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X-Ray Radiography of EB Welded Joints in India

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Abstract

Electron Beam welding is becoming more important in Indian industries due to the growing automation of the process and superior weld quality, resulting from virtually zero heat affected zone (HAZ). Two main types of defects are often encountered in EB welding joints viz void type defects and crack type. EB welding joints must be radiographically inspected for all these types of defects and it is essential to use the basic and corona technique of X-Ray radiographic inspection. The crack like defects in EB welding are the result of missed joints, lack of penetration and lack of fusion during welding. To achieve the good quality of welds the gap between the joints should be less than 50 microns, and to pick up the defects of such narrow width in X-Ray radiography, the sensitivity level should be maintained around 0.7%. Indian industries and laboratories have not been able to achieve 0.7% radiographic sensitivity level at present. At MIDHANI we are developing the technique to achieve this sensitivity level and this paper highlights some of our experiences in the radiographic inspection of EB welded joints by 420 KV 30 mA X-Ray machine, Make: Phillips.

Keywords: *Image quality indicator (sensitivity), Missed joints, Corona technique*

1. Introduction

Electron Beam Welding is a reliable and cost effective method of joining a wide range of metals. It is used from pacemakers in the medical industry to sensors of fighter aircraft. Electron Beam applications are limitless. The welding is performed in a vacuum, this results in clean and oxidation free welds.

High weld 'depth to width' ratios up to 20-1 can be achieved with minimal or no distortion due to the extreme density and precise control of electrons. Electron Beam Welding is predominantly used in the final step of a production sequence, and offer advantages such as low heat input, minimal heat affected zone and practically no distortion. These attributes make it ideal for the welding of intricate final assembly products or sensors that have delicate instrumentation close to the weld joints. Precise control of the electron beam, high speed and repeatability makes it, the only viable solution to a difficult manufacturing problem.

EB welding is predominantly in use due to its superior weld quality, but there is a possibility of occurrence of missed joints, henceforth technocrats are in double mind, to use or not to use this process for critical applications. Presently in our Organization EB Welding is in use for Air Bottles of DRDL, Gas Bottles of VSSC and PTO Shaft of LCA Project. Ti-6Al-4V material is used in manufacture of these bottle and shafts. .Investigations revealed that failures of DRDL Air Bottles during Hydro Testing are due to presence of missed joints in EB Welding. Missed joints in EB Welding haunts us in the case of Gas Bottles of VSSC and PTO Shaft of LCA Project.

2. Experiment

In the present Radiographic technique for circem welding of hemispheres of Air and Gas Bottles, the central beam is directed at an acute angle to the run of the weld so that the weld is projected on the film as an ellipse rather than a straight band (corona technique). Through this technique we have achieved a sensitivity level of 2%, as required by the Customer, but in this technique only void type of defects can be detected.

Missed joints in EB Welding, which is the cause for the failure of DRDL Air Bottles, could not be picked up by the existing radiographic techniques.

Missed joints are crack–like defects, the width of which is less than 50 microns, and their detections require the sensitivity level of 0.7% or better as per literature (for a very good EB Weld joints, the gap should be less than 50 microns between the joints). We tried to achieve the sensitivity level of 0. 7% with a very slow film, large source to film distance in our X-Ray set up (420 kV, 30 mA, of PHILIPS MAKE, focal size of 1.5mmX1.5mm), but failed.

For the problems associated with detectability of the missed joint, Halmshaw [1] presents the following formula for the sensitivity of crack-like defect like missed joints in EB Welding.

$$d*W = 2*3*\Delta D*A1*A2/G*\mu \quad (1)$$

The terms of this equation is defined below

$A1 = (d \sin\theta + W \cos\theta + U_T)$

$A2 = (1+Is/Id)$

D = length of the missed joint

W = width of the opening of the missed joint

ΔD = change of radiographic density (minimum density difference detectable by eye on the radiograph and has a value between 0.006 and 0.01 depending on the viewing condition)

