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TECHNICAL NOTE

Elimination Back Gouging Operation in Submerged Arc Welding Butt without Chamfers ASTM A516

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A B S T R A C T

One of the processes of submerged arc welding is back gouging operations. This work, in addition to implementing high cost, requires to consuming much time in production line as well as environmental and acoustic pollutions which has with itself. This paper presents a way to remove the back gouging operation from the submerged arc welding process. For this purpose, effects of submerged arc welding parameters on A516-70 steel sample were investigated. 16 and 18mm thickness sheets without chamfering were prepared and by choosing the best parameters, they were welded from face and back. Also, the effects of stress-relief heat treatment and preheat were investigated. Microstructure and mechanical properties were in standard situation and shows the performance of this project. Removing the back gouging operation significantly reduced the cost, time and also reduced noise and environment pollution in submerged arc welding process. By implementation of this design, we will observe 80% reduction in costs welding and also elimination of the environmental and acoustic pollutions which are resulted from back gouging.

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1. INTRODUCTION

Submerged arc welding is used extensively in oil and gas industries, storage tanks, pressure vessels, ship building and etc. In the year 1932, in USA, by electric arc and carbon electrode buried below or under a thick layering of protecting, the submerged arc welding was invented. In second world war, submerged arc welding was used for ship building and today it is converted to one of the most important and most applicable methods of welding all over the world [1].

Submerged arc welding, generally takes place with relatively high current which leads to higher rate of precipitation and more penetration depth in comparison to other methods of welding. Among the variables which must be controlled for developing a submerged weld with appropriate quality current density, speed of welding process and voltage of welding are most important [2].

In the process of submerged arc welding, the weld pool is relatively massive and the melted metal is fluid. For this reason, for preventing of flow, the melted metal behind the weld seam backing weld or backing strip is required to be used.

However, in the above mentioned methods because of rupture in the root face and also existence of oxide layers in root face section, complete diffusion doesn't occur.

As a general rule, for removing this imperfect weld and omitting oxides, manual grinding were used. On the most cases, by means of melting this layer by electric arc method and graphite electrode, removing it's molten metal by air pressure takes place which this treatment is called back gouging. This treatment causes excessive stresses, because of warming in upper wall thickness

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and suddenly cooling of it by air pressure. Finally, after removing the oxides and omitting weld imperfections, liquid penetrant test were become assured from the remaining weld and in continuing, the weld is completed.

Performing this process, as well as to providing stress requires more time and has excessive costs. In addition, doing this process causes many environmental and acoustic pollutions.

In this project, by cancelling the back gouging procedure, it is tried to reduce the rate at resulted stresses and gain significant reduction in cost. The objective is also to have increased efficacious in welding and achievably to reduce the environmental and acoustic pollutions.

A complete review survey on the works which have been done in this field shows that all of the research have tried to evaluate experimentally and numerically the effect of welding parameters on mechanical properties and grain size and stress the jointed part which are connected to each other by welding. However, until now the effect of cancelling the back gouging treatment on the metallography and mechanical properties of submerged arc welding hasn't beam surveyed. In general case, the investigation taken place on this field can be classified in several groups:

Bead height, penetration depth and heat affected zone area increase with an increase in the heat input [3]. An increase in heat input from 2.5kj/mm to 10kj/mm decreases ductility three to four times from 100joul to 28joul that follows, while an increase in heat input from 100j to 28j doesn't causes much decrease in ductility [4]. The ducting of weld metal is a function of current and speed at welding. Ductility in a constant current at speed of 200mm/min is higher than ductility in speed at 300mm/min [5]. Modeling multi pass submerged arc welding by using ABAQUS software shows that stress and residual strain which have accrued in cross section of welded tubes causes geometrical distortion in them [6]. The rate at penetration depth in submerged are welding in the case of inverse polarity (positive electrode). It is more than that which exists in direct polarity (negative electrode). By reducing electrode's diameters, the penetration depth increases. By increasing the current, the penetration depth and bead height increases but bead width decreases. By increasing the current, rate of melting also increases [7].

