Establishing relationship between welding current and weld metal deposition rate (productivity) for metal cored tubular (MCT) wire in submerged arc welding process

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KEYWORDS

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Weld Metal Deposition Rate (WMDR),
Productivity,
Heat Input (HI),
Current Density.

ABSTRACT

Submerged arc welding (SAW) process is used to weld large, heavy metal deposition jobs that warrant critical requirements, and this metal joining process alone is used to weld approximately 10% of the deposited weld metal worldwide. Any augmentation in productivity of SAW process, will immensely benefit the welding industry, as this process is widely used on variety of common metals & alloys. This paper focusses on establishing relationship between welding current and productivity (in terms of weld metal deposition rate as an index), for a given filler wire diameter. Productivity rates of three most commonly used SAW wire sizes Metal Cored Tubular wires were studied, at different current values, covering full current range through bead-on-plate experiments. At each current value, the bead was optimized for acceptable visual quality, by varying arc travel speed and voltage, then the wire feed rate making acceptable bead was noted. The current density, the heat input and corresponding weld metal deposition rate were calculated for establishing an empirical relationship. The established relationship can be effectively used, to estimate the productivity from the current values, for a given wire diameter.

1. Introduction

Conventional arc welding processes are helpful in meeting large percentage/volume of common welding needs of the engineering industries. With differing needs, engineering industries employ various arc welding processes, such as shielded metal arc welding (SMAW), flux cored arc welding (FCAW), gas tungsten arc welding (GTAW), gas metal arc welding (GMAW) and submerged arc welding (SAW) in varying percentages during fabrication of engineering components. While SMAW and FCAW processes are used on almost all jobs involving common engineering materials, GTAW and GMAW processes are used for some special needs/materials. SAW is preferred where heavy weld deposition (like in pressure vessels, heat exchangers, nuclear reactors, offshore structures, ship building, steel structures, etc.) is needed, and where joints can be welded in flat/horizontal positions [1]. There are many reasons for the popularity of SAW process in the welding industry, because it is versatile, scalable, can be mechanized, acceptability of moderately skilled welders, ability to achieve more reliable & high-quality welds with deeper penetration and excellent surface finish without spatter/flash/fumes/radiation. All these resulting in reduced overall welding time, improving welding cost economy [2,3]. Hence, SAW is the first process industry use for "heavy and critical" welding applications and approximately 10% of weld metal is deposited by SAW worldwide [4].

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The traditional single solid wire DCEP SAW process has seen lot of developments, since its inception in 1930s, making SAW process more productive, and now many variations of SAW process are available [5]. Though many variations of SAW (such as Tubular wire, Tiny Twin Wire, Tandem, Twin Tandem) have been explored/established in the welding industry for decades, still the traditional single solid wire DCEP SAW method/equipment is used even now by most, for its simplicity, adaptability, low cost, compact equipment size, easy to use package even by lesser skilled welders, still depositing large percentage of weld metal every day [6]. So, any incremental improvement in productivity/economy using this traditional SAW method/equipment will result in significant improvement in overall output of welding industry. Cyclic nature of welding shop loading (i.e. sometimes peak loading otherwise normal loading) also makes the fabricators hesitant to invest in large/expensive/sophisticated Twin/Tandem SAW packages [7]. Instead, using the same single wire DCEP SAW system, making it give higher productivity (along with equal/ better quality) will be a smarter way, especially for the companies having existing large fleet of SAW packages. So, this research study evaluates the use of “Metal Cored Tubular (MCT) SAW wire”, in place of “solid SAW wire” in the same “traditional single wire DCEP SAW” systems and analyses its productivity levels.

From the literature review [8-10], it is understood that most of the published information are focused on bead geometry analysis only. Available published information (either on bead geometry or on weld metal deposition rate)are based on SAW solid wires. Productivity information on MCT wires are very scant. Hence, present investigation is carried out to establish a relationship between welding current and weld metal deposition rate (productivity) for the most commonly used three SAW wire sizes. The prime objective of this work is to bring out the procedure needed to get full current range and optimum parameters for the most common wire sizes so that it is possible for the users to process the data and choose the best MCT wire size and parameter that suits every production condition.

