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Automatic Wet Underwater Welding at Horizontal Position of Tubes Using Water Curtain type GMA Welding Technique*

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Summary

As one of applications of water curtain type underwater GMA welding technique, automatic girth welding of tubes at a horizontal position was carried out at a water dpeth of 2 *m and a water depth of* 50 *m. In the welding at a water depth of* 2 *m, a* 450 *mm diam.* 6.4 *mm thick tube and a* 560 *mm diam.* 16 *mm thick tube were used. In the welding at a water depth of* 50 *m, a* 250 *mm diam.* 16 *mm thick tube was used. Satisfactory welding results were obtained for all the tubes with no defects at all appearing in the welds in* 180° *bending test and radiographic inspection test.*

1 Introduction

Authors reported that multi-pass welds of 12 mm thick mild steel using the water curtain type GMA welding technique at a water depth of 90 m showed successful results in tension test and bending test. But this study was a fundamental experiment in which welding achieved was a straight butt joint at down hand position. As an experiment of applying the water curtain type GMA welding technique, this time, automatic girth welding of tubes at a horizontal position was carried out assuming a repair welding of riser of underwater pipe line and vertical tubes in offshore structure. Experiments were performed mainly at a water depth of 2 m, but some of them were done at a water depth of 50 m using a high pressure chamber.

2 Experimental apparatus, method and materials

2.1 *Experiment at a water depth of* 2 *m*

For the girth welding of tubes used for offshore structure, needless to say, a tube is fixed, so that a torch has to be rotated around the tube. Fig. 1 shows the experimental apparatus, which is set underwater in a condition of clamping tube, a wire and a wire feeder being provided in the box shown at right of the picture lest they should be wet with water, and the wire feeder needs therefore no special motor, and the feeder which is used for CO_2 arc welding on land can be applied, except that only the regulator for wire feeding rate is taken away and set on land. In the existing welding, the box for the wire and the wire feeder can not be rotated around the tube, thus it is made movable straightly as shown in Fig. 2, so that smooth wire feeding may be kept with a large curvature of conduit.

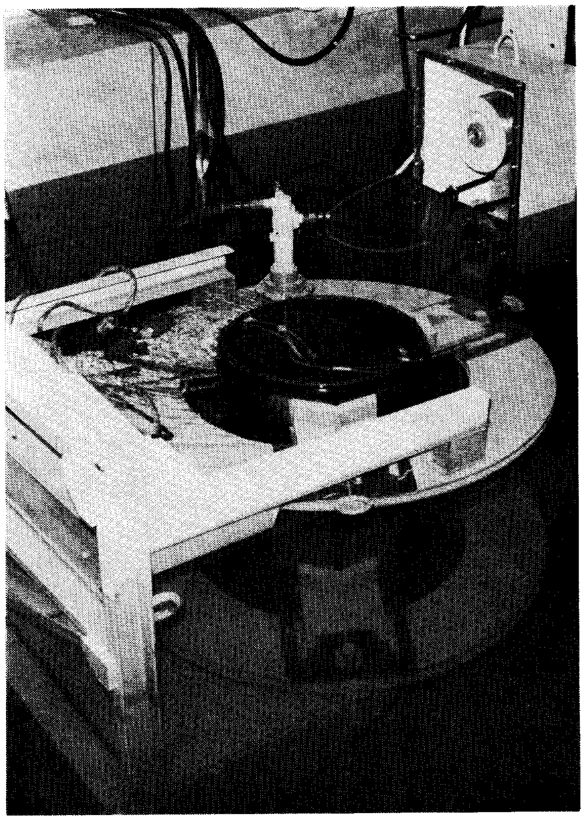

Fig. 1 Experimental apparatus used in this girth welding at a water depth of 2 m

2.2 *Experiment at a water depth of* 50 *m*

Water pressure of 50 m for girth welding is simulated in a 3 m long 1.5 m diam. high pressure chamber shown in Fig. 3. The best thing for actual offshore structure is to make the torch rotatable as mentined above. But for the same process applied to this experiment, a very large high pressure chamber is needed, and the torch fixed condition as shown in

