THE BEHAVIOR UNDER LOAD OF THE PORTAL GANTRY CRANES, REFERING TO STRENGTH, STIFFNESS AND STABILITY PART I – THEORETICAL CONSIDERATIONS

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: The paper's subject is highly topical, is very interesting from scientific point of view but also very complex. The authors propose to study the elastic structures of the cranes on basis of the similarity criteria, for this purpose the two basis criteria are shortly presented: Hooke and Cauchy. One underlines that the gantry and the half gantry cranes work outside, being subjected to actions as time changing loads; under these circumstances one needs a special check of the crane's stability. The basic study is that one based on the analysis with finite elements, using ABAQUS software – an advanced software with highly efficient possibilities of modeling. By graphical post processing are presented the equivalent fields of stresses von Mises and of deformations.

Keywords: Gantry crane, stress, deformation, similarity, ABAQUS, windbracing, graphical post processing.

1. INTRODUCTION

The practical utility of the portal cranes is demonstrated by their large spread as destination and work conditions. One requires a theoretical and modern experimental study, using advanced software. The subject is very complex but also very interesting from scientific point of view. In a modern acceptation the cranes are lifting equipment, having a complex structure composed of a metallic frame, of changing shape, construction and dimensions; the structure upholds more mechanisms which serve to the lifting and to the moving of loads.

A very important finding is that the gantry cranes and half gantry cranes work "outside"; they are subjected to some actions as time changing loads, so that it needs a special verification of the stability.

Based on the existing theoretical studies, on the operative normative, on the experts recommendation, on the restrictive indications used in designing, one establishes that the problems regarding the vibratory state of the cranes are not taken into account.

We specify the fact that the first signs regarding a bad work or the first obvious changes in the evolution of the technical state appear in their "vibrating stamp". In order to increase the work safety of the gantry cranes, one proposes a theoretical study by elaborating of some modern methods of structural check, using the numerical analysis software ABAQUS [1, 2].

---

* Corresponding author, email: rngh@unitbv.ro

2. THE STUDY OF THE ELASTIC STRUCTURES BASED ON THE SIMILARITY CRITERIA [1], [2]

In order to establish a calculus methodology for the big structures two similarity criteria (theoretically) have been used: HOOKE and CAUCHY. The calculus relations are from paper [3], mentioned at the references. One sets out from the explanation that $K_\sigma = K_E$ which represents the stress scale written on basis of HOOKE's law in normal stresses $\sigma = E \cdot \varepsilon$; were ε being the deformation per unit length – a nondimensional unit. The relations above lead to the similarity criterion HOOKE written between the real structure and the model attached to it:

$$\varepsilon_r = \varepsilon_m = ct. \quad or \quad \frac{F_r}{A_r \cdot E_r} = \frac{F_m}{A_m \cdot E_m} = H \tag{1}$$

Equation (1) express the static similarity; were F is the traction internal force, A – the cross sectional area; E – the longitudinal modulus of elasticity.

The similarity criterion given by (1) may be written as:

$$\varepsilon = \frac{\Delta\ell_r}{\ell_r} = \frac{\Delta\ell_m}{\ell_m}..... \tag{2}$$

which shows that the deformations have the same scale as the length:

$$k_{\Delta\ell} = \lambda \tag{3}$$

If the stress scale have the expression $K_\sigma = K_E$, then the relation between the forces scale K_F and the length scale, according to HOOKE's criterion is:

$$k_F = \lambda^2 \cdot k_E \tag{4}$$

The concise presentation above shows that the number H from equation (1) has the same value both from the real body but for the prototype (the two elastic systems will be loaded identically) the criterion refers to the finite elastic deformations and it is achieved only if one achieves the geometrical similarity between the model and the prototype.

The similarity criterion CAUCHY refers to the dynamic strains due to the vibrations. One refers to elastic systems. If one refers to the prismatic beams of changing section, it results relation:

$$E\frac{\partial^2}{\partial x^2}\left(I \cdot \frac{\partial^2 v}{\partial x^2}\right) + \rho \cdot A \cdot \frac{\partial^2 y}{\partial t^2} = 0 \tag{5}$$

where: ρ is the material density of the beam; $\rho \cdot A$ is the mass per unit length; $\rho \cdot A \cdot \frac{\partial^2 y}{\partial t^2}$ is the force of inertia per unit length; I is the axial moment of inertia of the cross section A; v is the deflection measured from the static equilibrium position of the beam; x is the distance to the cross section, measured from the origin; t is the time.

Based on the transformations and by introducing nondimensional units, one gets the similarity criterion Cauchy under the form:

$$\frac{\ell_0}{t_0}\bigg/\sqrt{E_0/\rho_0} = \frac{v}{c} = C_a \tag{6}$$

where: v is the velocity of the oscillation motion of the beam's point; c is the propagation velocity of the longitudinal waves.

