THE BEHAVIOR UNDER LOAD OF THE PORTAL GANTRY CRANES, REFERING TO STRENGTH, STIFFNESS AND STABILITY
PART II – EXPERIMENTAL DETERMINATIONS OF THE FIELD OF STRESSES AND STRAINS

GHEORGHE N. RADU[1], IOANA COMĂNESCU [2], MARIAN POPESCU [3*]

[1, 2]*TRANSILVANIA University of BRAŞOV, B-dul Eroilor 29, RO - 500036 Romania*

[3]*I.T. ISCIR Craiova, Brestei 55A, RO - 500036 Romania*

Abstract: This paper presents some experimental determinations concerning the dynamics under changing loads of the forces in windbracings and of the stress in the elements sensitive to fracture.
The experiments are achieved after a preliminary analysis of the potential failure zones of the crane is done.
The achievement of the experiments is based on the following logical structure of the experiment: the preparation of the measurement devices and of the used transducers, the achievement of an assembling diagram, the establishment of the quantities (parameters) which will be recorded, the execution of the mounting and of the experimental determinations, the presentation of diagrams and/or tables, conclusions, comparisons to the theoretical data established in the former paper. The paper presents the field of stresses and sectional strains in windbracings.

1. THE PRESENTATION OF THE EQUIPMENT USED FOR THE EXPERIMENTAL DETERMINATIONS

The sequence of the used equipment is the following one: electronic system for the numerical measurement of the analogical data, type SPIDER 8, specialized in numerical acquisition of mechanical quantities, such as: forces, stresses, accelerations, velocities, displacements, temperatures, etc.; the signal conditioner, the piezoelectric accelerometer, the impact hammer, the inductive transducer of linear stroke, resistance transducers for the measurement of linear strokes, strain gages, transducers for the measurement of the traction – compression forces in windbracings [1].

The signal conditioner is specially introduced to magnify the electric signal and to convert the very high output impedance of the accelerometer into a lower one; thus the stresses can be measured with the endowment equipment (from the laboratory). We used classical electrotensometric transducers which are based on the electric resistance variation phenomenon of a resistivity conductor, ρ. Depending on the law of change of the electric resistance R, the length and the cross section of the conductor, this one lengthens with $\delta\ell$. Classic

assembling with the strain gages in a Wheatstone bridge was used. The work is based on the classical equations known from the specialty theory. Supplying the bridge with the voltage E, the output voltage e_0 is obtained [1, 2, 3, 4]:

$$e_0 = \frac{R_1 \cdot R_3 - R_2 \cdot R_4}{(R_1 + R_2)(R_3 + R_4)} \cdot E \tag{1}$$

If a strain $\varepsilon = \dfrac{\delta \ell}{\ell}$ of the strain gage's support is produced, this one modifies its resistance with an elementary value ΔR, the output voltage of the bridge having the value;

$$e_0 = \frac{(R_1 + \Delta R) \cdot R_3 - R_2 \cdot R_4}{(R_1 + \Delta R + R_2)(R_3 + R_4)} \cdot E \tag{2}$$

where $R_1 = R_2 = R_3 = R_4 = R$, the value of R being much higher as the variation ΔR. It results a simplified calculation equation:

$$e_0 = \frac{1}{4} \cdot \frac{\Delta R}{R} \cdot E = \frac{1}{4} \cdot K_s \cdot \varepsilon \cdot E \tag{3}$$

where K_s defines the constant value of the electrotensometric transducer. The determination of the traction – compression forces in the beams named "windbracings" represents a very important stage in the calculation of the crane. The sectional forces are due to the lifting and to the descent of the loads (those which give a strain). One fixed electrotensometric transducers in "complete bridge" on the 4 windbracings, as shown in Figure 1; one specifies the notations $T_1 \dots T_4$. Transducers of the type LY 10 mm/120 Ohm have been used. After the bridges achievement their covering with a protecting coat of silicone varnish was performed.

Fig. 1. The assembling scheme for the measurement of forces in windbracings and of stresses in the fracture sensitive elements [1].