2. Experimental Work

The rolled plates of 25 mm thick, ASME IIA specified SA 36 grade steel, were used as base plates for depositing Bead on Plate (BoP) trials. Metal Cored Tubular (MCT) wires confirming to the specifications of ASME IIC SFA 5.17 and AWS EC1, were used to deposit BoPs. Three most commonly used SAW wire sizes 2.4, 3.2, 4.0 mm diameter MCT wires were chosen for this investigation. Agglomerated aluminates basic flux meeting the specifications F7A8-EC1 as per ASME IIC SFA 5.17 was used in this investigation. Table 1 presents classification and chemical composition of weld metal and wire type, source, brand name, sizes used in this investigation. Table 2 presents composition, size distribution, type, basicity index, density, brand name, make, source of flux used in this investigation. Miller Summit Arc 1000/1250 power source (with 1,000 A at 100% Duty Cycle capacity from USA), with HDC 1500DX Digital Controller (with CV+C mode feature) with Column & Boom set up was used in this investigation (refer Fig.1a).

Small lengths of all three wire sizes (Fig.1b) were cut and measured for its length & weight, to calculate weight of wire/unit length (gms/ inch or gms/mm). Cross section of these three wires was studied for wire strip area (to calculate current density), metal powder area, type of wire construction (Fig.1c). Top side of the base (BoP) plate coupon was thoroughly cleaned by grinding (to white finish condition) so that the arc starting and welding (throughout the test length) can be smooth. The photograph of flux powder used is shown in Fig.1d. During welding, wire feed rate values displayed on the controller

Table 1

Chemical composition (wt%) of Composite electrode weld metal used in this investigation.

	C	Mn	Si	S	P	Cu	Cr, Mo, V, Ni, Ti	Rest
ASME IIC SFA 5.17 AWS EC1 Requirements	≤0.15	≤1.8	≤0.90	≤0.035	≤0.035	≤0.35	-	Fe
MCT Wire, Flux Combination used (typical #s)	0.073	1.30	0.31	0.018	0.021	0.068	-	Fe
Other Information								
Flux-Wire Classification	F7A8-EC1 (as per ASME IIC, SFA 5.17 Specification) with below Flux							
Wire Data (Type, Source, Brand Name)	Metal Cored Tubular Wire, from Hobart Brothers USA, Brand Name: SubCOR EM13K-S, Sizes: 3/32”, 1/8”, 5/32” (~2.4, 3.2, 4.0 mm) diameter							

Table 2
Chemical composition (%) of flux used in this investigation.

	SiO_2	$Al_2O_3+TiO_2$	MnO+FeO	CaO+MgO
Flux (used lot) properties	18.4	28	20.3	31.4
Flux Size Distribution (%) Typical				
+12 Mesh	+20 Mesh	+40 Mesh	+60 Mesh	+80 Mesh
1.754	67.77	27.48	2.947	0.046
Other Information				
Flux Type		Agglomerated aluminates basic flux		
Flux Basicity Index (BI)		1.6		
Flux Density		1.5 g/cm^3		
Flux Data (Brand Name, Make, Source)		TF-565, Tientai, Taiwan		

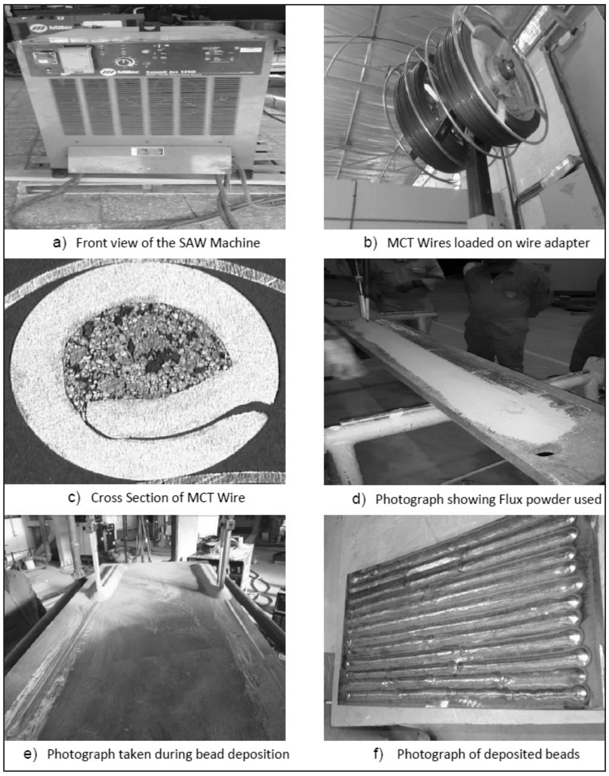


Fig.1. Photographs showing the experimental work sequence.