The martensite – austenite constituents with large size can greatly decrease the crack initiation energy in the HAZ because they can stimulate the formation of cleavage crack, while the deterioration effect of martensite – austenite constituent on the WM toughness may weaken because of their small size [8].

The FGHAZ has fine effective grains and high density of high disorientation grain boundary, which play vital role in both inhibiting the crack propagation and improving the toughness. Therefore, refinement of the crystallographic grains is an effective method to improve the HAZ toughness [9]. The fatigue life of repaired welded tubular joints, which had been subjected to fatigue loading until a certain length of crack reached, is presented. Shot peening and repair are presented as alternatives for fatigue life improvement [10]. In welding process, the heating and cooling cycle causes shrinkage in both base and weld metal and subsequently shrinkage tend to cause distortion in members and/or metal structures [11]. Tensile stress-strain curve is of high importance in mechanics of materials. The curve is usually obtained by experiment but is limited by necking phenomenon. Engineering stress-strain curve is converted to true stress-strain curve through simple formulas [12].

2. MATERIALS AND EXPERIMENTAL PROCEDURE

2. 1. Primary Consumable Materials

Welding equipment:

Automatically submerged arc welding equipment with direct current and reverse polarities used which was manufactured by ESAB Co. in Sweden country, and also ESAB LAF 1250 DC model was used.

Consumable wire of welding:

The characteristic Consumable wire for welding was AWS A5.17 with the diameter of 4mm and the characteristic of welding wire which one used is given in Table 1. The submerged arc welding powder:

The chemical composition of powder and its characteristics are shown in Table 2. Steel plate:

Steel plate was taken from steel which its mark was ASTM A516-70 and manufactured by Dillinger Hütte in Germany and its chemical composition is shown in Table 3.

2. 2. Butt Joints Welding without Bevel and Without Back Gouging

First of all, for achieving the maximum penetration depth in the best possible condition, a steel plate of material with mark A516-70 with the dimensions 300×400mm and thickness of 40mm was prepared and after that the surface was cleaned. It was welded in 17 parallel rows by changing main parameter at submerged arc welding, as shown in Table 4.

TABLE 1. Chemical composition (wt. %) of filler metal

AWS/ASME A5.17	C	Si	Mn
EH12K	0.12	0.35	1.75

TABLE 2. Chemical composition (wt. %) of flux

EN760	SiO_2+TiO_2	CaO+MgO	Al_2O_3+MnO	CaF_2
FB1 SA 55ACH5	15	40	20	25

In such a way, six rows were welded by changes in current (voltage and speed parameters also changes for the quality of weld). In the next, five rows stick out was variable and the remaining parameters were held constant. In six remaining rows voltage was variable and the parameters were held constant (were had relative increase in speed with respect to voltage).

In continuing, samples in dimension 150×300mm and thicknesses from 16 and 18 mm were prepared and the edges were without bevel and milled and grinded as zero degree.

For the purpose of canceling back gouging treatment; the required joint must have the following conditions:

- Preventing from pouring molten metal from opposite side of welding.
- The imperfects which exist at the end of weld's root pass must be removed from the joint.

As a result, joint design was prepared for welding with the following conditions:

- The root opening distance must be diminished (the parts must attach to each other's)
- And in second case eliminate the bevel for low thickness and increase the root face for higher thickness with respect to popular designs.

As a result, by using these two methods, the possibility molten metal pouring the behind of the part is cancelling. In addition, we can use of submerged arc welding instead of manual welding for making root pass. First at all, the welding was done on a sample with 16mm thickness as shown in Table 5, in such a way that after welding on the face of sample, back of the sample also without any back gouging and grinding treatment from back was welded. In fact welding was completed in two passes. The parameters were considered such that, penetration depth for face pass with respect to the relation $t/2<d<t$ was correct, where d is the penetration depth and t is the thickness of sample.