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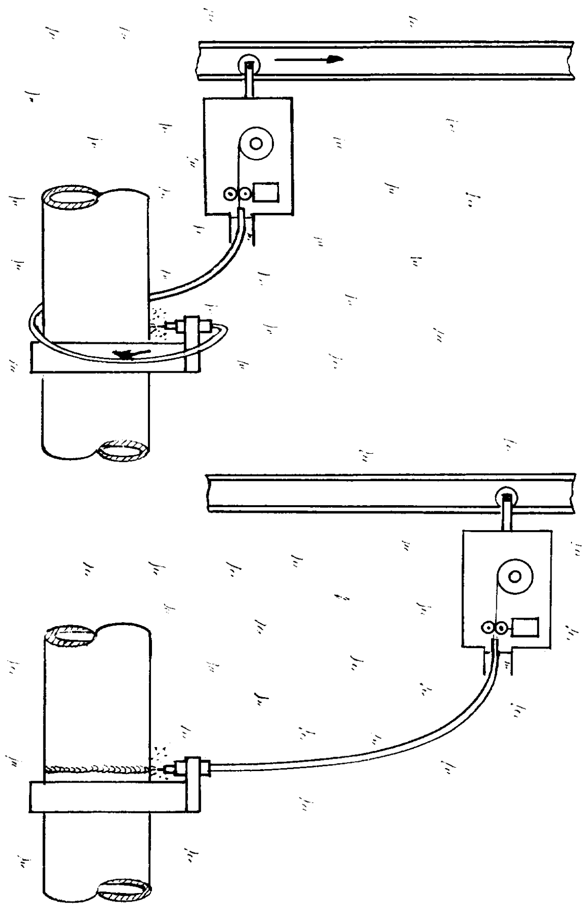


