TEST METHOD FOR DETERMINING INTERNAL STRESSES IN MATERIAL OF DESIGN BY MAGNETIC METHOD

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Scheme determination residual stresses arise from necessity of objective control quality by heating or control strain-stress statement construction at the time of exploitation. The value and distribution of residual stresses can be communicatory description for determination resource of material construction.

The main point of our express method consist in measuring magnetic parameter of material and converting this parameter in stress. For this method realization strukturoskop "КРМ-Ц-К2М" was used. The surface strain relief to the relieved principal stresses by the following relationship (1):

$$Hc_i = (C + D\cos 2\beta)\sigma_{\max} + (C - D\cos 2\beta)\sigma_{\min}, \qquad (1)$$

where:

Hc_i – magnetic parameter (Ampere/centimeter);

C and D – coefficients, which depend on behaviors by controllable material;

β - angle, which define the direction of component tensor stress σ_{max} relative zero direction "0";

σ_{max}, σ_{min} – maximum(most tensile) and minimum (most compressive) principal stresses on surface object investigation of control area.

Physical sense of magnetic parameters σ_{max}, and σ_{min}:

In object without deformations molecules location correspond to state of its thermal balance. If this object is deformated thermal balance changes and molecules in object transference. The forces which aspire to return object in arise balance state at that moment.

Usually these forces are represented as a three-dimensional tensor and it is considered off that this tensor is symmetrical.

$$\sigma_{ik} = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{bmatrix},$$

$$\sigma_{ik} = \sigma_{ki}.$$

The symmetrical tensor can be reduced to diagonal form:

$$\sigma_{пл} = \begin{bmatrix} \sigma_{\max} & 0 \\ 0 & \sigma_{\min} \end{bmatrix}$$

In respect to physics σ_{max}, and σ_{min} present the principal components of stress in flat task examination.

The parameters σ_{max}, and σ_{min} in that case define stress state in field of measuring.

Figure 1 presents σ_{max}, and σ_{min} as vector image of these parameters:

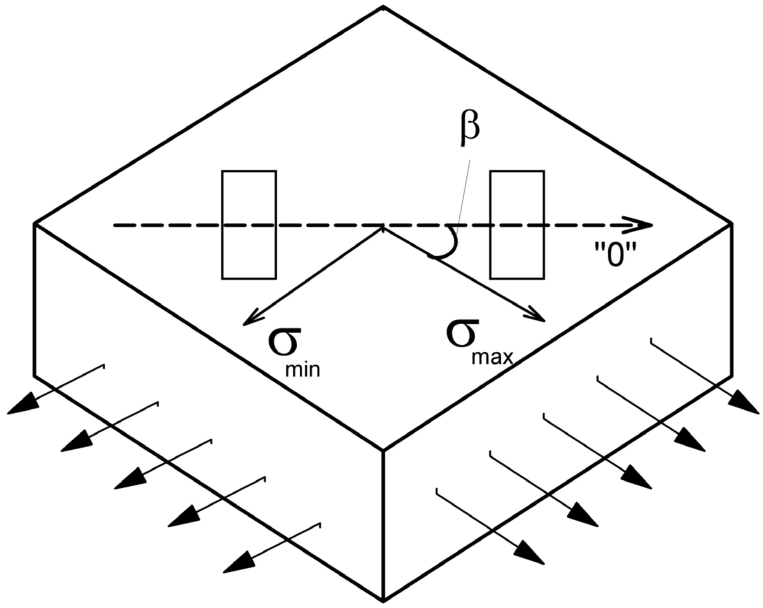
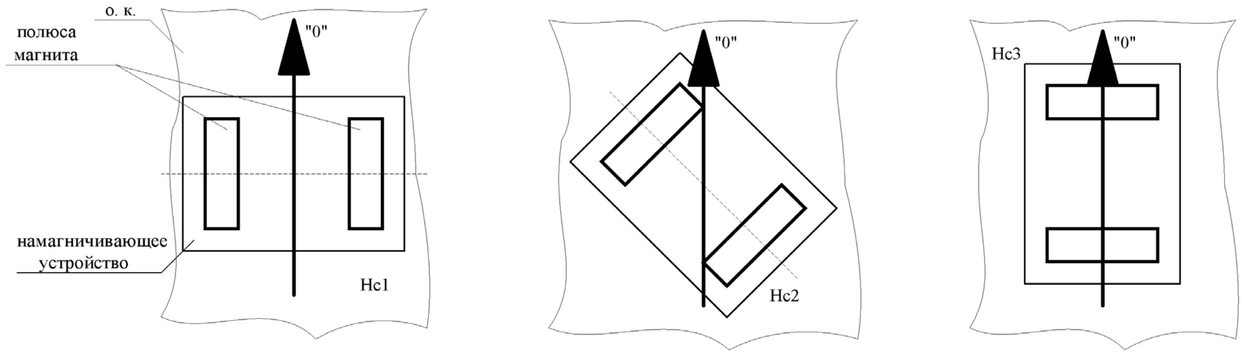