Is = scatter radiation intensity

Id = direct radiation intensity

G = gradient

μ = linear attenuation coefficient

U_T = total sharpness

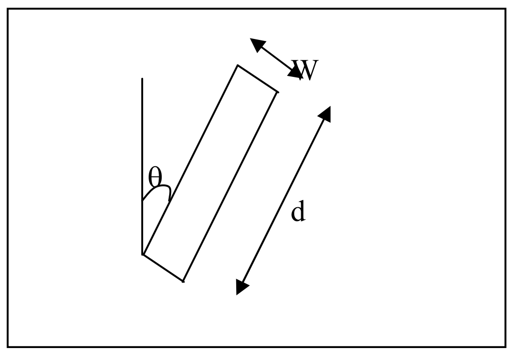

Fig. 1: Crack / Missed joint parameter sketch

It is known that extremely large number of variables affects the detectability of these types of defects mainly radiographic equipment, film, shot geometry, developing and interpretation factors.

In the case of crack–like defects like missed joint in EB Welding total sharpness decides the detectability of defects, when the sharpness is greater than width of the flaw, the spread out of the image causes the reduction in contrast and the detectability.

For the experiment, we have taken two numbers of rectangular pieces of 8X150X100 mm dimensions and from the center we have removed circular pieces of 80 mm diameter from both the rectangular pieces, this is done with the intention of simulating the conditions similar to the DRDL Air Bottles. In one set up the gap between the cut circular piece and remaining piece was approximately 60 micron and in the other set up the gap 120 micron.

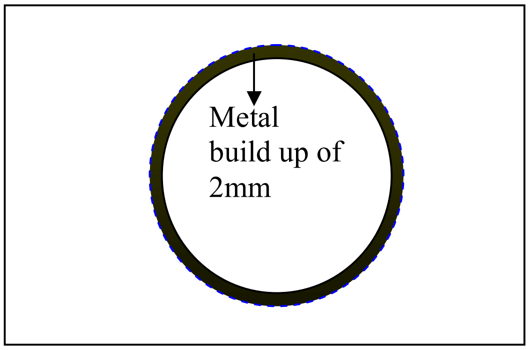

Fig. 2: Test Piece

At the black circular ring, metal build up was made by TIG Welding in MIDHANI.on the two sides of the rectangular piece.

In the first experiment the gap between the joints was between 40 to 60 microns of 8 mm thick plate and circular piece, a build up of 2 mm weld is done on the two sides of the plate, and in the second experiment the gap between the joints was 100 to 120 between of 8 mm thick plate and circular piece, a build up of 2 mm weld is done on the two sides of the plate. The sensitivity level of 1.2% always detected the missed joints in the second experiment but in the first case the missed joints were never picked in the radiography. But in the both cases a clear line of missed joint was observed in the radiography before welding.

We used the slowest available film (Agfa D2), a large source to film distance, a focal size of 1.5mmX1.5mm, a good masking, in our X-Ray equipment, 420 kV, 30 mA, of PHILIPS MAKE. We used Aluminium IQI for the sensitivity. We could not achieve the sensitivity better than 1.2% (with the Titanium IQI, it was not possible to achieve the sensitivity of 0.7% or better). A paper "use of Al IQI for Titanium" is being presented by Mr. G.S. Sharma in this seminar. From the above findings we can conclude that gap for EB Welding should be maintained between 100 to 120 microns, where we are sacrificing the weld quality for void type of defects to pick missed joints, which are more critical for aerospace applications.

In our experiment we could achieve the sensitivity level of 1.2% which was not sufficient to detect the missed joints of 50 microns or less, but it was sufficient to detect the missed joint of 100 to 120 microns. The gap of 100 to 120 microns for EB Welding is not ideal for the best quality of EB Weld joints.

3. Conclusions

Indian industries must evolve the radiographic techniques for achieving the sensitivity level of better than 0.7% for detecting the missed joints of width 50 microns or less in EB Welding Till it is achieved, it is better to maintain the gap between 100 to 120 microns to avoid any type of mishap due to missed joints.

4. Acknowledgement

We acknowledge the help of Mr.V S Srinivasan and his colleagues of TUBE shop for making the simulated test pieces.

5. References

1. Halmshaw, R., "An Analysis of the performance of X-Ray Television – Fluoroscopic Equipment in Weld Inspectione,", Material Evaluation, 45, 1298-1302, November 1987.