A STUDY ON THE MEASUREMENT OF RESIDUAL STRESS ACCORDING TO WELDING CONDITION OF STS304

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ABSTRACT

The HDM(Hole Drilling Method) is a relatively simple and accurate method in measuring residual stress of welded metal. Various methods of evaluating residual stress are studied in welding field. The method of cutting holes on the plate much affects the accuracy of result. Especially for the hard material like stainless steel difficult to cut preciously is difficult to measure residual stress on welded metal. Because heat conduction of stainless steel is lower than other general steel, the magnitude of residual stress might be different as to changing of welding conditions.

Therefore, The distribution of residual stress on the STS304 steel after welding using HDM is evaluated in this paper.

KEYWORDS

Residual stress, Strain gage, TIG welding, STS304, Hole Drilling Method

1.Intoduction

Residual stresses in a structural material or component are those stresses that exist in the object without the application of any service or other external loads. The effects of residual stress may be either beneficial or detrimental, depending upon the magnitude, sign, and distribution of the stress with respect to the load-induced stresses. Very commonly, the residual stresses are detrimental, and there are many documented cases in which these stresses were the predominant factor contributing to fatigue and other structural failures when the service stresses were superimposed on the already present residual stresses.

Welding residual stress is thermal stress with possibly superimposed transformation stress. In welding, the welding area becomes partially heated according to the arc heat, and thus unequal amounts of temperature distribution excess heat stress and inelastic change. The above phenomenon are common issues in most welding process. Which has led to many studies in this field. In order to solve these welding residual stress issues, first the distribution of residual stress on the welds must by understood and analyzed precisely.

2. Residual stress measurement using the hole-drilling method

2.1 Hole drilling method

The most widely used modern technique for measuring residual stress is the hole drilling strain gage method of stress relaxation. As the stress of free surface has to be zero, if an extremely small hole is drilled through the residual-stressed material, the stress in that area will become exposed. The relief of the radial stress, which exists in the hole area, and thus, localized stress changes on the measured workpiece surface. By measuring the strain of the hole area, the hidden residual stress of the material can be monitored. In teal application, a blind-hole which the depth is similar to the diameter of the hole and the depth of smaller than the measured workpiece, is used, not a through-hole. The structure of a blind-hole is more complex than the through-hole, thus, the elasticity theory, which calculates the residual stress from the strain, is difficult to use directly. In this study, blind-hole drilling method is applied under the ASTM standard base upon the theoretical foundation of through-hole theory.

3. Experiment

In order to measure the residual stress of welding structures, the size of the welded specimen have to be large enough to include residual stress that exists in the real structure. The length and the width effects of the welding structure are taken under consideration, and the following welding specimen is produced. STS304, which is the most widely used pressure vessel, is used as the basic material of the welding. This specimen, with a 120mm width, 300mm length, 3mm thickness, are welded by TIG welding, while changing the welding speed and current. The welding is performed under conditions shown in Table 1. The specimen used in the experiment is shown in Fig. 1.

Table 1 Welding condition

Diameter of electrode (mm)	2.3		
Distance of electrode (mm)	3		
Flow rate of Ar gas (*l*/min)	15		
Angle of touch (||)	90		
Welding speed (cm/min)	2.5	3.0	3.5
Welding current (A)	180 200 220	180 200 220	180 200 220

