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Control of Distortion During Welding and Stress Relieving of BURNER Panel Assembly

KEYWORDS: Welding, residual stress, Distortion; Heat source, Burner panel, Weld defects.

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

1. 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 CO_2) 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. Welding is a potentially hazardous undertaking and precautions are required to avoid burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to radiation. Until the end of the 19th century, the only welding process was forge welding, which blacksmiths had used for centuries to join iron and steel by heating and hammering. Arc welding and oxyfuel welding were among the first processes to develop late in the century, and electric resistance welding followed soon after. Welding technology advanced quickly during the early 20th century as World War I and World War II drove the demand for reliable and inexpensive joining methods. Following the wars, several modern welding techniques were developed, including manual methods like shielded metal arc welding, now one of the most popular welding methods, as well as semi-automatic and automatic processes such as gas metal arc welding, submerged arc welding, flux-cored arc welding and electro slag welding. Developments continued with the invention of laser beam welding, electron beam welding, electromagnetic pulse welding and friction stir welding in the latter half of the century. Today, the science continues to advance. Robot welding is commonplace in industrial settings, and researchers continue to develop new welding methods and gain greater understanding of weld quality.

2. BURNER 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 burner panel.

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2.2. Operation involved in Burner panel Fabrication
- Mini panel BT &Rework
- Mini panel hydro
- Mini panel shroud plate tacking
- Mini panel CO_2welding
- Mini panel reworks &edge welding
- Mini panel correction&marking
- Mini panel cutting &chamfering
- Rotary bends chamfering &grinding
- Joint feeding and completing
- Joint rework
- Finning and welding
- Frame setting
- Frame inspection
- Panel inserting
- Inside binder tacking
- Frame with panel welding
- Profile areas bend correction
- Finning
- Welding
- VOP bends loading and tacking
- Side panel setting
- Full welding
- Seal box assembly and welding
- Welding rework
- Heat treatment clearance
- Heat treatments
- Rework
- Edge setting and grinding
- Drilling clearance and drilling
- Hydro clearance and hydro
- Overall work and inspection
- Seal box covering and final sponge test


Figure 1.Burner panel fabrication

3. WELD 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 disastrous 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 edges 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.

3.2. 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. Figure 2 shows that the variation in welding distortion

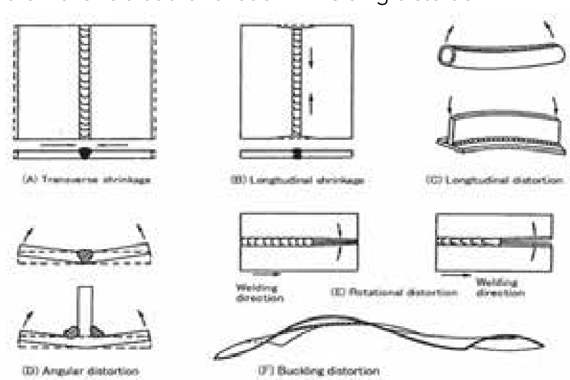

Figure 2. Variation in weld distortion

Distortion occurs in six main forms:
- Longitudinal shrinkage
- Transverse shrinkage
- Angular distortion
- Bowing and dishing
- Buckling
- Twisting

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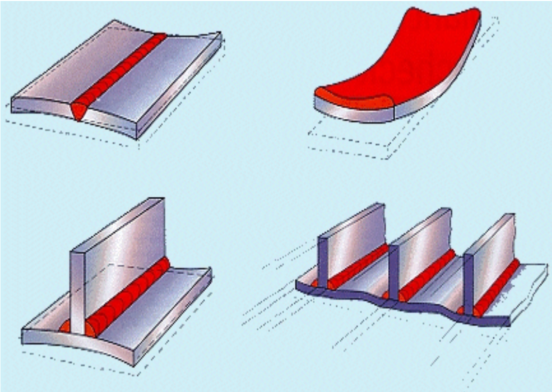

Figure 3. Forms of distortion for butt and fillet welds

The principal features of the more common forms of distortion for butt and fillet welds are shown in figure 3.Non-uniform contraction (through thickness) produces angular distortion in addition to longitudinal and transverse shrinkage. For example, in a single V butt weld, the first weld run produces longitudinal and transverse shrinkage and rotation. The second run causes the plates to rotate using the first weld deposit as a fulcrum. Hence, balanced welding in a double side V butt joint can be used to produce uniform contraction and prevent angular distortion. Similarly, in a single side fillet weld, non-uniform contraction produces angular distortion of the upstanding leg. Double side fillet welds can therefore be used to control distortion in the upstanding fillet but because the weld is only deposited on one side of the base plate, angular distortion will now be produced in the plate. Distortion due to elastic buckling is unstable: if you attempt to flatten a buckled plate, it will probably 'snap' through and dish out in the opposite direction. Twisting in a box section is caused by shear deformation at the corner joints. This is caused by unequal longitudinal thermal expansion of the abutting edges. Increasing the number of tack welds to prevent shear deformation often reduces the amount of twisting. This influences the degree of distortion mainly through its effect on the heat input. As welding procedure is usually selected for reasons of quality and productivity, the welder has limited scope for reducing distortion During this heating and cooling cycle, many factors affect shrinkage of the metal and lead to distortion, such as physical and mechanical properties that change as heat is applied. For example, as the temperature of the weld area increases, yield strength, elasticity, and thermal conductivity of the steel plate decrease, while thermal expansion and specific heat increase (Fig. 4). These changes, in turn, affect heat flow and uniformity of heat distribution.

