University of Novi Sad
Faculty of Technical Sciences
Department of Production Engineering
Novi Sad, Serbia

11th INTERNATIONAL SCIENTIFIC CONFERENCE
MMA 2012 - ADVANCED PRODUCTION TECHNOLOGIES

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ADVANCED PRODUCTION TECHNOLOGIES

PROCEEDINGS

Novi Sad, 20-21 September 2012

UNIVERSITY OF NOVI SAD
FACULTY OF TECHNICAL SCIENCES
DEPARTMENT OF PRODUCTION ENGINEERING
NOVI SAD, SERBIA

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Being held on a regular basis, like some other conferences with long tradition, the MMA 2012 – ADVANCED PRODUCTION TECHNOLOGIES contributes to continuous application of scientific results and professional know-how in the metalworking industry, regardless of the difficulties this industry has been facing during the last two decades.

By organizing the MMA 2012 Conference, the research potential of our country relies on its traditional enthusiasm and perseverance in order to contribute to advancement of production engineering in this region – not only through application of scientific results and professional know-how in practice, but also in education of engineers in the field of production technologies and techniques.

The eleventh International Scientific Conference MMA 2012 – ADVANCED PRODUCTION TECHNOLOGIES is for the tenth time being held with international participation. Throughout the years, by the number of contributions, their quality and participation of international authors, the Conference has earned a respectable reputation among scientists and industry professionals.

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- *METAL CUTTING*
- *MACHINE TOOLS AND AUTOMATIC FLEXIBLE TECHNOLOGICAL SYSTEMS, CAx AND CIM PROCEDURES AND SYSTEMS*
- *METROLOGY, QUALITY, FIXTURES, METAL CUTTING TOOLS AND TRIBOLOGY*
- *MECHANICAL ENGINEERING AND ENVIRONMENTAL PROTECTION*
- *OTHER PRODUCTION ENGINEERING TECHNOLOGIES*
- *BIO-MEDICAL ENGINEERING – CAx*

With 129 papers and contributions by international authors from 20 different countries, 11th International Scientific Conference MMA 2012 – ADVANCED PRODUCTION TECHNOLOGIES successfully maintains the high level set by the previous conferences. Participation of a large number of domestic and international authors, as well as the diversity of topics, justifies our efforts to organize this conference and contribute to exchange of knowledge, research results and experience of industry experts, research institutions and faculties which all share a common interest in the field of production engineering.

Novi Sad, September 2012 *PROGRAMME AND ORGANIZING COMMITTEE*

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11th INTERNATIONAL SCIENTIFIC CONFERENCE
NOVI SAD, SERBIA, SEPTEMBER 20-21, 2012

Mladenovic, G., Popovic, M.

MODELLING, CALCULATIONS AND TESTING OF SINGLE GIRDER BRIDGE CRANE AND CRANE RAILS

Abstract: *Bridge cranes are used for handling various types of cargo in the production halls, workshops, storage facilities, energy facilities, mills as well as in performing technological processes, assembly or disassembly of equipment. The main characteristic for these cranes are that a major girder (which in most cases is standard I profile) also represents a path on which moving movable hoist. This paper describes the procedures of using the command Frame Generator of the Software Package Autodesk Inventor 2011®, which use reduces the total time of modeling the structure which consists of standard profiles, as well as the module Frame Analysis which allows to predict the behavior of constructions under the influence of load. The end of the paper gives the experimental results for displacement and stress condition for given crane for the case of static load.*
Key words: *Single Girder Bridge Crane, Autodesk Inventor®, Frame Analysis*

1. INTRODUCTION

The uses of structures which are composed of standard profiles are common in mechanical engineering. An example of these structures is Single Girder Bridge Crane, Fig. 1.

