Sandeep Duhan al. International Journal of Recent Research Aspects ISSN: 2349-7688, Vol. 2, Issue 1, March 2015, pp. 135-137

A Review of Angular Distortion & its Prevention Techniques

Sandeep Duhan[1], Ashwani Mor[2], Deepak Malik[3]

[1]M.tech.Student, Bhara Institute of Management and Technology, Gohana

[2]H.O.D., Mech.deptt., Bhara Institute of Management and Technology, Gohana

[3]A.P., Mech.deptt., Rohtak Institute of Engineering and Management, Rohtak

Abstract: The welding presents a lot of challenges to the maker or designer during the joining of structures together mainly including residual stress and distortion. Distortions can be classified into various types like longitudinal, rotational, angular etc. distortion. In this paper we will present various features of angular distortion and how we can control the angular distortion. This survey will also present various techniques like fibrication, mechanical and thermal etc to prevent angular distortion.

Keywords: Welding, Gradient, Distortion, Conductivity, Elasticity, Elasticity, Restraint

I. INTRODUCTION

As a fabrication technology, welding presents a number of technical challenges to the designer, manufacturer, and end-user of the welded structures. While welding joins the components of a structure together, the complex thermal cycles from welding result in formation of residual stresses in the joint region, and distortion of the welded structure. Both weld residual stress and distortion can significantly impair the performance and reliability of the welded structures. They must be properly dealt with during design, fabrication, and in-service use of the welded structures. Distortion in a weld results from the expansion and contraction of the weld metal and adjacent base metal during the heating and cooling cycle of the welding process. Doing all welding on one side of a part will cause much more distortion than if the welds are alternated from one side to the other. 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.[1] Thermal distortion occurs when a process generates thermal gradients resulting in strains, due to non-uniform expansion or contraction that exceed the local yield point of the material. During the rapid heating cycle of a fusion welding process, material in the vicinity of the weld heats, expands in all directions and is compressed by the constraints of the much larger and cooler surrounding structure. The heated volume has a lower yield point than the cooler surrounding structure and is more readily upset to a smaller dimension, i.e. the heated volume yields in compression. On cooling, the weld deposit & the heated volume of the adjacent parent material contracts in all directions, creating tensile strains that are constrained by the attached cool structures that did not reach a yield point strain during the entire heating and cooling process. This localized contraction results in buckling, localized tensile yielding, or development of residual stress. On thinner members localized buckling will occur. On thicker members less localized distortion is evident; however residual stresses tend to be higher. Distortion and residual stress are two undesirable after-effects associated with welding. Often these imperfections affect the desired performance of the component. Excessive distortion that manifests as deviation from design dimensions and shape of the component, problems in the alignment of subassemblies, machining and buckling strength of component besides the aesthetic appearances of the component. Residual stresses are complimentary to distortion, have adverse effects on the fatigue strength and dimensional stability etc. [2]

II. TYPES OF DISTORTION

Nature of the shrinkage force generated in the weld metal regions, governs the type of distortion experienced in by the component. The rapidly cooling weld metal creates shrinkage forces in all three directions viz. longitudinal, transverse and thickness direction and these shrinkage forces produce deformations in the longitudinal, transverse and thickness directions. The six types of distortions can be categorized as:[3]

- Longitudinal shrinkage
- Transverse shrinkage
- Angular distortion
- Longitudinal bending or bowing
- Rotational distortion
- Buckling

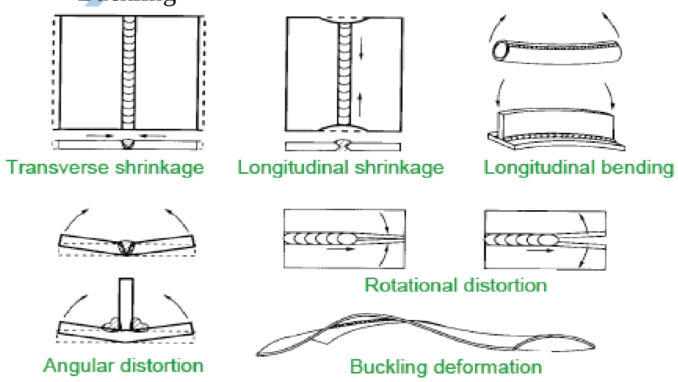

Figure 1: Types of Distortion

III. FACTORS DISTURBING ANGULAR DISTORTION

If a metal is uniformly heated and cooled, there would be almost no distortion. However, because the material is locally heated and restrained by the surrounding cold metal, stresses are generated higher than the material yield stress causing permanent distortion. The principal factors affecting the type and degree of distortion are:

Parent Material properties Parent material properties which influence distortion are Coefficient of thermal expansion ( ), thermal conductivity (k), Yield strength ( ), modulus of elasticity (E) and specific heat per unit volume. These properties of the material plays a significant role in determining the stresses generated during welding and hence, the degree of distortion.