The measurement is accomplished on a pattern built especially by the authors of the papers. That is the reason why the material characteristics of the beams of type tube used to the windbracings cannot be known precisely. For the accuracy of the results one achieved a "control" force transducer, accomplished from the same type of tube; on this one electrotensometric transducers LY 10 mm/120 Ohm, in complete bridge have been fixed, in the same way as to the windbracings. The control transducer, Figure 2, was calibrated in the laboratory on an advanced equipment type LFV 50 – HM, produced by the Walter – Bai A. G. firm from Switzerland (in the endowment of the laboratory of the Strength of Materials Department, from Transilvania University of Brasov). One patterned a force diagram, Figure 3.
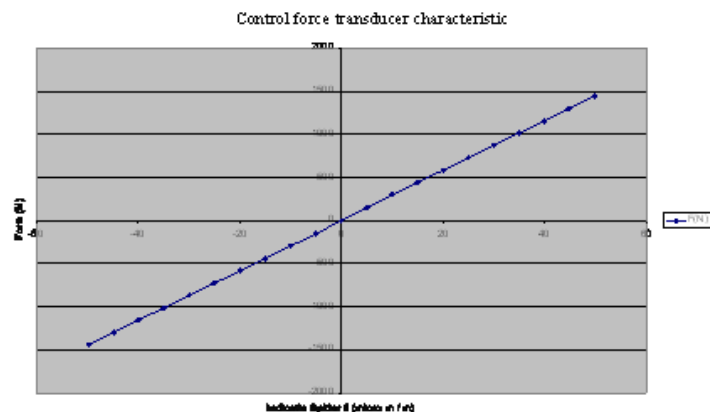

Fig. 2. Control force transducer.   Fig. 3. Control force transducer characteristic.

For the measurement of the signals from the control force transducer and from the standard transducer U2B10 kN, one used the acquisition system SPIDER 8.

The "experimental" records have been processed with the "Dinamica – Macara.tst" software, achieved by Test Point.

The recorded parameters and those notations recovered in diagrams and table are:
- the traction force at the crane's hook F, in [N];
- the sectional traction – compression forces in windbracings, T1 … T4, in [N];
- the normal stresses σ in the failure sensitive zones, denoted by Si1 … Si5 in Figure 1, in [MPa].

2. EXPERIMENTAL RESULTS

The crane's carriage has been successively positioned (put) in the points P1 … P7, the loading being achieved by plates of weight 140 (N). The load was joined at the crane's hook by help of the force transducer U2B 10 kN.
For each position of the carriage in the points P1 … P7, the following operations:
1. the successively load of the scale with 4, 6, 8 and 10 weights;
2. the starting of the data acquisition system and the recording of the parameters, Si1 … Si5 (MPa), T1, T2 (N);
3. the lifting of the changing load at a height of about 500 mm;
4. halt of load lifting with waiting about 10 s;
5. descent of the changing load and waiting about 5 s;
6. stop the data acquisition system;
7. the resumption of the operations 1-6 for: Si1, …, Si5 (MPa), T3, T4 (N).

For all the measurement cases, the recording velocity was 2400 Hz/channel.

