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THE RESIDUAL STATE OF STRESS IN OLD RAILROADS FOR PUBLIC TRANSPORT BY TRAM VEHICLES

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Abstract: *Nowadays , a lot of the tram lines in the city of Timisoara are under a complete modernization process. From financial reasons , some of the railroad lines must be kept in service and rectified from time to time without dismantling. The paper suggests a non-destructive experimental method which can estimate the state of residual stress in old urban transport railroads. In order to estimate the state of stress, the strain gage measurement procedure is preferred.*
Keywords*: rail, stress, wear, strain gage*

1. INTRODUCTION

The city of Timişoara is located in the south-west Romania`s side ,closely to the border with Serbia and Hungary. The main public transport operator in the city of Timisoara is the Public Transport Administration Timişoara (R.A.T.T.) which continues a tradition of 130 years. Nowadays, R.A.T.T. provides 57,7% of the city`s transportation, which means 52 millions people transported a year. The tram line network passes through narrow streets covering a distance of 90,2 km. The swampy soil is inadequate for an underground transportation, so the surface transportation is prevalent. Some of the railroads have a very old design .During the last years, the wear of the rail and the level of noise strongly increased.

2. WORKING PROCEDURE

The experimental strain gage method consists in drilling the railroad in different areas (head, basement and core of the rail profile).Usually the hole diameter is of 6 mm and the depth is 9 mm. The bending capacity of the railroad is not adulterated after the drilling procedure and it can be kept in service. As a consequence of the drilling process, the residual surface stresses vanish around the hole, the deformations on three directions are measured with a 3/120 rosette transducer and the values of the previous residual stresses will be calculated using a special software. In figure 1 you can see : 2a-the hole diameter; σ_r-the radial stress; σ_t –the circumference stress; σ_1-the main maximum stress; σ_2-the main minimum stress; r-the radial distance between the center of the hole and the point of interest; θ-the central angle. For a reference plate without any hole (a=0) ,the radial and circumference stresses are, (Heymann ,1986; Mocanu et. al., 1985):

$$\sigma_r`=\frac{1}{2}(\sigma_1+\sigma_2)+\frac{1}{2}(\sigma_1-\sigma_2)\cos 2\theta \qquad (1)$$

$$\sigma_\theta`=\frac{1}{2}(\sigma_1+\sigma_2)-\frac{1}{2}(\sigma_1-\sigma_2)\cos 2\theta \qquad (2)$$

As a consequence of the drilling process, the residual surface stresses vanish around the hole and the deformations on three directions are measured with a $3/120^0$ rosette transducer (figure 1).

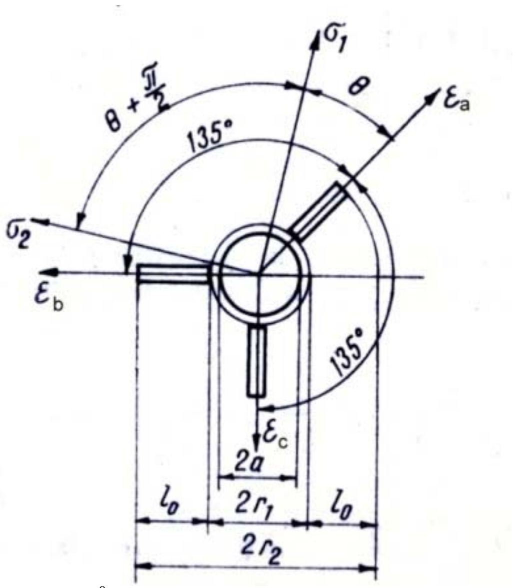

Fig.1. The $3/120^0$ rosette strain gage transducer

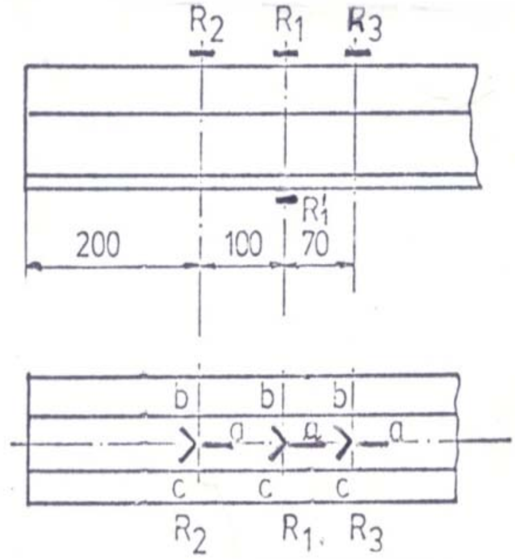

Fig. 2. The location of the rosette (triple) strain gage transducers

The deformations vary as it follows :

$$\varepsilon_r-\varepsilon_\theta=-\frac{1+\nu}{E}(\sigma_1+\sigma_2)\frac{a^2}{r^2}+\frac{1+\nu}{E}(\sigma_1-\sigma_2)\left(-2\frac{a^2}{r^2}+3\frac{a^4}{r^4}\right)\cos 2\theta \qquad (3)$$

The main stresses σ_1 , σ_2 and the central angle θ must be estimated. So , the state of surface stresses will be completely defined.

