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REDUCTION IN FABRICATION COST BY SPOT WELDING IN COMPARISON TO SMAW PROCESS: CASE STUDY

Gyanendra Singh[1], Dheeraj Sagar[1], Sunil Kumar Dubey[2]

[1]Asst. Professor Invertis University Bareilly (U.P), [2]M.tech Student Invertis University Bareilly (U.P)

ABSTRACT

This paper is basically a comparison made between the fabrication done by spot welding process and shielded metal arc welding (SMAW) process. Spot welding is an important process in today's manufacturing scenario. A case study is done here to prove that the fabrication cost by spot welding process is significantly lesser than that of shielded metal arc welding process. Design of experiments has been used to support this analysis and t- test has been used to reject the null hypothesis.

Keywords: Spot Welding, SMAW, Hypothesis, t-test

I. INTRODUCTION

Welding is one of the oldest fabrication processes used by human being. Man have been shifting from gas to arc welding process and now to more advance welding processes like resistance welding, solid state welding, etc. Spot Welding method has a lot of advantages over the most of the other welding processes. Spot Welding process assists in reducing fabrication cost, fabrication time and even gives more strength to the joint.

X. SUN, E. V. STEPHENS et al have worked on the effects of fusion zone size on failure modes, static strength, and energy absorption of resistance spot welds (RSW) of advanced high-strength steels (AHSS). E. S. SURIAN et al analyzed the influence of chemical composition and welding parameters on microstructure and mechanical properties of medium- and high strength steels. J. W. SOWARDS described the collection procedures and presented data on the fume generation rates (FGR), particle number and mass distributions as a function of size, and identified compounds present in the bulk fume. H. FURUYA et al examined the HAZ toughness for both multilayer and single-layer weld joints, and the characteristics of both methods were compared. Z. H. RAO et al developed mathematical models that included the cooling water flow impinging onto the underside of the cap, resistance (or Joule) heating, as well as the heat transfer between the weld cap and the cooling water. M. TUMULURU in his research showed that post weld baking increased the load-bearing ability of the welds in shear-tension tests compared with that of the samples in the as-welded condition. He also compared the welding behavior of dual-phase steel coated with HDGI and HDGA. H. ZUHAILAWATI et al in their study evaluated the shear strength and micro structural characteristics of the spot brazed titanium and nickel base metal.

But in this paper the comparison of fabrication costs between resistance spot welding and that of shielded metal arc welding has been done and it has been shown that fabrication by resistance spot welding is less expensive than that of shielded metal arc welding. This fact can be seen from the case study in which the comparison of fabrication cost of stainless stool by the spot welding process and SMAW process has been done.

II. LITERATURE SURVEY

2.1. Shielded Metal Arc Welding (SMAW)

Shielded Metal Arc Welding (SMAW) or Stick welding is a process which melts and joins metals by heating them withan arc between a coated metal electrode and the work piece. The electrode outer coating, called flux, assists in creatingthe arc and provides the shielding gas and slag covering to protect the weld from contamination. The electrodecore provides most of the weld filler metal.When the electrode is moved along the work piece at the correct speed the metal deposits in a uniform layer calleda bead.The Stick welding power source provides constant current (CC) and may be either alternating current (AC) or directcurrent (DC), depending on the electrode being used. The best welding characteristics are usually obtained using DCpower sources.

The power in a welding circuit is measured in voltage and current. The voltage (Volts) is governed by the arc lengthbetween the electrode and the work piece and is influenced by electrode diameter. Current is a more practical measureof the power in a weld circuit and is measured in amperes (Amps).The amperage needed to weld depends on electrode diameter, the size and thickness of the pieces to be welded,and the position of the welding. Thin metals require less current than thick metals, and a small electrode requires lessamperage than a large one.