Coefficient of thermal expansion It is a measure of expansion and contraction. The higher the coefficient of thermal expansion of a material, the greater the distortion is likely to be, for example, as stainless steel has a higher coefficient of expansion than plain carbon steel, it is more likely to suffer from distortion.

Thermal conductivity It indicates how readily the heat will spread through the material. Low thermal conductivity leads to high thermal gradients, and high thermal gradients lead to high distortion because distortion depends upon internal or external restraints.

Yield Strength The higher the yield strength of the material, the greater the residual stresses available for causing distortion.

Modulus of Elasticity The modulus of elasticity is a measure of stiffness of a material so that higher the modulus the more it will resist distortion.

Restraint If a component is welded without any external restraint, it distorts to relieve the welding stresses. So, methods of restraint, such as 'strong-backs' in butt welds, can prevent movement and reduce distortion. As restraint produces higher levels of residual stress in the material, there is a greater risk of cracking in weld metal and HAZ especially in crack-sensitive materials.

Joint Design Both butt and fillet joints are prone to distortion. It can be minimized in butt joints by adopting a joint type which balances the thermal stresses through the plate thickness. For example, a double-sided in preference to a single-sided weld. Double-sided fillet welds should eliminate angular distortion of the upstanding member, especially if the two welds are deposited at the same time.

Edge preparation and Part fit-up Edge preparation and Part Fit-up should be such as to require the minimum amount of weld metal and should be uniform to produce predictable and consistent shrinkage. Excessive joint gap can also increase the degree of distortion by increasing the amount of weld metal needed to fill the joint. Close fit-up reduces the amount of weld metal and hence weld metal shrinkage. The joints should be adequately tacked to prevent relative movement between the parts during welding.

Welding Procedure The factors determining the deformation of a structure during welding are partly of a technological and partly of a constructional nature. A suitable welding procedure is usually determined by productivity and quality requirements rather than the need to control distortion 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. As a general rule, weld volume should be kept to a minimum. Also, the welding sequence and technique should aim to balance the thermally induced stresses around the neutral axis of the component.[4, 5]

IV. DISTORTION CONTROL

In general, the welder has little influence on the choice of welding procedure but assembly techniques can often be crucial in minimizing distortion. Precautions therefore need to be taken to control this otherwise the welded structure may well be unusable.

In general, three basic rules are followed to minimize distortion.

Rule 1 - Reduce the effective shrinking force:

Do not over weld

The use of excessive weld metal over and above that needed to meet the service requirements of the weld is not only wasteful but increases distortion. Ensure proper edge preparation and fit up. This will allow the minimum amount of weld metal to produce a strong joint.

Use few passes

The use of many, small passes increases lateral distortion. Use of fewer passes with a large diameter electrode minimizes lateral distortion.

Place welds near the neutral axis of the device

This concept along with proper sequencing can significantly reduce unwanted distortion. The objective is to make the shrinkage forces exert their influence against each other in order to balance out. In most cases the forces created by shrinking weld metal will act thru the central axis as a fulcrum.

Use intermittent welds

This also reduces the amount of weld metal and can result in significant cost savings as well as minimizing distortion.

Welding Sequence

The direction and sequence of welding is important in distortion control. Generally welds are made in the direction of free ends. For longer welds, back-step welding or skip welding is used.

For back-step welding short weld lengths are placed with welding in the opposite direction to the general progression.

For skip welding a sequence is worked out to minimize and balance out shrinkage stresses.

Rule 2 - Make shrinkage forces work to minimize distortion:

Locate parts out of position

Pre-setting the parts such that the contracting weld metal pulls them into proper alignment when the weld cools is a common way of using the shrinkage of the weld metal to advantage.

Space the parts to allow for shrinkage

Calculation backed up by experiments will indicate how much space needs to be left for parts to shrink into correct alignment when the weld cools. Pre-bending components may be appropriate so that the contracting weld metal straightens them as it cools.

Rule 3 - Balance shrinkage forces with other forces / with another:

This can often be achieved by adhering to a welding sequence, which places weld metal at different points around the structure so that the shrinkage of one weld counteracts the distortion caused by a previous weld. Peening the weld bead as it cools stretches the weld, thus counteracting its tendency to contract and shrink as it cools. Use jigs and fixtures - the most common method of distortion control, it relies on clamping the work firmly so that the weld is forced to stretch as it cools.