was recorded, averaged out for calculating average wire burn off rate which has been considered as average weld metal deposition rate (WMDR in kg weld/ arc hour). Fig.1e shows the photograph taken during bead deposition. Current (A), voltage (V), wire feed rate (WFR) were observed and recorded from the welding controller display, the welding arc travel speed (S) value was taken from Column & Boom settings (cross checked by dry run trials). These three values (A, V, S) are the experimental input data, with observed WFR data, weld metal deposition rate, heat input, current density was calculated using below standard expression [6].

- $WMDR_{(kg/arc\ hour)}$ = Length of wire fed in one arc hour x wire weight per unit length
- $HI_{(KJ/mm)}$ = (AxVx60)/(Sx1000)
- $CD_{(A/mm2)}$ =Current in Amps/Wire strip section area (passing current)

Before commencing the actual BoP experiments (for recording WFRs at different preset current values), each size of wire was trial welded at different current values (from lowest to highest in increments of 50 A). Each resultant bead was visually inspected for appearance and quality as per standard norms. When needed, voltage and speed values were changed for getting visually acceptable quality weld beads, at all preset current values. Some of the trial weld beads made on BoP are shown in Fig.1f.

In the first phase, 2.4 mm diameter MCT wire was used to deposit the weld bead, varying the current from 250 A onwards in 50 A increments. The welding conditions and parameters used to deposit the weld metal are presented in Table 3. Acceptable welding beads (that which can be used for single and multiple pass welding application in both fillet and groove joints) could be achieved in this current range. Above 650 A range, beads deposited were not meeting the acceptance criteria for visual inspection, with the wire and flux tried. For all BoP trials, within 250-650 A range in 50 A increments, similar

Table 3
Welding parameters used and deposition rate obtained for 2.4 mm diameter filler wire.

Expt. No.	Current (A)	Voltage (V)	Arc Travel Speed (mm/ min)	Current Density (A/mm^2)	Heat Input (kJ/mm)	Weld Metal Deposition Rate (kg/hour)
1	250	30	290	79	1.6	3.6
2	300	30	290	95	1.9	5.0
3	350	30	370	111	1.7	6.4
4	400	30	495	126	1.5	8.2
5	450	34	495	142	1.9	10.4
6	500	36	605	158	1.8	12.3
7	550	40	605	174	2.2	14.5
8	600	44	715	190	2.2	16.3
9	650	46	840	205	2.1	19.6

Table 4
Welding parameters used and deposition rate obtained for 3.2 mm diameter filler wire.

Expt. No.	Current (A)	Voltage (V)	Arc Travel Speed (mm/ min)	Current Density (A/mm^2)	Heat Input (kJ/mm)	Weld Metal Deposition Rate (kg/hour)
1	1	250	28	290	48	1.4
2	2	300	28	290	58	1.7
3	3	350	28	290	67	2.0
4	4	400	30	495	77	1.5
5	5	450	30	495	87	1.6
6	6	500	30	495	96	1.8
7	7	550	30	495	106	2.0
8	8	600	32	605	116	1.9
9	9	650	34	605	125	2.2
10	10	700	40	715	135	2.3
11	11	750	40	840	144	2.1
12	12	800	44	840	154	2.5

welding sequence/procedure were followed: starting the welding, allowing the arc to stabilize, letting the welding machine ramp up the current to preset ampere, and during smooth welding, recording the displayed wire feed rate (WFR), then moved to the next current setting (i.e. +50 A from previous bead). Whenever the bead was not looking good, arc travel speed (S) and or voltage (V) was adjusted till acceptable quality bead was achieved and the corresponding WFR value was recorded. Similar procedure was employed to evaluate the WMDR (productivity) for 3.2 mm and 4.0 mm diameter MCT wires. The welding parameters used to deposit the weld metal are presented in Table 4 and 5 for 3.2 mm and 4.0 mm diameter MCT wires respectively.

