Productivity in Welding —Our Experience in Welding of Pressure Parts

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"An important factor contributing to high productivity in welding is "Operator Factor" or "The Arc Time". This represents the percentage of the work day spent in actual welding. The average figure for "arc time" in moderately heavy and large works is approximately 50%. This can go up to 75%, where excellent handling facilities exist and the welders are operating under favourable conditions. Firms in U.S.A., U.K., and West Germany are extremely conscious of the importance of the "Operator Factor" in bringing down the welding costs.

Firms abroad are equally conscious of the effect of deposition rates on the ultimate cost of a product. High deposition rates can be maintained by using as large an electrode as is permitted by the job. Electrodes of 6 mm. and 8 mm. diameter are most commonly used for all welding work in large structural workshops".

So reads the N.P.C. Report No. 34 titled "Welding Industry in U.S.A., West Germany and Britain". In the light of the above reading, I would like to share our experience in this field, with the readers.

The Background

The High Pressure Boiler Plant unit of Bharat Heavy Electricals Ltd. manufactures boilers for power stations and also for process industries. Valves and other fittings required for the boilers are also made here. One of the major activities here is welding. Manual arc welding is the predominant one among the different types of welding done here. But the situation encountered in our shop is different from the one found in conventional welding shops, because

1. Most of the products manufactured here are subjected to high pressures of the order of 100 atms, 137 atms and so on.

2. The welding process and the quality of the work are both governed by number of statutory regulations. The welds are to be radiographically tested for penetration, porosity, slag inclusions, etc.

3. Failure of the weld joints is of serious consequence. The welders are to be qualified to meet the Indian Boiler Regulations requirement and certified by the Boiler Inspector. The performance of each welder is recorded and if the defective joints exceed a particular percentage, the welder will have to re-qualify and pass the tests satisfying the requirements of Indian Boiler Regulations.

4. Most of the products are made from tubes of thickness 28 mm, 32 mm, 36 mm and so on. The materials used are carbon steels and alloy steels, Molybdenum, Chromium and Vanadium

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being the chief alloying elements. The high thickness and alloying elements, necessitate the welding to be done at temperatures of the order of 200°C, 250°C, etc.

The output from this shop was below our expectation. The products of this shop have been critical items in the past and cotinue to be so. Hence, the investigations proceeded.

The Approach

Not much improvement could be thought of in the joint design. The design itself was subject to Indian Regulations. Joint designs approved by Indian Boiler Regulations or the Boiler Inspector, alone can be adopted. The type of products was also such that no elaborate fixtures or manipulators were necessary. There were no frequent changes of job. The welder, once assigned to the work, could go on welding without interruption for the entire shift. Hence, the studies were aimed at the following three aspects :

(1) amount of weld metal deposited
(2) the electrodes used
(3) the "arc time" factor.

Weld Metal Deposition

This was one of the areas, where, in general, control was needed. The welders were generally careful about a good weld appearance and finish at the expense of over deposition.

The weight of weld metal to be deposited in grams was theoretically calculated from the joint design. This was compared with the weight of metal actually deposited. All the stub ends of the electrodes used were collected and their length measured. From this the length of electrodes used was calculated and from that the weight deposited. In general there was a tendency for excess deposition. The weight deposited varied from welder to welder though the size of the joint was the same.

It was suggested that checking templates should be used for controlling the deposition.

The Diameter of Electrode Used

This has got very great bearing on the welding time. The time for fusion of the electrodes, or the "arcing time" depends very much on this.

Table No. 1 gives, at rated current values, the deposition rates of basic coated electrodes of different diameter. The increase in deposition rate with an increase in the dia. of electrode is shown in the graph.

