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ANALYSING OF STRESS STATES APPLIED ON WELDED SAMPLES WITH STRAIN GAGE ROSETTES

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ABSTRACT

Residual stress states in structural parts can cause the harmful but also a favorable effects on strength, depends of that are the stresses disposed in the same direction or oposite direction. In every case for the evalution of structural part behaviour it is advantage to know more correctly residual stress states.
Measuring and calculation of welding residual stresses it is possible determine with electro-resistance strain gage rosettes applying drill-hole method.Results of these measurements can be compared with the results acquired by other methods.Most often for the comparison we establish mathematical model where we applying computer modeling and simulation of welding parameters.
In this work it is given an analysis of residual stresses in welded samples by mathematical modeling with the calculation results acquired with drill-hole method and strain gage rosettes.
Keywords : welding, strain gage rosettes, residual stresses, deformations, welding parameters, stainless steel

1. INTRODUCTION

Local input of heat is the cause of residual stresses and residual strains. When strong tensions occur during heating or cooling in any zone over (vield strength) constant strains appear, then after complete cooling residual stresses will appear in that area. Residual stresses occur in coldly deformed items as well, during heat treatment in castings and forgings, during each local heating on the temperatures when material transfers to plastic state. Grinding with strong local heating will result in residual stresses on strain.
During welding quasi – stationary elastic field of current stresses can be set up based on temperature fields, e.g. for fast moving linear source in an infinite thin tin:

$$\sigma_x = -\frac{\alpha \cdot \mathrm{E} \cdot q}{4\pi \cdot \lambda \cdot \delta} \left\{ \exp\left(-\frac{\nu x}{2a}\right) \left[Y_0\left(\frac{\nu \cdot r}{2a}\right) - \frac{x}{r} Y_1\left(\frac{\nu \cdot r}{2a}\right) \right] + \frac{2a \cdot x}{\nu \cdot r^2} \right\} \qquad (1)$$

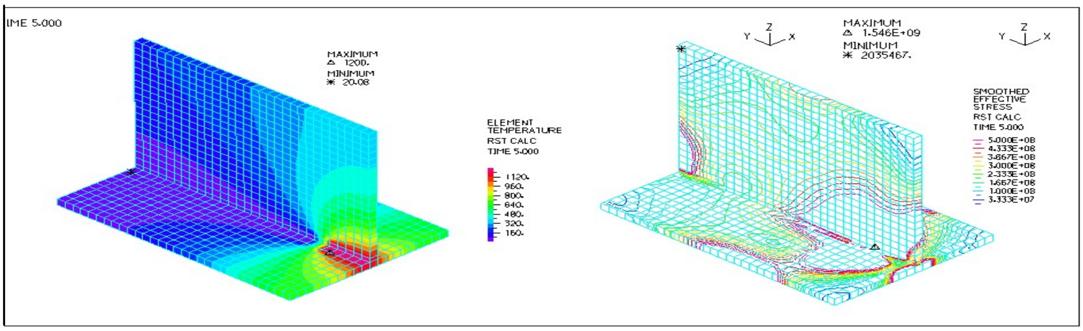
$$\sigma_y = -\frac{\alpha \cdot \mathrm{E} \cdot q}{4\pi \cdot \lambda \cdot \delta}\left\{\exp\left(-\frac{\nu x}{2a}\right)\left[Y_0\left(\frac{\nu \cdot r}{2a}\right)+Y_1\left(\frac{\nu \cdot r}{2a}\right)\right]-\frac{2ax}{\nu \cdot r^2}\right\} \qquad (2)$$

$$\tau_{xy} = \frac{\alpha \cdot \mathrm{E} \cdot q}{4\pi \cdot \lambda \cdot \delta}\left[\exp\left(-\frac{\nu x}{2a}\right)\frac{y}{r}+Y_1\left(\frac{\nu \cdot r}{2a}\right)-\frac{2ay}{\nu \cdot r^2}\right] \qquad (3)$$

Y_0 and Y_1 are Bassel's functions of second kind of zero, or of first order. σ_x are stresses in the direction of weld, and σ_y vertically to weld. This defined field is idealized. Bodies do not act totally linear and plastic deformations occur, so it is better to use elastic – plastic field of thermal stresses. Besides thermal residual stresses, during welding internal stresses also appear because of increase of volume during structural transformations.