Fig. 2 Schematic drawing of automatic girth welding of tube

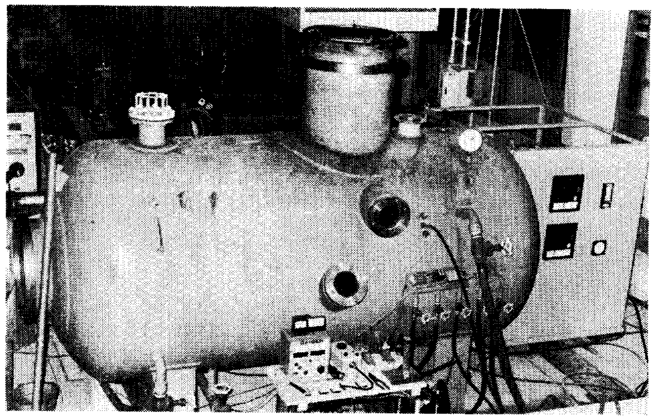


Fig. 3 High pressure chamber used in this experiment

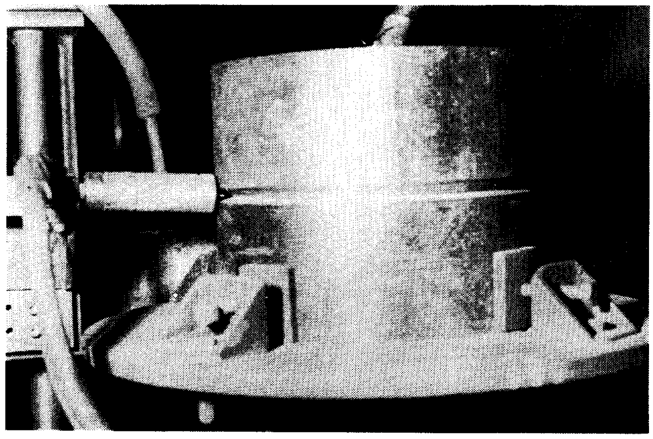


Fig. 4 Inside view of this high pressure chamber

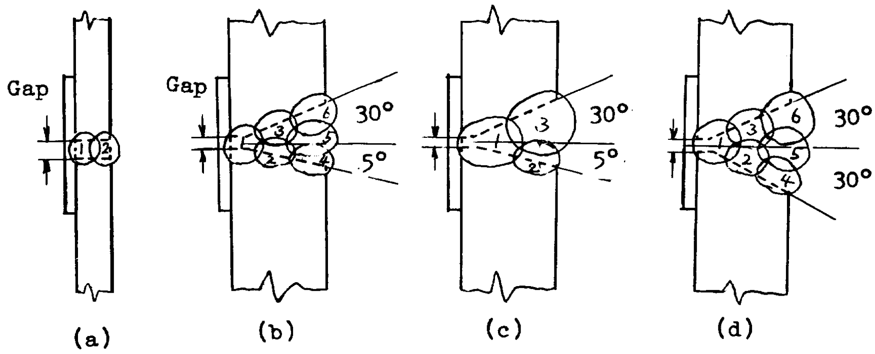


Fig. 5 Various grooves used in this welding

Fig. 4 is therefore applied. But in my opinion since rotation of the torch and the tube is relative condition, if a successful result can be obtained in the torch fixed condition, the same result will be obtained undoubtedly in the tube fixed condition.

2.3 *Materials used*

Tubes used are 450 mm diam., 6.4 mm wall thick and 560 mm diam., 16 mm wall thick. I type joint with gap as shown in Fig. 5 (a) was adopted for 6.4 mm thick tube and welds were executed in 1∼2 passes. V type joint with gap (root opening) of 2∼3 mm as shown in Fig. 5 (b) was adopted for 16 mm thick tube at a water depth of 2 m. Fig. 5 (c) (d) is execution at a water depth of 50 m; and 3 and 6 passes welding was carried out with a torch at horizontal position to the tube. Numbers in Figs. represent the welding sequence. Tube used for welding at a water depth of 50 m was 250 mm diam., diam., 16 mm wall thick. All the tubes used in this experiment were rimmed steel and the joints were executed with backing plate to prevent invasion of water in to molten pool from back side. Wire used was a solid wire of 1.2 mm diam.. The reason is as follows: joints are executed multi-pass welding, in the welding with flux cored wire, slag must be removed after every pass, but every pass of welding with solid wire can be done in welded condition.

3 Experimental result and its discussion

3.1 *Experimental result at a water depth of* 2 m

(a) Welding of 6.4 mm thick tube

Short circuiting transfer welding technique was recommended for thin tube. As the result of preliminary experiments, arc voltage of 20 V, curtain water flow rate of 24 l/min and shielding gas flow rate of 80 l/min were found as good conditions, which were adopted as they are, and the gap was changed 2～6 mm. Fig. 6 shows experimental results of relation between welding speed and current to obtain full penetration to backing plate and both sides. When the current is small compared with the welding speed in a case of narrow gap, needless to say, poor penetration results. Even though the current is small in a case of a comparatively large gap of 6 mm, good penetration to backing plate is obtained, but lack of fusion to both sides is recognized. In comparison of gaps 4 mm and 6 mm, 6 mm gap can be selected as the welding with less current. When the current is large as compared to welding speed, arc becomes unstable and an irregular weld bead forms, because molten metal overflows from the gap. Backing plate should be selected with proper thickness lest it is burned through by over current. Narrow gap is better than wide gap so far as good penetration is obtained, because the narrower the gap selected, the less of molten metal will be required.

But, under 2 mm gap condition, good result could not be obtained. The reason was that a little water remained in gap since the gap was too narrow. From our experiment I think that acceptable condition will be a gap of 3 mm, but experiment on this condition was not carried out, because good result was obtained with a gap of 4 mm.