3. Results

A total of 37 BoP trials were conducted to evaluate the effect of welding current on WMDR (productivity) using 3 MCT wire sizes. 9 BoP trials on 2.4 mm diameter MCT wire were carried out and the results are presented in Table 3. Similarly, 12 BoP trials were conducted using 3.2 mm diameter MCT wire and the results are given in Table 4. Another 16 BoP trials were conducted using 4.0 mm diameter MCT wire and the results are listed in Table 5.

Other than WMDR, the current density (with calculated strip area of 3.16, 5.19, 7.47 mm^2 for 2.4, 3.2, 4.00 mm dia MCT wires respectively)

Table 5
Welding parameters used and deposition rate obtained for 4.0 mm diameter filler wire.

Expt. No.	Current (A)	Voltage (V)	Arc Travel Speed (mm/ min)	Current Density (A/mm^2)	Heat Input (kJ/mm)	Weld Metal Deposition Rate (kg/hour)
1	250	27	290	33	1.4	2.9
2	300	27	290	40	1.7	3.8
3	350	27	290	47	2.0	4.4
4	400	27	290	54	2.2	5.4
5	450	27	495	60	1.5	6.0
6	500	27	495	67	1.6	7.3
7	550	27	495	74	1.8	8.6
8	600	28	495	80	2.0	9.8
9	650	28	605	87	1.8	11.3
10	700	31	605	94	2.2	12.7
11	750	31	605	100	2.3	13.8
12	800	34	605	107	2.7	15.1
13	850	34	605	114	2.9	16.1
14	900	36	1080	121	1.8	17.0
15	950	40	605	127	3.8	18.2
16	1000	38	980	134	2.3	18.9

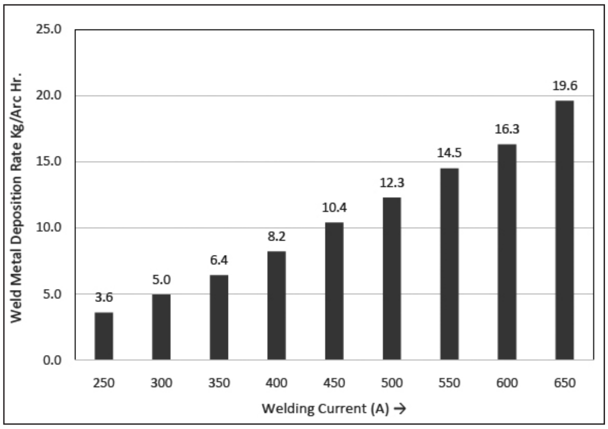
and heat input were calculated (as per formula mentioned in paragraph 2.0) for all 37 trials and the values are presented in respective Tables 3-5.

Fig.2 presents the weld metal deposition rate of all the three wires for different preset current values. Fig.3a displays the current density of all three wire sizes at all current preset values (within the range) tried. Fig.3b reveals the same information (three wire sizes current density values at different current values) in graphical form. Fig.3c shows deposition rate divided by current (how many grams of weld metal is deposited per every ampere current applied) at different preset current values of all three wires.