It is preferable to weld on work in the flat or horizontal position. However, when forced to weld in vertical or overheadpositions it is helpful to reduce the amperage from that used when welding horizontally. Best welding results areachieved by maintaining a short arc, moving the electrode at a uniform speed, and feeding the electrode downwardat a constant speed as it melts. [3]

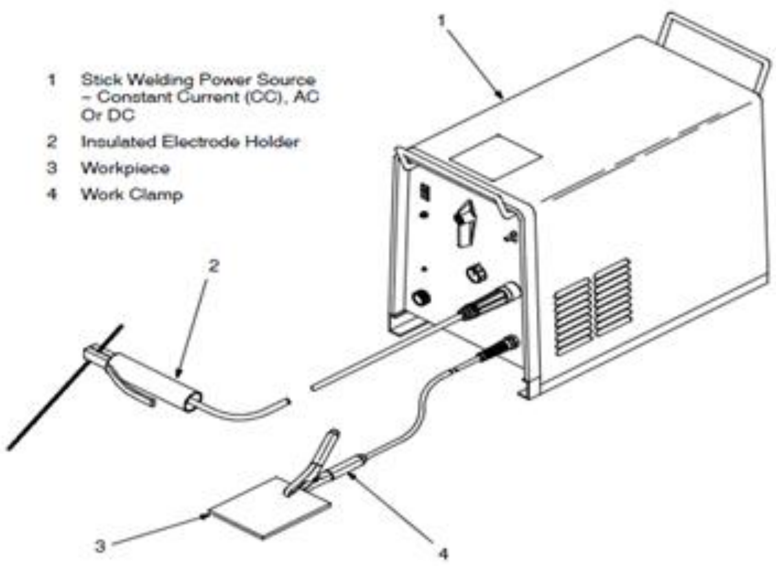

Figure 1: SMAW Machine

2.2. Resistance Spot Welding

Resistance Spot Welding is accomplished when current is caused to flow through electrode tips and the separate pieces of metal to be joined. The resistance of the base metal to electrical current flow causes localized heating in the joint and pressure is applied which causes the weld. [1]

Typically the sheets are in the 0.5-3.0 mm thickness range. The process uses two shaped copper alloy electrodes to concentrate welding current into a small "spot" and to simultaneously clamp the sheets together. Forcing a large current through the spot will melt the metal and form the weld. The attractive feature of spot welding is a lot of energy can be delivered to the spot in a very short time (ten to one hundred milliseconds) that permits the welding to occur without excessive heating to the rest of the sheet. [4]

The amount of heat (energy) delivered to the spot is determined by the resistance between the electrodes and the amplitude and duration of the current. The amount of energy is chosen to match the sheet's material properties, its thickness, and type of electrodes. Applying too little energy won't melt the metal or will make a poor weld. Applying too much energy will melt too much metal, eject molten material, and make a hole rather than a weld. Another attractive feature of spot welding is the energy delivered to the spot can be controlled to produce reliable welds.

The resistance spot weld is unique because the actual weld nugget is formed internally with relation to the surface of the base metal. *Figure 3* shows a resistance spot weld nugget compared to a SMAW weld. [1]

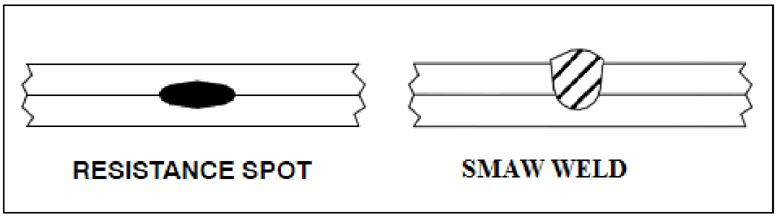

Figure 2: Resistance Spot and SMAW Weld Comparison

2.3 Comparison between Spot Welding & SMAW process

Theweld is unique because the actual weldnugget is formed internally with relation to thesurface of the base metal. A SMAW weld, on the other hand, starts at the surfaceof one piece and goes through it and into thesecond piece to form the weld nugget. SMAW weld is made from one side only,while the resistance spot weld is normallymade with electrodes on both sides of thework pieces. [2]

The strength of joint is even more than the welding of SMAW joint. Welding defect is even less in spot welding with better finishing which increases the aesthetic look of the work piece or job.