Fig.2. The vector image of σ_{max}, and σ_{min}.

In the area of control so called zero axis “0” is selected. Positions of magnetizer at time of measuring in regard to zero axis “0” are placed.

The positions of magnetizer is regard to concerning zero axis are schematically illustrated in Fig 2:



As measuring equipment is used П-shaped magnet with pulse magnetization. Getting one value of stress is possible during the six measures of the magnetic parameter receipt (meaning in tree positions).

Intermediate parameters p, q, t, S1 and S2 are the determined with help of measured magnetic parameters Hc_1, Hc_2, and Hc_3 by formulas (2) and (3):

$$p = \frac{Hc1 + Hc3}{2}, \quad q = \frac{Hc3 - Hc1}{2}, \quad t = \frac{Hc1 + Hc3 - 2Hc2}{2} \tag{2}$$

$$S1 = p + \sqrt{q^2 + t^2}, \quad S2 = p - \sqrt{q^2 + t^2} \tag{3}$$

Components of stress tensor σ_{max}, σ_{min} and angle β are calculated by expressions (4)-(5):

$$\begin{bmatrix} \sigma_{\max} \\ \sigma_{\min} \end{bmatrix} = \begin{bmatrix} C-D & C+D \\ C+D & C-D \end{bmatrix}^{-1} \cdot \begin{bmatrix} S1 \\ S2 \end{bmatrix} \tag{4}$$

$$\beta = arctg\left(\frac{t}{q}\right) \tag{5}$$

Coefficients C and D are connected with magnetic and mechanical characteristics of the material. These coefficients are stable for all area of construction. Coefficients C and D may be founded by measuring magnetic parameters of material and residual stresses at some areas of construction. RS can be founded by hole-drilling strain-gage method (ASTM E-837-01$^{\epsilon}$).

Experiments for determining RS were made on the railway wheel rim. The wheel was subjected to special heating. Residual stresses determination served as an important technological task.

Fig 3 shows railway wheel with measuring instrument at the time realization test-method in condition workshop.

