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Reviews on Residual Stresses and Distortion of Welded Joints in Manual Metal Arc Welding

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***Abstract*—This paper deals with the problems related to residual stresses, distortion and their consequences on the integrity and it also focuses on the phenomenological aspects of these effects and the methodologies available for their analysis. Welding is extensively used today in the fabrication of many structures including ships, airplanes, buildings, pressure vessels and pipelines and certainly provides many advantages over other techniques including riveting, casting and forging. Welded structures, however, are by no means free from problems. The local non uniform heating and subsequent cooling, which takes place during any welding process, causes complex thermal strains and stresses to develop that finally lead to residual stresses, distortion and all their adverse consequences. In that effect the designer is confronted with the formidable task of selecting design and fabrication parameters in such a way that the adverse effect of residual stresses and distortion can be kept under acceptable limits. Such design parameters include the geometry of the structure, the plate thickness and the joint types that are used. The fabrication parameters include the type of the welding, processes employed, the actual procedure parameters, welding sequence, etc. as for the effect of material properties the designers must be concerned with both base and the filler metal selection**

***Keywords*— Residual Stress, Distortion, Finite Element Method.**

I. Introduction

Welding plays a significant role in fabrication, erection and commissioning of plants and machinery for power, petroleum, chemical and steel and other industrial sectors. Welding can be broadly classified in to two major categories namely, fusion welding processes and solid phase welding processes.

In fusion welding processes, the coalescence between two surfaces is brought about by melting the filler metal and the joining surfaces, re-solidifying them in the weld region. Fusion welding covers arc welding, gas welding, thermit welding, electron beam welding and laser welding etc. in the solid phase welding technique, pressure is applied between the laying in faces to deform them plastically and bring about coalescence along the interface. Under solid phase welding processes various pressure welding techniques such as friction welding, diffusion welding, induction pressure welding, ultrasonic welding, explosive welding etc., are covered.

At the start of 20th century, manually metal-arc welding came to be industrially accepted. Oscar Kjellberg of Sweden is credited with being the pioneer of modern coated arc welding electrodes. Manual metal arc welding is a versatile and flexible process requiring simple equipment, a skilled welder, welder's accessories and electrodes. Welding can be carried out in all positions, both in shop and at site. Welded joints of sound quality and adequate mechanical properties can be obtained by using correctly designed electrodes and proper welding procedures. The process is intermittent, because welding has to be interrupted from time to time to discard the unused stub and to place a fresh electrode into the holder, and also to deslag the joint, i.e. to remove the layer of slag covering the weld. For higher productivity, semi-automatic or fully-automatic welding processes are performed.

Residual stresses are those stresses that would exist in weldment after all external loads are removed. A weldment locally heated by most welding process, therefore the temperature distribution in the weldment is not uniform and structural and metallurgical changes take place as welding processes along a joint. Typically, the weld metal and heat effected zone immediately adjacent to the weld arc at temperatures subsequently above that of the unaffected base metal. As the weld pool solidifies and sinks, it begins to extract stresses on the surroundings weld metal and heat effected zones. When it first solidifies, the weld metal is hot, relatively week and can exert little stress. As it cools to ambient temperature, however, the stresses in the weld area increase and eventually reach the yield point of the base metal and heat affected zone.

Distortion is caused when the heated weld region contracts non-uniformly causing shrinkage in one part of a weld to exert eccentric forces on the weld cross section. The weldment strains elastically in response to these stresses, and detectable distortion occurs as a result of this non-uniform strain. Among the various factors influencing distortion and residual stresses magnitude and distribution, the material properties, specimen dimension, heat input, welding processes and welding sequence are considered to be the most important ones.

Distortion and residual stress decrease the fracture strength of welded structure only when certain condition exists; however, the loss of strength can drastic under these conditions. In general, the effects of residual stresses and distortion are significant if fractures can take place under low applied stress. Residual stresses have their origin in complex thermal and/or mechanical interactions. Consequently, their reduction or removal demands the use of mechanical or thermal treatments.

The various mechanical and thermal treatments performed on weldments to reduce residual stresses include proof stressing, peening, vibratory conditioning, preheating, post weld thermal treatment and so forth. Control of distortion can be achieved by economical design, proper assembly procedure, elastic pre- straining, and preheating. Correction of distortion can be achieved by thermal strain and mechanical straining.

