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STRESS AND DEFORMATION STATES ANALYSIS OF VERTICAL SHEET METALS ON BOX-SHAPED GIRDER

Adil Muminovic & Mirsad Colic
Faculty of Mechanical Engineering
Vilsonovo setaliste 9, Sarajevo
B&H

Mirza Colic
InterEngs
Vratnik Mejdan 40, Sarajevo
B&H

ABSTRACT
In this paper, an engineering (stress deformation) analysis of several different models of the main crane bridge carrier with box-shaped cross section on which the rail is located above one of the vertical sheet metals is performed. Stresses and deformations of the vertical sheet metals were analyzed depending on their mutual distance and the thickness of the strap sheet metals. The task was to get the appropriate mutual dependencies of vertical sheet metals stress states. The results could be used afterwards for defining boundary conditions when optimizing the carrier with the box-shaped cross section (i.e. optimization using nonlinear programming with constraints). This could be one of possible ways for the dimensioning of carriers that would be lighter than the existing ones of the same material with equal working conditions. For the analysis CAD / CAE (Computer Aided Design / Computer Aided Engineering) software CATIA V5 has been used.
Keywords: box girder, bridge crane, optimization, stresses and deformations

1. INTRODUCTION
The dimensions and the cross section shape on a tin girder while designing bridge cranes are mostly based on experience and recommendations (empirical terms). Height of the ribs varies in a relatively wide range and depends on the length of the girder. They are usually adapted to standard widths of tin plates. As for the thickness of the ribs, from the economic aspect it should be as small as possible. By increasing the thickness of the sheet the bearing capacity does not receive a significant increase in bending, but significantly increases the total weight of girder. However, the cross sectional area of the ribs (webs) directly influences the shift resistance of the girder. This means that the thickness of the ribs should be minimal, but significant enough to safely hold the shifting forces or stresses. The thickness of the ribs influences dominantly on its resistance to buckling due to shift and normal stresses. Empirical expressions that specify the height and the thickness of the ribs are just the starting point. The right dimensions choice of the ribs was confirmed only after the control of girders load and stability. In the following text the box-shaped cross section girder will be discussed with the rail over the ribs (webs), Figure 1. The stress check is done in cross section points 1, 2 and 3, as shown in Figure. This means that the calculation relates to the rib below the rail and to the pressed sheet metal band. It is implied that the thickness of both ribs is the same and that the sheet metal bands thickness is the same. Normal stresses in the fiber at positions 1 and 2, caused by the effect of bending moments are determined from the expression:

$$\sigma_{Zi} = \sigma_{Zi}^{V} + \sigma_{Zi}^{H} = \frac{M^{V}}{W_{Xi}} + \frac{M^{H}}{W_{Yi}} \quad \dots (1)$$

Where σ_{Zi}^{V} i σ_{Zi}^{H} - normal stresses from the effects of momentum in the vertical and horizontal plane, M^{V} i M^{H} - bending moments in the vertical and horizontal plane, W_{Xi} i W_{Yi} - resistant moments. Special attention should be given to checking for buckling on the ribs. Because of its high slender ribs are very sensitive to buckling. The critical buckling stress is calculated from the expression:

$$\sigma_{z,cr} = k_{\sigma} \frac{\pi^2 E}{12\left(1-\nu^2\right)}\left(\frac{t}{h_t}\right)^2 = k_{\sigma}\ \sigma_E \qquad \text{... (2)}$$

Where: k_{σ} - buckling coefficient, σ_E - Euler-critical stress.

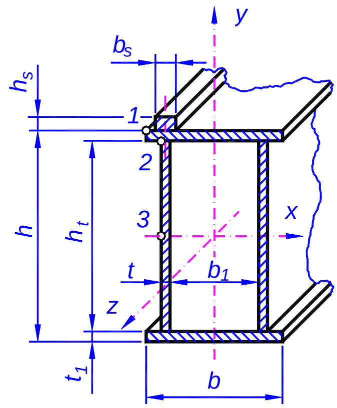

Figure 1. Girders cross-section

2. EXAMPLES AND CALCULATION RESULTS

CAD / CAE (Computer Aided Design / Computer Aided Engineering) software CATIA V5 has been used for the analysis. Stress analyses were done on box-shaped girder models with different distances of vertical plates b1 and thickness of belt plates t1, according to Figure 2. According to the markings on the figure: h_t = 80 mm, t = 4 mm, h_s = 6 mm, b_s = 8 mm. The length of the girder model is 580 mm. Width of belt plates (distance between vertical plates) is varying as given b = 70, 80, 90 and 100 mm (B_1 = 50, 60, 70 and 80 mm) while the thicknesses of belt plates are t_1 = 4, 6 and 8 mm. The model is in the middle of the length of the rail loaded with a concentrated vertical force R = 10 kN (inertial force in the horizontal plane F_H = 0). Stress check is made in cross-section points (below the force R), indicated in Figure 2.