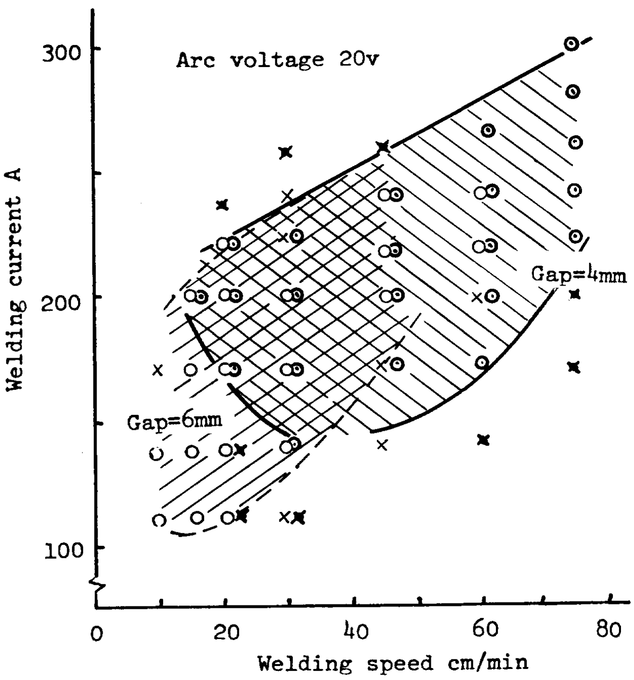
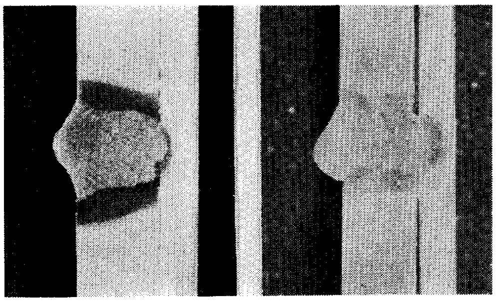


Fig. 6 Relation between current and welding speed



(a) (b)

Fig. 7 Macro-structures of 6.4 mm thick tube. One pass welding (a), Two pass wed welding (b)

Under 4 mm gap condition as can be seen in macrostructure of Fig. 7 (a), successful result was obtained by one pass welding, which is the only welding condition; arc current is 220 A, welding speed is 25 cm/min.

But in a case of the only one pass welding acceptable penetration of backing plate and both sides in gap is obtained but a very concaved bead is generally formed, because the gap is not filled with molten metal. Thus two pass welding is used; welding condition of the first pass is selected in proper range of Fig. 6 and the second pass is carried out for cosmetic run. Fig. 7 (b) shows macrostructure of two pass welding as an example. Welding speed is fixed, current and arc voltage of the first pass and the second pass are 180 A, 150 A and 20 V, 18V respectively.

In destructive testing of two pass welds, in a tension test a fracture occurred in the mother metal and in a bending test cracks and blowholes did not appear at welds as shown in Fig. 8. Fig. 9 shows radiographic inspected result in contrast to bead appearance. The defects such as blowholes, slag inclusion, cracks etc. were not recognized at all.

(b) Welding of 16 mm thick tube

In the horizontal welding on land, a welding torch is tilted 10 degrees against horizontal line and welding is carried out with single bevel, but in a case of water curtain type GMA welding technique applied to underwater horizontal welding, torch angle is required to be 0° or 5° against horizontal line and V type groove or modified V type is adopted. The reason is to prevent the intrusion of curtain water which is reflected from mother metal to welds. In this experiment at shallow water only the modified V type groove was used.

Welding was carried out in 4～6 passes. To penetrate the root of thick tube, for only the first pass, spray transfer arc welding was used and after second pass short circuiting transfer welding was used.

Referring to the past experiment, shielding gas of 120 l/min, arc current of 200～300 A and welding speed of 30 cm/min were fixed and welding was executed with kinds of shielding gases changed to Ar, CO_2. Ar + 5 %O_2 and 70 %Ar + 30 %CO_2. It was made clear that 70 %Ar+30 %CO_2 mixed gas