The welding of sample with 18mm thickness is similar to the sample which its thickness was 16mm, in two passes face and back passes according to parameters which are shown in Table 6.

TABLE 3. Chemical composition (wt. %) of base metal

C	Si	Mn	P	Cu	Mo	Ni	Cr	V	Nb	Ti	B	Ca
0.183	0.375	1.16	0.01	0.033	0.008	0.041	0.028	0.001	0.001	0.003	0.0002	0.001

TABLE 4. Parameters for welding without bevel

Weld No	A (Current)	V (voltage)	speed (cm/min)	Heat input (kj/cm)	Stick out (mm)
1	650	30	50	23	15
2	700	30	50	25	15
3	750	30	55	25	15
4	800	31	60	25	15
5	850	32	65	25	15
6	870	33	65	26.5	15
7	600	30	50	cons	15
8	600	30	50	cons	20
9	600	30	50	cons	25
10	600	30	50	cons	30
11	600	30	50	cons	35
12	700	28	50	24	20
13	700	30	50	25	20
14	700	32	50	27	20
15	700	34	55	26	20
16	700	36	55	27	20
17	700	38	56	28	20

TABLE 5. Parameters for welding sample with 16mm thickness

Pass No	Filler (AWS5.17)	Flux (EN760)	Electrode diameter (mm)	polarity	Current (A)	Voltage (V)	Travel Speed (cm/min)	Heat input (kj/cm)	Penetration (mm)
face	EH12k	FB 155 ACH5	4	DCEP	750	34	70	21.8	9
back	EH12k	FB 155 ACH5	4	DCEP	850	34	70	27.7	10.5

TABLE 6. Parameters for welding sample with 16mm thickness

Pass No	Filler (AWS 5.17)	Flux (EN760)	Electrode diameter (mm)	polarity	Current (A)	Voltage (V)	Travel Speed (cm/min)	Heat input (kj/cm)	Penetration (mm)
face	EH12k	FB 155 ACH5	4	DCEP	850	34	66	26.3	10.5
Back	EH12k	FB 155 ACH5	4	DCEP	850	34	66	26.3	10.5

TABLE 7. Parameters for stress relief heat treatment

Postweld Heat Treatment (QW – 407)	
Temperator:	600+/-10 °C
Time :	75 min

In continuing, again one of the sample with 18mm thickness with preheat equal to 120°C was welded with the same parameters which are shown in Table 6. Also, on half section of the same sample, stress relating heat treatment was taken place according to ASME Sec9 and as shown in Table 7 [13].

It's required to mention that in all the stages of welding and at the end of operation, visual inspection and ultrasonic test and radiography test controlled the correct test of welding procedure and we were assured from its perfection.

3. RESULTS AND DISCUSSION

50mm from the mid-point of steel plate which 17 rows welding was come down on it, was taken as a sample, such that beginning and end of welding has no effect on it.

After that grinding and polishing was done for determining the weld's sections (penetration depth, HAZ, weld metal bead heightand bead width) and then sample was etched by nital solution (Figure 1).

After the etching and measurement of different weld's section, the diagrams drawn on Figure 2 obtained which contain changes in current, stick out, voltage.

By paying attention to the graphs, the following results are obtained:

1- By increasing the current, penetration depth is increased.
2- The variation of stick out has no sensible effect on weld's appearance and also penetration depth.
3- By increasing the voltage we saw an increase in bead width and a decrease in bead height also it causes a very little reduction in penetration depth.

Finally, we can conclude that the most important facture which influenced on the penetration depth is value of current.