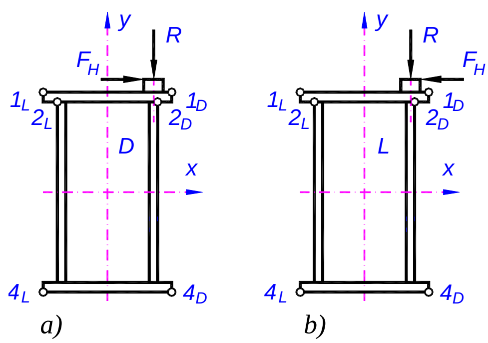

Figure 2. Points of intersection where the normal stress is calculated

Table 1. Stresses at points 1_L i 1_D of the metal band width 70 mm of width and 6 mm thickness.

b / b_1	σ_{Z1D}	σ_{Z1L}	$\sigma_{Z1,SR}$	$\sigma_{Z1,A}$
70 / 50	-45,45	-21,92	-33,68	-33,62

Table 2. Stresses at points 4_L i 4_D of the metal band width 70 mm of width and 6 mm thickness.

b / b_1	σ_{Z4D}	σ_{Z4L}	$\sigma_{Z4,SR}$	$\sigma_{Z4,A}$
70 / 50	48,2	19,65	33,9	35,97

A good matching of results can be seen from the tables ($\sigma_{X\,i,SR}$) obtained using CATIA V5 software, and results ($\sigma_{X\,i,A}$) obtained by using the expression (1). The results obtained with stress analyzes of the models for different widths of the sheet metal band (the distance between the ribs-Webs) and their different thickness, and refer to the points 2_D and 2_L are shown in Table 3 (for the 4 mm thickness of the belt plate), Table 4 (for the 6 mm thickness of the belt plate) and Table 5 (for the 8 mm thickness of the belt plate).

Table 3. Stresses in 2_L and 2_D Web points for different band widths sheet thickness of 4 mm.

b / b_1	70 / 50	80 / 60	90 /70	100 / 80
σ_{Z2D}	-56,2	-56,77	-55,7	-55,7
σ_{Z2L}	-21,94	-17,52	-13,3	-8,5
$\sigma_{Z2,SR}$	-39,1	-37,14	-34,5	-32,1
$\sigma_{Z2,A}$	-40,5	-36,96	-34,0	-31,48

Table 4. Stresses in 2_L and 2_D Web points for different band widths sheet thickness of 6 mm.

b / b_1	70 / 50	80 / 60	90 /70	100 / 80
σ_{Z2D}	-41,72	-40,3	-42,4	-42,2
σ_{Z2L}	-16,8	-10,9	-6,0	-4,8
$\sigma_{Z2,SR}$	-29,3	-25,6	-24,2	-23,5
$\sigma_{Z2,A}$	-29,1	-26,2	-23,9	-22,0

Table 5. Stresses in 2_L and 2_D Web points for different band widths sheet thickness of 8 mm.

b / b_1	70 / 50	80 / 60	90 /70	100 / 80
σ_{Z2D}	-31,4	-31,2	-31,2	-31,4
σ_{Z2L}	-10,9	-7,6	-4,1	-2,0
$\sigma_{Z2,SR}$	-21,2	-19,4	-17,6	-16,7
$\sigma_{Z2,A}$	-22,3	-20,0	-18,1	-16,6

Results of medium stresses obtained here ($\sigma_{Z2,SR}$) and compared with stresses ($\sigma_{Z2,A}$) calculated according to the equation (1) show good matching. The tables show also that increasing the distance between the ribs the normal stress at point 2, in the rib below the rail, has the approximately equal value while the stress value is falling in the second rib (web).

Tabela 6. Stresses in 2_L and 2_D, web points according to Figure 2.1a

b/b_1	70 / 50	80 / 60	90 /70	100 / 80
σ_{Z2D}	-36,6	-37,4	-38,4	-39,3
σ_{Z2L}	**-23,8**	**-17,2**	**-11,7**	**-9,4**
$\sigma_{Z2,SR}$	-30,2	-27,3	-25,05	-24,35

Stress values ratio ($\sigma_{Z2D}/\sigma_{Z2L}$) increases with the increase of the width of the band sheet or by increasing its thickness. All these indicators are in favor that the rib (web), which is not below the rail, can be made of sheet metal with thickness less than the rib below the rail.

Table 7. Stresses in 2_L and 2_D, web points according to Figure 2.1b

b/b_1	70 / 50	80 / 60	90 /70	100 / 80
σ_{Z2D}	**-46,8**	**-46,3**	**-46,2**	**-46,4**
σ_{Z2L}	-10,0	-4,5	-0,5	+0,4
$\sigma_{Z2,SR}$	-28,4	-25,4	-23,35	-23,0

Because on the girder do not only influence bending moments in the vertical plane but also moments in the horizontal plane, of the inertial forces, the stress analysis is performed for these cases as well. Only examples were analyzed with the 6 mm thickness of the band plate and inertial force acting in the horizontal plane, and according to Figure 2, has the value of : $F_H = k_a\ R = 0{,}1\ R$.

Table 8. Stress relations in 2_L and 2_D web points for the 6 mm

b/b_1	70 / 50	80 / 60	90 /70	100 / 80
$\sigma_{Z2D}/\sigma_{Z2L}$ [1]	2,48	3,69	7,07	8,8
$\sigma_{Z2D}/\sigma_{Z2L}$ [2]	1,97	2,69	3,94	4,94

1- Refers to table 4,
2- Refers to bold values in tables 6 and 7.

All results were obtained on a girder model with the largest movements (shifting) of 0.18 mm.

3. CONCLUSION

To obtain better results several different examples should be done. The results presented in Table 8 could be used as a basis for determining the relationship between the critical stresses and the rib (wb) buckling just below the rail and the long rib (web). The established relationship between the critical stresses of the two ribs (webs) should be used for defining the boundary conditions of the girder cross section optimization. As an optimized cross section provides lower girder weight which also implies it's lower price.

4. REFERENCES

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