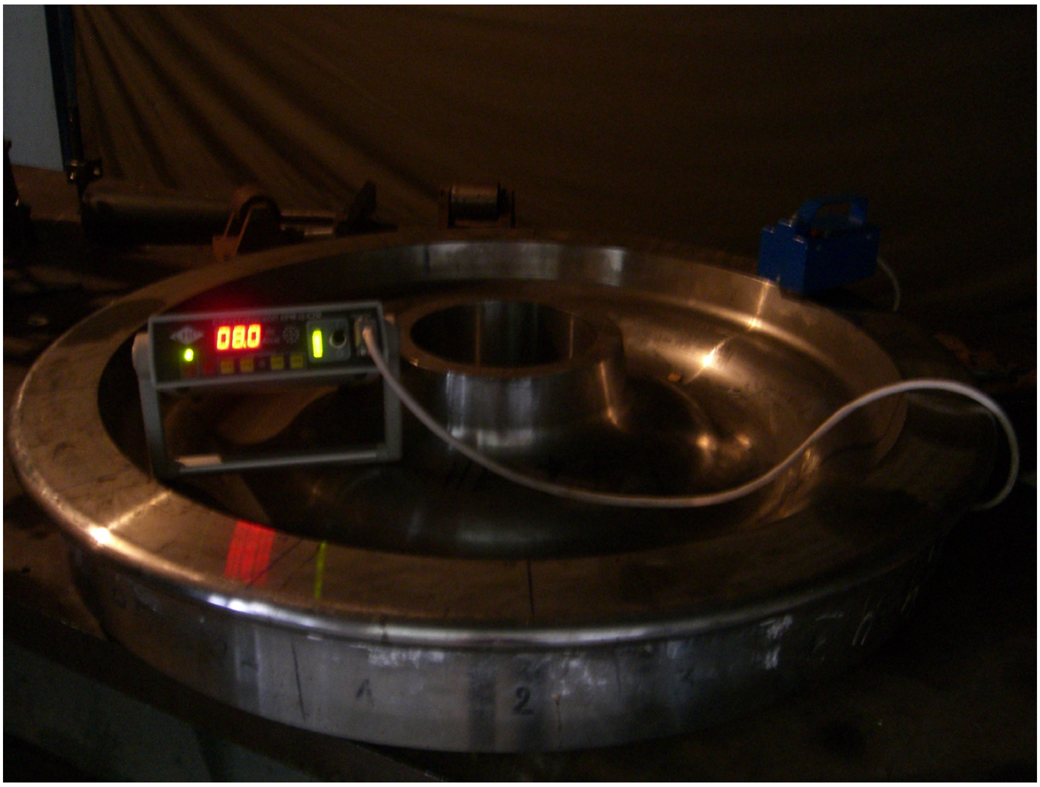


Fig. 3. The photo of railway wheel.

The results calculated by magnetic method and other often described “semi-destructive” method are presented in Table 1 and showed in Fig.4:

Table 1. The comparison results calculated by magnetic and “semi-destructive” methods.

	Sector 1		Sector 3		Sector 10	
	Strain Gage	Magnetic	Strain Gage	Magnetic	Strain Gage	Magnetic
σ_{max}, MPa	368,24	410,23	459,58	491,16	187,61	264,76
σ_{min}, MPa	-394,51	-352,52	-450,23	-433,81	-222,57	-206,88
β°	0	7	0	0	-1	-5
σ, MPa	539,67	540,88	643,36	655,31	291,13	336,0
α°	47	48	44	41	49	32

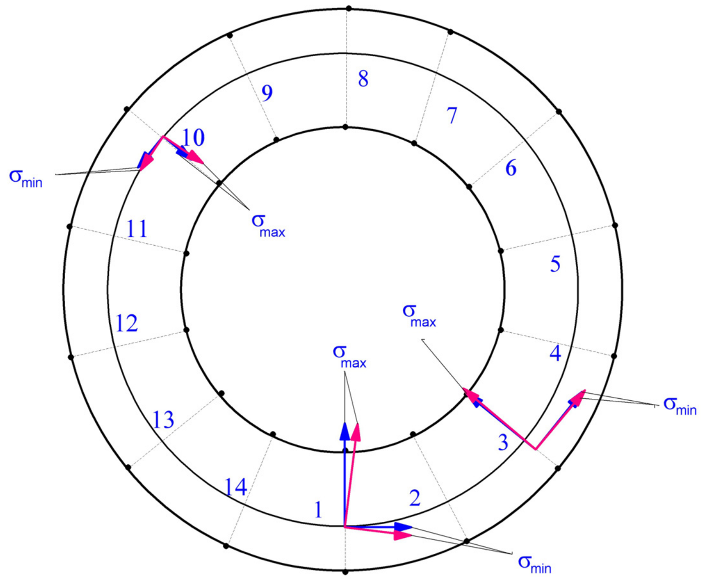


Fig. 4. The comparison results calculated by magnetic and “semi-destructive” methods.

The results of magnetic method conform with results of strain gage method. Operational properties comparison of these two test-methods is presented in Table 2:

Table 2. Results of magnetic and strain gage methods.

	Magnetic method	Strain Gage method
Duration test	2-3 minutes	35-45 minutes
Surface	No demand	Ra≤2.5micrometre
Complexity of measuring (quantity of technological operations)	1	5
Consumable	Not necessary	Strain-gages, glue, emery paper

Thus our test-method permits to receive values of residual stresses which are comparable with values received by strain gage test-method

This test-method was applied at various large size products: tubing, welded constructions, extensive pipelines.