

PATENT SPECIFICATION

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- (21) Application No. 46990/72 (22) Filed 11 Oct. 1972
 (31) Convention Application No. 87296/71
 (32) Filed 1 Nov. 1971 in
 (33) Japan (JA)
 (44) Complete Specification published 3 Sept. 1975
 (51) INT CL² B23K 9/02, 37/04
 (52) Index at acceptance B3R 31 32B 36 37A1A



(54) METHOD AND APPARATUS FOR PREVENTING CRACK FORMATION IN A PLATE SEAM DURING ARC-WELDING

(71) We, KAWASAKI JUKOGYO KABUSHIKI KAISHA, a Japanese Company, of No. 14, Higashi-kawasaki-cho, 2-chome, Ikuta-ku, Kobe-shi, Hyogo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of and apparatus for preventing crack formation at end zones of a welded seam during the process of automatically arc-welding steel plates from one side thereof.

The rapid development of the Japanese shipbuilding industry is due in part to the rapid progress in welding techniques, especially in the process of automatically welding together steel plates from one side thereof, which achieves a substantial saving in time in the construction of ship hulls in the assembly shops and on the building berth.

Various problems in this welding process have been solved during the course of its development, and at the present time this process has been employed in all recent ship building within the yards in Japan and serves to increase the productivity thereof. While this welding process is quite effective, it has one outstanding defect in that a crack often occurs near the end zone of the weld seam between any two given plates being welded. One of the typical weld cracks observed in the bead formed by the known welding process is shown in Fig. 1 (see below), which in most cases is caused near the end zone of the weld seam. This crack is called an "end crack" for the above reason. The formation of the end crack is considered to be the result of the fact that the large heat source or high electric power, capable of joining the thick plates with one pass of the welding apparatus, generates a high thermal stress in the plates during welding and causes a

strong tearing force near the end zone of the weld seam.

Two types of methods are in use for preventing crack formation. One is characterized in that the end zone of the weld seam is preliminarily tacked over a length of approximately three hundred millimetres by hand welding or semi-automatic welding thereby to restrain the end zone and to increase its resistance to deformation. The tack welding of this end zone by hand or by semi-automatic welding means, must be carried out at both surfaces of the plates to exhibit the full effect necessary to prevent crack formation and, accordingly, the plates are required either to be turned over just for the tack welding of the rear faces of the plates for a distance of three hundred millimetres, or alternatively, difficult and inefficient overhead welding techniques must be applied to the rear face of the plates being welded. This complicates welding and requires increased time and cost.

The second method for preventing crack formation in general use, is characterised by both halves of the weld seam being subjected to automatic welding in mutually opposite directions starting from the outer ends of the weld seam and progressing towards the centre with both ends of the weld meeting at the centre zone of the weld seam. This method is quite effective to reduce crack formation at the ends, since the fine cracks due to the thermal stresses are not present at the end zone of the weld seam, but the configuration of the rear part of the weld bead is deficient at the centre zone as a result of the process and the efficiency of the welding process is low.

The object of the present invention is to overcome, or at least reduce, the above defects and to provide an effective method of preventing end crack formation in the process of automatic welding of steel plates

from one side without any complicated preliminary and supplemental processes.

Generally, welding cracks between steel plates are caused by metallurgical and dynamic factors, except in certain steels. The end crack which is formed in the conventional one side automatic welding processes is also derived from the tearing force caused by the high electric power of the welder and by the formation of an easily cracked micro structure. Therefore, when welding steel plates having a short weld seam of about two metres, crack formation can be prevented by improving the metallurgical configuration of the weld bead, since the tearing force is small.

As shown in Fig. 2 (see below), when a plurality of electrodes, such as electrodes 1, 2 and 3, are arranged at desired intervals along the weld seam, crack formation can be prevented by making successive welds upon a starting weld 5, which forms the rear bead. The successive welds cause the slag layer 4 to rise to the surface, and improve the metallic configuration of the weld bead. Numeral 6 designates the completed weld seam. The results of an investigation of the relationship in terms of the intervals between the first electrode 1 and the second electrode 2 to that between the second electrode 2 and the third electrode 3 in cases of welding relatively short (2 metres) weld seams are illustrated in Fig. 3, wherein the parameters corresponding to crack formation conditions are indicated.

