Experimental Investigations on Welding Distortion Correction in "OTSC" Boiler Panels in BHEL Industries

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Abstract: This project takes us through a journey that deals with the control of distortion during welding of boiler panel assembly. During the study of this project we found that the distortion control was a major problem. The combined handwork put by us together has revealed that there is a solution to control the distortion during welding of boiler panel assembly. The data collected tells us that the distortion can be controlled by improved technique. The suggestion put forth by us in control of distortion during welding of boiler panel assembly has the project to new dimension and the final outcome for this project is productive for us and also to company.

Index Terms – Gear Shifting, Button typed, Pneumatic operated, Electro Magnetic Coil.

I. INTRODUCTION:

Most of the products manufactured today are necessary by welding, brazing, soldering or adhesive bonding. Joining is important for making products ranging from the very small (chips) to the very big (ships).Almost all products are assemblies of a large number of components. Some of the components or sub-assemblies can move with respect to each other, others are physically fixed together, with no relative motion possible. The first type of connection is called a kinematic joint, and the second type is called a rigid joint (or a structure). Both types of joints are important in manufacturing, and there are many ways of achieving such joints. The process and methods used for joining depend on the type of joint, the required strength, the materials of the components being joint, the geometry of the components, and cost issues. Welding is a fabrication or sculptural process that joins materials, Usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure Sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the work pieces to form a bond between them, without melting the work pieces.

There are several different ways to weld, such as: Shielded Metal Arc Welding, Gas Tungsten Arc Welding, Tungsten Inert Gas and Metallic Inert Gas. MIG or Metallic Inert Gas involves a wire fed "gun" that feeds wire at an adjustable speed and sprays a shielding gas (generally pure Argon or a mix of Argon and CO2) over the weld puddle to protect it from the outside world. TIG or Tungsten Inert Gas involves a much smaller hand-held gun that has a tungsten rod inside of it. With most, you use a pedal to adjust your amount of heat and hold a filler metal with your other hand and slowly feed it. Stick welding or Shielded Metal Arc Welding has an electrode that has flux, the protectant for the puddle, around it. The electrode holder holds the electrode as it slowly melts away. Slag protects the weld puddle from the outside world. Flux-Core is almost identical to stick welding except once again you have a wire feeding gun; the wire has a thin flux coating around it that protects the weld puddle. Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding may be performed in many different environments, including open air, under water and in outer space.

II. BOILER PANEL FABRICATION

2.1. Introduction

Boiler has a panel of flat tubes to circulate water inside their surface area. On passing over the circumference of furnace, it absorbs heat and changes the state of fluid flowing. Mean while the boiler furnace which is otherwise called as ring header has its area to be polygon. It dampens or restricts the use of flat panels in the angular area. Also this necessitates the fabrication of angular panels. The purpose of burner panel is to accommodate wind box assembly at four corners of the boiler furnace. The tubes are spread out to permit opening to insert the projected nozzles in the wind box. One frame is welded on the end tubes of burner panel over which the wind box is mounted. It is noted that the burner panels are same if the firing angles are same. Normally for a rectangular furnace firing angles of opposite corners are same.Such type of angular panels is called as burner panels. These are even said to be Heart of the Boiler. They are so called because these panels bear some space for the fuel nozzles to penetrate them. A nozzle round the corner creates a ring of fire in the centre of furnace thereby, facilitating higher heat transfer rate. Figure 1 shows the fabrication of boiler panel.

