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Microstructurs and Toughness of High Heat Input Electro-Slag Weld Metal of 50Kgf/mm^2 Class Constructional Steels†

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Abstract

Nowaday,the steel frame structure of four side thick plate box column construction are often used for general multistoried buildings.
Various high heat input welding process have recently been applied to the manufacture of four side thick plate box column. The purpose of this report is to clarify the joint characteristics and especially the toughness of weld metal in thick plate joints made by some of these high heat input welding processes,which are the method of electro-slag (ES) and heavy current submerged arc (SAW) welding processes. The steel plate of 50kgf/mm^2 grade such as SM 50A of 40mm thickness are used for test plate. The summary of test results is shown in the following; (1) *The impact characteristics of weld joint by one pass welding,the absorbed energy (E_A) by ES procese is found to be generally lower than that by SAW processes.* (2) *As for the impact characteristics of the weld metal by ES,the absorbed energy (E_A) of core part of weld metal is found to be remarkably lower than that of its periphery part.* (3) *According to the increase of weld heat input (Q),the E_A value of weld metal made by both procese of ES and SAW showed a tendency to decrease.* (4) *The decreasing rate of E_A as a function of the increase of Q is found not to specially relate to change of chemical compositions of weld metal such as,C,Si,Mn and N but O is effective.*

KEY WORDS :weld metal toughness, electro-slag process,Received on 4th Nov.1992

1. Introduction

Recently the demand for steel frame buildings of four side plate box colum construction is prospering due to a rush to install a super high-rise building. For keeping up with the increase of these building works,the automatic box column manufacturing line was introduced into workshop.

The characteristics of this line are to weld the corners first by heavy current submerged arc (SAW) welding method and then to weld four sides of each diaphragm by an electro-slag (ES) welding method. The whole view of this line,the welding work by heavy current SAW and ES (high heat input welding) are shown in Figure.1.2 and 3[1],respectively. This study was carried out to clarify the performance of weld joints,especially the notch toughness

