EVALUATION OF RESIDUAL STRESSES IN WELDED STEEL CONSTRUCTIONS

A.Milosavljević[1], R.Prokić[1], P.Smiljanić[1], M.Zrilić[2], P.Kerečki[3]

Residual stresses phenomenon and deformation are inevitable during welding process. Determination of residual stresses magnitude, sign and distribution is very important, because residual elastic stresses in welded constructions have a significant influence on a crack origination and growth, material brittleness, fatigue, stress corrosion, etc. Residual stresses determination with known techniques is rather difficult in welded constructions (1). In this paper, magnetic method for residual stress evaluation will be discussed, along with its disadvantages and possible improvements.

WELDED JOINTS STRESS AND DEFORMATION STATE

Welded constructions and their elements, depending on their purpose, are exposed during the exploitation to the various static and dynamic external loads. Applied force is resulting in stress condition. Beside that, residual stresses which are not resulting from the external load, can be found in material .They are the consequence of some other factors, as are: casting, thermal treatment, cold plastic deformation, welding, etc. In the case where residual stresses have the same sign as acting stresses, their sum can exceed elasticity boundary. Permanent plastic deformation is happening then, which is leading to the material decomposition. Besides rigid regulations, which must be fulfilled by the welding construction performers, catastrophic accidents are still trailing welding constructions (2). If the residual stresses have the opposite sign then acting stresses, actual stress state will be less then calculated. Residual stresses as welding consequence are induced by thermal

[1]Faculty of Mechanical Engineering, University of Belgrade;
[2]Faculty of Technology and Metallurgy, University of Belgrade;
[3]Fabrika Vagona, Kraljevo, Yugoslavia

cycles of heating and cooling. With the temperature change, phase changes are occurring, where stress and deformation state are influencing warm crack origination (3). After cooling to the room temperature, pressure or tensile residual stresses are occurring.

Distribution and magnitude of residual stresses in welded constructions are in function of various parameters, as are: quantity of assimilated heat, arc movement velocity, shape, rigidness, welded elements dimensions, and, of course, material properties.

Quantity of assimilated heat is of great importance for stress state analysis, so the heat conductivity in unhomogeneous and anisotropic material is given in base equation:

$$\rho \cdot C \cdot \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(\lambda_x \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(\lambda_y \frac{\partial T}{\partial y}\right) + Q \qquad \text{.................. } 1$$

T - temperature (K)
t - time (s)
ρ - specific mass (gr/cm^3)
C - specific heat (J/kgK)
Q - temperature change velocity over the volume unit

In the case isotropic material with constant conductivity, i.e. $\lambda_x = \lambda_y = \lambda$, well known form of this equation is acquired:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{Q}{\lambda} = \frac{1}{a} \cdot \frac{\partial T}{\partial t} \qquad \text{............................ } 2$$

where is: $a = \frac{\lambda}{\rho} C$; C - thermal diffusion coefficient

INQUIRY METHOD AND EXPERIMENT

Application of magnetic method for residual stress determination will be presented in this paper, on the specimens taken from the spherical tanks. One of the spherical tanks is made of boiler steel Č1204 and the others of microalloyed steel "Nioval 47". For better understanding of magnetic method measurement, basic characteristics will be given. Its operation is based on the magneto-elastic al effect. Two solenoids, positioned with the 90 degrees between them, are base of this device. Solenoids have nucleus made of magnetic material so they can obtain bigger excitation. Device is measuring stress in the plain along the selected direction because of the nucleus orientation, from one to the other pole. Another nucleus is measuring 1kHz response, transversal on selected direction. Therefore, using this equipment, linear stresses can be measured.

Correlation between magnetic properties and stress is obtained through the measure curve. Standard specimen for tensile test is taken out from the same material which is used for these tanks.

Specimen load is increasing until it reaches 0.8Re, i.e. up to the flux boundaries. For every additional step, magnetic characteristics were read and recorded as a reference for later translation to stress values. Residual stress measurement made on boiler steel Č1204 spherical tank were discussed in reference (4), and on "Nioval 47" tank in reference (5). Results from approximately same places on sphere lid will be presented in this paper, Fig. 1. and Fig. 2, for both investigated material.

