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A Work on Welding Productivity and Economy for Smaw & Fcaw Processes

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***Abstract:** Every welding process possess its own advantages and limitations and selected after careful analysis and study of variables related to the process /product form and application criteria. Factors governing the selection of welding process includes the type of the product to be welded, material, joint geometry, field and service conditions, productivity expectations, capital cost, availability of resources, quality requirements, net cost savings etc. Currently in India, shielded metal arc welding is the major welding process dominates the welding industry and plays a key role compared to other welding processes. To achieve the higher productivity and cost savings, it is necessary to adopt suitable welding process, which can be superior to SMAW and can be justified fully in terms of productivity, quality and cost. Comparative production studies were conducted to establish the facts and to arrive conclusion. This concept will be applicable for pipe spools welding in a fabrication shop for welding groove and fillet weld joints in out of position. Process will be applied for large bore spools welding i.e. for Pipe diameter equivalent or greater than 168 mm OD and wall thickness of 7.11 mm and above. For study purpose only two welding processes were taken into account i.e. SMAW and FCAW. Since carbon steel pipe spools fabrication is 85% of the total scope, selection of the high productive and cost economic welding process plays a vital role.*

***Keywords:** SMAW, FCAW.*

I. INTRODUCTION

This experiment was conducted to find the facts of productivity and cost economy of two welding processes viz. SMAW and FCAW when compared to each other. Other welding processes were not taken into account in this study after careful evaluation and analysis of their advantages and disadvantages with respect to specific application i.e. welding of large bore pipe spools of medium to heavy wall thick in out of position. The organization has given directive to increase the productivity and quality by using FCAW with the same input that costs for SMAW or even decrease the input costs proportionately for achieving higher technical and economical efficiencies. These experiments were conducted for decision making and forward planning.

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1.2Objective of this experiment

The prime objective of conducting this experiment was to select the most productive, qualitative and cost competitive welding process for the said application. Before we select the above two welding processes for comparison in this paper, it is necessary to describe the back ground for not taking the other welding processes into account.

II. METHODOLOGY:

In this work two welding methodology used SMAW &FCAW.Following details are given billow

2.1Methodology of SMAW:

1. Pipe material: A106 GR.B
2. Pipe diameter: 168 mm outside diameter.
3. Wall thickness of the Pipe: 18.25 mm
4. Test Pipe length: 150 mm each
5. Type of joint: Butt
6. Type of groove geometry: Single V Groove weld
7. Groove angle: 75 degree included angle
8. Root face: 1 mm
9. Root Opening or root gap: 2.5 mm
10. Welding Position: 5G
11. Electrode used for Root Pass: E6010
12. Electrode used for Fill up/Capping runs: E7018
13. Polarity: DCEP

2.2.Methodology of FCAW:

1. Pipe material: A106 GR.B
2. Pipe diameter: 168 mm outside diameter.
3. Wall thickness of the Pipe: 18.25 mm
4. Test Pipe length: 150 mm each
5. Type of joint: Butt
6. Type of groove geometry: Single V Groove weld
7. Groove angle: 75 degree included angle
8. Root face: 1 mm
9. Root Opening or root gap: 2.5 mm
10. Welding Position: 5G
11. Electrode used for Root Pass: E6010
12. Electrode used for Fill up/Capping runs: E71T-1
13. Shielding gas used: 100% Co2 and 75%Argon+25%Co2.
14. Polarity: DCEP

Experiment details

Sheet 1

Test Data OF SMAW Process with E6010 + E7018

Pass details	**AWS Class**	**Diameter of electrode**		**Voltage**	**Ampere**	**Travel speed in mm per min.**	**Total time in min**	**Arc time in min**	**Cleaning time in min**	**No. Of electrode used**	**Weight per electrode in gram.**	**Total weight of used electrode in gram**
Root	E6010	2.5		23 - 26	45 - 60	60	8	5.5	2.5	9.5	15	142.5
Hot pass	E7018	2.5		22 - 24	75 - 85	100	7	5	2	5	25	125
Fill up – 1	E7018	3.15		20 - 24	90 - 100	70	15	10	3	6	41	246
Fill up – 2	E7018	4		20 - 24	120 - 130	35	21	14	7	8	60	480
Fill up – 3	E7018	3.15		20 - 24	90 - 100	85	12	6	3	4.5	41	184.5
Final – 1	E7018	3.15		20 - 24	90 - 100	75	12	6	3	4.5	41	184.5
Final – 2	E7018	3.15		20 - 24	90 - 100	75	12	6	3	4.5	41	184.5
Final – 3	E7018	3.15		20 - 24	90 - 100	75	12	6	3	4.5	41	184.5
Total Time							**91**	**53**	**24**			