V. PREVENTING ANGULAR DISTORTION

A. Fabrication Techniques

Workshop personnel have control over a number of activities as follows:

Precision in Marking out and Cutting Modern shipyards are utilizing CAD/CAM in their laser and plasma cutting operations. The same equipment is now increasingly used for component identification and marking out. Marking out for subsequent assembly as part of the CAD/CAM cutting process minimizes subsequent requirements for marking out, greatly reduces errors in marking out and improves assembly times. This enables:

High accuracy in cutting leading to good fit up in the fabrication shop, leading to less minor corrections and accompanying distortion. Identification of parts and marking out of cut pieces using dot matrix, laser or plasma systems. This leads to greatly enhanced traceability of parts, enhanced precision of assembly, minimizing errors and rework.

Precision in Weld Preparation Preparation of bevels for plate butt welds is now commonly by machining. While machining is more expensive than thermal cutting it enables compound bevels to be produced with precision not achievable by thermal cutting processes. Extremely accurate fitment of parts to be joined can be achieved. This is particularly important for larger welds such as main plate butt welds where major gains can be made in controlling overall distortion.

Precision in Assembly This is where it all comes together and precision in assembly is dependent on accuracy of design, accuracy of cut parts, accuracy of marked assembly lines and last but not least the skills of the people doing the assembly.

Tack welding Tack welding plays a critical role in firstly holding the assembled structure together ready for welding and secondly in maintaining correct root gaps in butt welds and preventing movement in the structure as welding progresses. The number of tack welds, the length tack welds and the distance between them will depend on the length and thickness of the weld, the degree of rigidity needed, the details of the weld preparation and the welding process being used. The tacking sequence can also have an effect and may need to be controlled to ensure correct root gaps are maintained along the length of a joint.

Pre-setting Where a known amount of angular distortion will occur, presetting the joint by the amount of angular distortion expected ensures the alignment of the finished weld. This method can be very effective if consistent shrinkage rates are achieved through close control of welding procedures.

Jigs and Fixtures Jigs and fixtures can be used for assembly and welding of subassemblies where the components are held rigidly until welded. This approach works well for production of multiple smaller sub-assemblies.

B. Mechanical Techniques

The following techniques rely on applying a force to change the shape of a component to correct the distortion produced by welding.

Hammering and Peening This is a simple, cheap and sometimes effective method of correcting minor distortions. Hammering has limited application because it can lead to local surface damage and work hardening.

Peening of welds is an effective means of countering distortion due to weld metal shrinkage. Peening is carried out progressively as each weld or layer of weld is deposited in a multi-layer welds. The surface of the weld is spread out to reduce the tensile shrinkage stresses across and along the joint. Peening must be done carefully to avoid introduction of undesirable features on the peened surface and is not allowed by some fabrication codes.

Pressing Hydraulic presses can be used to correct distortion in the form of bowing and angular distortion. This approach is limited by the size of press available and the size and complexity of the component. Distortion can be corrected progressively, and with care there will be minimal damage to component surfaces. [5, 6]

C. Thermal Techniques

Thermal techniques are based on creating compressive yielding at locally heated sites, which then provide a tensile stress to "shorten" the heated zone. The part to be shortened is rapidly heated to generate a temperature gradient with thermal strain sufficient to cause compressive yielding as it expands against the surrounding cold, higher yield strength metal. When the heated area cools the part that underwent compressive yielding contracts to a smaller size than before it was heated.

VI. CONCLUSION

As a fabrication technology, welding presents a number of technical challenges to the designer, manufacturer, and end-user of the welded structures. While welding joins the components of a structure together, the complex thermal cycles from welding result in formation of residual stresses in the joint region, and distortion of the welded structure. Both weld residual stress and distortion can significantly impair the performance and reliability of the welded structures. In this paper we presented various features of angular distortion and how we can control the angular distortion. This survey also present various techniques like fabrication, mechanical and thermal etc. to prevent angular distortion. The study can be extended on various other strains and distortion. And, welding can be done on stainless steel etc. material and performance can be measured.

VII. REFERENCES

[1]. AMITAVA MITRA, Fundamentals of Quality Control and Improvement, PEARSON Education, Second Edition, pp 157.

[2]. MICHALERIS and ANDREW DEBICCRI Edison, Prediction of Welding Distortion, Panagiotis Welding Institute Columbus, Ohio.

[3]. MONTGOMERY "Design of Experiment" 6th Edition, pp.294

[4]. P. MICHALERIS, J. DANTZIG and D.TORTORELLI, 1999, Minimization of Welding Residual Stress and Distortion in large structure, supplement of The Welding Journal, November, pp.361-366

[5]. MIAMI, FLA, Welding Handbook, American Welding Society, Volume 1, 8th Edition.

[6]. P. MICHALERIS and A. DEBICCARI, 1997, Prediction of welding distortion, Welding research supplement, pp 172-181