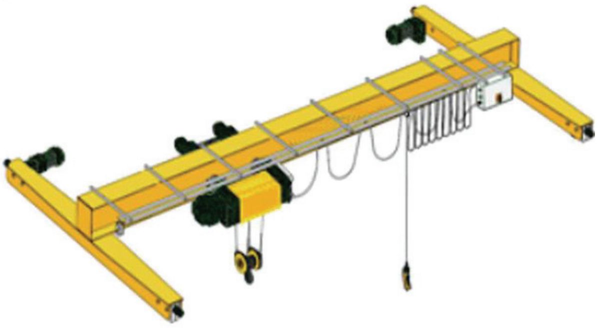

Fig. 1. Single Girder Bridge Crane

For the cross section is most commonly used hot rolled "I" profile that serves as rails, Fig. 2a. Sometimes it is necessary to achieve stability against side buckling, which can be achieved by placing additional elements on the upper belt Fig. 2b,c.

Fig. 2. Examples of cross-section of the main girder and the reinforcement of the upper belt

Therefore it is necessary to find as simply as possible way of modeling and calculations for given constructions. Depending of used software there is different speed of modeling, where most of the software requires drawing a sketch of the cross section, and then the sketch extrude through a trajectory. But, Software Package Autodesk Inventor 2011® has the possibility to select standard profiles from database. First it is necessary to draw skeleton of the structure, and then just set up some of the standard profiles on the corresponding segment of the skeleton. Besides the quick making 3D models, the advantage of this type of modeling is that the Frame Generator assembly is automatically converted into simplified model of beams and nodes with the starting of the Frame Analysis environment and starting a new analysis.

2. MODELING CRANE

As it is said in the introduction, for obtaining a 3D model of constructions which are composed of standard profiles it is first necessary to sketch skeleton of structure. It is enough to draw a sketch in the one "sketch"-a. The look of the skeleton crane is shown on Figure 3.

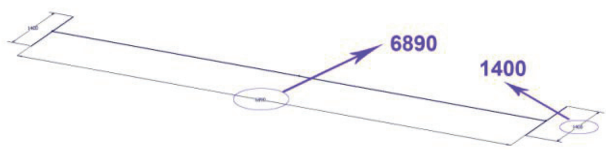

Fig. 3. The skeleton structure with defined dimensions

The command Frame Generator can be used only in environment for working with assemblies. Activation of command (Insert Frame) requires the definition of the standard profile, the choice of materials and segments (lines) on which will be set given profile or defining the start and the end points of segment. It is also defines the position and orientation of the profile in cross section. It can be selected one of the 9 cases, to position the center of gravity of the profile on the selected line or to one of 4 sides profiles match with the projection of line in that plane or the profile that can be moved along the diagonal. For all these cases it is possible to rotate the cross section for the desired angle and to move it by a some direction.
Length of the selected profiles match the length of lines in the sketch and it is necessary to subsequent repair

ends of the profiles using the commands Trim, Extend, Notch, and Miter. Using commands Change it is easy and quick to change a profile on construction which is of great importance for optimization process. For the main girder the standard profile DIN1026 **I260** is used, and for reinforcement for the upper bend the standard profile DIN1026 **U100** is used. For the side girder standard profiles DIN1026 **U120** mutually spaced 110mm are used.

3. CALCULATIONS OF CRANE AND CRANE RAILS

When the skeleton of the construction were formed this way it is possible to calculate the construction by activation of Frame Analysis Environment. Frame Analysis is used to understand the structural integrity of a given frame with respect to deformations and stresses, when subjected to various loading and constraints. Once when the criteria are defined, it is possible to run the simulation and view the behavior relative to the conditions which are defined. Simulations help to identify performance issues and find better design alternatives. Beam elements are linear. Frame analysis does not support curved beams. When the Frame Analysis environment is opened and a new analysis starts, the Frame Generator assembly is automatically converted into simplified model of beams and nodes. In the software it is very easy to define a new node (command Custom Node). There is only a need to define on which beam node is and how away it is from the end of the beam. This very simplifies the calculations of structures and reduces the total time of preprocessing. There are two approaches which give identical results, first to define a new node and then set the load on that place. Another way is to define, on which beam load is acting, and how away from the end of beam is the point on which concentrated force is acting. Besides the request for dimensions of construction another request was capacity of a construction which is designed to be 1t. Also, it was given the constraint that the carts can get close to maximum 500mm from the end of the main girder. As the given modeled crane should be installed into the building described in [4] it is analyzed the four loading cases shown on Fig. 4 and these are:

(a) The axis of the main girder intersects poles axis, the load on the middle of the main girder
(b) The axis of the main girder intersects poles axis, load on the 500mm from the end of main girder
(c) The axis of of the main girder on the middle between the two poles, the load on the middle of the main girder
(d) The axis of of the main girder on the middle between the two poles, load on the 500mm from the end of main girder

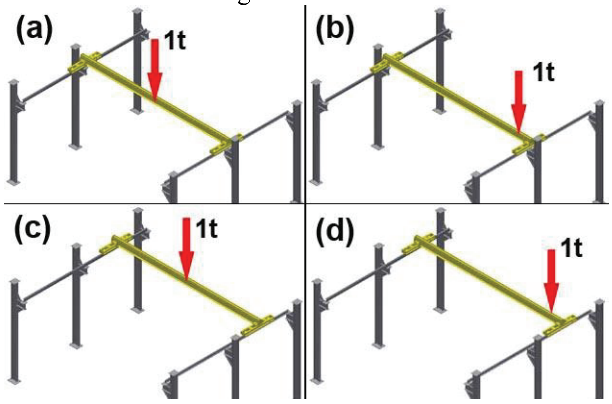

Fig. 4. Four cases of construction loads

Addition to the above the software allows to define rigid links (command Rigid Link) between nodes, which is necessary to do by analyzing the four loading cases. The connection between the crane and crane rails going across wheels, but the Frame Analysis environment works with beams so it is necessary to define a new node on place where wheels are (which is on 150mm from the end of side girder). By analog procedure it is necessary to define a new node on the crane rail at the same vertically relative to the previously formed on the side girder and then mentioned two rigidly connected in order to transferred the crane load to the crane rails as shown on Fig. 5.

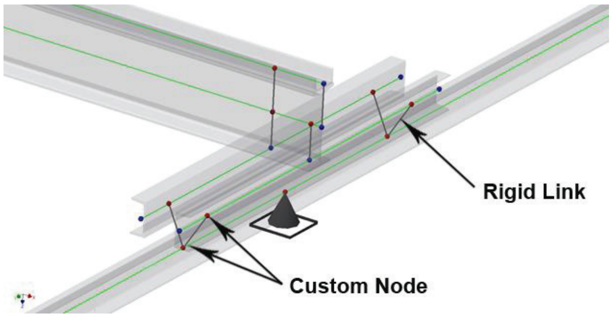

Fig. 5. Defining connection crane with crane rails

Calculation results are given in Table 1. mark δ represents the value of deformation. Beside to considering the stress state of the main and side girders, it was also discussed the stress state for the crane rails for that have been selected standard profiles DIN1026 **U120**, and the length of the crane rails is 3m.

Element	Serial number	δ [mm]	S_{MAX} [MPa]	S_{MIN} [MPa]	$S_{MAX}(M_x)$ [MPa]	$S_{MAX}(M_y)$ [MPa]	$S_{MIN}(M_x)$ [MPa]	$S_{MIN}(M_Y)$ [MPa]	Saxial [MPa]
Main girder	a i c	5.05	31.4	-41.49	35.76	8.68	-35.76	-3.9	22.72
	b i d	1.82	12.6	-12.28	10.49	4.04	-10.49	-3.28	8.56
Side girder	a i c	0.13	15.77	-15.77	15.77	0	-15.77	0	0
	b i d	0.20	25.45	-25.45	25.45	0	-25.45	0	0
Crane rails	a	0.38	26.59	-26.59	26.59	0	-26.59	0	0
	b	0.57	40.94	-40.94	40.94	0	-40.94	0	0
	c	**4.53**	58.68	-58.68	58.68	0	-58.68	0	0
	d	**7.12**	92.12	-92.12	92.12	0	-92.12	0	0

