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STRAIN GAUGE MEASUREMENTS FOR ESTIMATING THE SAFETY OF ROLLING PROCESS

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Abstract: The present paper is focused on some experimental measurements concerning forces appearing at contact between wheel and rail during the rolling process. Experiments have been performed for real working conditions on a railway testing circuit located near Bucharest. Strain gauge measurements have been preferred in order to estimate some typical parameters for the safety of the rolling process.
Keywords: railway, rolling, transducer

1 INTRODUCTION

The estimation of the parameters characterizing the safety of the rolling process is representing a problem of a great importance for railway administrations. There were used special measuring axles, produced by A.F.E.R. (Romanian Railway Authority) Bucharest, which were assembled as driving axles of a LDU 450 CP railway engine. The vertical contact force "Q" between wheel and rail, as well as the lateral contact force "Y", have been estimating by using the strain gauge technique, [1],[2]. There were used spoken wheels, having 10 real spokes and 10 faked additional spokes.

2 VERTICAL, LATERAL AND LONGITUDINAL CONTACT FORCES

For vertical force measurements, strain gauges a, b were placed in the area with circular hole of the additional spokes (fig. 1). A faked additional spoken consist in a responsive element with strain gauges (1), the rim area(2), the hub area (3) and connective elements(4).

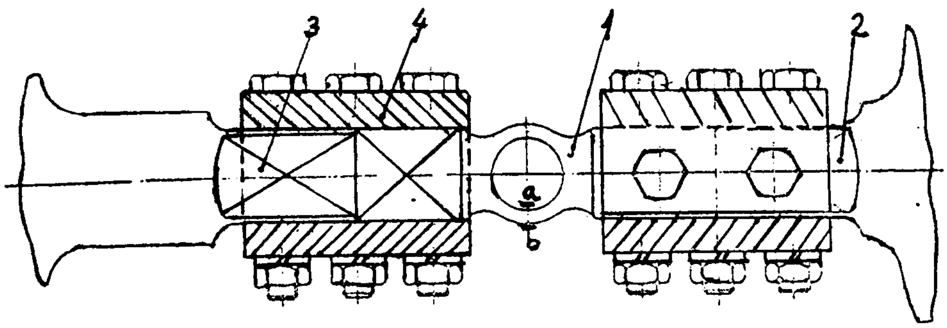

Figure 1. Faked additional spoken for vertical force measurements in a rolling contact problem.

It was prefered an electric bridge connection, as in [2], between strain gauges placed on every faked spoke.

The electrical signal, converted as the strain is proportionally influenced by the vertical contact force "Q".

For lateral force measurements, strain gauges were placed on the real spokes (fig.2).

There was used the classical "technique of two torques", [1], which eliminate the influence of vertical "Q" force on the electrical circuit for estimating the lateral "Y" force.

For a spoken railway wheel, a real spoken is presented in figure 2:

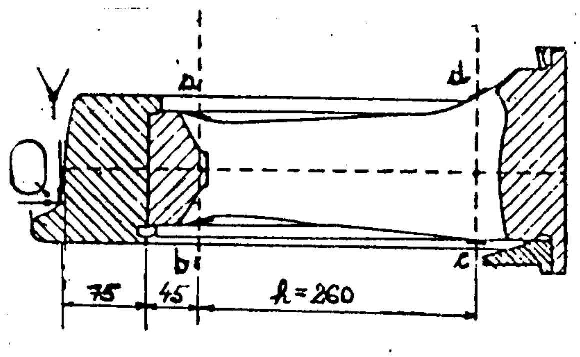

Figure 2. Real spoken for lateral force measurements in a rolling contact problem

A special electrical connection for the circuit extended for five real spokes, as in [2], has been performed.
Lateral contact force "Y" was estimated as:

$$Y = (M_{II} - M_{I}) / h \tag{1}$$

The electrical signal, converted as the strain is proportionally influenced by the bending torques M_I, and M_{II}. The radial distance between the two pairs of strain gauges a, b respectively c, d placed in the cross-sections I and II, was considered as h=260 mm.

For longitudinal force measurements, there was used an electric measuring system, as in figure 3:

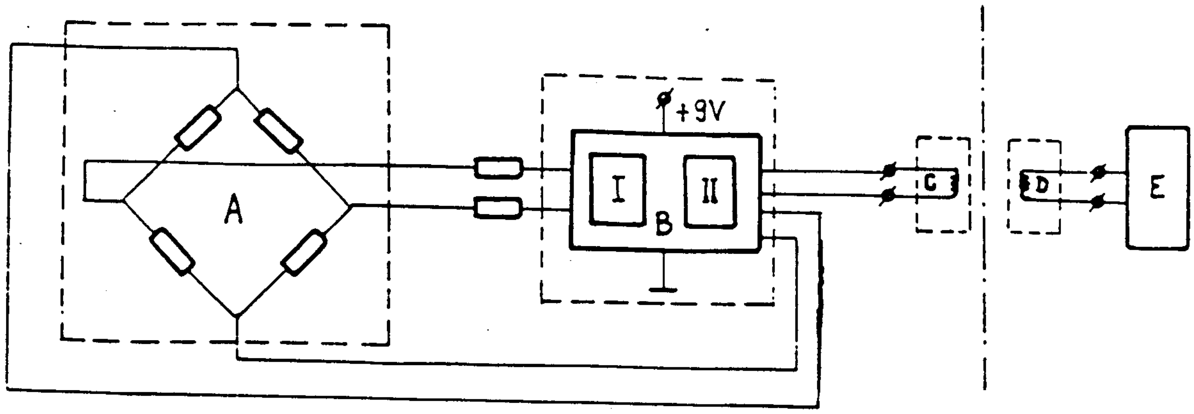

Figure 3. Electric measuring system for longitudinal force measurements

The working on principle is based on the frequency modulation between an arbitrary sinusoidal signal and an electric signal which is proportional with the torsional torque acting on the axle. The influence of the torsional torque has been assumed from the diagonal of an electric bridge connection which consists in four strain gauges placed at 45° in the ending cross-section of the axle. The arbitrary sinusoidal signal was supplied by an electric
oscillator B, composed by two modules I and II. The electric elements A and B, together with an emission coil C and a 9 V battery have been assembled on the measuring axle and were rotated together with the axle. A reception coil D has been placed on an immobile structure of the railway engine, in the near vicinity of the emission coil C.
The reception coil D transmitted the measuring electric signal to a modulator E. So, the traction force, supplied by the torsional torque, has been recorded.

3 ON-LINE MFASUREMENTS

Measurements have been performed on the Railway Testing Point Faurei, located near Bucharest. The state of rails on the testing ring was in accordance with the reglementation number 314 of the Romanian Railway Society, for velocities under the value of 160 km/h. The purpose of the "in situ" tests consists in a continuous recording of the vertical and lateral contact forces between wheel and rail in order to estimate typical parameters for the safety of railway circulation, for different rolling conditions.

The strain gauge waggon contained strain transducer amplifyer-Hottinger, tape recorder with 14 channels EAM 500 - Tesla, analogical filters - Robotron, computer PC AT-486 DX 2/66, data acquisition plate 5411-Axiom, printer HP 550-C.

The connection between the measuring driving axles of the LDH 450 CP railway engine and the electric signal recording apparatus has been ensured by special electric wires. The static vertical load acting on a single wheel has the value Q_{1st}= 100 KN.

Signals were recorded for different combinations between the velocity of railway vehicle (v [km/h]=30, 40, 80 and 120) and the radius of the route (R [m]= 180, 250, 400, 800 and 1800).

Measuring parameters have been recorded on a magnetic tape, than analyzed by using a computer.

Finally, the typical parameters for the safety of the rolling process have been calculated by using the following relations:

C - safety coefficient for running of the rail

$$C = Y/Q \quad (2)$$

S - amplitude of lateral force acting on the rail

$$S = Y_1 - Y_2 \quad (3)$$

There are presented in table 1 the results of the "in situ" measurements.

Table 1.

Velocity [Km/h]	Radii [m]	Left wheel		Right wheel	Safety coeficient for running of the rail Y_1/Q_1[-]	Vertical impact coefficient $\psi = Q_{1d}/Q_{1st}$	Amplitude of lateral force acting on the rail $S=Y_1-Y_2$ [KN]
		Lateral force Y_1[KN]	Vertical force Q_1[KN]	Lateral force Y_2[KN]			
30	180	55	128	25,3	0,43	1,28	29,7
	250	45,7	123	24	0,37	1,23	21,7
	400	36	120	20	0,3	1,2	16
	800	28	116	17	0,24	1,16	11
40	180	57	130	26	0,44	1,3	31
	250	49,6	127	25	0,39	1,27	24,6
	400	38	122	21	0,31	1,22	17
	800	31	117	18	0,26	1,17	13
80	1800	21	105	17,1	0,2	1,05	3,9
120	1800	24	107	18,2	0,22	1,07	5,8

4 CONCLUSIONS

Results have to be compared with the railway regulations, [3], which stipulate the following limits for the safety coefficients for running of the rail respectively for the amplitude of lateral force acting on the rail:

$C_{max} = (Y / Q)_{max} = 1,2$ respectively

$S_{max} = 0,85 [10 + (2Q_{st} / 3)] = 65$ KN

According with table 1, the above mentioned safety parameters are under the prescribed limits.

The accuracy, the sensitivity and the deviation of measurements are under acceptable practical limits for the proposed electrical connections of transducers. So, for all measurements, sensitivities respectively deviations were under the value of 3,5 [µm / mKN] respectively of 3 %.

The velocity and the temperature have a non-important influence on the measuring signal.

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