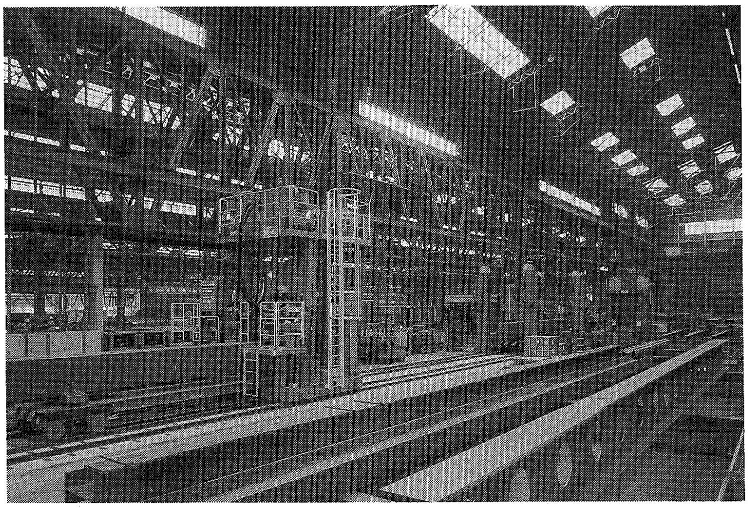

Fig.1 Whole view of automatic manufacturing line for four side plate box columns

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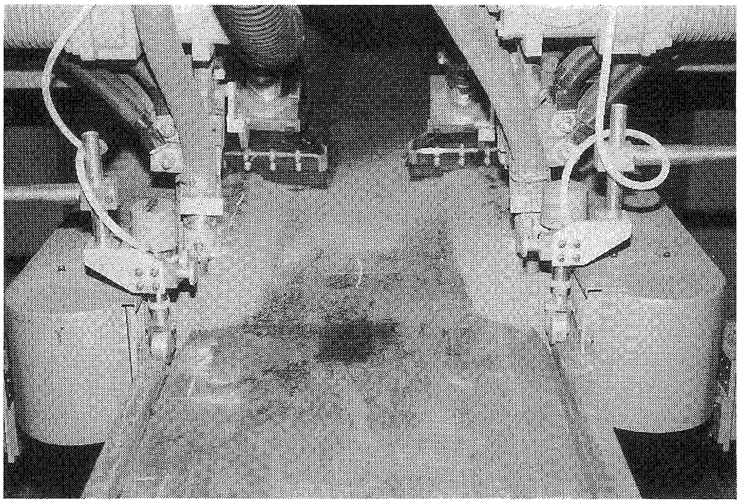

Fig.2 Heavy current twin tandem SAW work

of weld joints made by two high welding heat input processes.

In addition to the clarification of weld toughness of weld joints made by both ES and SAW weldings,the relation between the impact value of weld metal and the amount of heat input has been estimated. In this paper,toughness of ES weld metal were discussed mainly.

2. Experimental Procedure

2.1 Material

The chemical composition of materials used in this study is shown in Table.1 Base metal BM-1 of SM50A plate was used to evaluate the toughness characteristics of high heat input weld metal made by using the standard welding parameters. Base metal BM-2 was used to evaluate the effect of heat input on weld metal toughness. The test piece size for ES and SAW welding was 300 x 600 x 1200mm respectively.

The diameters of welding wires for ES and SAW welding are 1.6 and 6.4mm respectively.

2.2 Welding parameters

The Table 2 shows the standard welding parameters of ES and SAW for 40mm thickness plate and Figure.4 shows the geometry of these welding grooves. Table 3 shows both ES and SAW welding parameters used to change the amount of heat input. The heat input for each welding method was changed to four levels.

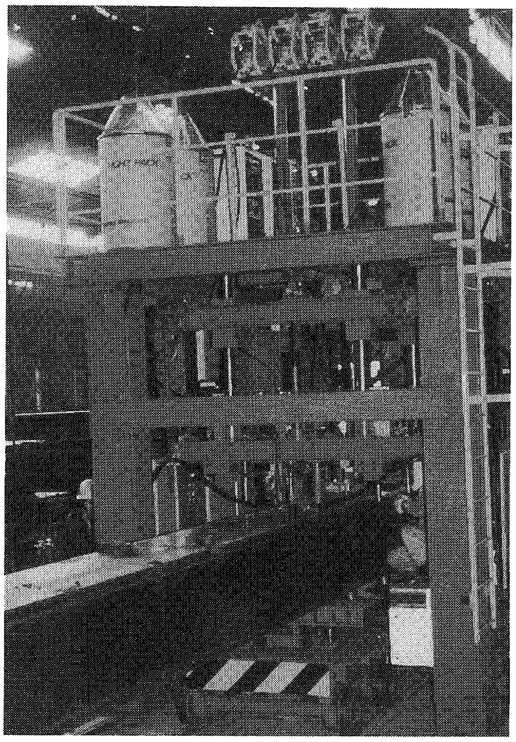

Fig.3 Electroslag (ES) welding work

2.3 Impact Test method

2.3-1 Impact test of the weld joint made by standard welding parameters (BM-1 base metal)

Impact test was carried out at the temperature of 0° using 10mm square standard size charpy test piece with 2mm v notch. The specified impact value for SM50B base metal is not less than 2.8kgf·cm at the temperature of 0℃

Table.1 Chemical composition of both base metal and welding wire

		C (Wt・%)	Si	Mn	P	S	O (ppm)	N	Absorption Energy $_0E_A$ (kg－m, 0℃)
Base Metal SM 490A (40mm)	BM-1	0.14	0.35	1.30	0.008	0.002	10	26	9.4
	BM-2	0.18	0.46	1.45	0.024	0.007	10	30	5.2
Welding Wire	ES-Wire (YM55A 1.6φ)	0.06	0.42	1.26	0.006	0.002	0.2 %Mo		－
	SAW-Wire (YA,6.4φ)	0.07	0.58	0.58	－	－	－		－

Table.2 Standard welding parameters for base metal of 40mm tickness.