Huge amount of money is saved during working time of Spot welding although it has a bit more initial installation cost compared to SMAW process but in long run they become negligible.

2.4 Hypothesis

Hypothesis is usually considered as the principal instrument in research. Hypothesis may be defined as a proposition or a set of proposition set forth as an explanation for the occurrence of some specified group of phenomena either asserted merely as a provisional conjecture to guide some investigation or accepted as highly probable in the light of established facts.

2.4.1 Null Hypothesis and Alternative Hypothesis

In the context of statistical analysis, we often talk about null hypothesis and alternative hypothesis. If we are to compare method *A* with method *B* about its superiority and if we proceed on the assumption that both methods are equally good, then this assumption is termed as the null hypothesis. As against this, we may think that the method *A* is superior or the method *B* is inferior, we are then stating what is termed as alternative hypothesis. The null hypothesis is generally symbolized as H_0 and the alternative hypothesis as H_a. Suppose we want to test the hypothesis that the population mean (m) is equal to the hypothesised mean (m$H_{0)\,=}$ 100.

Then we would say that the null hypothesis is that the population mean is equal to the hypothesisedmean 100 and symbolically we can express as:

H_0: m H_0 =m = 100

If our sample results do not support this null hypothesis, we should conclude that something elseis true. What we conclude rejecting the null hypothesis is known as alternative hypothesis. In otherwords, the set of alternatives to the null hypothesis is referred to as the alternative hypothesis. If weaccept H_0, then we are rejecting *Ha* and if we reject *H*0, then we are accepting H_a. ForH_0: m H_0 =m = 100, we may consider three possible alternative hypotheses as follows:

Table1: Alternative Hypothesis

Alternative Hypothesis	**To be read as follows**
$H_a : \mu \neq \mu_{Ho}$	(The alternative hypothesis is that the population mean is not equal to 100 i.e., it may be more or less than 100)
$H_a : \mu > \mu_{Ho}$	(The alternative hypothesis is that the population mean is greater than 100)
$H_a : \mu < \mu_{Ho}$	(The alternative hypothesis is that the population mean is less than 100)

2.5 T-Test

t-test is based on t-distribution and is considered an appropriate test for judging the significance of a sample mean or for judging the significance of difference between the means of two samples in case of small sample(s) when population variance is not known (in which case we use variance of the sample as an estimate of the population variance). In case two samples are related, we use paired t-test (or what is known as difference test) for judging the significance of the mean of difference between the two related samples. It can also be used for judging the significance of the coefficients of simple and partial correlations. The relevant test statistic, t, is calculated from the sample data and then compared with its probable value based on t-distribution (to be read from the table that gives probable values of t for different levels of significance for different degrees of freedom) at a specified level of significance for concerning degrees of freedom for accepting or rejecting the null hypothesis. It may be noted that t-test applies only in case of small sample(s) when population variance is unknown.

Population normal, population infinite, sample size small and variance of the population unknown, Ha may be one-sided or two-sided:

$$t = \frac{\bar{X} - \mu_{H_0}}{\sigma_s/\sqrt{n}} \quad \text{with d.f.} = (n-1)$$

$$\sigma_s = \sqrt{\frac{\Sigma\left(X_i - \bar{X}\right)^2}{(n-1)}}$$

III. CASE STUDY

We have taken the case study of manufacturing of stool of stainless steel by Spot Welding process and by Shielded Metal Arc Welding process. The actual dimensions of stools made by both the processes are same with only difference of fabrication process. One is fabricated by the use of spot welding while another by SMAW process. Now the comparison is done between them to know which is better.