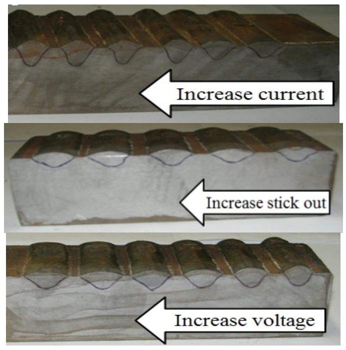

Figure 1. Macrographs of primary sample

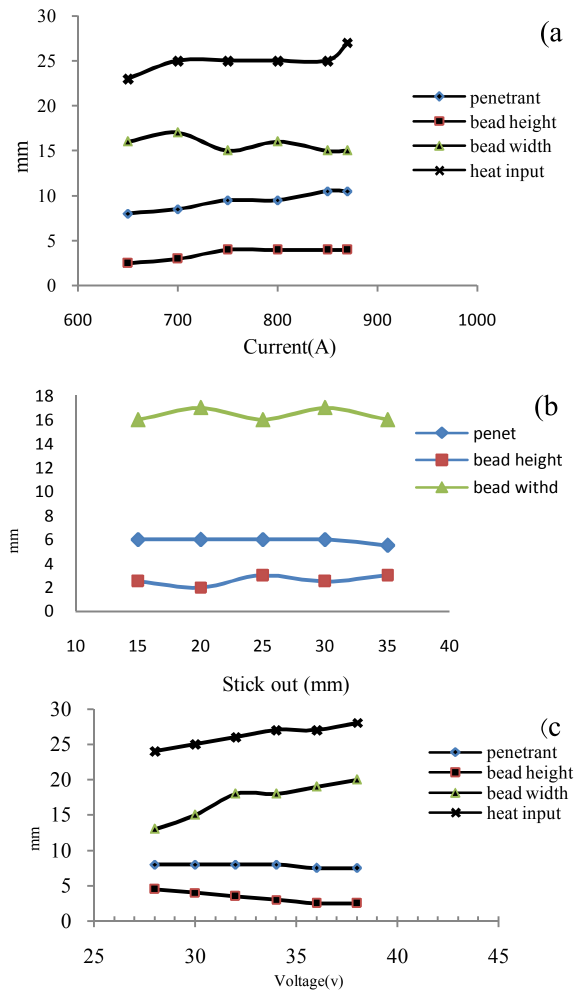

Figure 2. Effect of current (a), stick out (b), voltage(c) on different weld's section

3. 1. Result From The Welded Sample With 16mm Thickness From welded plate some samples were taken and prepared for testing mechanical properties. Tensile test was carried out on two samples, and the results are shown in Table 8 and also the strain-stress diagram was resulted which is shown in Figure 3. For bend test in four samples in side bend direction was taken place which all four samples were acceptable. Hardness test was carried out on a sample bases on brinell scale and in 19 different locations from base metal, heat affected zone and weld metal, the amount of hardness number was obtained as shown in Table 9.

TABLE 8. Results of tensile test of 16mm thickness

Tensile test				
Thk. (mm)	**Width (mm)**	**Area (mm^2)**	**Y.P. (Mpa)**	**U.T.S. (Mpa)**
15.74	18.86	297	404	561
15.88	18.63	295.8	416	575

TABLE 9. Results of hardness test of 16mm thickness

No	Hardness(HB)	No	Hardness(HB)
1	144	11	185
2	190	12	195
3	195	13	198
4	200	14	189
5	195	15	190
6	190	16	150
7	192	17	192
8	145	18	205
9	150	19	190
10	188		

TABLE 10. Results of charpy impact test of 16mm thickness

Charpy Impact Test		
	C.W	H.A.Z
Dimensions: 10. 10. 55 mm	30	140
Temperature(°C): -28	24	148
Notch Type : V	24	158
Scale : Joule	Ave	Ave
	26	146