WELDING METHOD	CURRENT(A)-VOLTAGE(V)		SPEED (cm/min)	WELDING HEAT INPUT Q(KJ/cm)	NOTE
ES (Electro -slag)	380A-48V		2.4	456	1.6mmφWire(YM55A) Flux(YF15)
SAW (Tandem Submerged)	Preceding (L)	1850A -37V	23.0	323	6.4mmφWire(Y-A) Flux(NSH-52S) Distnce between Electrods : D_l= 60mm
	Second (T)	1200A -46V			

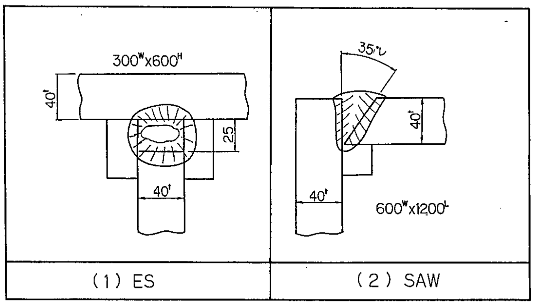

Fig.4 Geometry of standard welding grooves

according to the JIS. However,no specific value is specified in JIS for the material of SM50A used in this study.

The impact characteristics in weld metal,bond and heat affected zone of the weld joint made by standard ES and SAW welding parameters in Table 2 were tested. Their notch locations of test piece are shown in Figure.5

2.3-2 Effect of welding heat input (Q) on the imapct test value of weld metal (BM-2 base metal)

The effect of welding heat input (Q) on both ES and SAW weld metals were tested. Each notch location in weld metal is shown in Figure.6. As for ES weld metal,the difference of impact characteristics among the test pieces taken from different locations along the welding line and that among the test pieces of different sizes were also tested.

Further,main five elements such as C,Si,Mn,P,S and gas components O and N were analyzed.

3. Impact Characteristics of Weld Metal Made by Standard Welding Parameters in High Heat Input Welding Processes.

3.1 Macrostructure of weld joint

Figure.7 shows the macrostructures of both ES and SAW weld joints. Both weld joints are one pass sound weld of 40mm plate and made by heat input of 456 and 323 KJ/cm respectively. ES weld metal vary in microstructure from core part to periphery and show fine grain in core part, coarse grain in periphery part respectively. But, SAW weld metal show homogeneous microstructure.

3.2 Results of impact test

Figure.8 shows the comparison of absorbed energy-transition temperature curve between ES and SAW weld metals. The absorbed energy (E_A) of ES weld metal is generally less than that of SAW weld metal. Location of

Table.3 Electroslag and SAW welding parameters

	TEST PIECE MARK	CURRENT (A)	VOLTAGE (V)	WELDING SPEED (cm/min)	AMOUNT OF FLUX (g)	DIAPHRAGM THICKNESS (mm)tD	GAP (mm)g	HEAT INPUT (KJ/cm)
E	EA	380	42	5.5	30	20	20	175
S	EB	380	45	3.2	55	30	25	320
	EC	380	48	2.4	70	40	40	456
	ED	380	50	1.5	90	60	60	790
	TEST PIECE MARK	CURRENT (A)	VOLTAGE (V)	WELDING SPEED (cm/min)	ERECTRODE DISTANCE (mm)	GROOVE SHAPE (°)	GROOVE DEPTH (mm)	HEAT INPUT (KJ/cm)
S	SA	L. 1400 T. 1050	32 40	52	30	L Type 40, t=40	19	100
A W	SB	L. 1800 T. 1200	37 46	24	50	L Type 35, t=40	38	305
	SC	L. 1800 T. 1200	37 46	18	50	V Type 48, t=40	37	405
	SD	L. 2000 T. 1300	40 46	15	50	V Type 66, t=40	35	560