Table 1 presents the stresses Si which appears in the failure sensitive zones. For each position of the carriage the load was made under 4, 6, 8 and 10 weights.
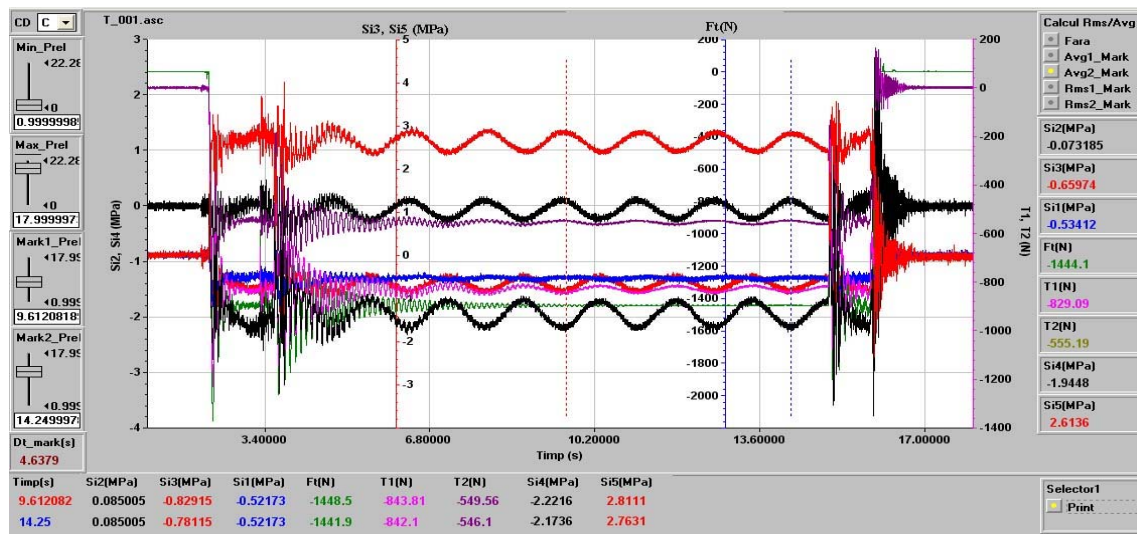
Fig. 4. Recording of stresses in the zones denoted by Si and of forces in windbracings at a load in point P1, [1].
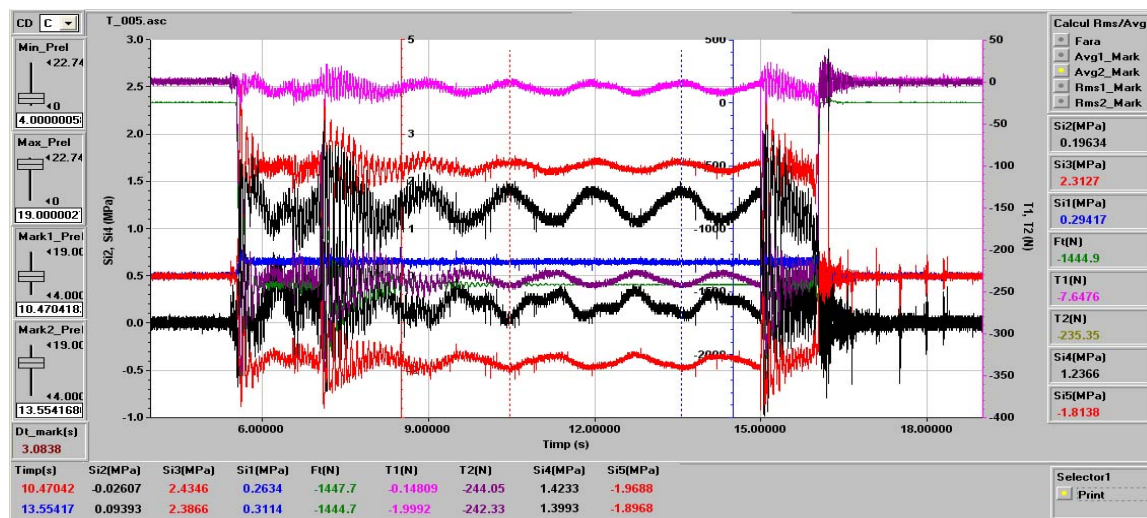

Fig. 5. Recording of stresses in the zones denoted by Si and of forces in windbracings at a load in point P4.

Table 1. The stresses Si which appear in the failure sensitive zones.

Application point	Number of weights	Ft (N)	Si1 (MPa)	Si2 (MPa)	Si3 (MPa)	Si4 (MPa)	Si5 (MPa)
P1	4	583.3328	-0.28681	-0.08416	-0.37049	-0.70892	1.086433
P1	6	868.7676	-0.3959	-0.09174	-0.47035	-1.06058	1.680689
P1	8	1158.472	-0.49697	-0.06315	-0.57373	-1.3924	2.266022
P1	10	1444.092	-0.56341	-0.07319	-0.65974	-1.94479	2.61358
P2	4	583.3328	0.891048	0.147195	0.401483	-1.09387	-0.0185
P3	4	583.3328	0.234848	0.461476	1.084563	0.11005	-0.62083
P4	4	583.3328	0.11045	0.165878	0.969304	0.505078	-0.72989
P5	4	583.3328	0.047676	-0.1286	0.658351	0.564331	-0.61751
P6	4	583.3328	-0.011	-0.06181	0.1154	0.145073	-0.0945
P7	4	583.3328	-0.05259	-0.17848	0.064437	0.341755	-0.13712
P7	6	868.7676	-0.07396	-0.25509	0.116943	0.520546	-0.21624
P7	8	1158.472	-0.09182	-0.33864	0.166251	0.694758	-0.2772
P7	10	1444.092	-0.13577	-0.42991	0.173065	0.882781	-0.37164

Table 2. The sectional forces in windbracings.