Sheet 2

Test Data for FCAW Process E6010 + E71 T-1 with CO2 gas

Pass details	**AWS Class**	**Diameter of electrode**		**Voltage**	**Ampere**	**Travel speed In mm per min.**	**Total time In min**	**Arc time In min**	**Cleaning time In min**	**No. Of electrode used**	**Weight per electrode In gram.**	**Total weight of used electrode In gram**
Root	E6010	2.5		23 - 26	45 - 60	55	6	5.5	1	9.5	15	142.5
Pass details	AWS Class	Diameter of filler wire		Voltage	Ampere	Total time In min	Arc time In min	Clearing time In min	Flow rate of gas In LPM	Wire speed In mm per min.	Travel speed In mm per min.	Wire weight per meter In gram
Hot pass	E71 T-1	1.2mm		23 - 24	130 - 150	8.5	4	1.5	12 to 15	5.46	112.5	6.95
Fill up – 1	E71 T-1	1.2mm		24 - 25	150 - 160	10.5	6	1.5	11 to 14	5.9	81.82	6.95
Fill up – 2	E71 T-1	1.2mm		24 - 25	140 - 150	10	6.15	1.5	12 to 15	5.9	81.82	6.95
Fill up – 3	E71 T-1	1.2mm		25 - 26	140 - 150	6.25	3.25	1	12 to 14	5.9	180	6.95
Fill up – 4	E71 T-1	1.2mm		25 - 26	140 - 150	6.6	3.75	1	12 to 14	5.9	180	6.95
Final – 1	E71 T-1	1.2mm		25 - 26	140 - 160	9.85	5.35	1.5	10 to 12	5.9	120	6.95
Final – 2	E71 T-1	1.2mm		25 - 26	140 - 160	8.3	4.5	1	10 to 12	5.9	120	6.95
Total Time						**60**	**33**	**9**				

Sheet 3

Test data for FCAW Process E6010 + E71 T-1 with 75% Argon+25% Co2

Pass details	**AWS Class**		**Diameter of electrode**	**Voltage**	**Ampere**	**Travel speed In mm per min.**	**Total time In min**	**Arc time In min**	**Cleaning time In min**	**No. Of electrode used**	**Weight per electrode In gram.**	**Total weight of used electrode In gram**
Root	E6010		2.5	23 - 26	45 - 60	62	8	5.5	3	9.5	15	142.5
Pass details	AWS Class		Diameter of filler wire	Voltage	Ampere	Total time	Arc time	Clearing time	Flow rate of gas In LPM	Wire speed In mm per min.	Travel speed In mm per min.	Wire weight per meter In gram
Hot pass	E71 T-1		1.2mm	29	175	9	4	1	24	5.6	110	6.95
Fill up – 1	E71 T-1		1.2mm	31	180	10	5	1	24	5.6	100	6.95
Fill up – 2	E71 T-1		1.2mm	31	180	6	5	0.5	24	5.6	130	6.95
Fill up – 3	E71 T-1		1.2mm	31	180	8	4	0.5	24	5.6	130	6.95
Final – 1	E71 T-1		1.2mm	31	180	6	4	0.5	24	5.6	130	6.95
Final – 2	E71 T-1		1.2mm	31	180	6	4	0.5	24	5.6	130	6.95
Total Time						45	26	4				