Likewise one writes the scale of the time T and of the velocities, K_v.

The resulted conclusions from the beam may be extended to the elastic structures. We can specify the following conclusions (these may have a general rank):
- if the Cauchy's criterion has the same value both of the real structure and on the model, the studied phenomenon on the model is similar to that on the real structure;
- the studied model must be achieved from the same material as the real structure;
- from the geometrical point of view both must respect a certain scale;
- one grants a special attention to the elastic constants of the material.

The structure of the gantry crane is very complex, both from constructive point of view and from the point of view concerning the behavior under load. This is the reason why the concise theoretical considerations concerning a study by similarity between the pattern – model and the real model will be in this way understood: the study methodology which will be performed on a model at scale ("pattern") may be spread to any other structure, inclusively to the real one.

3. THE ANALYSIS WITH FINITE ELEMENTS OF A GANTRY CRANE (ABAQUS SOFTWARE)

One achieved a functional pattern, using 1/10 scale, of a real structure, Figure 1.

Fig. 1. Pattern of a gantry crane.

The pattern shown in Figure 1 consists mainly of a central beam, achieved from an I section, with 42 x 80 x 2660 mm dimensions, reinforced by a truss. On the main beam of I profile are marked the points P1, P2, …, P4, …, P7 (equal distances between two successive points) where are applies an external load (for lifting; descent) [3, 4].

The structure contains also: 4 tubes of ϕ 25 and the thickness of the wall t = 2 mm, called also windbracings, as well as bars with the dimensions: ϕ 14 mm, t = 2 mm; carriage, electric hoist, marked weights etc.
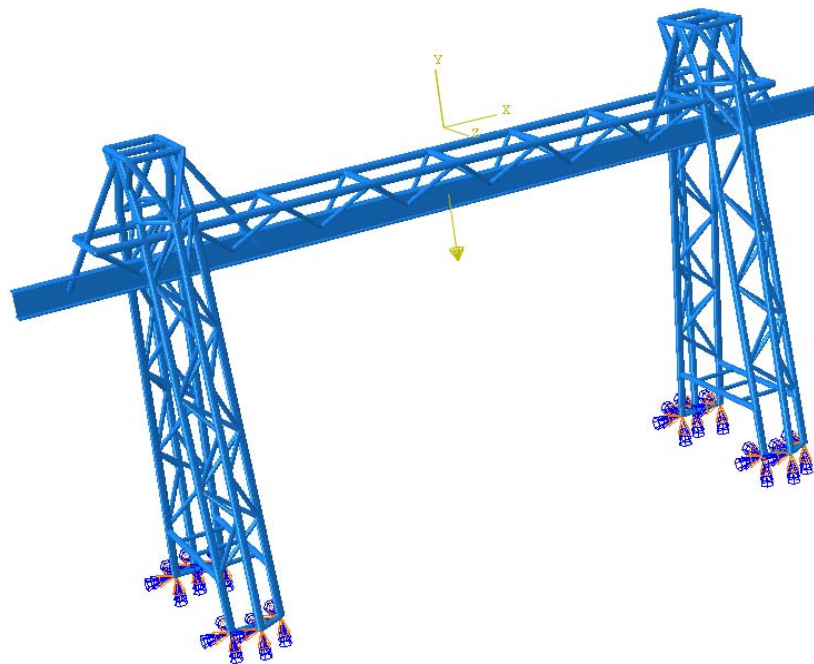
Fig. 2. Geometrical model of a crane with windbracings subjected to a load of 1444 N in point P4.

Figure 2 presents the geometrical model conceived for a crane with windbracings. One used the ABAQUS software, an advanced software, with the possibility of modeling with great efficiency and refinement. In pattern – making was achieved for the whole structure, but the main element which was in sight is the main beam. The mathematical model which was achieved includes a number of 2818 elements of type Beam 3D.

Two constructive types are studied: crane with windbracings and crane without windbracings.

The load of 1444 N is successively applied in points P1, P3 and P4. One extends the results by the symmetry of the structure.

REFERENCES

[1] Vasilescu, Al., Praisler, G., Similitudinea sistemelor elastice, Ed. Academiei, Bucureşti, 1974.
[2] Popescu, M., Radu, N. Gh., Reports II and III for PhD Thesis, Braşov, 2008.
[3] Segal, H., Linde C., Purcariu, I., Maşini de ridicat şi transportat, Bucureşti, Ed. Tehnică, 1957.
[4] Spinakovski, A. O., Rudenko, N., Maşini de ridicat şi transportat, Bucureşti, Ed. Tehnică, 1953.