Application point	Number of weights	Ft (N)	T1 (N)	T2 (N)	T3 (N)	T4 (N)
1	4	583.3328	-366.777	-249.698	2.099316	17.15721
1	6	868.7676	-541.094	-364.537	2.507816	27.88273
1	8	1158.472	-714.217	-480.649	2.820725	33.96707
1	10	1444.092	-829.093	-555.193	2.986383	42.43365
2	4	583.0404	-77.3679	-67.1541	-7.38523	5.350258
3	4	586.1524	-25.8232	-116.621	-64.9434	9.851587
4	4	585.5376	-3.49574	-99.2354	-100.327	-3.56565
5	4	592.2682	9.73477	-64.2368	-116.621	-25.8232
6	4	584.56	5.297285	-7.27609	-67.1541	-77.3679
7	4	584.2636	16.90365	2.078531	-249.698	-366.777
7	6	869.5993	27.47067	2.482986	-364.537	-541.094
7	8	1155.5	33.46509	2.792797	-480.649	-714.217
7	10	1444.887	41.80655	2.956815	-585.193	-859.093

Table 2 presents the sectional forces in windbracings, denoted by T1 … T4, figure 1 and these are measured in [N] [5].

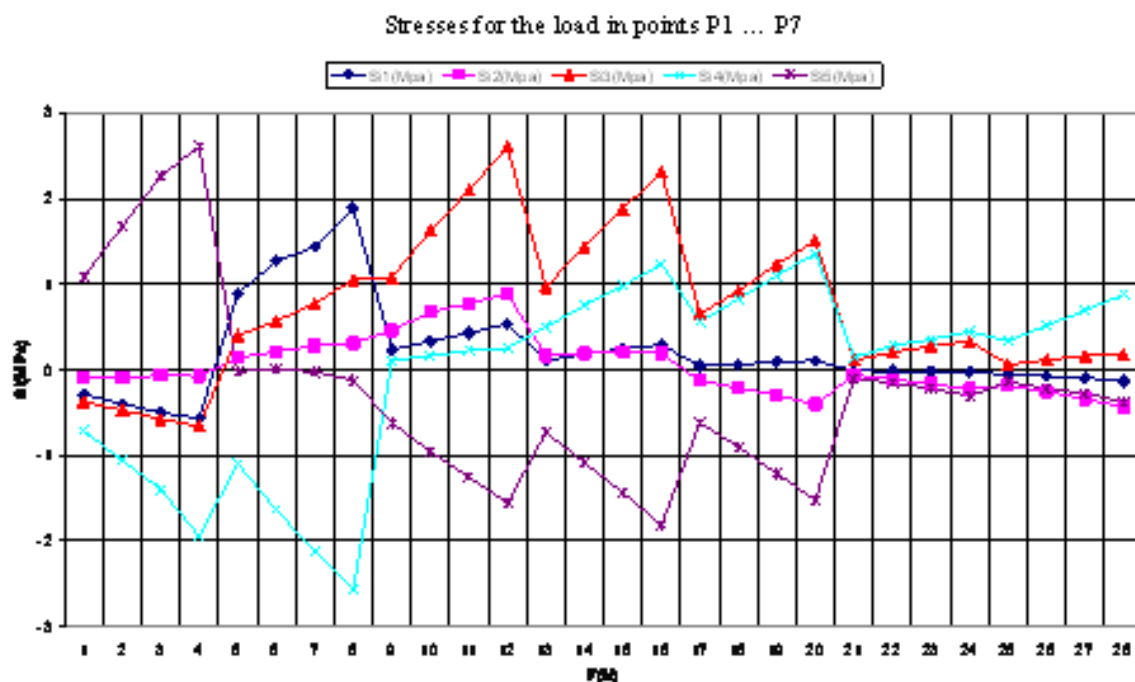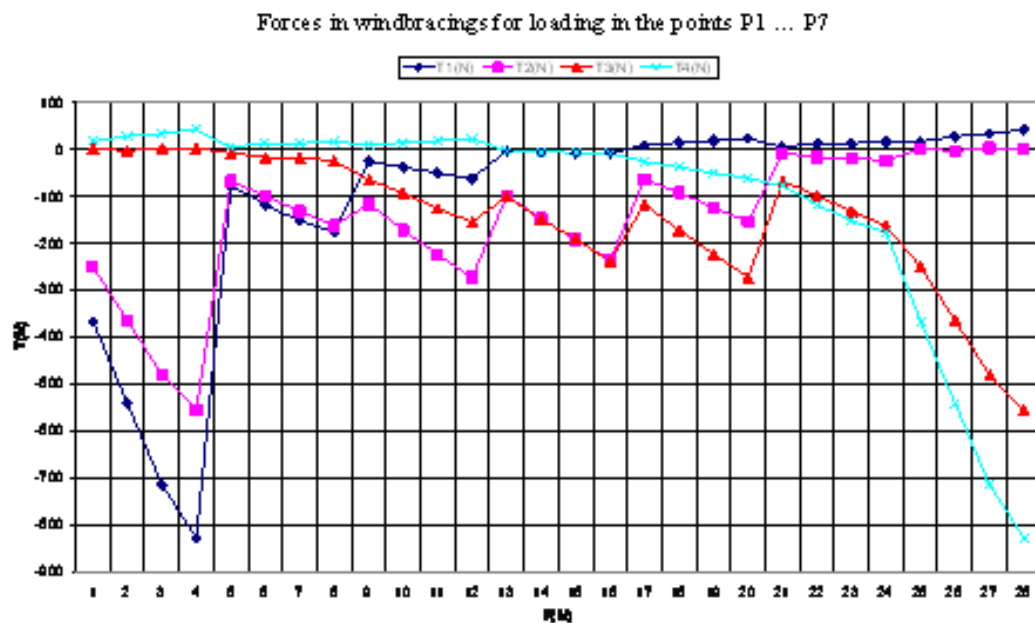Fig. 6 The change of stresses field in points Si1 … Si5 when the load acts in P1 … P7, [1, 3].