2.2. Operation involved in Boiler panel Fabrication:

- Draw materials from Stores. Verify the attestation.
- Roto blast the Tubes as per the Cutting plan. Transfer color coding and thickness identification.
- Cut the Tubes as per the Cutting plan. Transfer color coding.
- Edge preparation as per the Cutting plan. Transfer color coding.
- Inspect the prepared Tubes at random and certify the lot.
- Build the tubes by Straight tube butt welding (STBW) as per the STB plan.
- Conduct fluoroscopic examination. Affix green / red stickers for accepted / rejected joints respectively.
- Cut, edges prepare and re-weld the rejected joints as per STB rework plan. Conduct fluoroscopic examination.
- Grind and flush the STB weld reinforcement.
- Set and prepare the PEMA MEK m/c and flat calibrator machine for welding and processing the panels and weld the panels as per the loading schedule.
- Provide panel identification mark as per Panels loading schedule.
- Clean the slag on the both sides of the panels.
- Full weld the edge bars as per the drawing.
- Inspect the panels visually and mark lack of fusion, skips, voids, porosity, burn through etc.
- Carry out the weld repair.
- Flame straightens the panels, if necessary.
- If the panels with excessive degree of transverse bow shall be post weld heat treated before straightening. Provide stress relief heat treatment. Cool in air. Verify the HT chart / HT movement sheet and clear the HT.
- Provide identification marks. Conduct ball test and certify.
- Mark the panels for Insert openings / slots / Structural attachments / slit ends as per drawing.
- Gas cut the panels as per marking at the required locations.
- End scarf the required tubes in the panels to weld the inserts/spool pieces for Burn through.
- Verify First of Trial (FOT) reports for the combination of size / spec. / radius wise. If not available, conduct FOT and qualify. (For inserts & loose bends).
- Do rotary bending as per the drawing. First piece is to be checked and approved.
- Inspect the bent tubes at random. Do hot correction if required.
- Prepare the inserts/loose bends/spool pieces. Match with the panels. Fit and tack weld as per drawing by GTAW manual.
- Weld the inserts/loose bends/spool pieces by GTAW manual.
- Conduct RT 100%.
- Repair the defective joints by GTAW manual. Retest and certify.
- Collect, check and prepare the fins, plates, rods etc. as per drawing for openings and voids and weld it to the panels to fill the voids.
- LPI to be carried out for these welds.
- Fit and tack weld all attachments as per the assembly drawing.
- Weld all attachments as per the drawing.
- Conduct LPI on attachment welds.
- Visually check the assembly for completeness. Certify and clear for PWHT.
- Do the PWHT. Verify the heat treatment movement sheet / chart and clear the heat treatment cycle.
- Check all the dimensions and ensure the marking for panel end cutting line and edge bar cutting lines.
- Gas cut the panel ends & edge bars, and maintain the length and width of the panels.
- Grind and clean the gas cut portions of the panels; Scarf the end of the panels.
- Visually check the assembly for completeness. Certify and clear for Gang Bending. Mark the panel for Gang Bending.
- Set the panel bender and bend the panel as per drawing. Check the angle of bend.
- Prepare Lay out. Check the panels with lay out and flame correct the shape if required.
- Place the panel and bent tubes in the fixture. Fit and tack weld.
- Do the TIG welding.
- Evaluate TIG joint.
- Repair the rejected TIG joints. Retest and certify.
- Check the dimensions of the structural attachments and pre-assemble as per the relevant drawing, if required.
- Fit and tack weld all attachments as per the assembly drawing.
- Weld all attachments as per drawing.
- Conduct LPI/MPI on attachment welds.
- Ensure the Dimension of the Lug plates/sub Assy. Fit and tack weld the lug plates/sub assy. as per drawing.(Ensure PWHT carried out to the sub assembly).
- Weld the Lugs as per drawing and conduct LPI.
- Stress Relieve the Lug welds locally. Verify the H.T chart/H.T movement sheet and clear the H.T.
- Visually check the assembly for completeness. Certify and clear for Hydraulic Testing.

- Conduct Hydraulic Testing with Demineralized water.
- Rectify the defects found in Hydraulic Test. Repeat the Hydro test for the soundness of the defects rectified.
- Fit and tack weld the 'Erection attachment'.
- Conduct Final inspection and Sponge test. Conduct Spectroscopic test for alloy steels.
- Provide color code and identification marks and 'TOP' mark by painting.
- Provide VCI pellets, End caps and capping channels.
- Handover to shipping for painting, packing and dispatch.

Figure 1.Boiler panel fabrication

III. WELDING DEFECTS:

A welding defect is any flaw that compromises the usefulness of a weldment. There is a great variety of welding defects. Welding imperfections are classified according to ISO 6520 while their acceptable limits are specified in ISO 5817 and ISO 10042. Common weld defects include:

- Lack of fusion
- Lack of penetration or excess penetration
- Porosity
- Inclusions
- Cracking
- Undercut
- Lamellar tearing

Any of these defects are potentially disastorous as they can all give rise to high stress intensities which may result in sudden unexpected failure below the design load or in the case of cyclic loading, failure after fewer load cycles than predicted.

3.1. Types of Defects

To achieve a good quality join it is essential that the fusion zone extends the full thickness of the sheets being joined. Thin sheet material can be joined with a single pass and a clean square edge will be a satisfactory basis for a join. However thicker material will normally need edge cut at a V angle and may need several passes to fill the V with weld metal. Where both sides are accessible one or more passes may be made along the reverse side to ensure the joint extends the full thickness of the metal. Lack of fusion results from too little heat input and / or too rapid traverse of the welding torch (gas or electric). Excess penetration arises from too high a heat input and / or too slows transverse of the welding torch (gas or electric). Excess penetration - burning through - is more of a problem with thin sheet as a higher level of skill is needed to balance heat input and torch traverse when welding thin metal.

i. Porosity - This occurs when gases are trapped in the solidifying weld metal. These may arise from damp consumables or metal or, from dirt, particularly oil or grease, on the metal in the vicinity of the weld.

ii. Inclusions - These can occur when several runs are made along a V join when joining thick plate using flux cored or flux coated rods and the slag covering a run is not totally removed after every run before the following run.

iii. Cracking - This can occur due just to thermal shrinkage or due to a combination of strain accompanying phase change and thermal shrinkage. In the case of welded stiff frames, a combination of poor design and inappropriate procedure may result in high residual stresses and cracking.