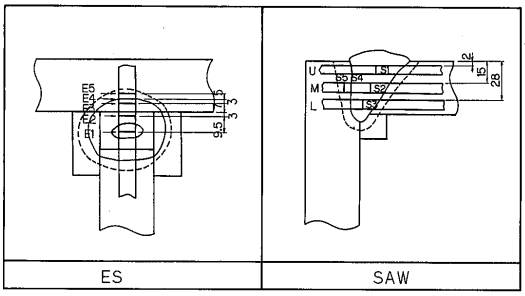

Fig.5 Notch location of test piece extracted from weld

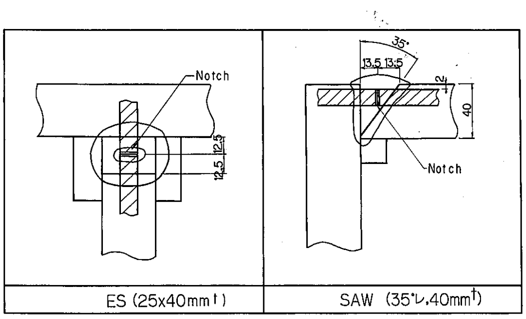

Fig.6 Notch location of impact test samples extracted from weld metal

notch is center of weld metals.

Figure.9 shows absorbed energy (E_A) of ES weld metals which changed location of notch. It was found that the difference of E_A between the center and periphery in ES weld metal is significantly large. The core part value is lower than that of the periphery part value. Both macrostructure and example of impact test piece fracture surface are shown in Figure.10. The remarkable difference of microstructures even in the same weld metal is expected.

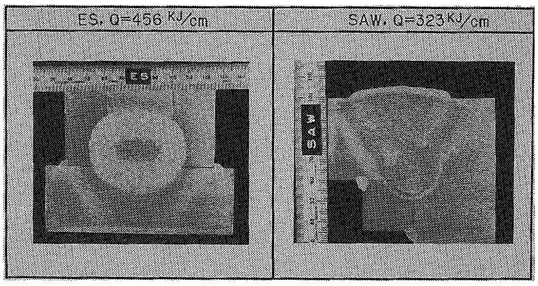

Fig.7 macrostructure of ES and SAW weld joints

Figure.11 shows absorbed energy (E_A) of weld metal (ES) as a function of notch location of weld metals. E_A from core part,bond and HAZ shows the lowest value. But weld metals in periphery part have a good thoughness.Figure.12 shows the example of the cross section macrostructure of ES weld metal made by different heat input. The fine structure in core part and the coase structure in periphery part are observed.

As described in Figure.11 and Figure.12, thoughness and microstructure of ES weld metals are not uniform. It must be pointed out that

(1) difference of microstructures between core part and periphery part in weld metal.

(2) Big difference of E_A between the core part and periphery part,the former is lower E_A than that of the later.

This paper examines on the lower thoughnes of ES weld metals mainly.

Figure.13 shows the comparison of E_A of weld metal between the different directions of notch against the weld

