MEASURING THE RESIDUAL STRESSES IN WELDED JOINTS BY MAGNETIC-ELASTIC METHOD

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Residual stresses are one of the main factors of reliability and life of welded structures under conditions fluctuating loadings, low temperatures, corrosion-active environments. One posibility for non-destructive control of the residual stresses in welded joints used in the pressure pipes of water-power plant on the basis of magnetostriction phenomen has been considered. The way of measuring, the advantages of the method and the area of application are shown. The magnitude and the distribution of the residual stresses in the welded joint has been investigated and as preconditions to estimate the resistance to initation and developement of cracks and spontaneous destruction of the structures.

INTRODUCTION

Residual stresses in the weld are one of the factors wich strongly affect the quality of welded joints and structures. Under certain conditions the accumulated potential energy may cause crack initiation and propagation, fatigue strength decrease, intensification of corrosion processes, etc. One specific characteristic of the stresses in the weld is the fact that they are generated and exist in the welded joint without the action of any external forces. That makes their measuring very difficult. Rapid and precise determination of the sresses in the weld would enable not only the assessment of welded joint relability but also the precising and improving both their structure and welding technology.

INVESTIGATIONS

This work presents the results of the investigations of residual stresses in the weld pressure water conduit of pumped-storage plant "Chaira". These investigations have been carried out for the purpose of proving

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its reliability and serviceability after an emergency situation by means of original apparatures and methods based on magnetostriction phenomenon-elastic size change of feromagnetic group in a magnetic field. Relative changes in length are in the order of 10E-5 at a magnetic field strength of 100 Oersted. Residual stresses in the weld, on the other hand, cause elastic change of crystal lattice parameters which leads to the respective change of the magnetic characteristics. This change is registered and compared with the data obtained for free specimen. The procedure is carried out by means of specially designed device with a magneto-elastic transducer.

Measurement of residual stresses is connected with the callibration of the dependence of the device relative indications $\Delta\mu$ on the stress magnitude σ_N (MPa). For a given ferro-magnetic material such dependence is determined through testing of heat treated reference specimens from the studied material.

Heat treatment effect on the relation $\sigma_N = f(\Delta\mu)$ is shown in Fig1. The diference in the measuring device indications is due to residual stresses in the tested material, resulted from the preceding technological operations. The data show that the heat treatment of the reference specimens is a necessery condition for achieving correct measuring results. Each respective type of specimen is subjected to tension and compresion to yield strength σ_{ys} and then released. Stress is calculated in accordance with the formula $\sigma_N = P/F$, MPa, where P is the force (N), F is the cross sectional area of the tested specimen (m^2). Results are averaged and the dependence of stress on the relative indications of the device is set $\Delta\mu$ .Fig.1 shows the dependence $\sigma_N = f(\Delta\mu)$ for the tested steel, set after numerical processing of the data obtained by means of regression analysis.

Tested HT-80 steel joint has been made by manual coated arc welding with electrodes of the LB - 118 type.

Chemical compositions of base material as well as their mechanical parameters are given in Table.1 and Table 2.

Table 1

C	Mn	Si	P	S	Ni	Cr	Mo
0,06	1,5	0,54	0,012	0,007	1,84	0,27	0,43

Table 2

σ_{YS}, (MPa)	σ_{TS}, (MPa)	A_5, %	σ_S, (-20°C)
720	820	23	110 J

Measuring have been carried out at four sections of the welded joint, the relative position of which is shown in Fig.4. Section surfaces have been cleaned of oxides, stain, paint and spatter of molten metal and their class of roughnes does not exceed 2.5 as per Bulgarian State Standard 783-74 and the radius of curvature is not less than 30 mm. The influence of tested surface roughness on the measuring device indications is shown in Fig.3. The surface, prepared in these way, has been lined up as shown in Fig.4. Transducer orientation as a function of the magnetostriction coefficient of the test material has been strictly maintained in the measuring process.

