MEASUREMENT OF RESIDUAL STRESSES IN WELDED SAMPLE OF DISSIMILAR MATERIALS

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Abstract. *The welding of dissimilar metals has several applications in the industry. Especially in the nuclear industry, this joint type, common between carbon steel and stainless steel, it is always reason of analysis and special cares tends in view the need to maintain the integrity of the equipments. Residual stresses are introduced in the material as a result of processes as welding, machining, sanding and polishing that can to produce deformation in the proximities of the surface of the material. Residual compressive stresses can be introduced in the material through the jetting process (bombardment of the surface for small glass spheres, dry sand or steel). That procedure allows a fine subsurface layer to suffer yielding, compressing the superficial layer and reducing the formation of areas of concentration of traction stresses, increasing the resistance of the material to the fatigue. The welding process introduces residual stresses due to the geometry resulting from the fusion of the material welded and of the heterogeneous cooling. Besides the microstructural alteration and chemical composition of the material in the affected area for the heat, introduced by the welding, it is also had the effect of the discontinuity of the passes and the formation of bubbles and emptiness that can contribute to the cracks nucleation, reducing the resistance to the fatigue. In the great majority of the times residual stresses are harmful and there are many documented cases which us these stresses went predominant factors for the failure for fatigue. A particularly dangerous aspect of the residual stresses is that their presence is not usually observed, what usually happens with an applied load to the structure. The knowledge of the surface residual stresses is important to predict the emergence of failure when the component or structure is requested. In nuclear power plants it is common to welding of piping of stainless steels with mouthpieces of carbon steel of pressure vases of reactors, what can generate significant residual stresses due so much to the welding procedure as for the difference of the coefficients of thermal expansion of the involved materials. In this work, are shown the results of the measurement of residual tensions in welded sample of steel carbon SA 508 Cl 3 and stainless steel 316L. The Inconel 182 was used as weld metal.*

Keywords*: Residual stress, dissimilar materials, welding*

1. INTRODUCTION

Residual stresses are those presents in a material or structural component, in the absence of external loads or temperature variations. The causes more common of the emergence of residual stresses they are the production processes. In this work it was studied the residual tensions developed by the welding process in materials dissimilar carbon steel SA 508 CL 3 and stainless steel 316L with addition of Inconel 182.

The welding of dissimilar metals has several applications in the industry. Especially in the nuclear industry, this joint type, common between carbon steel and stainless steel it is always reason of analysis and special cares tends in view the need to maintain the integrity of the equipments. Thermal and dimensional variations during the use of equipments that possess joints of dissimilar materials are always preoccupying because not always the report of manufacture is known or even of the recovery, when it was done. The premature Knowledge of these variations through the knowledge of the fatigue life can contribute a lot in the project, in the choice of the production process, in the choice of the weld metal and obviously in the conservation and integrity of the equipment. Additionally, the knowledge of the thermal behavior as temperature field in the neighborhoods of the puddle and that will result in residual stresses, they are also of great importance. This knowledge can to contribute to the improvement of the welds and same they be used as input in the study the fatigue life.

In this work the residual stresses are measured and compared using the Hole-Drilling Strain Gage Method.

2. METHODOLOGY USED FOR THE MEASUREMENT OF THE RESIDUAL STRESSES

The modern technique more thoroughly used for measurements of residual stresses is "Standard Test Method for Determining Residual Stresses by the Hole-Drilling Strain Gage Method " [ASTM E 837-01]. This is a semi-destructive method, could be in some cases considered nondestructive. In this method, after the installation of the strain gages (special rosettes) in the surface of the component to be investigated, Fig. 1, a small and shallow hole is machining in the center of these rosettes.

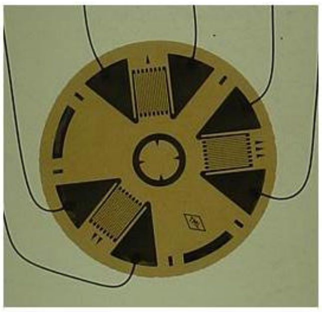

Figure 1: Typical strain gage rosette for the Hole-Drilling Method. TML Pam E-101N.