3.1 Detail of Stainless Steel Stool fabricated by Spot Welding

Table 2: Detail of Stainless Steel Stool fabricated by Spot Welding

S. No.	Resources Consumed	Quantity used
1	Weight of metal used	3.300 Kg
2	Number of spots done	40
3	Time for labour work i. Cutting and bending of four legs ii. Cutting and bending of seat iii. Cutting and bending of supports Hence, total labour time needed	 10 + 20 = 30 min. 5 + 15 = 20 min. 10 + 20 = 30 min. 80 min or 1.33 hrs
4	Labour cost per hour	Rs. 20
5	Total labour cost for Cutting and bending	1.33 X 20 = Rs. 27
6	Machine operation cost	40 X 0. 015 =Rs. 0.6
7	Material cost per kg	Rs.130
8	Net material used cost	3.300 X 130 = Rs. 429
9	Overhead cost	0.25 X 27.6 = Rs. 6.9
10	Net Cost of product = Net material used cost + Overhead cost + Total labour cost for Cutting and bending + Machine operation cost	429 + 6.9 + 27 + 0.6 =**Rs. 463.5**

3.2. Detail of Stainless Steel Stool fabricated by Arc Welding

Table 3: Detail of Stainless Steel Stool fabricated by Arc Welding

S. No.	Resources Consumed	Quantity used
1	Weight of metal used	3.300 Kg
2	Time for labour work i. Cutting and bending of four legs ii. Cutting and bending of seat iii. Cutting and bending of supports iv. Welding time Hence, total labour time needed	 10 + 20 = 30 min. 5 + 15 = 20 min. 10 + 20 = 30 min. 15 min. 95 min or 1.5 hrs
3	Total labour cost for Cutting and bending	1.5 X 20 = Rs. 30
4	Labour cost per hour	Rs. 20
5	Weld bead arc length	3.5 X 4 + 4 X 4 + 3 X 4 +2 X 4 +1 X 4 = 14 + 16 + 12 + 8 + 8 = 58 cm = 580 mm
6	Length of electrode consumed	= 830 mm
7	Number of electrodes used	830 / 350 = 2.38 = 3
8	Machine operation cost	40 X 0. 015 = Rs. 0.6
9	Cost of and Stainless steel electrode	Rs. 6
10	Total cost of electrodes used	6 X 2 = Rs. 12
11	Material cost per kg	Rs. 130
12	Net material used cost	3.300 X 130 = Rs. 429
13	Overhead cost	0.25 X 33 = Rs. 8.25
14	Net Cost of product = Net material used cost + Overhead cost + Total labour cost for Cutting and bending + Machine operation cost	30 + 3 + 429 + 8.25 + 12 = Rs. 482.25

3.3. Comparison between Stainless Steel Stools fabricated by Spot Welding and Arc Welding Process.

Table 4: Cost Comparison

	SMAW Process(Rs.)	Spot Weld(Rs.)	Saving (Rs.)	Saving (%)
Labour Cost	30	27	3	10
Machine Operation Cost	3	0.6	2.4	80
Cost of Electrodes	12	0	12	100
Other Costs	8.25	6.9	1.35	16.36
Net Saving	53.25	34.5	18.75	35.21

Hence amount of Money saved by fabricating by Spot Welding Process= **Rs. 18.75**

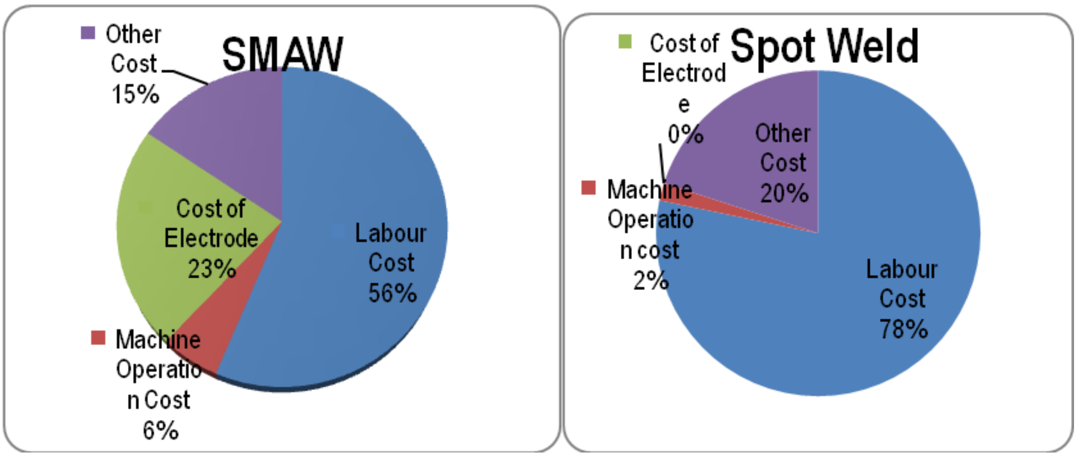

Figure 3: Comparison between Stainless Steel Stools fabricated by Spot Welding and Shielded metal Arc Welding Process

3.4. Solving Strategy

Null Hypothesis : Cost of Fabrication by both Spot Welding & SMAW is same.