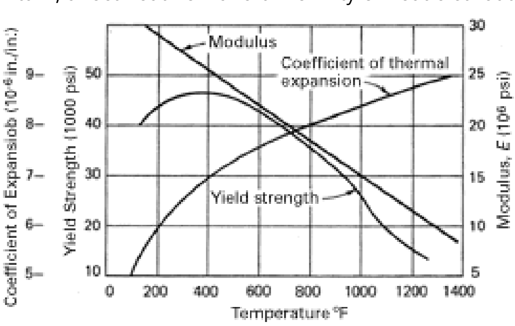

Figure. 4 Changes in the properties of steel with increases in temperature complicate analysis of what happens during the welding cycle - and, thus, understanding of the factors contributing to weldment distortion.

3.3. Residual stress

Residual stresses are stresses that remain in a solid material after the original cause of the stresses has been removed. Residual stress may be desirable or undesirable. For example, laser peening imparts deep beneficial compressive residual stresses into metal components such as turbine engine fan blades, and it is used in toughened glass to allow for large, thin, crack- and scratch-resistant glass displays on smart phones. However, unintended residual stress in a designed structure may cause it to fail prematurely. Residual stresses can occur through a variety of mechanisms including inelastic (plastic) deformations, temperature gradients (during thermal cycle) or structural changes (phase transformation). Heat from welding may cause localized expansion, which is taken up during welding by either the molten metal or the placement of parts being welded. When the finished weldment cools, some areas cool and contract more than others, leaving residual stresses. The predominant mechanism for failure in brittle materials is brittle fracture, which begins with initial crack formation.

3.4. Factors that cause residual stresses

Residual stresses can be present in any mechanical structure because of many causes. Residual stresses may be due to the technological process used to make the component. Manufacturing processes are the most common causes of residual stress. Virtually all manufacturing and fabricating processes such as casting, welding, machining, moulding, heat treatment, plastic deformation during bending, rolling or forging introduce residual stresses into the manufactured object. Residual stress could be caused by localized yielding of the material, because of a sharp notch or from certain surface treatments like shot peening or surface hardening. A good common example of mechanically applied residual stresses is a bicycle wheel. A bicycle wheel is a very light and strong because of the way in which the components are stressed. The wire spokes are radial aligned and tightening the spokes creates tensile radial stresses. The spokes pull the rim inward, creating circumferential compression stresses in the rim. Conversely, the spokes pull the tubular hub outward. If the thin spokes were not under a proper tensile preload load the thin wire spokes could not adequately support the load of the rider. Residual stresses can be sufficient to cause a metal part to suddenly split into two or more pieces after it has been resting on a table or floor without external load being applied.

3.5. Residual stress measurement methods

- x-ray diffraction
- Ultrasonic methods
- Magnetic methods
- Electronic Speckle Pattern Interferometry
- Hole drilling and strain gage technique
- Core Hole drilling and strain gage technique
- Photo elastic technology for residual stress measurement in glass
- Barkhausen noise effect for ferromagnetic materials

3.6. Sources of residual stress

Residual stress in welds is produced by localized metal tensions occurring immediately after welding, which are:

a) Contraction stress.
b) Stress due to higher surface cooling.
c) Stress due to phase transformation.

The three types of residual stress usually take place at the same time. Experience proves that the individual effects of each one can be linearly superposed.

3.7. 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 s 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

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wire to the pipe by capacitor discharge unit. This will eliminate the error in measurements (see figure 5).

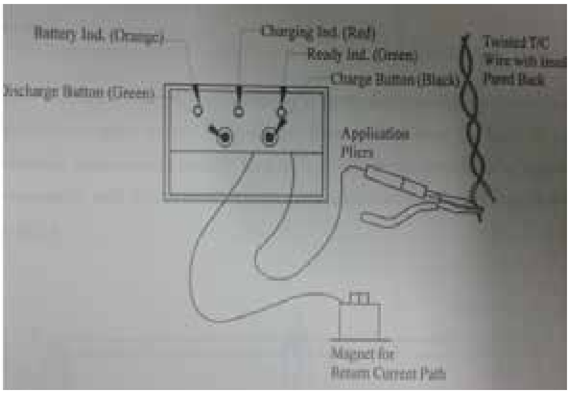

Figure 5. Fixing thermocouples by capacitor discharge unit

A mimimum of two thermocouple is recommended to monitor the temperature of weldments on pipes above 150 mm diameter and 20 mm wall thickness. On larger diameter pipes additional thermocouples must be fixed so as to indicate the temperature at significant points on the weld.CEGB-UK recommendations for location of thermocouple is shown in figure 6.