It is easy to notice in Fig. 1 that the base material residual stresses for carbon steel are mainly in the tensile stress area, except for the measuring points 6 and 9. Tensile stress values are also bigger for carbon then for microalloyed steel. According to the Fig. 2, residual stress is mainly in tensile area or somewhere close to zero. Considerable increase of tensile stress in weld material area (measuring point 5) is very interesting, and it is especially distinctive for microalloyed steel. Residual stress behavior in heat affected zone (measuring points 4 and 6) is principally stipulated with small volume share and different structural characteristics of particular areas in HAZ.

CONCLUSIONS

- Residual stress values obtained by magnetic method, for all specimens, are treated as more reliable then values obtained by direct measurement on welded joints (4,5), which means that the surface condition has great importance on results precision.

- Although obtained residual stress values are lower then 0.8·Re, they can be considered as reliable, but comparison with results obtained by rentgen diffraction technique is necessary.

REFERENCES

1. B.S.Kasatkin, Eksperimentalnije metodi issledovanija deformacii i naprjazenim, Nauk.dumka, 1981 (in russian).

2. H.I.McHenry et al, Analiza loma suda pod pritiskom apsorbera amina, Monografija "Perspektive razvoja i primene mehanike loma", TMF,-Goša, Beograd, 1987 (in serbian).

3. K. Vilken et al, Klasifikacija i ocena metoda ispitivanja sklonosti ka toplim prslinama na zavarenim elementima, Zavarivač, XXXVI, 1991 (in serbian).

4. A. Milosavljević et al, Primena magnetne metode za merenje zaostalih napona na zavarenom loptastom rezervoaru za tečni amonijak, Zavarivač, XXXVI, 1991 (in serbian).

5. A. Milosavljević et al, Odredjivanje zaostalih napona na mikrolegiranom čeliku povišene čvrstoće, Medjunarodna letnja škola mehanike loma, Vrdnik, 1991 (in serbian).

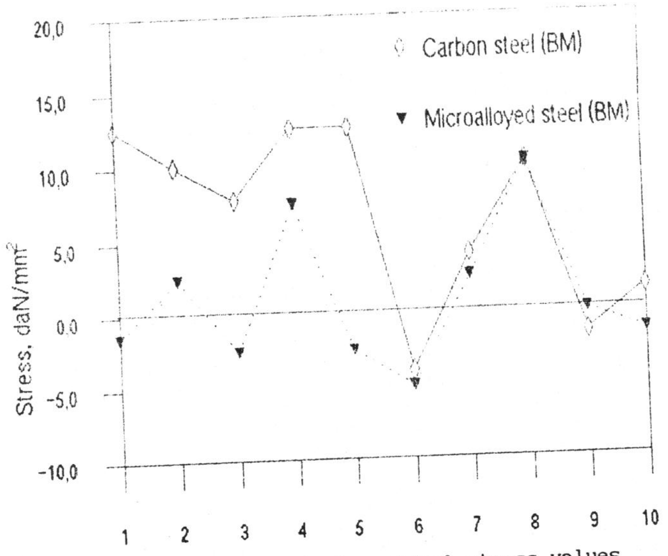

Figure 1. Base material (BM) residual stress values

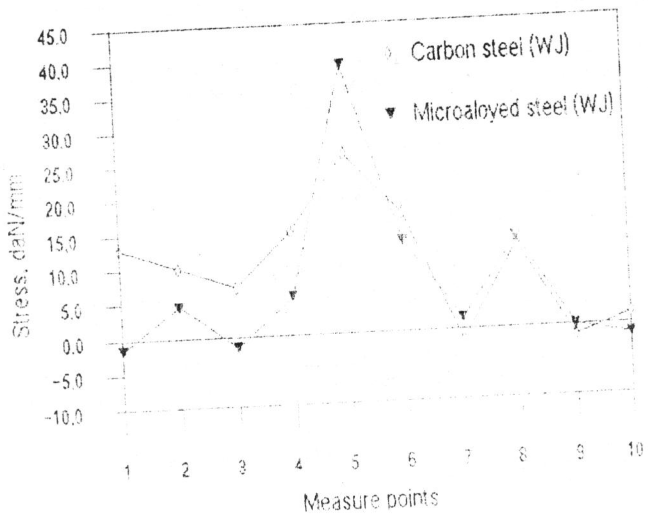

Figure 2. Welded joints (WJ) residual stress values