12th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

OPTIMIZING THE WEIGHT OF THE OVERHEAD CRANES GIRDER

Mirsad Čolić, Adil Muminović, Nedžad Repčić
Faculty of Mechanical Engineering
Vilsonovo šetalište 9, Sarajevo
B&H

ABSTRACT
In this paper the optimization of the weight for the overhead cranes girder is presented. This allows to ensure and to optimize the material costs participation in overall costs in the projects starting phase.
The aim of this task is the calculation of the girders dimensions cross-section, which ensure the constructions minimal weight, with the condition of satisfying the predicted limits. The mathematical model is resolved with the SUMT (Sequential Unconstrained Minimisation Technique) nonlinear programming method where the new function without limitation is formed from the cost function with limitations, implementing the punishment function, and then the function minimum is determined. The dependency of the girders weight from the cranes carrying capacity, the length of the girder, allowed deflection and slenderness (the ratio between height and thickness) of the vertical sheet metal is established and alongside values of the gained results are given.
Keywords: overhead cranes, optimizing, girder

1. INTRODUCTION
While designing the overhead crane, the girders dimensions and the shape of the cross-section are mostly got on the basis of experiences and recommendations. By doing so the height of the vertical sheet metals is adjusted to the standard sheet metal plates width. For carriers that are chosen this way the inertia moment and the cross-sections resisting moment in the critical intersection is calculated and the deflection tension is tested and compared with the allowed. While doing this, of course, it is taking care of the carrier’s deflection to not cross the limits. The experience has shown that these solutions are acceptable, but not always optimal. The savings on the constructions weight often means that the construction will be cheaper. In this paper an overhead crane main carriers weight optimization example is shown, which allows to ensure and to optimize the material costs participation in overall costs in the projects starting phase. Optimization examples are made for the I carrier with cranes standard carrying capacities of 50kN, 100kN, 125kN, 160kN, 200kN, 250kN and 320kN for spreads of 8m, 12m, 16m, 20m and 25m and different allowed deflections. The same procedure can be used for optimizing box carriers. The aim of the task was the calculation of the girders cross-section dimensions, which allows the construction minimal weight with the clause for satisfying the given limits.

2. THE MATHEMATICAL MODEL
The function that is being minimized is the girders weight and has the shape

$$F(t,t_1,h,b)=\left[t\cdot h+2\cdot b\cdot t_1+\left(b\cdot t-t^2\right)\cdot\frac{h}{l_T}+a\cdot c\right]\cdot l\cdot\rho\cdot g \qquad \ldots (1)$$

Where: t, h, t_1, b, a, c and l are shown on Figure 1, l_T - the distance between the rigid verticals whose thickness is equal to the thickness of the vertical sheet metal *(t)*, *ρ* - specific mass of steel, *g* - speed of gravity.

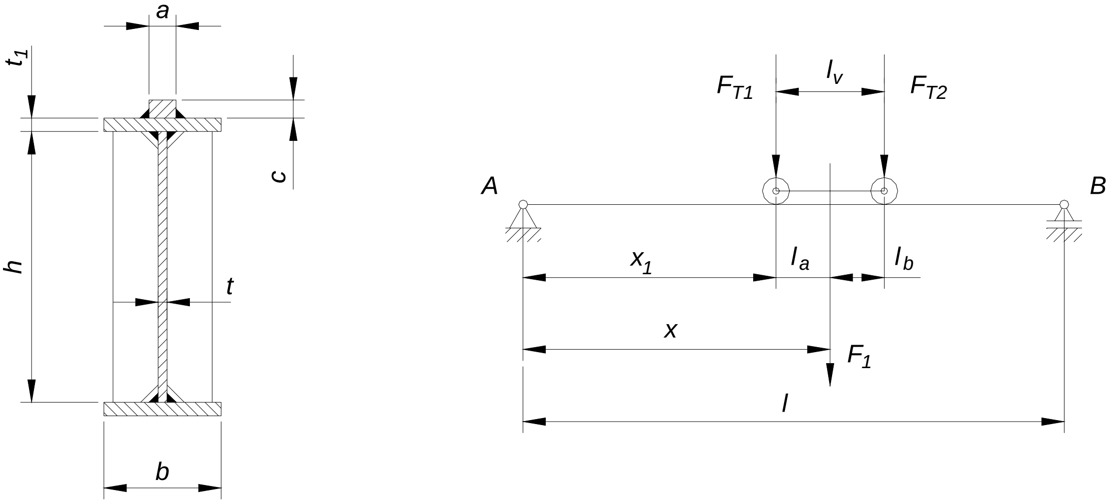

Figure 1. The shape of the girders cross-section (left) and the calculation draft (right).