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III. WELD METAL RECOVERY DATA – TAKEN FROM ACTUAL TESTS

Serial No.	**Details**	**SMAW**	**FCAW (100 % CO2)**	**FCAW (75%Ar + 25% CO2)**	**Remarks**
1	Pipe dia.	6.00 inch	6.00 inch	6.00 inch	
2	Pipe thickness	18.25 mm.	18.25 mm	18.25 mm.	
3	Pipe weight before root	19.130 kg	19.200 kg	19.020 kg	Weighted physically
4	Weight of electrode used for root	142.5 gram	142.5 gram	142.5grm	Taken from sheet 1 & it is taken by physically weighting the electrode
5	Stub loss for 6010	30 gram	30 gram	30 gram	All the end rods of electrode which is thrown cumulatively weighed for root pass
6	Pipe weight after root	19.200 Kg.	19.270 kg	19.090 kg	Weighted physically
7	Weight of electrode/filler wire used for fill up & final	1.589 kg.	1.341 kg	1.011 kg	Taken from sheet 1 & it is taken by physically weighting the electrode, In case of filler wire it is calculated by equation: **Arc time x Wire speed x Weight of wire per meter.**
8	Stub loss for 7018	0.210 kg	-----------	-----------	All the end rods of electrode which is thrown cumulatively weighed for fill up & final pass
9	Material use for welding excluding stub loss	1.379 kg	1.341kg	1.011 kg	**Weight of electrode used of 7018 - stub loss of 7018**
10	Pipe weight after welding	20.15 kg	20.360 kg	19.990 kg	Weighted physically
11	Weld metal deposited in 7018/ E71 T-1	0.95 kg	1.09 kg	0.9 kg	**Weight of pipe after welding - weight of pipe after root welding**
12	Material loss in 7018 / E71 T-1	0.429 kg	0.251 kg	0.111 kg	**Weight of electrode used for fill up & final pass - weld metal deposited in 7018/E71 T-1**
13	**Percentage of Weld metal recovery**	**68.89%**	**81.28%**	**89.02%**	**(Weld metal deposited / Actual material used for welding)*100**

6.2.Formula used for calculation of numerical values in above tables with respect to serial number reference:

4 = Cost of Electrode/Kg of weld metal deposit = one kg weld metal deposited x cost of electrode per kg / weld metal recovery

5 = Cost of Shielding gas/Kg of weld metal deposit = one kg weld metal deposited x cost of gas per kg / weld metal recovery

6 = Deposition rate Per Hour = Deposition rate in kg x weld metal recovery x 60 / minute

B = power cost of welding = cost per kWh x volt x ampere / 1000 x deposition rate per hour

C = Power Cost for Mother Oven for re drying low hydrogen electrodes/kg of electrode = 6 hour (cycle time) X rating in kilo watt per hour x cost per kWh / over capacity

D = Power Cost for Holding Oven (BIG)/kg of electrode = 24 hour x rating kilo watt per hour x cost per kWh / oven capacity

E = Power Cost for Portable oven/kg of electrode = Rating in kg per hour x cost per kWh / 2

H = Labor and over head cost = Labor and over head cost per hour / deposition rate per hour x operator factor