IV. DISTORTION:

Distortion or deformation can occur during welding as a result of the non-uniform expansion and contraction of the weld and base metal during the heating and cooling cycle. Stresses form in the weld as a result of the changes in volume, particularly if the weld is restrained by the fixed components or other materials surrounding it. If the restraints are partly removed, these stresses can cause the base material to distort and may even result in tears or fractures. Of course, distortion can be very costly to correct, so prevention is important. Different heating techniques can also be used to correct distortion by applying local or spot heating in various ways. In fabrication of metallic structures, fundamental dimensional changes that occur during welding are often found. This is what we call "Weld Distortion". When fusion welding is performed, the melted metal irregularly contracts on cooling from the solidus to room temperature, resulting in shrinkage over the weld and exerting eccentric force on the weld cross section.

The weldment elastically strains in response to the stresses caused by the contraction of the weld metal; hence you notice the irregular strain in macroscopic distortion.

4.1 Distortion occurs in six main forms:

- Longitudinal shrinkage
- Transverse shrinkage
- Angular distortion
- Bowing and dishing
- Buckling
- Twisting

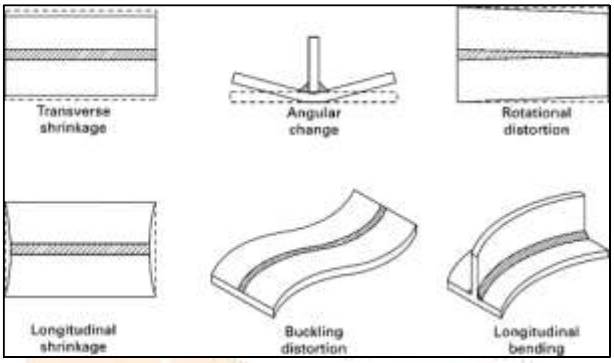

Fig.2. Types of Distortion

4.2 Measurement of temperature:

During the heat treatment cycle the temperature is measured and recorded with the help of thermocouples and recorders. Fixing of thermocouple on the spot is very important. If the thermocouples are not properly fixed, serious errors in measurement of temperature can exist. If the thermocouple wire touches each other after leaving the hot junction, then the recorder may not read the temperature of the spot where the thermocouple is attached. The fool-proof method of fixing the thermocouple is to weld directly 21 SWG thermocouple wire to the pipe by capacitor discharge unit. This will eliminate the error in measurements.

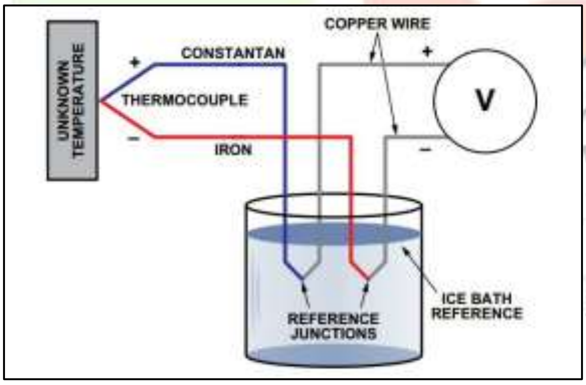

Fig.3.Thermocouple Temperature Measurement

4.3 Changes in the properties of steel with increases in temperature during welding:

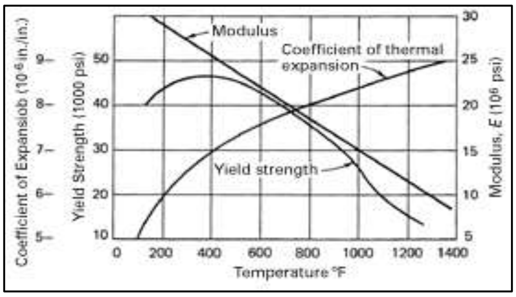

Fig.4. Changes in properties of steel

V. METHOD OF REDUCING WELDING DISTORTION:

Considering a panel of length – **18000** mm without distortion (According to customer requirement).

But the panel length after welding process is 18400mm (with distortion)

(i.e.) additional width = **400** mm.

