CONTENTS AUTHORS

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OPTIMIZATION OF DOUBLE BOX GIRDER OVERHEAD CRANE IN FUNCTION OF CROSS SECTION PARAMETER OF MAIN GIRDERS

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ABSTRACT
Double box girder overhead cranes are used for heavy duty applications in the industry. A detailed design optimization in function of cross section of the main girder of box type is performed for a 7 ton capacity and 20 m span double box girder crane, in accordance with relevant design rules. Design optimization is performed using principal calculations and detailed 3D finite element analysis by changing primarily thickness of the box girder plates. The number, shape and location of vertical stiffeners along the length of the girder was not changed. Principal static and dynamic calculations (stress- strain and frequency analysis) for two models of double box girder, in options with 12 mm thick main girder plates and optimized with 7 mm thick plates, are given in the paper. As a result of optimization a reduction of mass of 38 % achieved and stress-deformation characteristics considering yield stranght and stability of construction was not endangered.
Keywords: optimization, box girder, overhead crane.

1. INTRODUCTION
Cranes are the best way of providing a heavy lifting facility covering virtually the whole area of building. An overhead crane is the most important materials handling system for heavey goods, so due its enormous appliance in every type of industry, in open space or under roof, it is reasonable to review real stress-deformation states, with the possibility of optimal utilization of used materials.

2. GEOMETRY AND STRESS CALCULATIONS
An overhead crane model with basic dimensions is presented in Picture 1. According to initial model of main girder with middle hight of profile 762 mm and plate thickness 12 mm, an optimized model of main girder was changed to 900 mm middle hight of profile and plate thickness reduced to 7 mm. All other dimensions and relations between components of crane remains unchanged.

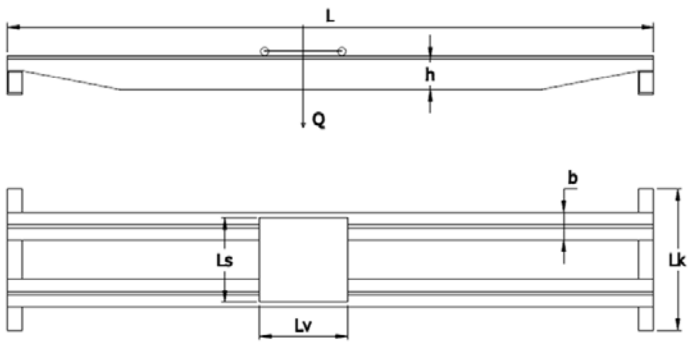

Figure 1. Basic geometry parameters of a crane with trolley

Table 1. Basic geometry characteristics of a crane with two models of main girder

Mark	Value	Description
Q	70 [kN]	Carrying capacity
L	19700 [mm]	Span of crane girder
L_k	3000 [mm]	Length of side girder
L_s	1000 [mm]	Distance between trolley wheels between two crane girders
L_v	1200 [mm]	Distance between trolley wheels along crane girder
b	348 [mm]	Middle distance between side plates of main girder
h_p	762 [mm]	Middle hight of main girder-first model of girder
h_k	900 [mm]	Middle hight of main girder-optimized model of girder
δ_p	12 [mm]	Plate thickness of first girder model
δ_k	7 [mm]	Plate thickness of optimized girder model

Total stress in the cross section I, Picture 2 and 3, of main girder (at the midpoint of span) for initial, and optimized model of main girder are calculated according to formula:

$$\sigma_u = \sqrt{(\sigma_{zv} + \sigma_{zM})^2 + \sigma_{xM}{}^2 - (\sigma_{zv} + \sigma_{zM}) \cdot \sigma_{xM}} \leq \sigma\ all. \qquad \ldots(1)$$

Initial model of girder:

$$\sigma_{up} = \sqrt{(2.8 + 6.9)^2 + 7.5^2 - (2.8 + 6.9) \cdot 7.5} = 8.8 \left[{}^{kN}/_{cm^2}\right] \qquad \ldots(2)$$

Optimized model of girder:

$$\sigma_{uk} = \sqrt{(3.1 + 6.2)^2 + 6.7^2 - (3.1 + 6.2) \cdot 6.7} = 8.3 \left[{}^{kN}/_{cm^2}\right] \qquad \ldots(3)$$

$$\sigma_u \leq \sigma\ allo. = 18 \left[{}^{kN}/_{cm^2}\right] \qquad \ldots(4)$$

So, it can be seen that the total stress does not cross allowed limits for both models of girder according to analytic calculations.

3. STRESS-DEFORMATION NUMERICAL ANALYSIS

An overhead crane with all characteristic constructional parts is very complex assembly and a preparation for numerical analysis is a quite quantity of job to be done. Numerical analysis is performed using SolidWorks software with tetrahedral solid elements.

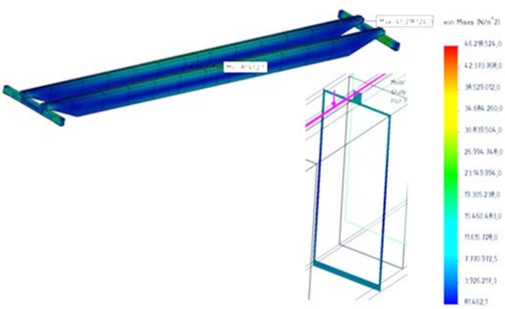

Figure 2. Von Mises stress for first model of crane

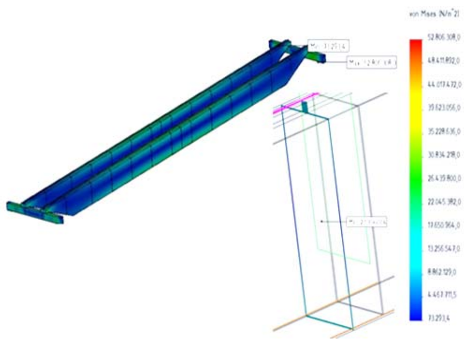

Figure 3. Von Mises stress for optimized model of crane

From results of numerical analysis, presented in Table 2, it can be seen that enlarged hight of main grider box profile with reduced thickness of plates leads to a slightly increased values of enlarged stress-deformation characterstics, but the stress remains inside allowed limits.