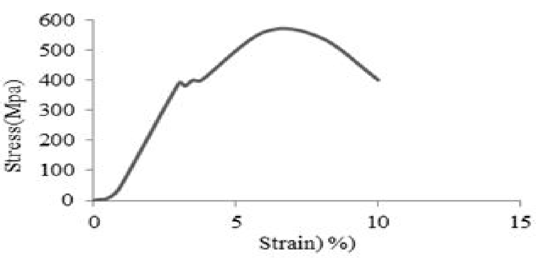

Figure 3. Strain-stress diagram of 16mm thickness

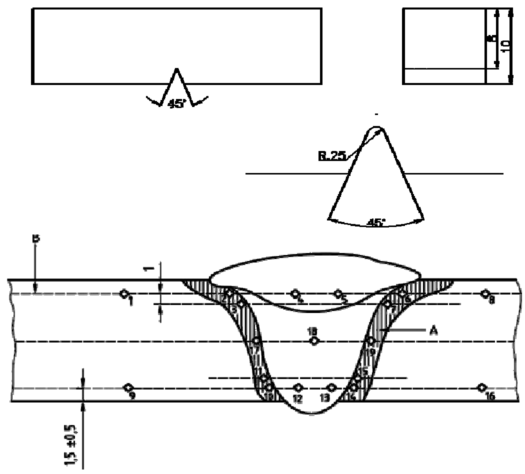

Figure 4. Geometry of charpy impact test specimen (all dimensions are in mm)

For charpy impact test, samples were prepared as ASTM A370 standard [14] (Figure 4). Three specimens of samples were taken from weld metal and three other were taken from heat affected zone with v-notches machining. Impact test was done at -28°C temperature and its results are shown in Table 10. Finally, upon the ASME Sec9 standard all of the tests were acceptable which indicates the practicality of welding process and it's soundless.

3. 2. Results Obtained from the Welded Sample of 18mm Thicknesses From welded plate with 18mm thickness, some samples were taken and prepared and mechanical testing was done similar to the plate with 16mm thickness. The results of tensile test are shown in Table 11 and diagram of stress- strain is shown in Figure 5. The results of charpy impact test are shown in Table 12 and the results of hardness test are also shown in Table 13. Bend test carried out on four samples were taken from side bend in weld, which all of the four samples were acceptable. In continuing, metallography was taken place on the sample with 18mm thickness. For macrograph examinations, first of all, the surface of the sample was grinded and polished, after that etching was done for taking macrographs and weld metal and heat affected zone are clearly specified (Figure 6). Then, the micrographic examinations was carried out and the samples were etched by the solution which contain 2.5% nitric acid. Microscopic examination was done by optical microscope (Olympus) and some pictures were photographed from base metal, head affected zone and weld metal. These pictures can be observed in Figure 7. As it is evident from the pictures, we can observe grain extension and dendritic structure in weld metal area, which this factor causes a reduction in ductility and low values charpy impact test for the weld metal area of the samples.

TABLE 11. Results of tensile test of 18mm thickness

Tensile test				
Thk. (mm)	**Width (mm)**	**Area (mm^2)**	**Y.P. (Mpa)**	**U.T.S. (Mpa)**
17.7	19.4	344.5	395	562
17.2	19.2	330.2	401	567

TABLE 12. Results of charpy impact test of 18mm thickness

Charpy Impact Test		
	C.W	H.A.Z
Dimensions: 10. 10. 55 mm	22	58
Temperature(°C): -28	20	76
Notch Type : V	22	64
Scale : Joule	Ave	Ave
	21.5	66

TABLE 13. Results of hardness test of 18mm thickness

No	Hardness (HB)	No	Hardness (HB)
1	144	11	166
2	167	12	195
3	169	13	197
4	195	14	165
5	198	15	170
6	168	16	145
7	170	17	170
8	145	18	200
9	145	19	170
10	165		