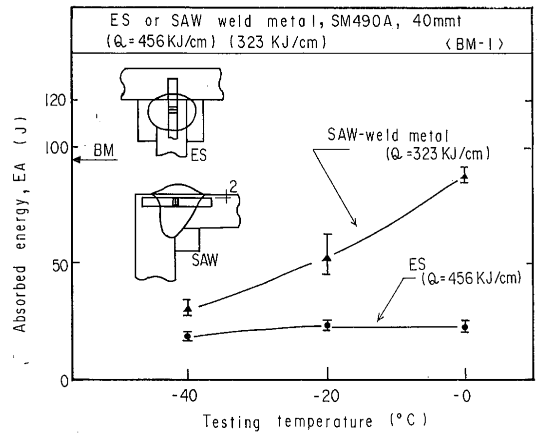

Fig.8 Absorparison energy - transition temperature curve

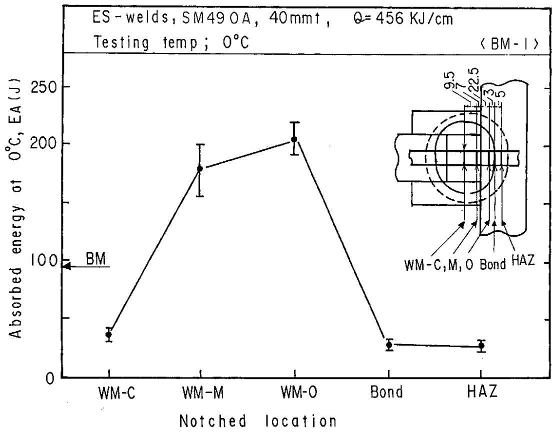

Fig.11 Comparison of E_A values in ES weld metal

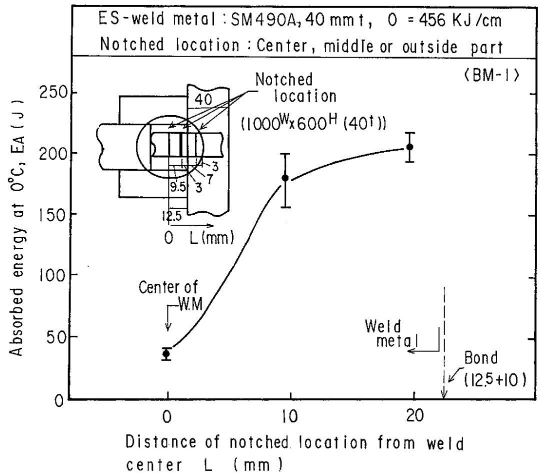

Fig.9 Comparison of E_A values in ES weld metal

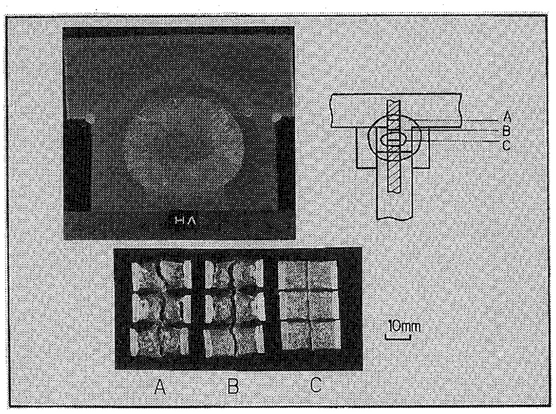

Fig.10 Fractured surface of impact test piece and macrostructure of ES weld metal

line. No difference of E_A was found in the two directions of notch in both ES and SAW weldmetals.

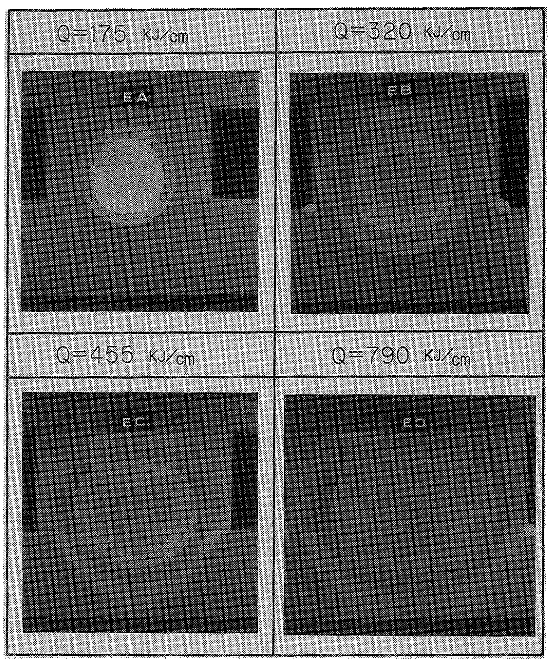

Fig.12 Effect of heat imput (Q) on macrostructure of ES wald metal

The effect of test piece size (the flange width was changed) on E_A is shown in Figure.14 EA was not significantly affected by the test piece size. Therefore,the standard size of test piece in this work was decided to be 300mm x 600mm.