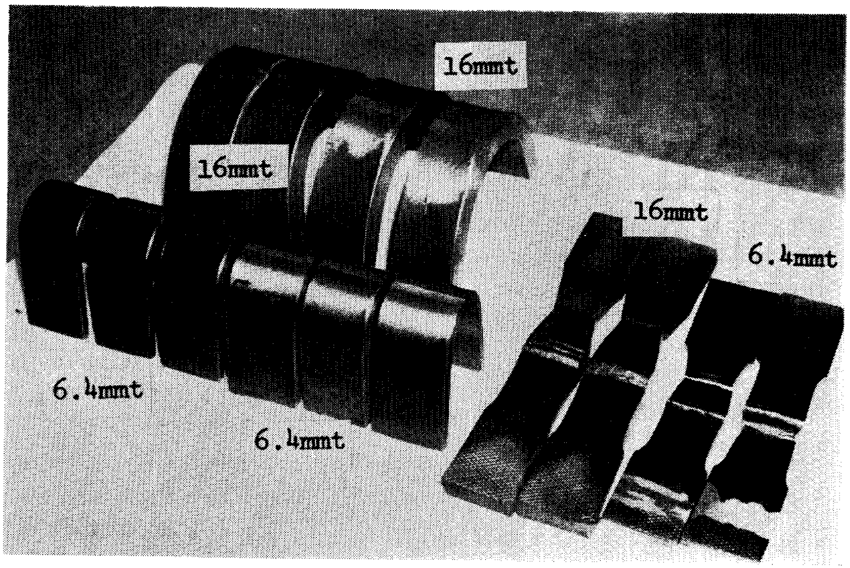


Fig. 8 Results of tension test and bending test

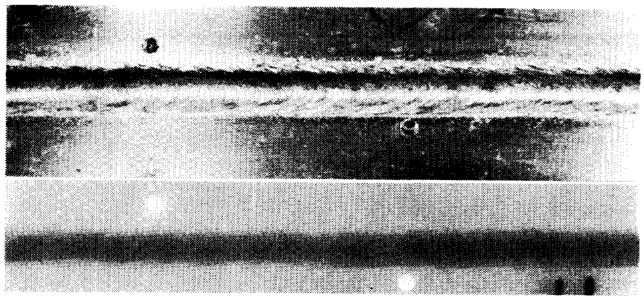


Fig. 9 Bead appearance of 6.4 mm thick tube and its radiographic inspected result

Fig. 10 16 mm thick tube which was welded at a water depth of 2 m

Table 1 Welding conditions o 16 mm thick tube at a water depth of 2 m

No of pass	Arc voltage V	Current A	Welding speed cm/min
1	29	280	30
2 3	20	180	30
4 5 6	19	150	30

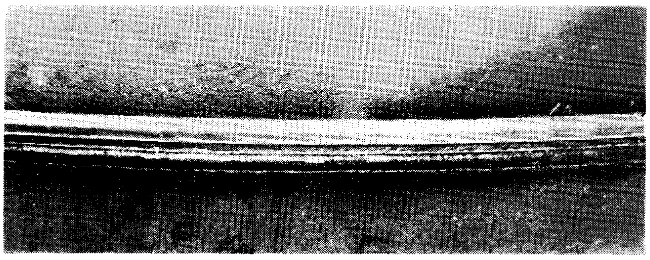


Fig. 11 Bead appearance at a water depth of 2 m

was the best among the said gases; in use of this gas, arc voltage of 29 V, arc current of 280 A and gap of 2 mm were adopted. Welding conditions for every pass are shown in Table 1. Fig. 10 shows apperarance of welded tube and Fig. 11 bead. In the tension test and bending test, welds show satisfactory results.

3.3 *Experimental result at a water depth of* 50 *m*

Grooves which were used in this experiment are shown in Fig. 5 (c) (d), in (c) of which was applied three passes welding and in (d) six passes welding. In the three passes welding the first and the third passes were made with spray transfer welding technique and the second pass with short circuiting transfer welding technique. Table 2 shows welding conditions for every pass. In the six passes welding all the passes were made with short circuiting transfer

Table 2 Three pass welding conditions of 16 mm thick tube at a water depth of 50 m