RESULTS

Measuring results obtained by means of the relation $\sigma_N = f(\Delta\mu)$ are shown in Fig.2. Main stresses obey the dependences [1]:

$$\tau_{xy} = (\sigma_x + \sigma_y)/(2\sin 2\alpha) + [(\sigma_x - \sigma_y)\cos 2\alpha]/(2\cos 2\alpha) - (\sigma_\alpha)/(\sin 2\alpha)$$

$$\sigma_1, \sigma_2 = (\sigma_x + \sigma_y)/2 \pm \{[(\sigma_x - \sigma_y)/2]^2 + \tau_{xy}^2\}^{1/2}$$

and stress direction is determined by :

$$tg 2\alpha = (-2\tau_{xy})/(\sigma_x - \sigma_y)$$

Maximum value of main stress has been obtained at point No2, location 1, i.e., at the same position where axial stress σ_x maximum value has determined, but σ_1 value exceeds σ_x value by 61.73 % and its direction is declined for -19°32'51" (Fig.4.) to these the σ_x direction.

Analysis of measured results shows the following:

1.Maximum measured residual stresses have the value of 324.26 MPa, representing about $0.4\sigma_{YS}$ and their direction is shown in Fig.4. They can't be an independent cause for cold weld crack initiation and propagation.

2.Stresses registered at points 8 and 9, location 2, can by assumed as basic, i.e. existing at all locations in the pipe.

CONCLUSION

By means of apparatures and method developed it is possible to determine the value, direction and sign of the residual and operating stresses in ferromagnetic materials. The method is non-destructive, can be used for proximate analysis and is applicable both in laboratories and regular production.

REFERENCES

1.Roark R.I. Formulas for Stress and Strain. N.Y. Mc Graw - Hill Book Co, 1974. 378 p.

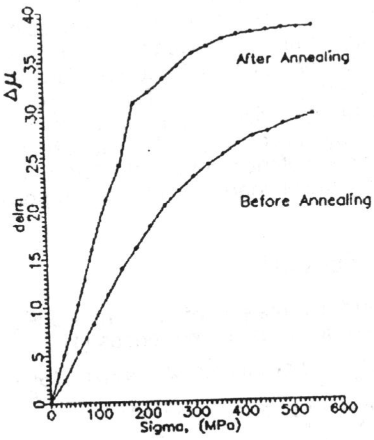

Fig.1. Stress as a function of transducer relative indications

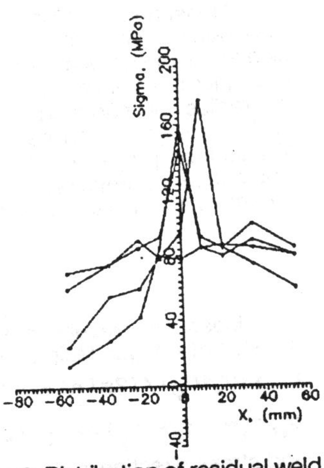

Fig.2. Distribution of residual weld stresses in the measured section at location 1,2,3 and 4.

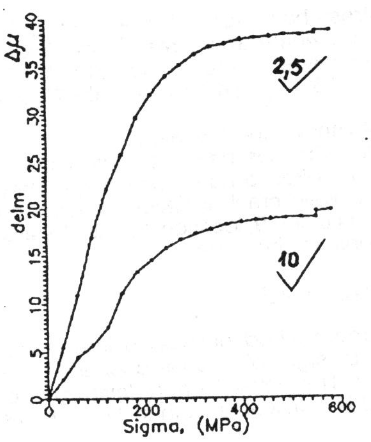

Fig.3. Surface roughness effect on the relation $\sigma_N = f(\Delta\mu)$

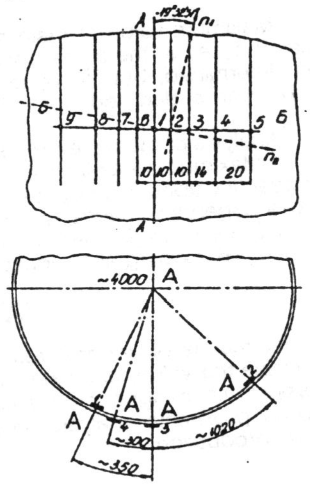

Fig.4. Position of measured locations (1-4) and of mesured points (1-9) at every location