Maximum level of bow = **20** mm

Our aim is to reduce the level of bow using,

AREA METHOD:

➢ Area of initial panel (with distortion):
Area (A) =length (L) × width (W)

Area of initial (A_a) = **3,24,00,000** mm^2.

➢ Final area required (without distortion):
Area (A) = length (L) × width (W)

Final area (A_f) = **3,22,20,000** mm^2.

➢ We have to find distortion area: (i,e) S A_i = 3,24,00,000 – S
Here, Segment area (S) $= \frac{R^2}{2}(\propto - sin \propto)$

5.1 USING THE BELOW FORMULAS WE HAVE TO FIND (∝):

Area (A) = **½ R^2 (∝-sin∝)**

Arc length (L) = **α R**

Chord length(C) = **2R sin α/2**

Segment height (h) = **R (1- cos α/2)**

Hence, $\boxed{\alpha = 8.9*10^{-3}, S = 2,40,000}$

Fig.5. Marking of Distortion

Heating the trapezoidal marked area using OXYACETELENE GAS at 400-600ºC,

Area of trapezoidal = ½ **h (a+b)**

= **342345** mm^2.

Finally by using the factor ,

$$= \frac{(A_i - A_f)}{\text{Trapezoidal heated area}}$$

Factor of distortion = **0.52**

VI. RESULTS AND DISCUSSIONS:

(i)Suggestions:

Since our study is about the reasonable methods of distortion control in burner panel assembly. So the source of distortion was studied a little deeper. As for as fabrication is concerned, we can also say B.P.A has nothing but welding. It confirms a large quantity of heat involvement. Ultimately; it becomes prey to the heat and behaves as per the thermal law(decrystallization, stress subjection, distortion).This is the point of concern to study exactly at welding. The following diameter shows the locations where the welding requires. When the welding is carried out as shown, the temperature difference between the parent metal and weld metal boasts the high heat input to the tubes. This in turn causes the tubes to bend lighter because of losing its strength or occurrence of a smaller expansion called bow. Therefore the tubes to withstand it characteristics, the heat input should be removed. In this case, it is quiet impossible to remove heat.

Normally heat removal process involves:

- Air cooling
- Water cooling

Air cooling is a method of dissipating heat. It works by making the object to be cooled have a larger surface area or have an increased flow of air over its surface, or both. An example
of the former is to add fins to the surface of the object, either by making them integral or by attaching them tightly to the object's surface (to ensure efficient heat transfer).In this case of the latter it is done by using a fan blowing air into or onto the object one wants to cool.

Water cooling is a method of heat removal from components and industrial equipment. As opposed to air cooling, water is used as the heat conductor. Water cooling is commonly used for cooling automobile internal combustion engines and large industrial facilities such as plants, hydroelectric generators, Petroleum refineries and chemical plants. Other uses include cooling the barrels of machine guns, cooling of lubricant oil in pumps; for cooling purposes in heat exchangers; cooling products from tanks or columns, and recently, cooling of various major components inside high-end personal computers. The main mechanism for water cooling is convective heat transfer.

(ii) Some steps to Minimize Distortion:

Follow this checklist in order to minimize distortion in the design and fabrication of elements:

- Minimize welding heat input
- Maximize component restraint
- Modify component design
- Implement active mitigation techniques
- Steps to improve the stress relief
- Do not over weld
- Control fit up
- Use intermittent welds where possible and consistent with design requirements
- Place welds near the neutral axis
- Use the smallest leg size permissible when fillet welding
- Weld alternately on either side of the joint when possible with multiple-pass welds.
- Use minimal number of weld passes.
- Balance welds about the neutral axis of the member.
- Weld toward the unrestrained part of the member.
- Use clamps, fixtures, and strong backs to maintain fit up and alignment.
- Plan the welding sequence
- Remove shrinkage forces after welding

(iii) DISTORTION CONTROL TECHNIQUES AND ADVANTAGES:

- Eliminate the need for expensive distortion corrections
- Reduce machining requirements
- Minimize capital equipment costs
- Improve quality
- Permit pre-machining concepts to be used

VII. CONCLUSIONS:

A number of steel tube (panel) welding distortion control techniques were developed based on a series of tests on candidate measures to improve the manufacturing quality of steam cooled panels for boiler structures. These tests concentrated on precision cutting of panel pieces, a new material-handling foundation system, new welding procedures for panel assembly, pre-fitting of stiffeners, precision high-speed welding ,use of transient-thermal-tensioning based distortion-prediction tools and hardware and improved manual welding an on-going program is investigating practical techniques for implementation, including:

- Restraining components
- Optimizing cutting and welding sequences

- Reducing cutting and welding heat input
- Transient thermal tensioning.

Based on results to date, a fabrication plan is being developed to demonstrate best practices for control of distortion in B.P.A.

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