Fig. 7 The change of the sectional forces in windbracings when the load acts in the points P1 … P7, [1, 4].

3.   CONCLUSIONS

Based on the graphs and on the tables 1 and 2, one ascertains that the crane has a linear behavior, the stresses are below the proportional limit of the material, at a load with forces between 0 – 1440 N. Under these circumstances the recordings from Tables 1 and 2 are very useful: one can establish, both the stresses from points Si and the sectional forces in windbracings by linear interpolation, for each changing load applied in points P1 … P7, in the field of linear behavior of the crane (Figure 4, 5, 6 and 7).

The lift of the load is made with a big jump of the drive force due both to the inertial effect but to the cable elasticity. One establishes that the force of the traction shock at the hook transmits a jump similar to that one in the sectional forces in windbracings and to the normal stresses in the crane's structure.

The drive of the electromechanical brake yields a dynamic shock load in the drive cable, which a top which reaches about 1991 N.

The effect of the shock is transmitted in the crane's structure (and to the value of the sectional forces in windbracings).

In the drive cable and in the crane's structure a damped harmonic oscillation is induced, with an eigenfrequency of the cable – load elastic system.

The oscillation is of equation, [1, 5]:

$$x(t) = X_0 \cdot e^{-\mu t}$$

(4)

where: x(t) represents one of the force parameters in the drive cable F, or forces in windbracings T; X_0 – the amplitude of the analyzed parameter; μ - the damping constant of the oscillation.

An estimate of the damping magnitude of the system is given by the logarithmic decrement definite as the natural logarithm of the ratio of two successive amplitudes of the damped vibration.

From the analysis of Tables 1 and 2 it results that outstanding values exists too. These either must be removed or will be subjected to new assessments. The errors between the values given by FEM ABAQUS and those experimentally established are in admissible limits. The mathematical pattern is accurate and can be used at the elements optimization, at the defining of failure sensitive zones, at comparisons of the structure's behavior subjected to various external connections, at the enlargement of the work safety of the cranes.

REFERENCES

[1] Popescu, M., Radu, N. Gh., Reports II and III for PhD Thesis, Braşov, 2008.
[2] Radu, N. Gh., Rezistenţa materialelor şi elemete de teoria elasticităţii, Transilvania University of Braşov, 2002.
[3] Năstăsescu, V. Ştefan, A., Lupoiu, C., Analiza neliniară a structurilor mecanice prin metoda elementelor finite, Editura Academiei Tehnice Militare, Bucureşti, 2002.
[4] Vasilescu, Al., Praisler, G., Similitudinea sistemelor elastice, Ed. Academiei, Bucureşti, 1974.
[5] Radu, Gh., Popescu, M., Studies and experimental determinations regarding the behavior of the gantry cranes, under static load – experimental regarding of the sectional stresses. Conference COMAT 2009, Brasov.