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Numerical analysis of stress fields generated in the gantry crane beam

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Abstract

The cranes are currently one of the most common devices for transporting loads and can be applied in many industry areas. This paper includes the numerical strength analysis only of the gantry crane beam. The mathematical model and numerical simulations of mechanical phenomena in the gantry crane beam are presented in this paper. The problem was solved by the finite element method. Analysis was made to the gantry crane beam, which cross-section was the I-beam or T-beam and it was loaded different loads. One takes into consideration in the numerical model the motion of the crane trolley along the beam. As a result of the computations carried out, the stresses and displacements of the structure of gantry crane were obtained. The influences of shape change of the crane beam on the Huber-Mises stress in the steel beam were estimated. It sought to that the maximum value of Huber-Mises stress induced in the gantry crane beam was less than the strength of material, because then the design is safe.
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1. Introduction

This work concerns the basic sectors of engineering, which are design and construction. These activities are intended to create new or improve existing mechanical constructions. The design of modern mechanical constructions is a complex task that requires use of appropriate tools [1]. Such a modern tool, that gives a broad opportunity to analyze strength parameters of designed structures, is numerical simulation which uses the various numerical methods. One of the most commonly used methods is the Finite Element Method [2-6]. Finite Element

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Analysis (FEA) is an essential tool for helping us in determining the cause of problems, it also recommends the solutions. FEA of structural failure should be adopted as standard tool in failure analysis [7].

In this paper, finite element method was used to analysis of mechanical phenomena in the gantry crane. A division of cranes was made, both in terms of the support structure and purpose. Gantry cranes provide an economical way to lift and move materials anywhere in a facility. Overhead cranes are currently one of the most common devices for transporting heavy loads. In turn portable gantry cranes are widely applied to lift and transport smaller items around a working area in a factory or machine shop [6-8]. The numerical simulations are limited to numerical strength analysis of the steel gantry crane beam which was variable loaded along its length. Analysis was made to the gantry crane beam, which cross-section was the I-beam or T-beam and it was loaded different loads, depending on the variant. The mathematical model of mechanical phenomena in the gantry crane beam has been presented. The analysis of the stresses and strains of the structure of gantry crane was made using the advanced software with highly efficient possibilities of modeling. Motion of the crane trolley along the beam was also taken into account in the study. The research performed allows the evaluation of the stress state, pointing out the critical areas and values which are made in order to increase the strength of the structure of the gantry crane. By graphical post-processing are presented the fields of Huber-Mises stresses for the selected location of the crane trolley.

2. Mathematical and numerical model

The analysis of mechanical phenomena is made on the basis solution of equilibrium equations, supplemented by constitutive relations and boundary conditions. Numerical simulation the moving of trolley crane is performed in Lagrange coordinates. Stress field in crane beam is determined using FEA engineering software, based on finite element method.

The mathematical model is based on the solution of the following system of differential equations [6-10]:

– the equilibrium equations:

$$\nabla \circ \boldsymbol{\sigma} = 0, \qquad \boldsymbol{\sigma} = \boldsymbol{\sigma}^T, \tag{1}$$

– the constitutive equations - Hook's law:

$$\boldsymbol{\sigma} = \mathbf{D} \circ \boldsymbol{\varepsilon}, \tag{2}$$

– the Cauchy's equations:

$$\boldsymbol{\varepsilon} = \frac{1}{2}(\nabla \mathbf{u} + \nabla^T \mathbf{u}) \tag{3}$$

where: $\boldsymbol{\sigma} = \boldsymbol{\sigma}(\sigma_{ij})$ - stress tensor, $\boldsymbol{\varepsilon} = \boldsymbol{\varepsilon}(\varepsilon_{ij})$ - strain tensor, $\mathbf{u}(u_i)$ - displacement vector, $\mathbf{D}$ - denotes matrix of elasticity or tensor of material properties.

Equations above are completed by boundary conditions (traction and displacement), which are assumed to ensure the external static determination of considered system [8-10]:

$$\boldsymbol{\sigma} \circ \mathbf{n} = \mathbf{p}\big|_{\Gamma}, \qquad \mathbf{u} = \mathbf{u}\big|_{\Gamma} \tag{4}$$

where $\mathbf{p}$ is component of force per unit area acting on a plane (Γ) with normal $\mathbf{n}$.

The numerical model uses FEM and is derived from the criterion of the method of weighted residuals [2-5]. Equation (1) is multiplied by the weighting function W and integrated over the considered region Ω:

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