For that purpose, the deformations on the three directions are experimentally measured:

$$\varepsilon_a = \frac{A}{E} (\sigma_1 + \sigma_2) + \frac{B}{E} (\sigma_1 - \sigma_2) \cos 2\alpha \quad (4)$$

$$\varepsilon_b = \frac{A}{E} (\sigma_1 + \sigma_2) + \frac{B}{E} (\sigma_1 - \sigma_2) \cos 2(\alpha + 135) \quad (5)$$

$$\varepsilon_c = \frac{A}{E} (\sigma_1 + \sigma_2) + \frac{B}{E} (\sigma_1 - \sigma_2) \cos 2(\alpha - 135) \quad (6)$$

where A and B are measurement constant values; E-Young`s modulus.

The values of the previous residual stresses (σ_1 -maximum stress; σ_2 -minimum stress) will be calculated using a special software:

$$\sigma_1 = \frac{E}{4A} (\varepsilon_b + \varepsilon_c) + \frac{E}{4B} [(2\varepsilon_a - \varepsilon_b - \varepsilon_c)^2 + (\varepsilon_c - \varepsilon_b)^2]^{1/2} \quad (7)$$

$$\sigma_2 = \frac{E}{4A} (\varepsilon_b + \varepsilon_c) - \frac{E}{4B} [(2\varepsilon_a - \varepsilon_b - \varepsilon_c)^2 + (\varepsilon_c - \varepsilon_b)^2]^{1/2} \quad (8)$$

$$\text{tg } 2\theta = \frac{\varepsilon_c - \varepsilon_b}{2\varepsilon_a - \varepsilon_b - \varepsilon_c} \quad (9)$$

3. RESULTS

Some experimental results (for the location of the rosette transducers in figure 2) are presented in table 1. The measured values of deformations and the calculated values of the main surface stresses are shown in the table 1.

ε_a [μ m/m]	ε_b [μ m/m]	ε_c [μ m/m]	σ_2 [MPa]	σ_1 [MPa]
45	170	175	155	185
-288	-300	-250	215	230
-225	-35	-80	-15	100
70	125	30	-65	-55
180	365	230	-250	-165
230	405	310	-280	-210
-190	220	-270	-175	-110
-495	-190	-255	-270	-255
150	170	75	-200	-50
-140	120	-40	-80	-30
-25	-40	45	-50	20

Tab. 1. The measured values of deformations and the calculated values of the main surface stresses

4. CONCLUSIONS

The values of the residual main stresses in the rail cover a stress range between –280 MPa and 230 MPa. The state of stress due to the vehicle loading will be superimposed on the residual state of stress. The location of the extreme values of the maximum and minimum main stresses is on the rail head surface. High stress values and faults or cracks located in the same region may lead to dangerous effects on the safety and comfort of the passengers,(Safta et al, 1986) .

In order to remove in depth the points of maximum stresses from the lateral rail head surface, the lubrication maintenance procedure is usually used. A mobile lubrication push-cart ensures the lateral lubrication of the linear portions of railroads on a distance of 200 meters. The device will be assembled on the front side of the experimental tram maintenance vehicle.

In association with the level of stresses, the proposed maintenance inspections include a periodical combined strain gage measurements and an ultrasonic procedure (in order to detect the cracks) every 6 months in different points on the route, especially the high crowded traffic areas. In order not to disturb the tram-traffic, these inspections are usually performed at night. Because of the high amount of measured data ,special automated measuring wagons have been introduced in order to inspect portions of 20-40 km of rail.

The rectification procedure of the rail head is allowed until a distance of 5 mm from the standard profile, because of safety reasons. The derailment coefficient at the wheel-rail contact (which means the ratio between the guidance lateral force from the rail and the vertical force on the wheel) must be less than 1,2-1,3. , (Ghita, 1998; Ghita & Turos ,2006).

From financial reasons, the rectification and the lubrication are performed first. However, the safety measures impose the replacement of the railroad whenever the residual stresses reach 250 MPa and the cracks are longer than 1 mm.

The proposed method is preferred because that is a half-destructive method ,but the bending capacity of the rail is not adulterated after the drilling procedure.

The ultrasonic crack analysis may be performed with a portable ultrasonic crack detector ,a lightweight, compact and handy-portable flaw detector designed for use on large workpieces and in high-resolution measurements, (*** USM 25,2001).

5. ACKNOWLEDGEMENTS

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