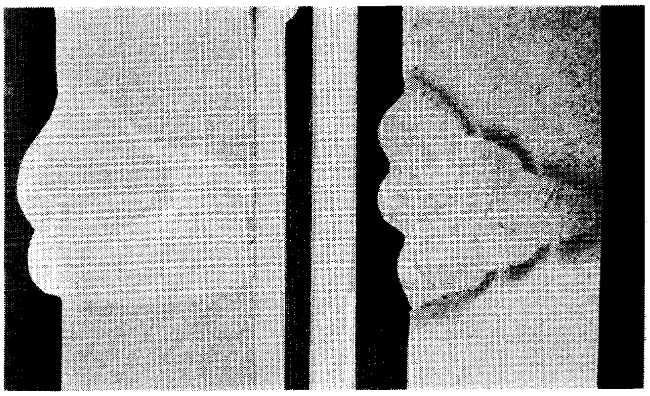
No of pass	Arc voltage V	Current A	Welding speed cm/min
1	39	280	30
2	21	150	30
3	39	260	30

Table 3 Six pass welding conditions of 16 mm thick tube at a water depth of 50 m

No of pass	Arc voltage V	Current A	Welding speed cm/min
1 2	21	150	25
3 4 5 6	21	150	25

welding technique, but the reason that short circuiting welding technique can be applied is in increased penetration at deep water. Even in this case, needless to say, only the first pass is done with spray transfer welding technique. Table 3 shows welding conditions for every pass, which refer to welding at a water depth of 2 m, but a little difference is recognized in both welding conditions, because of a change in penetration and in bead size with an increasing water depth. In spite of the same plate thickness, three passes welding could be done using spray transfer welding technique because of an increasing deposited metal. Welded tube is shown in Fig. 12. Fig. 13 shows macro-structures, of which (a) (b) are for welds executed in three and six passes respectively, and radiographic inspection results revealed no defects such as crack, blowhole, slag incrusion, but here they are omitted. Fig. 14 shows tension test and bending test results, in which no

Fig. 12 16 mm thick tube which was welded at a water depth of 50 m



(a) (b)

Fig. 13 Macro-structures of 16 mm thick tube which is welded at a water depth of 50 m. Three pass welding (a), Six pass welding (b)

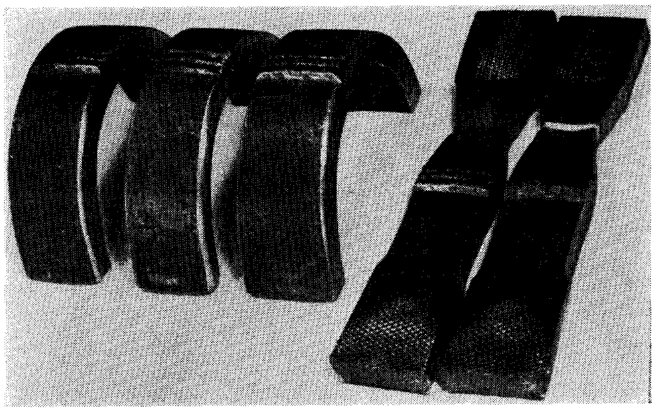


Fig. 14 Tension and bending test results of 16 mm thick tube which was welded at a water depth of 50 m

crack at all is observed in the welds even under 180° bending.

4 Conclusions

Automatic underwater girth welding of tubes at horizontal position was carried out at water depths of 2 m and 50 m, as the result of which no defects at all were observed in the welds in tension test, 180° bending test and radiographic inspection results, and the following conclusions were obtained:

(1) In the welding of 450 mm diam., 6.4 mm thick tube at a water depth of 2 m, satisfactory results were obtained by one and two passes welding with short circuiting transfer welding technique, even though adopted condition was in a very narrow range in case of one pass welding.

(2) In the welding of 560 mm diam., 16 mm thick tube at a water depth of 2 m, satisfactory results were obtained by six passes welding, of which the first pass was made with spray transfer welding technique, the other passes being done with short circuiting transfer welding technique.

(3) In the welding of 250 mm diam., 16 mm thick tube at a water depth of 50 m, satisfactory results were obtained by three and six passes welding. In the three passes welding the first and the third passes were made with spary transfer welding technique

and the second pass was made with short circuiting transfer welding technique. In the six passes welding all the passes were made with short circuiting transfer welding technique.

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