6.3.FINAL DATA REPORT BASED ON SUMMARY OF ALL TESTS CONDUCTED

Sl. NO.	Description and studies conducted	SMAW	FCAW 1	FCAW 2	Remarks
1	Cost of Electrode/Kg	75	115	115	True Prices including all taxes.
2	Cost of Shielding gas/KG of electrode consumption	NA	14.57	70	Current price of gases. Rs.765/Co2 cylinder and Rs700/Argo-shield cylinder.1 no Co2 Cylinder will burn 52.5 kg FCAW electrode and 1 no A-S cylinder is burning 10 kg FCAW wire. Measured.
3	Weld metal recovery	69%	89%	81%	From the weld recovery table by equation: **(Weld metal deposited / material used for welding)*100**
4	Cost of Electrode/Kg of weld metal deposit	109	129.2	142	**1 kg of weld metal deposited / (weld metal recovery * cost of electrode or filler wire)**
5	Cost of stub loss per kg of weld metal deposit	17	0.0	0	**60 * stub loss for 1 kg of weld metal deposited * cost of electrode / actual arc time in kg per minute**
6	Cost of Shielding gas/Kg of weld metal deposit	0	16	86	**1kg of weld metal deposited / (weld metal recovery * cost of gas per kg of weld metal deposited)**
A	**Electrode and shielding gas Cost of 1 kg of weld metal**	**125.3**	**145.5**	**228.4**	**Sum of sr. no. 4,5,6**
7	Deposition rate Per Hour	1.08	1.98	2.08	This is calculated as: **60*weld metal deposited / actual arc time in kg per minute**
B	Power Cost for Welding M/c=Cost/KWH*volt*ampere/(1000*Deposition rate)	12.22	9.70	13.41	Value of voltage & ampere taken averagely from attached sheet
C	Power Cost for Mother Oven for re drying low hydrogen electrodes/kg of electrode	5.4	0	0	Required power for oven is 4.5kw. & Cycle time for backing is taken generally as 6 hours with power cost assuming 5 Rs. Per kilo watt. Oven capacity is 25 kg **Power cost = (Cost per kwh * volt * ampere) / (1000 * oven capacity)**
D	Power Cost for Holding Oven (BIG)/kg of electrode	7.2	0	0	Required power for oven is 3.5kw. & It is work for 24 hours with power cost assuming 5 Rupees per kw. Oven capacity is 50 kg. **Power cost = (Cost per kwh * volt * ampere) / (1000 * oven capacity)**
E	Power Cost for Portable oven/kg of electrode	4.95	0	0	Required power for oven is 0.165-kilo watt assuming 12 hours working of oven & power cost is 5 Rs. Per kilowatts. Oven capacity is 2 kg. **Power cost = (Cost per kwh * volt * ampere) / (1000 * oven capacity)**
B+C+D+E	**Total Power Cost**	**29.77**	**9.70**	**13.41**	
8	Operator factor	40%	55%	58%	Taken on the basis of trial conducted.
F	Time for deposition of 1 kg weld metal in hours= 1 kg weld metal/Operator factor*Deposition rate/hour	2.31	0.92	0.83	
G	Labour & overhead cost/hour	150.00	150.00	150.00	
H	Labour & overhead cost	347.22	137.74	124.34	**150 / (deposition rate per hour * operator factor)**
J	**Total Cost in Rupees of A+B+C+D+E +H**	**502.27**	**292.94**	**366.15**	

IV. CONCLUSION :

1. When we compare to the productivity, quality, and economy of the two welding processes selected for studies, Gas shielded FCAW is the best process among all criterions.
2. FCAW with 75%Argon+25% Co2 as shielding gas is the best choice to be used for out of position welding applications, greater operator appeal and better arc characteristics than 100 percent Co2. Also when more variety of materials are required to be fabricated in a single shop, this will be the Common best shielding gas to use considering the use of FCAW with same mixture on multiple materials. We have bought liquid argon and liquid Co2 and processed the same to gases, where the gases was mixed at required proportionate by using gas proportionate mixers and piped to various welding stations for continuous supply of mixed shielding gas for FCAW. Deposition efficiency of this process is slightly higher than FCAW with 100 percent Co2 as shielding gas.
3. Whereas if there is no sufficient scope of work in other materials like stainless steels and low alloy steels, and majority of work scope is only carbon steel pipe spools, then the better option is to use Co2 alone considering its cost competitiveness and ability to meet the specified quality requirements in our case.

4. Currently we do not have much scope of work in other materials and hence we have decided to apply FCAW-GS with 100 percent Co2 as shielding gas.
5. FCAW with 100% Co2 as shielding gas will be the economical welding process. Product quality was verified by Visual examination and radiographic test and found satisfactory. Welding procedure was qualified and found meeting the mechanical and chemical requirements.
6. The same process can be used in all positions welding and mode of metal transfer will be spray transfer. Suitable welding technique should be adopted for overhead /vertical position welding to train the welders properly.
7. Current recommended by manufacturer is 120-300 Amperes and can be used depends upon the welding Position.
8. Deposition rate with respect to wire feed speed i.e. maximum amperage for 1.2 mm wire diameter will be a maximum of 5.6 kilograms/hour, which will be obtained in flat position only and in case of fillet welding with backing. More deposition rates can be achieved in flat position by using higher diameter wires.
9. This process can be mechanized for obtaining higher welding speeds and deposition rates in flat position for groove welds i.e. butt joints.
10. Voltage loss is measured and found as 1V for 10-meter length of welding cable.
11. The best-cost competitive welding process is FCAW with 100 percent Co2 as shielding gas. Since this process is meeting the weld acceptance criteria and mechanical properties requirements of B31.3 code, the same is recognized as the suitable welding process for welding the large bore pipe fabrication spools of medium wall thickness.

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