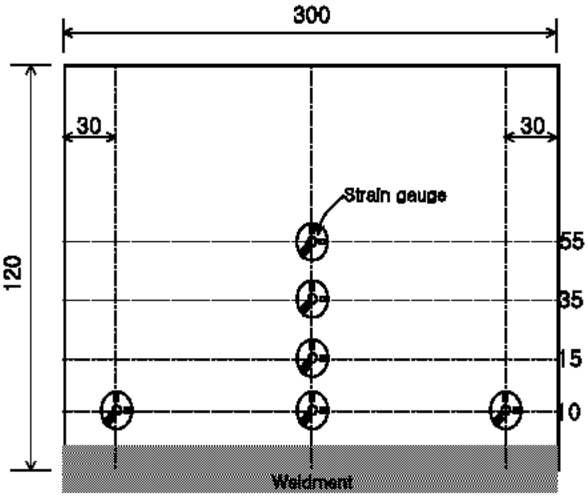

Fig. 1 Schematic draft of specimen

For the more precise experiment result, stress-measuring devices such as strain gauge, strain meter and hole drilling machine are decided carefully. It is extremely difficult to attach three different strain gages, with a fixed degree and distance. Therefore, a rosette strain gage, which is a gage that can contain three grids, is used. A high-precision digital strain indicator is used, as the measuring device for the change of strain. And by using a switch and balance unit, which can obtain more than three outputs simultaneously, three strains are obtained during the hole drilling process. A milling guide that supports drill shaft, is used, as the hole must be processed very accuracy in the center of the gage, regardless of the drilling vibration. As shown in Fig. 1, with the welding centerline as the standard line, four strain gages are attached on one side of the specimen. And two strain gages are attached on start and end point of welding respectively. The diameter of hole is decided as 1.6mm, considering the thickness of base metal and the characteristics of the gage. Also the depth (Z) of the hole depends on gage diameter (D). Therefore, in order to maximize the strain signals, the hole is normally drilled to a depth corresponding to at least Z/D=0.4 The principal stress is calculated, according to the measured strain, and with this the longitudinal residual stress and the transverse residual stress are calculated

4. Experiment result and discussion

1. The variation of relieved strain with depth is illustrated in Fig. 2, where the strains have been normalized, in this case, to 100% at Z/D=0.4. At hole depths corresponding to Z/D>0.2, the stresses in these increments have very little effect on the observed strains. This behavior is confirmed by the shape of the normalized strain graph in Fig. 2, where about 80% of the total strain relief normally occurs in the first half of the hole depth.
2. Distribution of residual stress on width-direction depends on welding current and welding speed. As the welding current is higher and the welding speed is slowly, the magnitude of residual stress on welded metal shows to be more large. (Fig. 3~Fig. 5)
3. As the base metal is limited, main direction of residual stress depends on position of measuring. Inside of base metal, its direction is almost welding-direction without distance of bead. However on edge of base metal, main direction aims at between bead and width-direction.(Fig. 6)

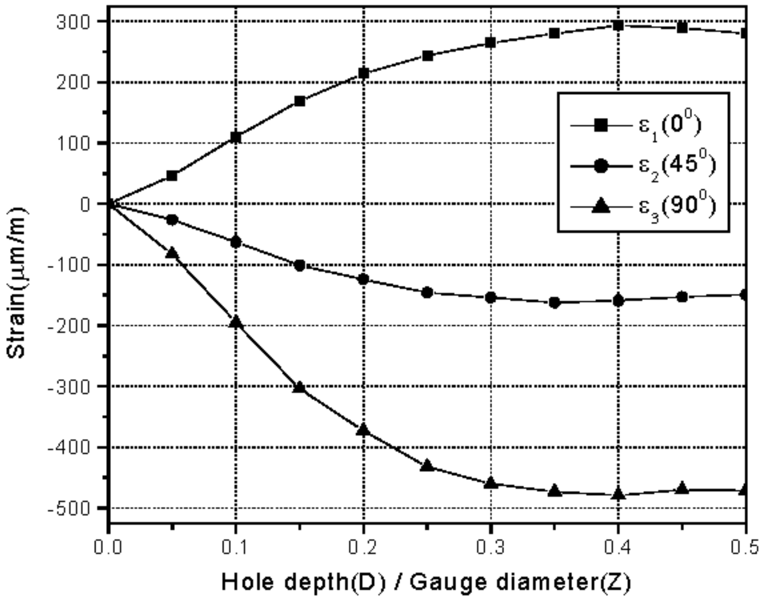

Fig. 2 Variation of strain vs. hole depth

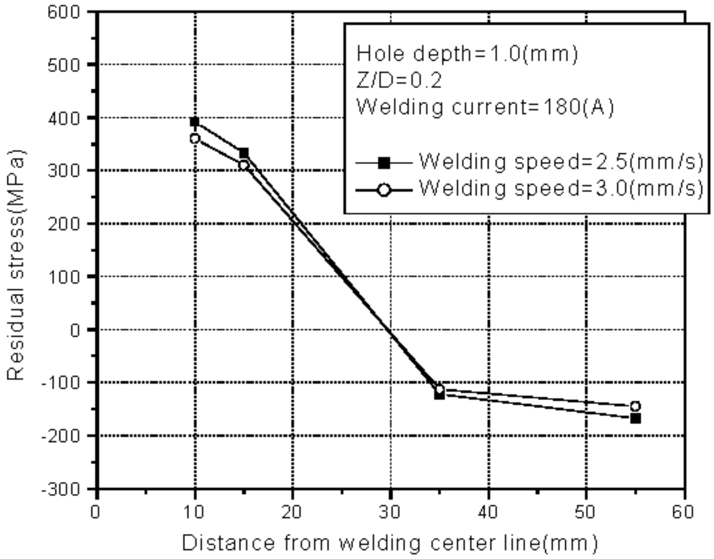

Fig. 3 Residual stress distribution on various welding speeds at welding current 180A