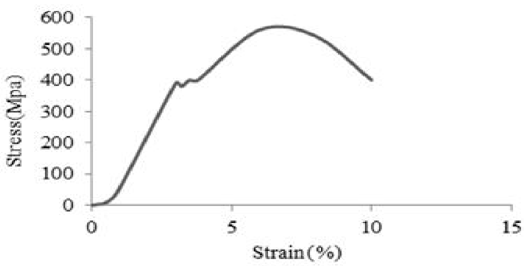

Figure 5. Strain-stress diagram of 18mm thickness

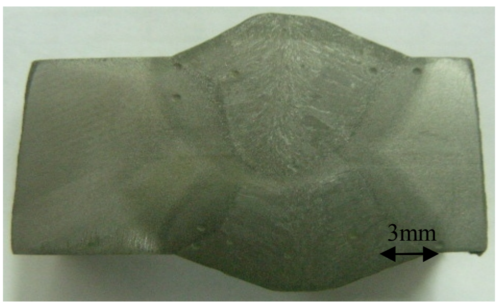

Figure 6. Optical macrographs of weld joints of 18mm thickness

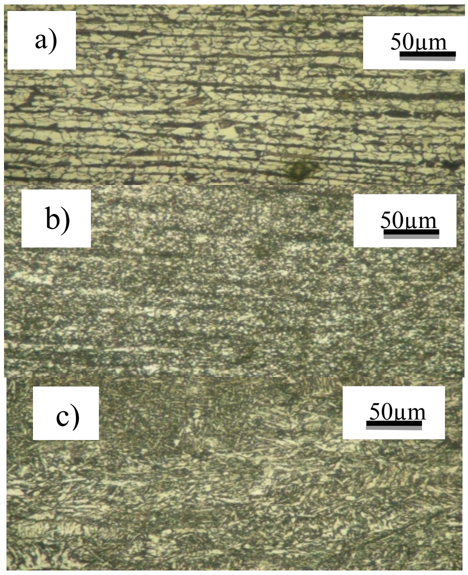

Figure 7. Optical micrographs of weld joints of 18mm thickness (a) base metal, (b) heat affected zone, (c) weld metal

TABLE 14. Results of charpy impact test of 18mm thickness with preheat

Charpy Impact Test		
	C.W	H.A.Z
Dimensions: 10. 10. 55 mm	32	60
Temperature(°C): -28	32	74
Notch Type : V	35	76
Scale : Joule	Ave	Ave
	33	70

3. 2. 1. The Results Obtained from the Welded Sample with 18mm Thickness which was Preheated and Then Stress Relief Heat Treatment On the sample which was preheated about 120°C, charpy impact test and hardness test were carried out. The results of charpy impact test and hardness test are shown in Tables 14 and 15, respectively which indicates relative increase of ductility in charpy impact test and decrease of hardness in weld metal area. On half section of the sample which was preheated and, welding had under gone stress relief heat treatment, again, charpy impact test and hardness test were done. The results of charpy impact and hardness tests are shown on Tables 16 and 17, respectively. This time, we observed twice increasing in ductility of weld metal area at charpy impact test and the effect of preheat and stress relief are clearly in dilated. Values ductility and hardness in three cases (without preheat, with preheat, with preheat and stress relief) were caparisoned in column charts (Figures 8 and 9). Finally, on Table 18, the common and familiar method suggested with respect to cost is comprised with each other.

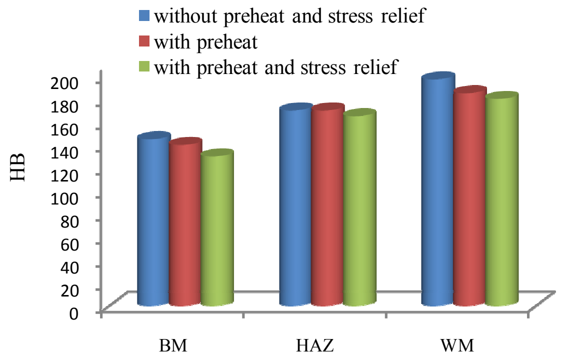

Figure 8. Comparison hardness in three cases (without preheat, with preheat, with preheat and stress relief) in weld joints