It is apparent from viewing Fig. 3 that welding cracks may be prevented by adjusting the intervals between the electrodes 1, 2 and 3, where the weld seam is relatively short.

This method, however, is not effective to prevent welding cracks where the weld seam is relatively long and the tearing force is relatively large.

According to one aspect of the present invention there is provided a method of arc-welding together, from one side, abutting plates along a weld seam defined by the abutting edges of the plates, wherein said plates are progressively welded along said seam, starting at one end and terminating at the other end, and the said plates are forcibly held together adjacent the said other end by external forces applied to the plates to prevent distortion of the plates and cracking of the welded seam, the welding being effected by means of three consumable electrodes spaced apart in the direction of progress of the weld, the distances between the adjacent electrodes during welding being adjustable and so selected as to further prevent cracking of the welded seam.

According to another aspect of the present invention there is provided an

apparatus for arc-welding together, from one side, abutting plates, along a weld seam defined by the abutting edges of the plates, comprising three co-linear, spaced apart, consumable electrode heads for progressive welding of the weld seam from one end to the other end thereof, and means for applying external forces to said plates adjacent said other end of the seam to prevent distortion of the plates and cracking of the welded seam, the relative spacing of the electrode heads from each other being adjustable, also to prevent cracking of the welded seam.

The invention is illustrated by way of example in the accompanying drawings, in which:—

Fig. 1, referred to above, is a cross sectional view of a bead showing the typical end cracks caused by prior art automatic one face welding processes,

Fig. 2, referred to above, is a schematic, sectional elevational view of a prior art arrangement employing a plurality of spaced consumable electrodes along the weld seam in an automatic one face welding method.

Fig. 3, referred to above, is a diagram showing the experimental relationship between the intervals between adjacent multiple welding electrodes and crack formation in the case of a short welding seam.

Fig. 4 is a schematic plan view of a device for applying an external force to the end zone of a welding seam in a method according to the present invention,

Fig. 5 is a schematic plan view of another arrangement for applying an external force to the end zone of a welding seam, in a method according to the present invention,

Fig. 6 is an elevation of the arrangement shown in Fig. 5,

Fig. 7 is a schematic plan view of another arrangement for applying external force to the end zone of a welding seam in a method according to the present invention,

Fig. 8 is an elevation of the system shown in Fig. 7, and

Fig. 9 is a diagram showing the relationship between the intervals between consumable electrodes and crack formation, in a method according to the present invention in which an external force is applied to the end zone of the welding seam and in a comparative method where no external force is applied.

Referring to the drawings, as one example of a method for applying a desired external force to the end zone of a welding seam in the method of the present invention, Fig. 4 illustrates a pair of tab plates 8 attached to a pair of abutting steel plates 7 adjacent the end of a welding seam occurring between said pair of plates. A pair of hydraulic rams

9 or other force applying means is employed to apply force to both the outer side edges of the tab plates 8 and to clamp them together and maintain an applied force on the steel plates 7, at the end zone. Alternatively, a loading means and wedge may be employed to achieve this function. The magnitude of the thrust force required is measured and welding is carried out by applying the desired restraint force to the end zone of the weld seam 10 and at the same time so controlling the interval or spacing between a plurality of consumable electrodes (not shown) as to enlarge the no-cracking zone. The results of the method are illustrated in Fig. 9. The no-cracking zone is enlarged from Zone B (where no cracking occurs even when no restraint force is used) to further include Zone A when an external holding force of four to ten tons is applied to the end zone of the weld seam and by suitably controlling the interval or spacing between the first and second electrodes and that between the second and third electrodes.

Another example of a method in accordance with the present invention for applying the desired external restraint force to the end zone of the welding seam is shown in Figs. 5 and 6, wherein two sets of downwardly directed hydraulic rams 9 attached to the machine frame are used to apply a desired fixing force to the end zone of the welding seam 10 between the steel plates 7 and to hold the plates 7 rigidly in position.