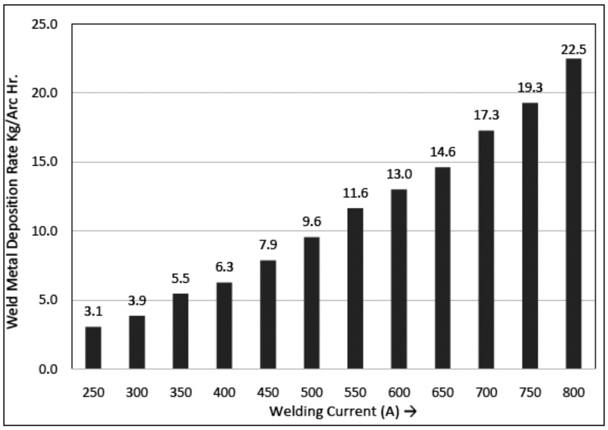
4. Discussion

4.1 Effect of Welding Current on WMDR

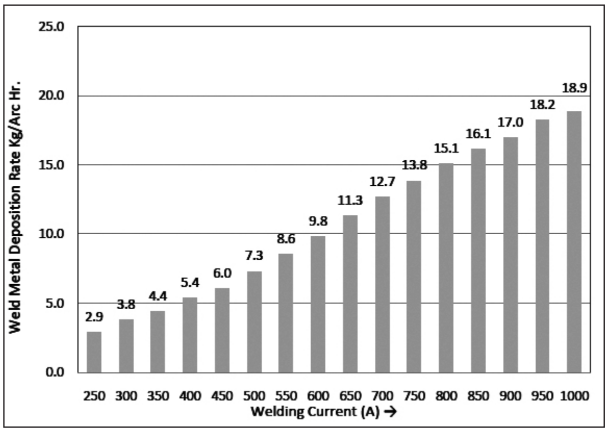
The WMDR achieved with various current values for 2.4 mm diameter MCT wire is presented in Table 3 and Fig.2a. WMDR of 3.6 kg/hr is achieved at 250 A welding current and it increases gradually at every 50 A incremental current value (from 3.6 at 250 to 5, 6.4, 8.2, 10.4, 12.3, 14.5, 16.3, 19.6. Compared to 250 A benchmark WMDR (3.6 kg/hr), with the same welding system (i.e. wire, flux, machine, welder, infrastructure/ accessories), every increase of 50 A applied current gives a proportional increase in WMDR say 38%, 79%, 129%, 189%, 242%, 304%, 354%, 446% as tabulated in Table 3. Compared to achieved kg/hr WMDR values at any particular current, every increase of 50 A applied current gives additional WMDR 1.4, 1.5, 1.8, 2.2, 1.9, 2.2, 1.8, 3.3 at 50 A higher current values as tabulated in Table 3. It can be noted that incremental kg WMDR values up to 450 A (for every 50 A raise) is moderate (1.7 kg/hr average), whereas the same (incremental kg WMDR for every 50A raise) above 450 A is higher (2.3 kg/hr average). When this incremental WMDR values are converted into % improvement (for every 50 A raise w.r.t. WMDR values 50 A lesser levels), we see 38%, 30%, 28%, 26%, 18%, 18%, 12%, 20% at 50 A higher current values. It is evident that every 50 A incremental current value, give higher % increase in WMDR in the first half (31% average in 300-450 A range), than the second half (17% average in 500-650 A range), which is close to its peak current value/ deposition rate potential of this wire type/ classification/size/flux characteristics. At higher current values, increasing denominator reduces the % increase in WMDR. Any attempt to use this wire/flux combination above this current value



(a) For 2.4 mm diameter MCT wire.



(b) For 3.2 mm diameter MCT wire.

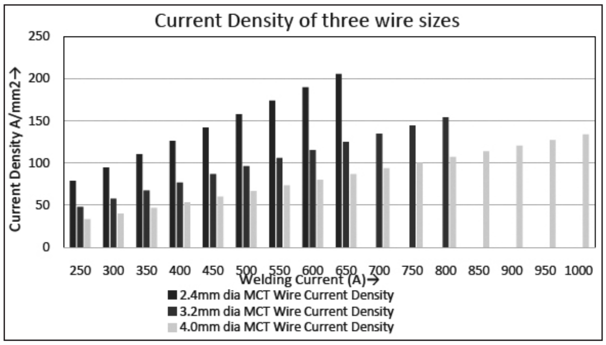


(c) For 4.0 mm diameter MCT wire.

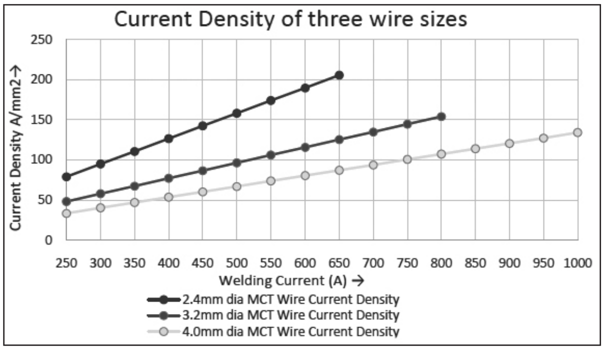
Fig. 2. Effect of welding current on weld metal deposition rate.