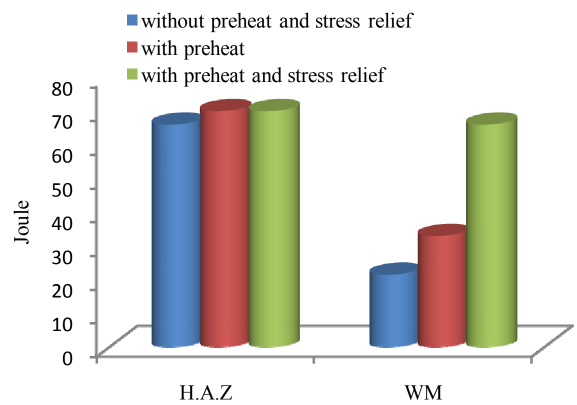

Figure 9. Comparison ductility in three cases (without preheat, with preheat, with preheat and stress relief) in weld joints

TABLE 15. Results of hardness impact test of 18mm thickness with preheat

No	Hardness (HB)	No	Hardness (HB)
1	139	11	169
2	165	12	189
3	169	13	176
4	190	14	165
5	185	15	172
6	165	16	141
7	172	17	172
8	139	18	190
9	144	19	172
10	169		

TABLE 16. Results of charpy impact test of 18mm thickness with preheat and stress relief

Charpy Impact Test		
	C.W	H.A.Z
Dimensions: 10. 10. 55 mm	32	60
Temperature(°C): -28	32	74
Notch Type : V	35	76
Scale : Joule	Ave	Ave
	33	70

TABLE 17. Results of hardness impact test of 18mm thickness with preheat and stress relief

No	Hardness(HB)	No	Hardness(HB)
1	130	11	159
2	165	12	172
3	162	13	172
4	180	14	159
5	185	15	165
6	162	16	130
7	169	17	162
8	132	18	180
9	127	19	159
10	169		

TABLE 18. Comparisons of the cost are in the familiar and suggested method

For one meter		
Welded plate with 18mm thickness	**Common method ($)**	**Suggested method ($)**
Cost of welding material	7	2.8
Cost of material for back gouging	1	0
Payment for welding	13	1.5
Total cost per one meter	21	4.3

4. CONCLUSIONS

By preheating at 120°C on welded sample with 18mm thickness, we observed an increase in ductility and a decrease in hardness in weld metal area. The stress relief heat treatment causes double increase in ductility of weld metal area. By paying attention to metallography samples, we observed grain extensionand dendrite structure in weld metal area which causes increase in hardness and decrease in ductility of weld metal area. The acceptance of non-distraction and mechanical tests as per standard on weldments, shows practicality for the suggested design. By implementation of this design and eliminating back gouging practice, we will observe 80% reduction in costs and also eliminating the environmental and acoustic pollutions which are resulted from back gouging.

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Heat Treatment

چکیده

یکی ازمراحل جوشکاری زیرپودری عملیات شیارزنی از پشت است. این کار علاوه بر اعمال هزینه، نیاز به گذاشتن زمان زیادی در خط تولید است و آلودگی صوتی و محیطی را به همراه دارد. در این مقاله روشی جهت حذف عملیات شیارزنی از پشت، از فرایند جوشکاری زیرپودری ارائه شده است. بدین منظور برروی ورق فولادی از جنسA516-70 پارامترهای مهم جوشکاری زیرپودری بررسی شد، تا پس از عملیات ماکروگرافی تاثیر هرکدام از پارامترها برروی جوش مشخص گردد. در ادامه نمونه ورق هایی با ضخامت های ۱۶و۱۸ میلیمتر تهیه شد و با انتخاب بهترین پارامتر، نمونه ها بدون پخ و فاصله و حذف عملیات شیارزنی از پشت، در دو پاس (رو و پشت) جوشکاری گردید. همچنین اثرات پیشگرم، تنش گیری و ارزیابی ریز ساختار و خواص مکانیکی مورد بررسی قرار گرفت. در انتها بررسی آزمایشات در حیطه استاندارد، نشانگر قبول و اجرائی بودن طرح بود. با اجرائی شدن این طرح شاهد کاهش۸۰ درصدی در هزینه های جوشکاری وهمچنین حذف آلودگی صوتی و زیست محیطی حاصل از شیارزنی از پشت هستیم.

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