A further example of the method of the present invention is illustrated in Figs. 7 and 8, for welding a welding seam 10 between a pair of steel plates 7. A plurality of hydraulic rams 9 which are attached to the machine frame thrust inwardly against vertical pusher plates 11, which in turn are fixed to the steel plates 7 and extend therefrom at right angles, the force thereby creating the desired fixing force with respect to the end zone of the welding seam 10 between the steel plates 7.

In all the embodiments illustrated in Fig. 4, Figs. 5 and 6, and Figs. 7 and 8, tab plates 8 are provided to extend the end of the weld-zone.

While various methods are illustrated to apply a force to the end zone of the welding line, other methods may be employed instead of those illustrated.

As particularly mentioned above, the one side automatic welding process of the present invention is carried out by employing a series of consumable electrodes at spaced intervals, by applying an external restraint force to the end zone of the welding seam, and by so controlling the intervals or spacing between the adjacent pairs of electrodes as to reduce the oc-

currence of crack formation. This method is advantageous in that it requires none of the complicated arrangements or preparations such as the upsetting of the steel plates, or the reversal of the welding direction, nor is any subsequent treatment for the weld or welded plates necessary. There is also much saving in both cost and labour.

Attention is directed to our Patent Specification No. 1,404,200 (Application No. 39585/72), the claims of which are directed to the urging together of the plates.

WHAT WE CLAIM IS:—

1. A method of arc-welding together, from one side, abutting plates along a weld seam defined by the abutting edges of the plates, wherein said plates are progressively welded along said seam, starting at one end and terminating at the other end, and the said plates are forcibly held together adjacent the said other end by external forces applied to the plates to prevent distortion of the plates and cracking of the welded seam, the welding being effected by means of three consumable electrodes spaced apart in the direction of progress of the weld, the distances between the adjacent electrodes during welding being adjustable and so selected as to further prevent cracking of the welded seam.

2. A method as claimed in Claim 1, wherein from 4 to 10 tons force is externally applied to the said plates to hold them together, and wherein welding is carried out by means of 3 spaced consumable electrodes, the spacing between the 1st and 2nd, and 2nd and 3rd electrodes respectively, being ascertained by reference to Fig. 9 of the accompanying drawings.

3. A method as claimed in Claim 1 or 2, wherein tab plates are so fixed respectively to the plates to be welded that edges thereof constitute an extension of the welding seam, and said external forces are applied to said tab plates.

4. A method as claimed in Claim 1 or 2, wherein the said externally applied forces are applied by clamping the said abutting plate by means of a plurality of hydraulic rams.

5. A method as claimed in Claim 1 or 2, wherein said abutting plates are provided with pusher plates fixed thereto at right angles and generally parallel to the weld seam and on either side thereof, and said externally applied forces are applied by forcing said pusher plates towards each other and towards the weld seam lying between them.

6. A method as claimed in Claim 1, substantially as described herein with reference to Fig. 2 in combination with Fig. 4 or with Figs. 5 and 6 or with Figs. 7 and 8 of the accompanying drawings.

7. An apparatus for arc-welding together,



9 or other force applying means is employed to apply force to both the outer side edges of the tab plates 8 and to clamp them together and maintain an applied force on the steel plates 7, at the end zone. Alternatively, a loading means and wedge may be employed to achieve this function. The magnitude of the thrust force required is measured and welding is carried out by applying the desired restraint force to the end zone of the weld seam 10 and at the same time so controlling the interval or spacing between a plurality of consumable electrodes (not shown) as to enlarge the no-cracking zone. The results of the method are illustrated in Fig. 9. The no-cracking zone is enlarged from Zone B (where no cracking occurs even when no restraint force is used) to further include Zone A when an external holding force of four to ten tons is applied to the end zone of the weld seam and by suitably controlling the interval or spacing between the first and second electrodes and that between the second and third electrodes.