(650 A) anticipating still higher % improvement results in unstable weld start/arc, peaky bead, undercut and unstable arc control system. Above this current level, it would be prudent to go for other wire type/size/flux combination to increase % improvement any further.

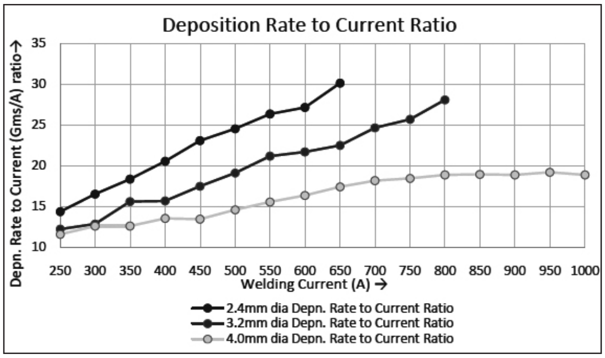
Similarly, Table 4 and Fig.2b show the WMDR achieved with various preset current values with



(a) Welding current Vs Current density.



(b) Welding current Vs Current density (Line graph).



(c) Deposition rate to current ratio at different current values for three wires.

Fig. 3. Relationship between welding current and current density.

3.2 mm dia MCT wire. WMDR of 3.1 kg/hr is achieved at 250 A welding current and it increases gradually at every 50 A incremental current value: say 3.90 kg/hr, 5.5 kg, 6.3 kg, 7.9 kg, 9.9 kg, 11.6 kg, 13 kg, 14.6 kg, 17.3kg, 19.3 kg, and 22.5 kg at 800 A as tabulated. Compared to 250 A benchmark WMDR, under the same welding system (i.e. wire, flux, machine, welder, infrastructure/accessories), an increase in applied current in steps of 50 A gives an increase of 26%, 79%, 105%, 158%, 213%, 282%, 326%, 379%, 466%, 532%, 637% at 800 A as tabulated. Compared to achieved kg/hr WMDR values at any particular current, every increase of current in 50 A steps gives additional WMDR :0.8, 1.6, 0.8, 1.6, 1.7, 2.1, 1.4, 1.6, 2.7, 2.0, 3.2. It can be noted that incremental kg/hr WMDR values

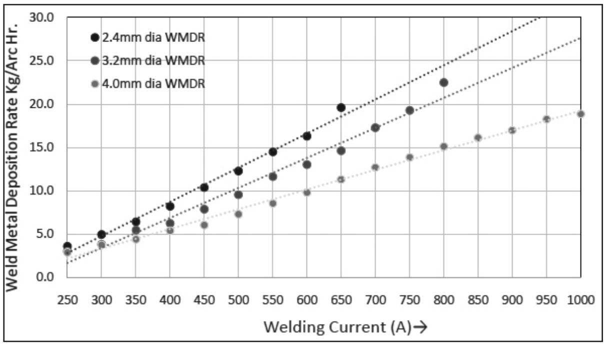


Fig. 4. Relationship between welding current and weld metal deposition rate (Productivity).

up to 550 A (for every 50 A raise) is moderate (1.4 average), whereas the same (incremental kg/hr WMDR for every 50 A raise) equal to and above 550 A is higher (2.2 average). In terms of % improvement of WMDR (for every 50 A raise), we observe that it is 26%, 42%, 15%, 26%, 21%, 22%, 12%, 12%, 18%, 12%, 17%. These values are listed in Table 4. It is evident that every 50 A incremental current value, give higher % increase in WMDR in the first half (25% average in 300-550 A range), than the second half (15% average in 550-800 A range), which is close to its peak current value/deposition rate potential of this wire type/classification/size/flux characteristics. At higher current values, increasing denominator reduces the % increase in WMDR. Any attempts to use this wire/flux combination above this current value (800 A) to achieve more productivity results in unstable weld start/arc, peaky bead, undercut and unstable arc control system. For a single wire DCEP SAW system, 22.5 kg/hr WMDR is the highest achieved in all the 37 trials conducted.