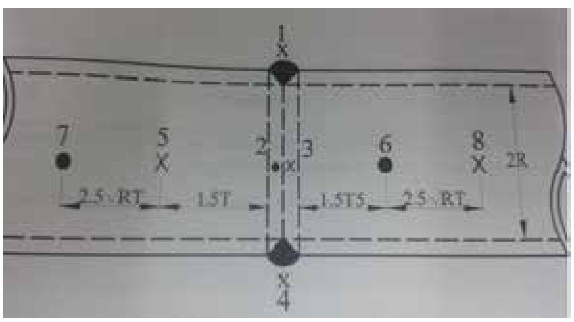

Figure 6. CEGB recommendations for fixing thermocouples

4. 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 (de-crystallization, 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
- Usage of refrigerants

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 the case of the latter it is done by using a fan blowing air into or onto the object one wants to cool. In many cases the addition of fins adds to the total surface area making a heat sink that makes for greater efficiency in cooling. In all cases, the air has to be cooler than the object or surface from which it is expected to remove heat. This is due to the second law of thermodynamics, which states that heat will only move spontaneously from a hot reservoir (the heat sink) to a cold reservoir (the air).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, Petroleumrefineries 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) Points to be cared

- The sand must be moisture free. It should be of free flow type
- Green sand and clay can be avoided, since its filling or removing consumes time
- The sands must be fine powdered, since the larger particles of sand contain sharply edges, which can cause harm to the inner surface.

(iii) Limitations

- Since the sand only maintains the temperature uniformity it may cause some stress formation as side effects
- On basis of time factor, sand filling and refilling gets bad impact
- After implementations and studies carried out, this system was found to be quiet reasonable in the economical point of view.

In order to reduce the time factor,

A tube of small specified length filled with sand which has a 90% dia of the parent tube is placed inside exactly at the location of welding. The tube is moved in such a way that it is always kept behind the welding portion. This reduces the quantity of sand used and time consumed.

(iv) Some steps to Minimize Distortion

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

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

According to ASME Rules, in section 239 it has been mentioned that increase in soaking time and decrease on temperature would be effective. So we suggested, using car bottom furnace instead of continued discharge furnace and at a tem-

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perature of 510◦C +/-10◦C for a soaking time of 130 minutes. This has considerably reduces the manual correction.

5. CONCLUSIONS

A number of thin-steel welding distortion control techniques were developed based on a series of tests on candidate measures to improve the manufacturing quality of thin panels for ship 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 and
- 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.

REFERENCE [1]Hilley, M.E., ed., (1971), "Residual Stress Measurement | by X-ray Diffraction," SAE J784a, Soc. Of Automotive Engineers, Warren dale, PA.3 | [2] "Standard Method for Verifying the Alignment of | X-ray Diffraction Instrumentation for Residual Stress Measurement," ASTM E 915-916. | [3] Prevéy, P.S., (1987), "The Measurement of Subsurface Residual Stress and Cold Work Distributions in Nickel Base Alloys," Residual Stress in Design, Process and Materials Selection, ASM, Metals Park, OH, 11-19. | [4] Keil, S., (1992),"Experimental Determination of Residual Stresses with the Ring-Core Method and an On-Line Measuring System," Exp. Tech., Sept/Oct. | [5] "Determining Residual Stresses by Hole-Drilling Strain Gage Method," ASTM E 837-95 | [6] Mura, T. (1987): Micromechanics of Defects in Solids. Martinus Nijhoff Publishers, Dordrecht. | [7] Korsunsky, A.M., S.P. Collins, R.A. Owen, M.R. Daymond, S. Achtioui, and K.E.James (2002): “Fast residual stress mapping using energy-dispersive synchrotron X-ray diffraction on station 16.3 at the SRS”, Journal of Synchrotron Radiation, 9: p. 77-81. | [8] Korsunsky, A. M. (1997): “An Analysis of Residual Stresses and Strains in Shot Peening”, Proceedings of 5th Intl. Conf. on Residual Stresses (ICRS-5), ed. T. Ericsson. | Linköping, Sweden. | [9]J.G. Williams (1995) Proc. Int'l Mechanical Engineering Congress, San Francisco, USA, November 12-17. | [10]. J. A. Nairn and S. Hu (1994) in Damage Mechanics of Composite Materials, eds., Ramesh Talreja, 187-243. | [11]. J. A. Nairn (2000) in Polymer Matrix Composites, eds., R. Talreja and J.-Å. E. Manson, 403-432. | [12]. S. R. Kim and J. A. Nairn (2000) Engr. Fract. Mech. 65, 573-593. | [13]. J. A. Nairn (2000) Adv. Comp. Letts. 9, 373-383. | [14]. S. Zhandarov, E. Pisanova, E. Mader, and J. A. Nairn (2000) J. Adhesion Sci. & Tech. 15,205-222. | [15]. D.-A. Mendels, Y. Leterrier, J.-A. E. Månson, and J. A. Nairn (2002) J. Comp. Mat. In press. |