Table 1. The calculations results for particular construction elements

Based on the table 1, which shows that the according to the stress and deformation, state dimensions of the crane are satisfying. Checking the lateral buckling of the main girder (in case that the cross section is only **I260** profile) was calculated analytically using the forms from [2] according to JUS U. E7 101/1986. Limit value for the lateral buckling stresses for this case is

$$\sigma_b = \frac{\sigma_D}{\nu} = \frac{18.86}{1.5} = 12.57 \quad kN / cm^2$$

and is greater than maximum normal stresses given in Table 1.

Based on this it can be concluded that there is no side buckling of the main girder. After verifying the previous conditions the creation of complete 3D model of the crane was undertaken. The ribs for reinforcement, bearing wheels with relevant bearings, wheels with relevant shafts were designed. It is foreseen that the drive motor being on the one side, and the motion transfer to the other side with PTO shaft. In accordance to this, the central bearing was projected. Of course, rails on which cables will move, were developed. Crane is designed that it is possible to separate the side girder from the main girder for easier transport or a later redesign of crane. In addition, it is possible to unmount middle bearing PTO. Image of complete 3D model is shown on Fig. 6.

Fig. 6. The complete 3D model of calculated crane

In contrast to crane that satisfies all three criteria, crane rails do not satisfies maximum allowed deformation ($\leq l/1000$=3mm) so it is necessary to reinforcement the same or change dimensions of the standard profiles which were made.

Based on the fact that the hall has been already made, it was approached to the design of the reinforcement of existing crane rails composed of the standard DIN1026 **U120** profile. The idea was to underside of the crane rails form a truss structure composed of the standard pipes with square cross-section 40x40mm, with wall thickness of the 2.9mm. The position of the lower profile is the 500mm and parallel to the rail. Other profiles consists the grid and placed each other at angle of 45°, Fig. 7.

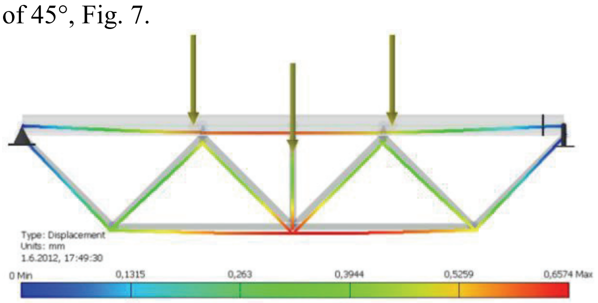

Fig. 7. Image of reinforced rails with corresponding deformation

For this purpose the complete project has not been changed but only the 3D model of reinforced crane rails was made. The effect of the crane was replaced by concentric force that represents the weight of the whole crane that was obtained from the previous analysis, of course with a predefined load capacity of the construction of 1t. It was considered only the worst case of load (case (d) from fig. 4) and the results for the displacement are shown on Fig. 7 (maximum displacement is 0.6574mm). The value of maximum normal stress for a given case of load is 32.26 MPa.

4. MAKING CRANE

Based on the model from item 3 of this paper the creation of technical documentation and making the crane was undertaken. For welding electrodes Jasenice EVB50 Ø4mm were used (software has the possibility to define the welded joints, but it is not considered for this time). The wheels are made of cast iron to minimize wear of crane rails. For the drive wheels double row ball bearings 4208 are used which are placed in housings. For a driven wheel single row ball bearing 6208 was used which is placed in the wheels, and the corresponding shaft was fixed, i.e. realized tight fitting in the side girders.

At this stage it was not performed reconstruction of crane rails and the crane was placed on the existing rails.