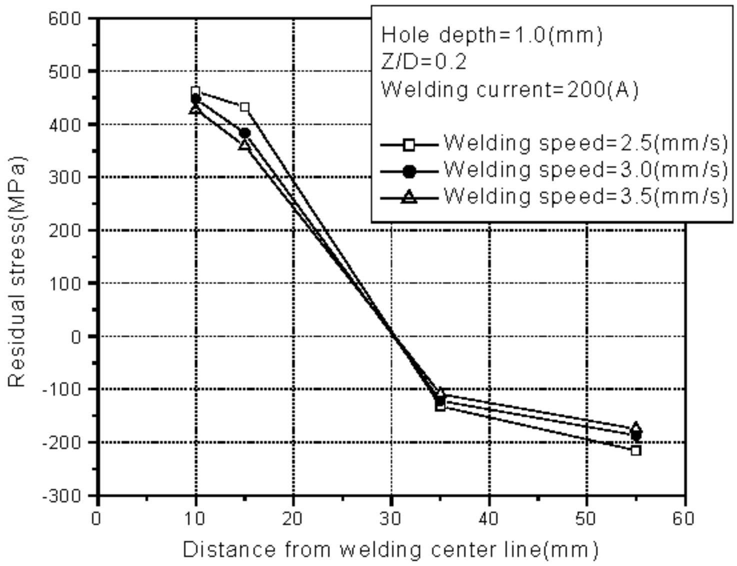

Fig. 4 Residual stress distribution on various welding speeds at welding current 200A

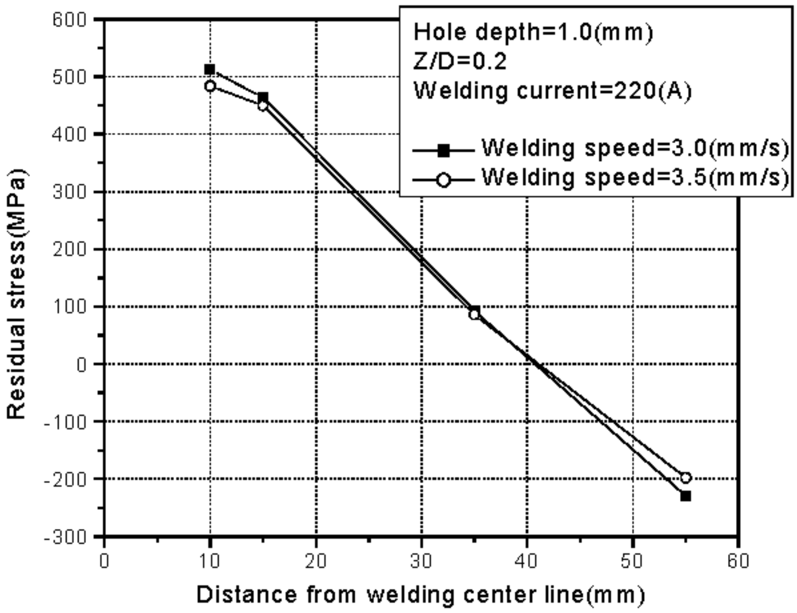

Fig. 5 Residual stress distribution on various welding speeds at welding current 220A

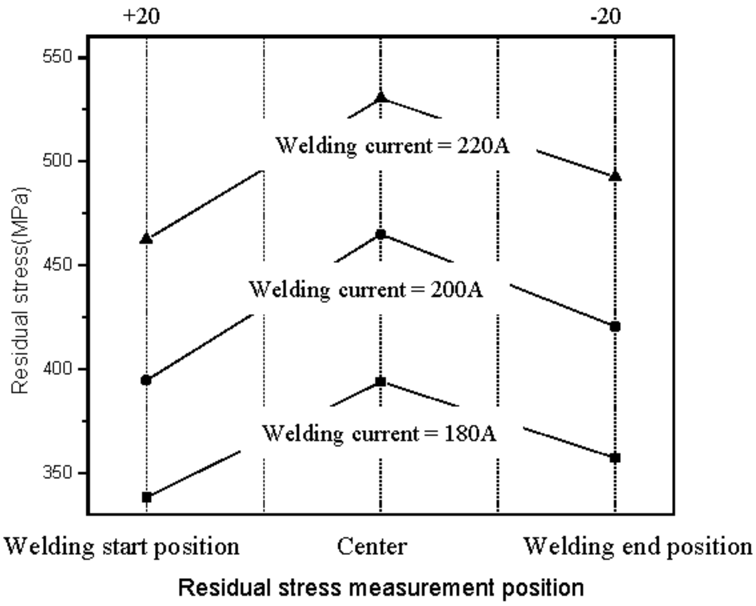

Fig. 6 Variation of residual stress on welding position and various welding currents at welding speed 3.0mm/s