II. Manual Metal Arc Welding

Manual metal arc welding is an arc welding process in which the heat for welding is generated by an arc established between a flux covered consumable electrode and the surface of work. It is the most widely used welding process for joining metal parts, mainly because of its versatility. The core of the flux covered electrode consists of either a solid metal rod of drawn or cast material, fabricated by enhancing metal powders in a metallic shealth. In MMAW, an arc is struck by touching the work-piece and the tip of the electrode. Sufficient electric current is required to melt the tip of the electrode and surface of the work beneath the arc. The typical current range used for MMAW is between 50 A and 500 A. In this manner the filler material is deposited as the electrode is progressively consumed. The tip of the electrode must be close enough to the work to ensure that molten metal from electrode will be transferred directly into the weld pool. Many types and sizes of power sources are used for MMAW. The current may be either alternating or direct, depending on the type of covering and type of electrode used. Constant current or dropping type of power source is preferred because it produces a small change in amperage with considerable change in arc length.

Experimental Procedure to Measure Distortion

Mild steel is selected for the experimental work as the base plate. The size of the work piece is 250x125x 6 (length x width x thickness) in mm, the number of plates selected for the experimental work is 40.

The plates are thoroughly cleaned to remove oil, grease and dust. The plates are then subjected to edge preparation. The edge preparation is the process of machining the edge of the plates to be subjected to welding to get different joint Parameters like Groove profile, included angle and Root face. The different edge preparations planned for the experimentation are as follows:

1) Groove Profile
    a) Square Butt Joint (Without Groove)
    b) V-Butt Joint
    c) Bevel Butt Joint
    d) Double V-Butt Joint
2) Included Angle
    a) 45 degree
    b) 60 degree
    c) 30 degree

Total numbers of specimens have been chosen for welding with all the possible combinations of joint parameters. The two plates of different combinations of joint parameters are tack welded to get 20 specimens. Tack weld is the weld made to hold the parts of the weldment in proper alignment until the final welds are made. The tack weld is done just to join the two plates. Due to tack weld, the plates resort to a small amount of distortion. This is termed as initial distortion since it takes place prior to the final welding.

Once all the plates have been tack welded into 20 specimens, each specimen is marked into a symmetric grid of equal dimensions. The spacing given between each grid line in this experiment is 0.05m (50mm). Once all the specimens are marked, any one end of the specimen is taken as a reference point and initial distortion is measures along x and y axes at the intersection of each grid line using a dial gage. This will give the reading at every 0.05m (50mm) of the specimen along x and y axes.

The initial distortion readings are tabulated in the following table. After the measurement of initial distortion, all the specimens are welded using manual metal arc welding keeping all other weld parameters constant. The welding current and voltage used are 160A and 35V. After welding, the plates are allowed to cool. During cooling, the plates undergo distortion due to non-uniform cooling and residual stresses induced in them.

The final distortion is measured similar to the measurement of initial distortion. The measurements are made at the intersection of each grid line along x and y axes taken from the same reference point. The readings are obtained at a distance of 0.05m in x and y directions from every intersection point of the grid lines. The final distortion readings are tabulated similar to the initial distortion readings. A graph of initial distortion and the final distortion is drawn for each specimen which gives the distortion behavior for each specimen.

The difference in minimum initial distortion reading and the maximum final distortion reading for each specimen is calculated. This gives the total distortion that has occurred in that specimen. By the analysis of the graphs and the total distortion magnitude, it is possible to conclude which specimen has resorted to least distortion and which specimen has developed the maximum distortion. Likewise, it is possible to know the optimum weld joint and groove angle which develops least distortion.

III. Test Specimens

Total numbers of specimens have been chosen for welding with all the possible combinations of joint parameters. The twenty specimens based on joint parameters are as given below.

The one specimen is square butt joint (specimens 01) have been prepared by using tack at the two ends for welding, and which is welded on both sides. The three V-Butt joint specimens have been prepared for welding for three different included angles of V-Groove (specimens 02 to 04). In case of Bevel Butt Joints, three specimens for three different included angles (specimens 05 to 07). The included angles in this case are half of the angles of V-Butt Joints. The three double V-groove butt joints for different included angles (specimens 08 to 10). These specimens were welded with straight polarity. The same parameters were used for welding with reverse polarity (specimens 11 to 20).

IV. Conclusion

The results obtained from experimental research will be very useful for designers to estimate the degree of contraction caused by contraction during construction. The main results of the current research range are as follows: Inverse contraction increased with increasing bevel angle at bevel-groove joints. And similar observations have also been found for longitudinal contraction. Longitudinal contraction was found to be less than transverse contraction. Variation of transverse contraction is noted to be significant but variation of longitudinal contraction in bevel-groove joints is small.

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