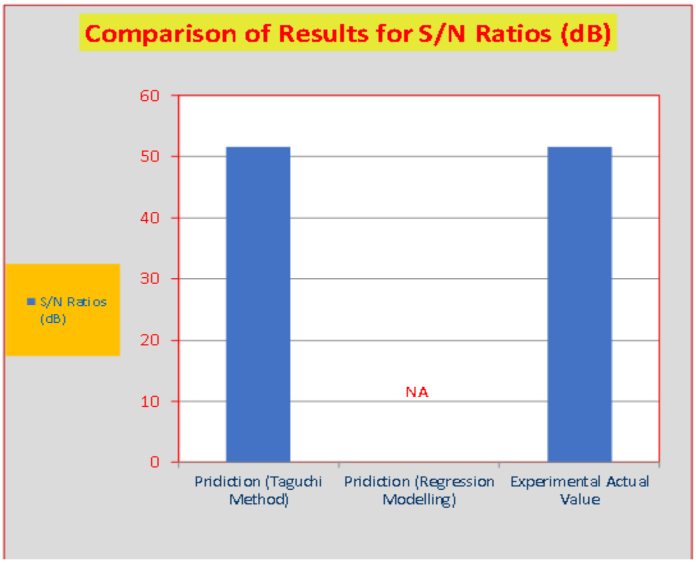


Fig.13 Comparison of Results for S/N Ratios

V. CONCLUSIONS

The outcome of the calculations and formulation for the optimization by the methods i.e. Prediction by Taguchi Method. By using the optimum factor – level combination suggested by Taguchi methodology the experiments are conducted and the results are summarized .

Experiments conducted and subsequently analysis performed by using the Taguchi Method. The optimum characteristics for the high Breaking Strength in welding operation are identified and the confirmation experiments are conducted, then the results obtained are compared with the above said optimization methods and are discussed as follows:

1. From the (Table 5.3) Average (Mean) Effect Response Table for the Raw Data, the factor (C) Weld Design represents the largest influence on weld strength followed by factor (B) Electrode Diameter, factor (A) Hardness and (Table 5.4) Average Effect Response Table for S/N Ratio.
2. From Table 5.5, it is apparent that the F-ratio values of factor A (Hardness), Factor B (Electrode Diameter), and factor C (Weld Design) are all have effect.

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SJIF Impact Factor : 6.008

3. From response graphs (Graphs 5.1 & 5.2) for mean and S/N ratio, observational findings are illustrated as following:
   (a) **Level I** for **Hardness A2 = medium** indicated as the optimum situation in terms of mean value.
   (b) **Level III** for **Electrode Diameter B3 = 5.70 mm**, indicated as the optimum situation in terms of mean value.
   (c) **Level I** for **Weld Design C1 = V type**, indicated as the optimum situation in terms of mean value.

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