$H_o = D = 0$

Alternative Hypothesis : H_a $\mu_1 < \mu_2$

where, μ_1 = Cost for fabrication by Spot Welding

μ_2 = Cost for fabrication by SMAW process

Level of Significance = 0.1

Method Adopted : t – test

$$t = \frac{\bar{X} - \mu_{H_0}}{\sigma_s/\sqrt{n}} \quad \text{with d.f.} = (n-1)$$

and
$$\sigma_s = \sqrt{\frac{\sum (X_i - \bar{X})^2}{(n-1)}}$$

3.5 Calculations

Table 5: Calculation

	Spot Weld Xi	SMAW Yi	D i= Xi – Yi	Di^2
1	27	30	-3	9
2	.6	3.0	-2.4	5.76
3	0	12	-12	324
4	6.9	8.25	-1.35	1.8225
			$\sum D = -18.75$	$\sum D^2 = 160.528$

Hence, the value of t from the table will be:

t = - 1.9045

3.6. Result

From table for = 0.1 the value of t = -1.638

As the Value of Calculated‘t‘lies outside acceptance region, therefore null hypothesis (H_0) is rejected.

Hence, $\mu_1 < \mu_2$

Therefore, by use of spot welding method for fabrication the overall production cost is reduced.

Hence, we have seen that the fabrication method by Spot Welding is more economical. It is seen that about 36% of money is saved. This is even backed by the t-test used above.

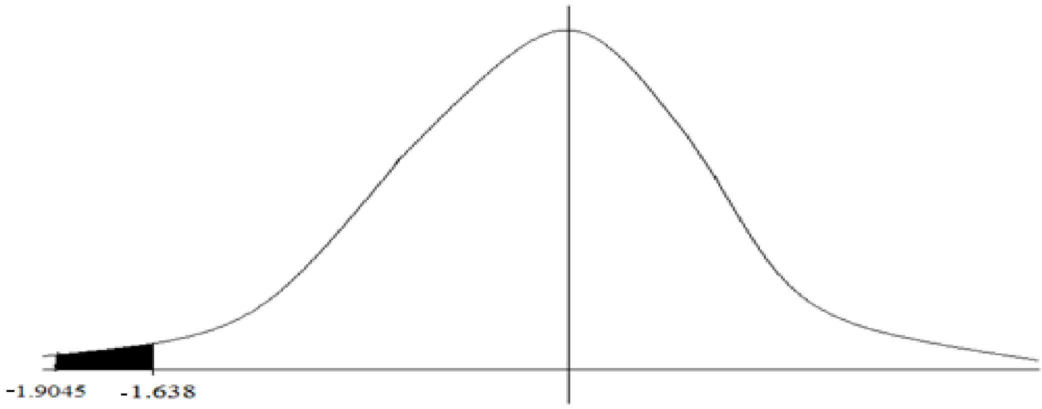

Figure4: Distribution Curve.

IV. CONCLUSION AND SCOPE FOR FURTHER STUDY

We have seen the comparison between the two most widely used fabrication processes (SMAW) and the emerging trend of metal joining (Spot Welding). Spot Welding method has been proved to be most cost effective as far as fabrication cost is concerned. This is well seen by the case study discussed here. The fact is even backed-up by the mathematical method of t-test. Thus if we use the spot welding process in place of SMAW where ever possible then loads of money can be saved which will increase the overall profit of the manufacturing firm. It can also be proved that the efficiency of the workers can also be increased which has been left for future work.

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