Figure.15 shows the relation between extracted locations of impact test piece along ES welding line and E_A. Only a little difference of E_A was found between the bottom (start) and the top (end) of ES welding line. All the impact test pieces for in this work were extracted from the usual location in weld metal.

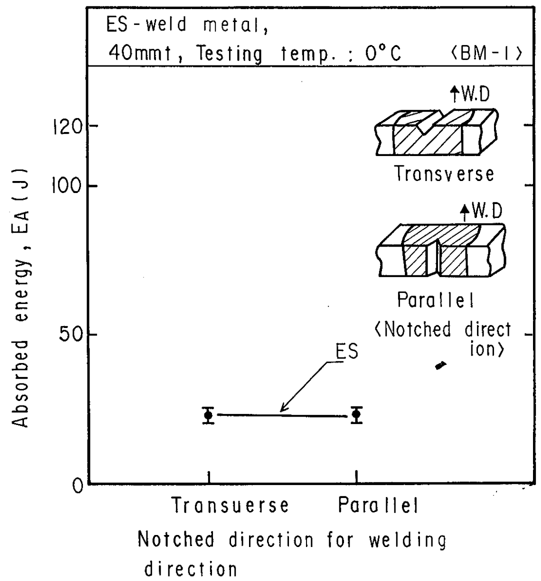

Fig.13 Comparison of E_A value of weld metal between two directions of notch

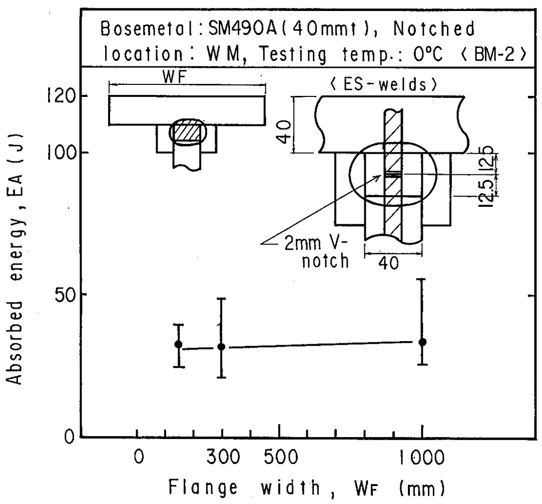

Fig.14 Effect of test piece size on E_A value

Figure.16 shows the comparison of E_A between two types of SM50A steel base plate. (carbon content is a somewhat different) The E_A of both weld metals is not significantly affected by the difference of base plate. Effect of heat input (Q) was investigated. Change of E_A as a function of heat input (Q) is shown in Fig.17. No significant change of EA in ES weld metal is noticed at the heat input level higher than about 300KJ/cm. E_A of SAW weld metal shows a tendency to decrease according to the increase of Q. The elements and gases content of weld metals are determined by chemical analysis. The results of chemical analysis of weld metal are summarizes in Table 4.