Table 2. Results of numerical analysis

INITIAL MODEL 348 x 762 mm, $\delta = 12$ mm			OPTIMIZED MODEL 348 x 900 mm, $\delta = 7$ mm		
Max. displacement at the midpoint of span: f = 6,6 [mm]			Max. displacement at the midpoint of span: f = 9,3 [mm]		
STRESS [N/mm^2]			STRESS [N/mm^2]		
Equivalent	Normal	Shear	Equivalent	Normal	Shear
46,2	21,7	14,7	52,8	28,5	17
$\sigma/\tau = 21{,}7/14{,}7$			$\sigma/\tau = 28{,}5/17$		

4. FREQUENCY NUMERICAL ANALISYS

Bridge overhead cranes are very complex also because of its cyclic character of work, and they represent 3D frames with dynamic character of forces and implifications during operation. Because of that it is very important to consider how process of optimization affects to dynamic characteristics of choosen geometry structure. After static numerical calculations, frequency analysis is performed in the SolidWorks software.

First and second modes of oscillation for initial and optimized models are presented in Figure 4. Values for natural frequencies are presented in Table 3.

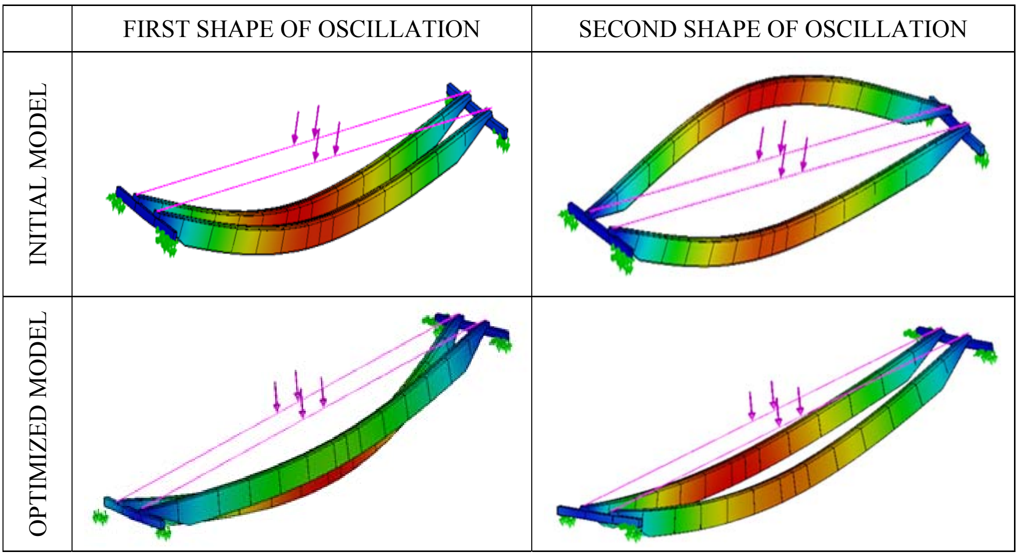

Figure 4. First and second shape of oscillation for two models of crane

According to results of frequency analisys, first frequency of oscillation for an optimized model is increased, so it can be concluded that the optimization process has possitive effect to dynamic characteristis of crane in this case.

Of course, the number of natural frequencies analysed could be bigger but for the most of industrial constructions the first natural frequency and adequate mode of oscillation are of the essence. So, for this dynamic analysis only two modes of oscillations are presented in Figure 4, but values for 5 natural frequencies are presented in Table3.

Table3. Results of numerical frequency analysis

FIRST MODEL 348 x 762 mm, δ = 12 mm			OPTIMIZED MODEL 348 x 900 mm, δ = 7 mm		
Frequency [Hz]	Max.displacement. [mm]	Plane	Frequency [Hz]	Max.displacement [mm]	Plane
f_{01} = 16,1	13,7	x-z	f_{01} = 25,4	21,3	x-z
f_{02} = 18,5	14,1	x-z	f_{02} = 25,7	18,3	x-z
f_{03} = 19,5	17,5	x-z	f_{03} = 26,4	21,9	x-y
f_{04} = 20,3	18,2	x-y	f_{04} = 27,5	18	x-z
f_{05} = 50,9	12,3	x-y	f_{05} = 51,3	16,5	x-z

4. CONCLUSIONS

This paper shows a short procedure of modern engineering approach to analysis of complex problems for industrial environment. For real constructios in industry applications it is very important, in form of initial or post process considerations, to perform static and dynamic numerical analysis or experimental measurings. For this problem, based on analytic calculations and numerical analysis in form of static and dynamic-frequency analysis, it is shown that the stress-deformation characteristics of construction remains in allowed limits, dynamic characteristics are slightly better, and the great and very significant reduction of mass for about 38% is achieved. It means that both, design and economical apsects of complex construction are achieved.

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