After the machining of the hole, the change of the deformation in the immediate neighborhood of the same is measured and the residual stresses are calculated with these data. The calculation of the relieved deformations is made being used the equation [Hoffmann, 1989]:

$$\varepsilon = \frac{\Delta R / R}{K} \tag{1}$$

Where:

$\Delta R = R_f - R_i$ (Ohm) for each cut increment

R_i is the resistance of the strain gage before the cut

R_f is the resistance of the strain gages for each depth increment

After the calculation of the relieved deformations, it is verified (ASTM E837, 2001) if the field of the residual deformations is uniform or not. Starting from this verification and following the recommendations contained in the norm (ASTM E837, 2001) and in (Tech Notices TN 503-6) it is calculated the values and the directions of the principal residual stresses if the field of stresses goes uniform. If the field of the stresses doesn't go uniform, it is calculated the equivalent uniform principal stresses and their respective orientations.

3. MATERIALS AND EQUIPMENTS

The welding of dissimilar materials was among the steel carbon SA 508 CL 3 and stainless steel 316l with addition of Inconel 182. The strength yield for the carbon steel A508 was 345 MPa and for stainless steel 316L it was 170MPa. The points studied in the top of the welded joint and the identification of the materials are shown in Fig. 2. The points RA and RB are placed in the root, in the part of the steel carbon, below of the points A and B. The points RC and RD are placed in the root, in the part of the stainless steel 316L, below of C and D.

The measurements of the residual deformations were accomplished being used the equipment RS-200, the digital multimeter Agilent model 34401, Fig. 3. The variation of the resistance of the strain gages was measured to four wires. For measurements of the residual deformations were used strain gages FRS-2-11, sticker cianoacrylic Loctite A 496 and covering protecting M coat A/MM.

Figure 2: Identification of the materials and the studied points.

Figure 3: Equipment for residual deformations measurement.

4. RESULTS

4.1. RESULTS OF THE RESIDUAL STRESSES MEASUREMENTS

In figures 4 and 5 are shown the profile of the equivalent uniform principal stresses. It can be observed in the figures that soon below the first measurement the values of the residual stresses had a small variation, tending to an uniformity of values.

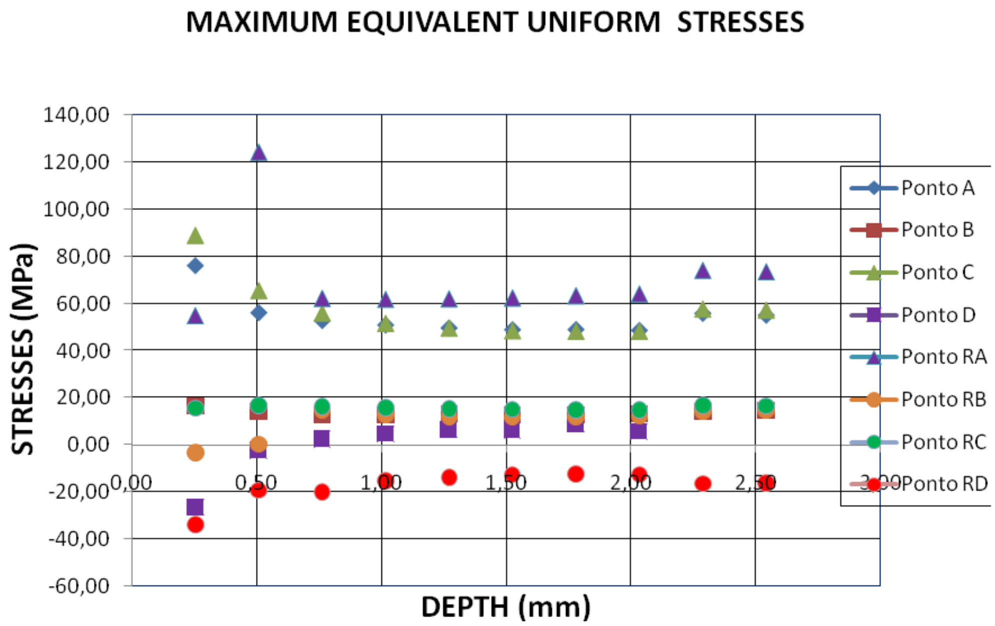

Figure 4: Maximum equivalent uniform stresses.