Another example of a method in accordance with the present invention for applying the desired external restraint force to the end zone of the welding seam is shown in Figs. 5 and 6, wherein two sets of downwardly directed hydraulic rams 9 attached to the machine frame are used to apply a desired fixing force to the end zone of the welding seam 10 between the steel plates 7 and to hold the plates 7 rigidly in position.

A further example of the method of the present invention is illustrated in Figs. 7 and 8, for welding a welding seam 10 between a pair of steel plates 7. A plurality of hydraulic rams 9 which are attached to the machine frame thrust inwardly against vertical pusher plates 11, which in turn are fixed to the steel plates 7 and extend therefrom at right angles, the force thereby creating the desired fixing force with respect to the end zone of the welding seam 10 between the steel plates 7.

In all the embodiments illustrated in Fig. 4, Figs. 5 and 6, and Figs. 7 and 8, tab plates 8 are provided to extend the end of the weld-zone.

While various methods are illustrated to apply a force to the end zone of the welding line, other methods may be employed instead of those illustrated.

As particularly mentioned above, the one side automatic welding process of the present invention is carried out by employing a series of consumable electrodes at spaced intervals, by applying an external restraint force to the end zone of the welding seam, and by so controlling the intervals or spacing between the adjacent pairs of electrodes as to reduce the oc-

currence of crack formation. This method is advantageous in that it requires none of the complicated arrangements or preparations such as the upsetting of the steel plates, or the reversal of the welding direction, nor is any subsequent treatment for the weld or welded plates necessary. There is also much saving in both cost and labour.

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2. A method as claimed in Claim 1, wherein from 4 to 10 tons force is externally applied to the said plates to hold them together, and wherein welding is carried out by means of 3 spaced consumable electrodes, the spacing between the 1st and 2nd, and 2nd and 3rd electrodes respectively, being ascertained by reference to Fig. 9 of the accompanying drawings.

3. A method as claimed in Claim 1 or 2, wherein tab plates are so fixed respectively to the plates to be welded that edges thereof constitute an extension of the welding seam, and said external forces are applied to said tab plates.

4. A method as claimed in Claim 1 or 2, wherein the said externally applied forces are applied by clamping the said abutting plate by means of a plurality of hydraulic rams.

5. A method as claimed in Claim 1 or 2, wherein said abutting plates are provided with pusher plates fixed thereto at right angles and generally parallel to the weld seam and on either side thereof, and said externally applied forces are applied by forcing said pusher plates towards each other and towards the weld seam lying between them.

6. A method as claimed in Claim 1, substantially as described herein with reference to Fig. 2 in combination with Fig. 4 or with Figs. 5 and 6 or with Figs. 7 and 8 of the accompanying drawings.

7. An apparatus for arc-welding together,

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from one side, abutting plates, along a weld seam defined by the abutting edges of the plates, comprising three co-linear, spaced apart, consumable electrode heads for progressive welding of the weld seam from one end to the other end thereof, and means for applying external forces to said plates adjacent said other end of the seam to prevent distortion of the plates and cracking of the welded seam, the relative spacing of the electrode heads from each other being adjustable, also to prevent cracking of the welded seam.

8. An apparatus as claimed in Claim 7, in which said means for applying said external force comprises a pair of tab plates fixedly secured to the edges of the plates to be welded, said tab plates being positioned in abutting relationship and constituting an extension of the welding seam, and means for applying a compressive force to the outside edges of said tab plates to maintain said tab plates fixed in abutting relationship.

9. An apparatus as claimed in Claim 7, in which each of said means for applying said

external force includes a pusher plate fixed to the surface of each of said abutting plates, on the same side as that from which welding is to be carried out and spaced from the weld seam, and means for applying a compressive force to said pusher plates in order to force said pusher plates together and to maintain the ends of the said abutting plates in fixed relation, to prevent deformation during welding.

10. An apparatus as claimed in Claim 7, substantially as hereinbefore described with reference to Fig. 2 in combination with Fig. 4 or with Figs. 5 and 6, or with Figs. 7 and 8 of the accompanying drawings.

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Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1975.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from
which copies may be obtained.



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