2. PROBLEM'S DESCRIPTION

For the needs of research greater number of samples was made (welded). On all samples research of stress and strain field was preformed as the most often kind of geometry discontinuity under the influence of thermomechanical stress.
Numerical analysis was done by final element method using program package. It is analyzed stress status for different material thickness and different welding parameters. By this method it is determined stress and strain status on discontinuity of geometry of analyzed samples.
Experimental analysis was done using method of electro – resistant strain gauges on measuring – amplifying system for measuring of mechanical variables. For setting, data transfer and visualization software "Catman Easy" was used as well as system of electronic measuring on PC (Spider 8). In this way local strain variables were received of research samples in laboratory conditions. On selected models of same geometry and thermo – mechanic load, that were used in numerical analysis, measuring of strains in particular points were performed, that were later calculated in stresses. In this way results of numerical analysis using procedures for computer modeling and calculating were verified.



Picture 1. 3D model, Presentation of distribution of temperatures and stresses

On picture 1 3D presentations of model of final elements is given, which was used for analysis of temperature distribution, stresses and strains in the elements of considered construction. During this shell elements were used.

$P = U \cdot I$ *(J/s)....................................(5)*

Where: U – voltage (V), and I – current (A)
Effective power transferred from the source in the material that is being welded is

$P_{ef} = U \cdot I \cdot \eta = P \cdot \eta$ (J/s) ....(6)

Where η is - efficiency of energy source *(* $\eta = 0{,}45 \div 0{,}75$ *).*

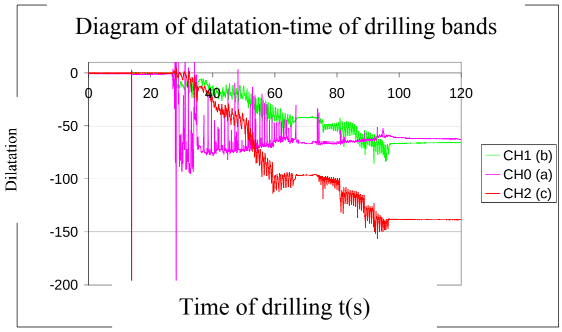
Effective operative energy or heat input – linear energy is:

$$E_{ef} = U \cdot I \cdot \eta / v = P_{ef} / v \ (J/mm) \quad (7)$$

Where v – welding speed (mm / s)

3. CALCULATION OF MAIN NORMAL STRESSES

3.1. Calculation of main normal stresses – sample of 5mm thickness



Picture 2. Diagram of measuring of dilatations during drilling of sample through rosette

Table 1. Values of dilatation of strain gauge (ε) on the sample of 5mm thickness

CH [μm/mm]	ε		$\Delta\varepsilon_a$	$\Delta\varepsilon_b$	$\Delta\varepsilon_c$
	Before measuring	After measuring	$\Delta\varepsilon_a = \varepsilon_{da} - \varepsilon_{ra}$	$\Delta\varepsilon_b = \varepsilon_{db} - \varepsilon_{rb}$	$\Delta\varepsilon_c = \varepsilon_{dc} - \varepsilon_{rc}$
CH 1 (b)	$\varepsilon_{rb} = 0{,}72$	$\varepsilon_{db} = 62{,}16$		**61,44**	
CH 2 (c)	$\varepsilon_{rc} = 0{,}24$	$\varepsilon_{dc} = 138{,}48$			**138,24**
CH 3 (a)	$\varepsilon_{ra} = 0{,}24$	$\varepsilon_{da} = 66{,}24$	**66,00**		

3.1.1. Main normal stresses σ_1 and σ_2 are calculated according to formula:

$$\sigma_{1,2} = -\frac{E}{4A}\left(\Delta\varepsilon_a + \Delta\varepsilon_c\right) \pm \frac{E}{4A}\sqrt{\left(\Delta\varepsilon_c - \Delta\varepsilon_a\right)^2 + \left(\Delta\varepsilon_a + \Delta\varepsilon_c - \Delta\varepsilon_b\right)^2}$$

Where:

E – module of elasticity of measuring material

A and B – constants that can be determined in following manner:

$$A = \frac{a^2\left(1+\nu\right)}{2r_0 \cdot r_i}; \qquad A = \frac{2a^2}{r_0 \cdot r_i} \cdot \left[1 - \frac{a^2\left(1+\nu\right)\left(r_0^2 + r_0 \cdot r_i + r_i^2\right)}{4r_0^2 \cdot r_i^2}\right]$$

ν - Poisson's coefficient for measuring material

r_0 – outer radius of measuring grid

r_1 – interior radius of measuring grid

a – radius of drilled hole

Module of elasticity and Poisson's coefficient for CrNi steal is

$E = 200000$ N/mm^2 ; $\nu = 0{,}28$

For drilled hole of rosette of type RY 61 values of $r_{0,}$ r_1 and a are:

$r_0 = 3{,}3$ mm , $r_i = 1{,}8$ mm , a = 0,75 mm.

A and B are the constants depending of the size of applied rosette and are calculated as

$A = 0{,}04735\ (1 + \nu) = 0{,}04735\ (1 + 0{,}28) = 0{,}060608$

B = 0,1894 – 0,01515 (1 + ν) = 0,1894 – 0,01515 (1 + 0,28) = 0,170008

$$\sigma_1 = -168,596 - 47,06 = -215,656 \left[N / mm^2 \right]$$

$$\sigma_2 = -168,596 + 47,06 = -121,536 \left[N / mm^2 \right]$$

Results received measuring of sample right after welding show that main stresses are on the limit of allowed stresses (σ_{dop}). Sample which is object of this measuring is welded with intentionally selected bed parameters of welding. Speed of welding was v = 5 cm/min which led to input of large amounts of heat that negatively influenced on the occurrence of residual stresses. Before measuring it was impossible for timely relaxation of stresses.

3.1.2. Angles of main stresses

For applied rosette RY 61 (0° / 45° / 90°) formula for calculation of angles of main stresses is:

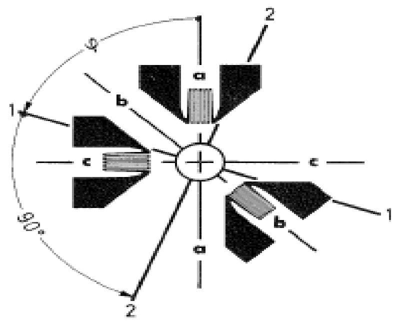
$$tg\psi = \frac{2\Delta\varepsilon_b - \Delta\varepsilon_a - \Delta\varepsilon_c}{\Delta\varepsilon_a - \Delta\varepsilon_c} \left| \frac{z}{n} \right. = \frac{2 \cdot 61,44 - 66,00 - 138,24}{66,00 - 138,24} = \frac{-81,36}{-72,24}$$

$$\psi = arctg 1,126245847 = 48^\circ 23' 52''$$

$$\varphi = \frac{1}{2}\left(180^\circ + \psi\right) = \frac{1}{2}\left(180^\circ + 48^\circ 23' 52''\right) = 114^\circ 11' 56''$$ - pravac glavnog napona 1-1,

Straight line of main stress 2 – 2 is vertical direction of main stress 1 – 1, so it is added 90° and in this case it is 204°11′56′′

z	≥ 0	> 0	≤ 0	< 0
n	> 0	≤ 0	< 0	≥ 0
φ	$\frac{1}{2} \arctan\left\|\frac{z}{n}\right\|$ $0 \leq \varphi < 45^\circ$	$\frac{\pi}{2} - \frac{1}{2} \arctan\left\|\frac{z}{n}\right\|$ $45^\circ \leq \varphi < 90^\circ$	$\frac{\pi}{2} + \frac{1}{2} \arctan\left\|\frac{z}{n}\right\|$ $90^\circ \leq \varphi < 135^\circ$	$\pi - \frac{1}{2} \arctan\left\|\frac{z}{n}\right\|$ $135^\circ \leq \varphi < 180^\circ$



Picture 3. Directions of main stresses

4. CONCLUSION

Tensometric methods of experimental analysis confirmed the accuracy of residual stresses and strains received using method of final elements processed in software package for computer modeling and calculation and hence necessity of using method of final elements imposes itself in solving problems on welded structures.

Numerical analysis of concrete structure, by defining parameters of welding and of order of laying certain passages of weld can result in allowed stresses and strains and so crossing of critical stress states will not occur.

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