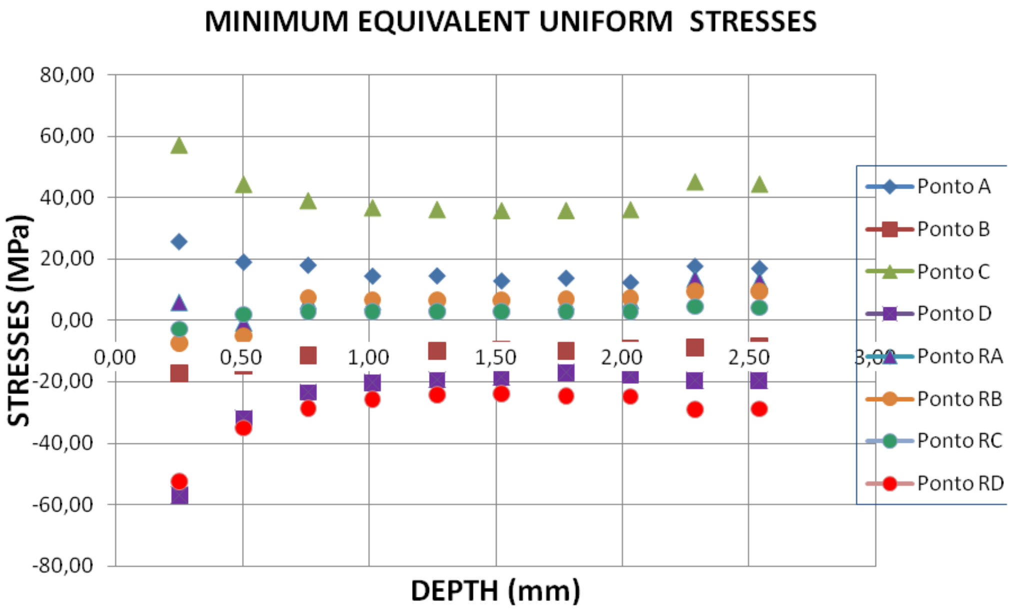

Figure 5: Minimum equivalent uniform stresses.

4.2. DIRECTIONS OF EQUIVALENT UNIFORM STRESSES

In the figure 6 the directions of equivalent uniform principal stresses is shown. In the construction of this figure was considered the medium angle for each point.

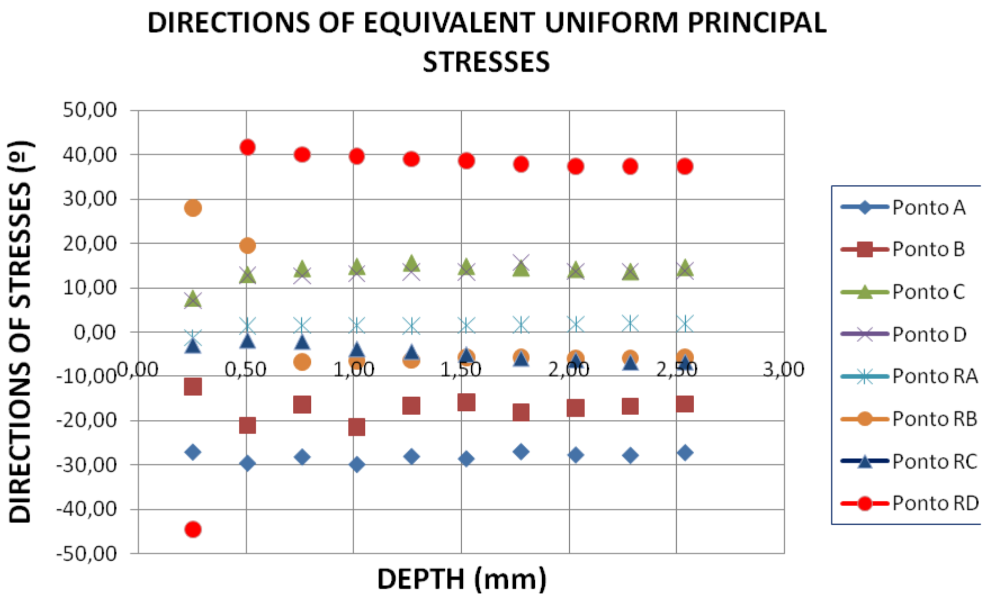

Figure 6: Directions of equivalent uniform principal stresses.

5. DISCUSSION AND CONCLUSIONS

The equivalent uniform principal stresses had a small variation with the depth of the hole, could be considered as uniform for a qualitative study.

The points A and C in the top of the welded piece and RA in the root of the piece, they are the points that had the largest values for the maximum equivalent uniform stresses, even so of low value and practically same.

The points A and C had equivalent uniform principal stresses of traction being, therefore the most susceptible to the corrosion, propitiating the crack nucleation and propagation.

For the measured points the observed equivalent uniform principal stresses was below of the strength yield for carbon steel A508 (σ_y = 345MPa) and for stainless steel 316L (σ_y = 170MPa).

6. REFERENCES

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