In the same way, Table 5 and Fig.2c show the weld metal deposition rate achieved with various preset current values using 4.0 mm diameter MCT wire. AWMDR of 2.9 kg/hr is achieved at the 250 A base welding current and the WDMR increases progressively at every incremental current value of 50 A i.e. 3.8 kg/hr, 4.4 kg, 5.4 kg, 6.0 kg, 7.3 kg, 8.6 kg, 9.8 kg, 11.3 kg, 12.7 kg, 13.8 kg, 15.1 kg, 16.1 kg, 17kg, 18.2 kg, 18.9 kg/hr with the same welding system (i.e. wire, flux, machine, welder, infrastructure/accessories). In terms of % increase (w.r.t. 250 A base line) it is 30%, 52%, 87%, 109%, 152%, 196%, 239%, 291%, 339%, 378%, 422%, 457%, 487%, 530%, 552%. Compared to achieved kg/hr WMDR values at any particular current, every 50 A incremental current gives additional WMDR :0.9 0.6, 1.0, 0.6, 1.3, 1.3, 1.3, 1.5, 1.4, 1.1, 1.3, 1.0, 0.9, 1.3, 0.6 as shown in Table 5. It can be noted that incremental kg/hr WMDR values up to half way 650 A (for every 50 A raise) is moderate (1.1kg average), which is also the same equal to and above 650 A, hence the second half higher improvement phenomenon (which is observed with 2.4 & 3.2mm dia wires) is not observed with 4.0 mm dia wire. When this incremental WMDR values are converted into % improvement (for every 50 A raise w.r.t. WMDR values 50 A lesser levels), we see there is 30%, 17%, 23%, 12%, 21%, 17%, 15%, 15%, 12%, 9%, 9%, 7%, 5%, 7%, 3%. It is evident that every 50 A incremental current value, give higher % increase in WMDR in the first half (19% average in 300-650 A range), than the second half (9% average in 650-1000 A range), which is close to its peak current value/deposition rate potential of this wire type/classification/size/flux characteristics. At higher current values, nearly constant numerator and increasing denominator reduces the % increase in WMDR.

4.2 Effect of current density on productivity

Fig.3a and 3b are the plot between current density Vs current for the 3 filler wires investigated. From both figures, it could be understood that current density is increasing w.r.t. increase in current because the cross section of wire remains constant. It can be seen that in Fig.4b, between 250 A and 650 A current range, the current density difference between 2.4 and 3.2 mm dia wires is much higher than the difference between 3.2 mm and 4.0 mm dia wires. Also, the slope of line 2.4 mm wire is higher than the other two. This is because, when the same magnitude of current (or the current difference) passes through the different cross sections, the effect is more pronounced in smaller cross section than the larger ones. So, 2.4 mm dia wire passes more current (per unit area) at same current compared to larger wires. This higher current density in 2.4 mm diameter wire and higher slope explains the higher productivity. The same explanation is true for 3.2 mm diameter wire (over 4.0 mm dia wire) as shown in Fig.4b.

4.3 Optimizing filler wire diameter and parameters for higher productivity

It is evident from the above analysis that at every current value (within 250-650A range), the 2.4 mm dia wire gives higher productivity than both 3.2 mm dia and 4.0 mm dia wires. Within this current range, the average increase in productivity (WMDR) for every 50 A increase is also the highest in 2.4 mm dia wire (i.e. 2 kg/hr for 2.4 mm wire, 1.4 for 3.2 mm wire, 1.1 for

4.0 mm wire). However, the 2.4 mm dia weld beads above 650 A is not acceptable. So, if the joint design, pass location in the joint (say hot pass on thin root/backing), or pipe/plate/section thickness/bevel/location of welding is such, that the welding current above 650 A is not feasible/needed, then 2.4 mm dia wire would give highest productivity, meeting required visual quality.

In case of 3.2 mm dia, due to increased cross section, this wire has little more current carrying capacity (up to 800 A), gives little higher productivity than 2.4 mm dia wire, and expected to be more stable when fed (straight) into deeper groove weld joints (like Narrow Groove joints). For these reasons, 3.2 mm dia wire at higher current values can be employed for much higher productivity compared to 2.4 mm dia wire, where ever higher current usage is feasible. With 4.0 mm dia wire, the productivity at any current value within 250-1000 A range is lesser than smaller sized wires, and also gives lower average incremental productivity for the current increase. Hence it does not give any compelling reason for selecting 4.0 dia for higher productivity.