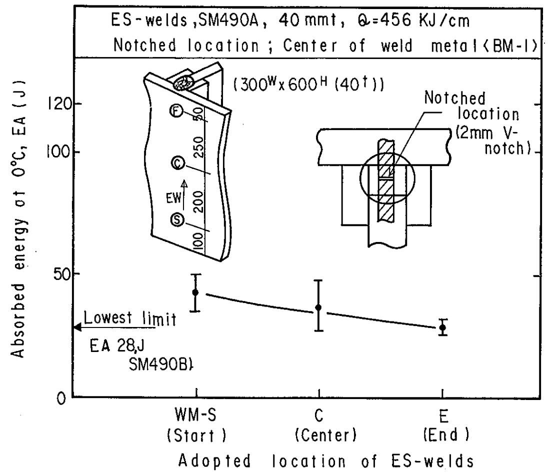

Fig.15 Relation between Charpy impact test piece locations and E_A

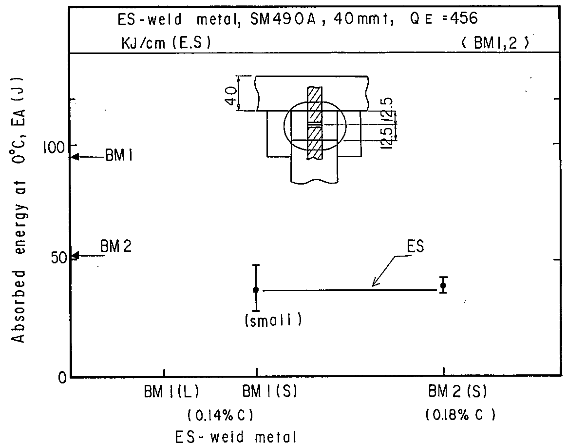

Fig.16 Relation between types of base metal and E_A of weld metal

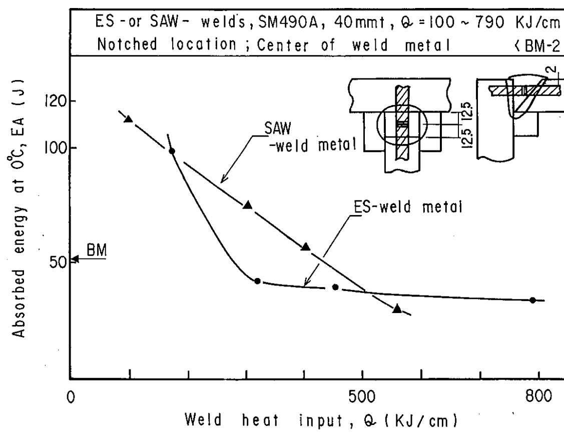

Fig.17 Effect on heat imput (Q) on the E_A of ES and SAW weld metal

Table.4 Analyical result of weld metal

	Q (KJ/cm)	NO	CHEMICAL COMPOSITION(Wt.%)					GAS CONP (ppm)	
			C	Si	Mn	P	S	O	N
ES	175	EA	0.10	0.42	1.36	0.013	0.006	130	55
	320	EB	0.11	0.41	1.36	0.014	0.004	109	55
	455	EC	0.13	0.43	1.43	0.016	0.005	104	45
	790	ED	0.13	0.43	1.42	0.016	0.004	111	49
SAW	100	SA	0.16	0.40	1.50	0.020	0.008	309	28
	305	SB	0.15	0.43	1.66	0.020	0.006	244	32
	405	SC	0.15	0.44	1.71	0.019	0.007	214	35
	560	SD	0.15	0.42	1.73	0.021	0.007	212	33

No significand change of chemical composition in weld metal is found regardles of the increase of weld heat input (Q). It was cleared that the improvement of the E_A of core part of ES weld metals can not expect by means of changing welding conditions. Therefore,the reason for the decrease of EA is interpreted as having been signicicantly caused by the grain coarsening in solidification metal and by the different structures.

So,it has to investigate more. For example

(1) Characterization of microstructure on core part and periphery part in solidified metals.
(2) Identify of non metallic inclution (size,composition) and microdefect in solidified metals.
(3) Addition of alloying elements to solidified metals for increase E_A.

4. Conclusion

This study was carried out to clearify the joint characteristics and especially the toughness of weld metals in thick plate joints made by electro-slag (ES) and submerged arc (SAW) welding process. The main test results are summarized as follow.

(1) The impact characteristics of weld joint,the absorbed energy by ES is found to be generally lower than that by SAW.
(2) E_A values by ES weld metal are different depend on the notch location,at the core part is lower than that of periphery part in weld metal.
(3) The microstructure of ES weld metal is not uniform,core part is fine but periphery part is coase structure respectively.
(4) The decrease rate of E_A of weld metal according to the increase of welding heat input is not obviously affected by the change of content of main elements.

References

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