TABLE No. 1

Rate of deposition of electrodes of different diameter

Diameter of electrode in mm.	*Rate for deposition in gms/min.*
2.00	11.4
2.50	12.2
3.25	19.2
4.00	25.3
5.00	35.5
6.30	51.5

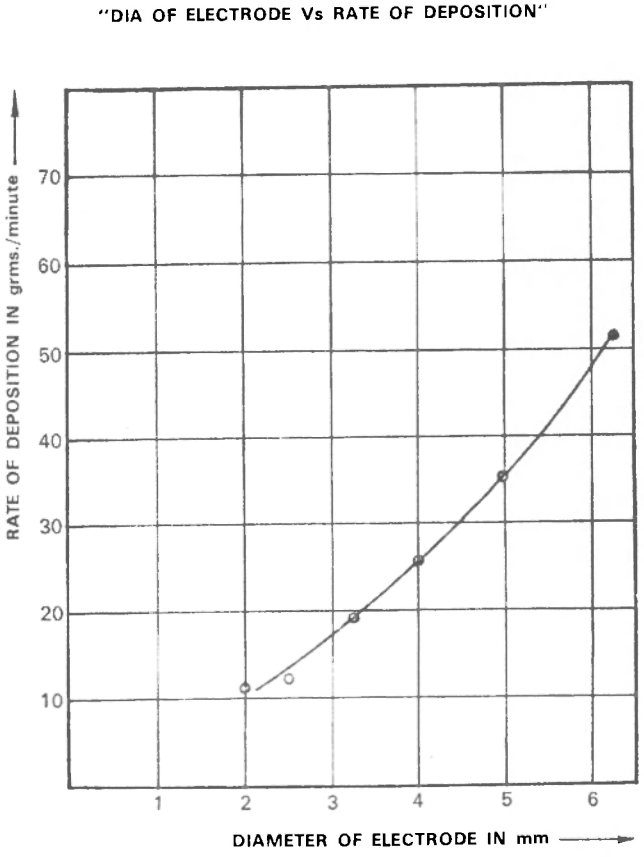

Table No. 2 shows how much time is gained (or lost) by using larger (or smaller) diameter electrodes.

The figures along the diagonal read 1.00. All the figures above the diagonal are more than 1. and all the figures below the diagonal are less than 1.

TABLE No. 2

Dia of elec-trode	2.00	2.50	3.25	4.00	5.00	6.30	8.00
2.00	1.00	1.07	1.69	2.22	3.12	4.51	5.63
2.50	0.935	1.00	1.58	2.07	2.92	4.23	5.35
3.25	0.590	0.632	1.00	1.32	1.85	2.68	3.40
4.00	0.450	0.483	0.756	1.00	1.40	2.04	2.58
5.00	0.320	0.342	0.540	0.714	1.00	1.45	1.84
6.30	0.222	0.238	0.373	0.490	0.63	1.00	1.27
8.00	0.178	0.187	0.294	0.388	0.543	0.787	1.00

Let us take an example.

Take the case of 4.00 mm. dia electrode. Looking at column 4 and row 4 we find the value to be 1.00 The values ABOVE this are 1.32, 2.07 and 2.22. These mean that, instead of a 4 mm, electrode, if a 3.25 mm electrode is used, the arcing time will increase to 1.3 times that of a 4 mm electrode.

If a 2.5 mm. electrode is used, instead of 4.00 mm. electrode, the arcing time will increase to 2.07 times.

On reading BELOW the diagonal, instead of using 4 mm. electrode, if 5 mm. electrode is used, the arcing time will decrease to 0.714 times—a saving of nearly 30% in arcing time.

For good penetration, it was necessary to use 2.5 mm electrode for the root and 3.25 mm. and 4.00 mm. electrodes for subsequent runs. This was the practice followed by the welders ; but electrodes of diameter higher than 4.00 mm. were not used. The main reason for not using larger diameter electrodes was that the welders feared about the rejection of the joint during X-ray test. It was a question of building up their confidence to use such higher diameter electrodes. Progressively the usage of 5 mm. was introduced. For the same size of joint, the time before and after this introduction is shown in Table No. 3.

TABLE No. 3

Reduction in Time by Using Electrodes of Higher Diameter and Controlling the Weld Deposit

No.	*Item*	*No. of Observations of Same Size of Joint*						
		Before the Studies			*After the Studies*			
		1	2	3	4	5	6	7
1.	No. of electrodes used in different dia. Electrodes of :—							
	Dia. 2.5 mm	8.0	5.3	6.00	5.0	6.0	6.0	7.5
	Dia. 3.25 mm	4.0	8.6	6.6	2.2	3.0	4.0	2.0
	Dia. 4.00 mm	36.0	28.6	24.0	16.2	4.0	11.0	6.5
	Dia. 5.00 mm	...	...	...	7.2	8.0	7.0	7.5
2.	Weld Deposition in gm.	965	900	790	762	764	672	627
3.	Total Welding time per Joint-minutes	180.10	165.60	163.40	81.04	77.25	72.15	66.01
4.	Time spent in Arcing-minutes	42.60	39.80	34.20	30.20	27.30	26.45	23.72
5.	Time spent in cleaning—minutes	101.00	91.00	80.60	34.14	35.73	25.28	27.62
6.	Time spent in manipulations* (minutes)	36.50	34.80	48.60	16.70...	14.12	20.42	14.67

* This includes time for changing the electrode, getting electrodes from the heater, adjusting current, etc.