Fig.3c presents the weld metal quantity (in grams) that is deposited per unit ampere of welding current. 2.4 mm diameter wire, between 250-450 A range, deposits 14-23 gms of weld metal for every ampere current, where as in 450-650 A range, the same wire deposits higher weld metal (23-30 gms/A). Based on the quantity of weld metal deposited (per ampere current applied), 2.4 mm dia wire in 600-650 A range, performs far superior than the larger diameter 3.2 & 4.0 mm dia wires, in that or even at higher current ranges. To compare at 650 A current value, 2.4 mm diameter wire deposits 30.14 gms per ampere and 3.2 mm dia wire deposits 22.49 gms per ampere which is 7.66 gms higher. This means that if 2.4 mm diameter wire is chosen and used at 650 A current, the deposition of weld metal will be 34% more with the same application of heat into the job. Conversely, while depositing same weld metal quantity (say finite weld size on finite length on the same/identical job), 2.4 mm dia would need around 34% lesser current application than larger sized 3.2 mm dia wire.

During heavy fabrication, due to application of heat, job undergoes linear and or angular distortion. Sometimes distortion can lead to even rejection of job. Most of the time, fabricators are forced to go for elaborate pre-setting, load application to reduce the distortion extent or go for extensive/expensive distortion (heat) correction post-welding activities. Under these circumstances, if the applied current (or hear input) is lower, then the distortion also will be correspondingly lower. The reduction in distortion % is directly proportional to reduction in heat input, to deposit the same quantity of weld metal. Use of 2.4 mm diameter wire at 650 A, depositing same weld metal quantity using 34% lesser current (or heat input) means, the distortion issues with 2.4 mm dia wire welded at 650 A will be very much lower, when other parameters/ conditions are identical.

4.4 Establishing relationship between welding current and WMDR

In this investigation, 37 BoP experiments were conducted to evaluate the effect of welding current on WMDR (productivity) and the results are presented in Tables 3-5. All the 37 WMDR values are related with preset welding current (A) values in the form of graph as shown in Fig.4. The data points are connected using a best fit line concept and the straight line is governed by the following equations.

WMDR for 2.4 mm dia MCT wire = {(0.0394 x A) - 7.0422} kg/hour (1)

WMDR for 3.2 mm dia MCT wire = {(0.0346 x A) – 6.9575} kg/hour (2)

WMDR for 4.0 mm dia MCT wire = {(0.0227 x A) – 3.4906} kg/hour (3)

With the help of above relations, the WMDR (kg/hour) for any of the three filler wire size (2.4, 3.2, 4.0 mm ϕ) can be predicted for any preset welding current value for the same/similar wire/flux combinations, with 90+% accuracy level using respective equation. From the graph (Fig.4), it is inferred that the WMDR is having directly proportional relationship with the welding current, i.e., if the welding current increases, WMDR increases and vice versa, irrespective of filler wire diameter.

5. Conclusions

1. From these 37 experiments, an empirical relationship has been established between

welding current and WMDR. It is found that the productivity (WMDR) is having directly proportional relationship with the welding current.

2. The developed relationship can be effectively used to predict the WMDR for a given welding current with 90+% accuracy level. Conversely, the developed relationship can also be used to estimate the welding current value for a required weld metal deposition rate with 90+% accuracy level.
3. It is found that 100% increase in welding current (250 to 500 A), increased the productivity by 242% with 2.4 mm dia wire, 213% with 3.2 mm wire and 152% with 4.0 mm wire.
4. From this investigation, the results show that smaller wire size at little lower/equal current levels, give higher productivity values than the larger sized wires at same or just little higher current levels.
5. Among the three MCT wire sizes evaluated, the 3.2 mm dia wire gives highest productivity level, meeting all required visual inspection criteria.
6. By using smaller diameter wire at high current value (2.4 mm used at 650 A), same weld quantity can be deposited using up to 34% lesser current (or heat input) and this will greatly reduce the distortion related issues during heavy welding/fabrication.

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