5. INVESTIGATION OF DEFORMATION CRANE AND CRANE RAILS

Fig. 8 shows the experimental scheme. Crane was loaded with known weights of Q=360kg exactly on the middle of the range of main girder. Position of the crane in relation to the crane rails was that the axis of the main girder intersects poles axis. With comparator were measured vertical displacements for two places, the place 1 for measurement deformation of the crane rails, and the place 2 for measurement deformation of the main girder.

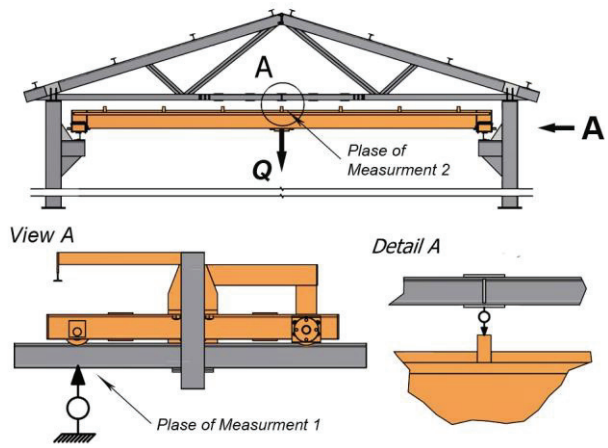

Fig. 8. Experimental scheme

In order to compare calculation results with the actual deformation it is necessary to do the following:

- Calculate the displacement of the 3D model for the case (a) from Fig. 4 only under the influence of self-weight of construction
- After this set a known concentrated load Q=360kg and calculate the displacement
- The difference of these two displacement should correspond to the comparator measurement because the deformation under own crane weight were included with setting comparator.

Bearing all this in mind another analysis in Frame Analysis environment was done and the results are shown in Table 2. Fig. 9 shows the simulation results (deformation of crane) obtained in Inventor.

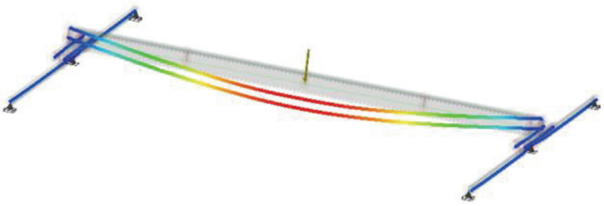

Fig. 9. Simulation from Inventor

	The deformation of the main girder [mm]	The deformation of the crane rails [mm]
The simulation results	1.35	0.09
The measured values	1.48	0.11

Table 2. Simulation results and experimental results

Differences in the data can be explained through the following:

- The dimensions of the profile, because of tolerance for free measures, differ with respect to the tabular values, and consequently are different to the characteristics of the cross section that directly affect on the value of deformation
- The software does not provide the possibility for reading specific deformation on specific place, but the deformation is read based on shades of color from color bar and even then it makes error in reading displacement as in the case of measuring deformation at the contact of the wheels and crane rails.

Fig. 10. Doing the experiment

Figure 10 shows the experimental determination for the deformation for the main girder and the crane rails.

6. CONCLUSION

This paper describes the procedures of construction, calculations and optimization at the example of Single Girder Bridge Crane and corresponding crane rails using a method that provides choice of standard profiles from database. Calculation results are compared with the experimentally determined displacement for made crane according to modeled and calculated 3D model of construction.

Using Frame Analysis environment of software package Autodesk Inventor allows the designer to perform with minimal knowledge of FEM analysis, because the software takes care of the required CP and FE, so it is possible to set a load on any part of the KE (beam) in one step, as a result of very advanced preprocessor that recognize and automatically form a network of FE. Analyzing the results from the software and the measured displacement was seen that there was deviation up to 10%, whose reasons described under item 5 of this paper.

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[5] Autodesk Inventor 2011® Profesional – Help

[6] http://usa.autodesk.com/

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