Time for Cleaning the Welds :

This was another area which required improvement. The fear of failure of a joint was uppermost in the welders' minds. Hence, excessive cleaning to very minute detail was the order of the day. Here again, it was a question of inducing confidence in the welders.

In general, for an arcing time of 100 minutes, the time taken for cleaning and other manipulations was about 200 minutes making a total welding time of 300 minutes. The ratio between arcing time to total time was as high as 1 : 3 This was a phenomenon observed wherever welding of parts subjected to high pressure, and radiographic tests, was involved.

Available data for structurals and sheet metal welding of non-pressure parts show that the ratio between arcing time and total time should be about 1 : 1.6. 500 cases were taken from the standards for different joints for plates of different thickness and in each case the arcing time as a percentage of the total time has been worked out. The result is tabulated in a frequency distribution as shown in Table No. 4.

The table shows that 66% of the welding time should be arcing time. This works out to a ratio of 1 : 1.5 between arcing time to total time. In the plant also, for non-pressure parts welding, this ratio was achieved. But in the case of pressure parts, the ratio was 1 : 3. The effect of this ratio can be explained as follows :—

In a shift of 480 minutes, leaving the time taken by the operator for initial preparation for the day like getting tools, electrodes, cables, etc., the time for pre-heating the joint at the beginning and also between successive layers and the breaks in the forenoon and afternoon for tea, other unavoidable delays and time for personal needs, rest, etc., not more than 330 minutes of clear welding time can be available. This results in an arcing time of only 100-110 minutes per shift for a ratio of 1: 3. Actually, the arcing time was around 90 to 100 minutes only, in most of the cases in pressure parts welding. This works out to only 20% of the shift time. This appears to be low compared to the figures given in welding text books.

J. A. OATES in his "Welding Engineer's Hand Book" says—

> "The cost of labour is assessed by the weight of metal deposited in a given time, that is how many minutes per hour the arc is actually in operation. The time expressed as a percentage is the *operating or output factor*..... In a well organised shop an output factor of 50% should cover the ordinary type of work. For site welding in the field, except in cases where there are large quantities of continuous welds, the output factor may be as low as 20%".
>
> Similar figures can also be found in the already mentioned "N.P.C. Report No. 34—Welding Industry in U.S.A., West Germany and Britain".

Steps were taken in this direction also. Table No. 3 shows how the cleaning time has come down as

TABLE No. 4

% of arc time to total welding time			*Mid Value*	*Frequency*	*Frequency %*
40.00	to	44.99	42.5	1	0.2
45.00	to	49.99	47.5	2	0.4
50.00	to	54.99	52.5	4	0.8
55.00	to	59.99	57.5	19	3.8
60.00	to	64.99	62.5	189	37.8
65.00	to	69.99	67.5	126	25.2
70.00	to	74.99	72.5	152	30.4
75.00	to	79.99	77.5	7	1.4
				500	100.0

the study proceeded. Trial jobs were welded with reduced cleaning time. These joints were X-rayed and found to pass X-ray test. Number of such successive joints proved that the reduction in cleaning time did not affect the joints getting accepted. This helped to boost the confidence of the welders. Efforts are still continued and ultimately it may be possible to reduce the total welding time to 2.5 times or even 2 times the arcing time. If that could be achieved, for the same 330 minutes of clear welding time, the welder can arc for about 130 minutes or an increase of 30% in the arcing time per shift figure.

Conclusion

This three pronged attack, namely, controlling the deposition of weld metal to the optimum level, usage of electrodes of larger diameter and reducing the cleaning time without sacrificing the quality of the joint, proved fruitful. Increase in the output of welders by 50% to 100% was possible in different cases, within a month.

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