The optimal cross-section must satisfy the next clauses [1, 2, 3] which refer on:
- vertical sheet metal

$$\left.\begin{aligned} &0{,}85\cdot\sigma_D-\sigma_{S1}\geq 0\\ &t-4{,}6953\cdot 10^{-4}\cdot\sqrt{\sigma_{kr}}\cdot h\geq 0\\ &\tau_D-\tau\geq 0\\ &t-3{,}903\cdot 10^{-4}\cdot\sqrt{\tau_{kr}}\cdot h\geq 0\\ &t-0{,}016\cdot\sqrt[3]{F_{kr}\cdot h}\geq 0\\ &t-5\geq 0 \end{aligned}\right\} \quad \text{... (2)}$$

- the girders upper belt

$$\left.\begin{aligned} &\sigma_D-\sigma_2\geq 0\\ &t_1-1{,}758\cdot 10^{3}\cdot\sqrt{\sigma_{kr}}\cdot b\geq 0\\ &t_1-1{,}2\cdot t\geq 0\\ &2\cdot t-t_1\geq 0 \end{aligned}\right\} \quad \text{... (3)}$$

- girders deflection

$$w_D-w\geq 0 \quad \text{... (4)}$$

Where the symbols represent: σ_D - the normal allowed tension, σ_{S1} - the bending tension in the vertical sheet metal, σ_2 - the total normal tension in the girders center, σ_{kr} - critical normal tension of the plate's buckling, τ_D - the allowed tangent tension, τ_{kr} - the critical tangent tension, F_{kr} - the critical concentrated buckling force, w_D - the girders allowed deflection.

3. THE SOLUTION METHOD

The mathematical model is resolved with the SUMT (Sequential Unconstrained Minimization Technique) nonlinear programming model where the new function without limitation (5) is formed from the cost function (1) with limitations (2),(3) and (4), which have the shape of non equivalence $c_j(t,t_1,h,b) \geq 0,\ \ j = 1,2,\ldots,m$, implementing the punishment function, and then the function minimum [5] is determined.

$$\phi(t,t_1,h,b,r) = F(t,t_1,h,b) + r \cdot \sum_{j=1}^{m} \frac{1}{c_j(t,t_1,h,b)} \qquad \ldots (5)$$

4. THE CALCULATION RESULTS

For resolving the problem and calculating the overhead crane girders weight, from figure 1, a computer program has been made. Optimization examples for standard carrying capacities and bridge spreads quoted on the beginning are made and analyzed, and some of the results are shown on coming pictures. The shown results are gained for vertical sheet metals calculated thickness values (t) and height (h) and for belt sheet metals thickness (t_1) and width (b), with non standard values of thickness and widths of the sheet metals.

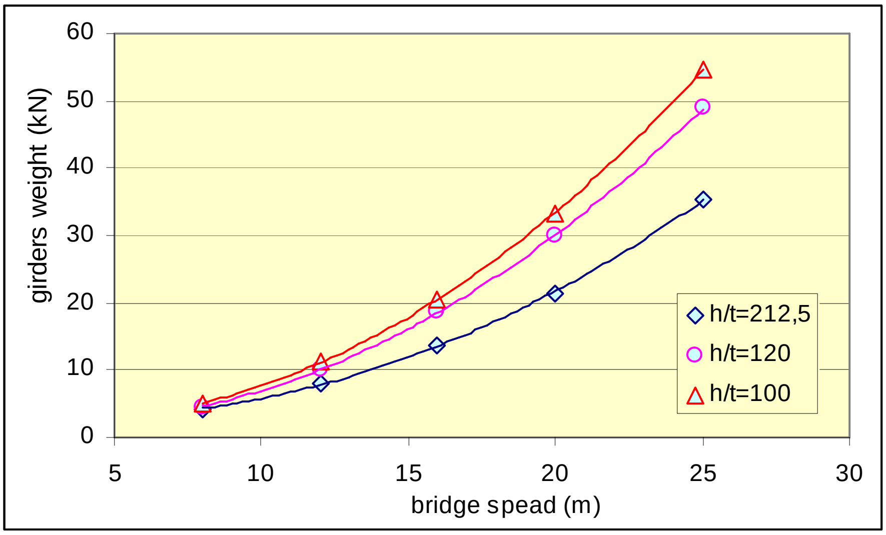

Figure 2. The weight of the girder depending on the bridge spread for the 100 kN carrying capacity of the crane and allowed deflection of l/1000 for three values of h/t

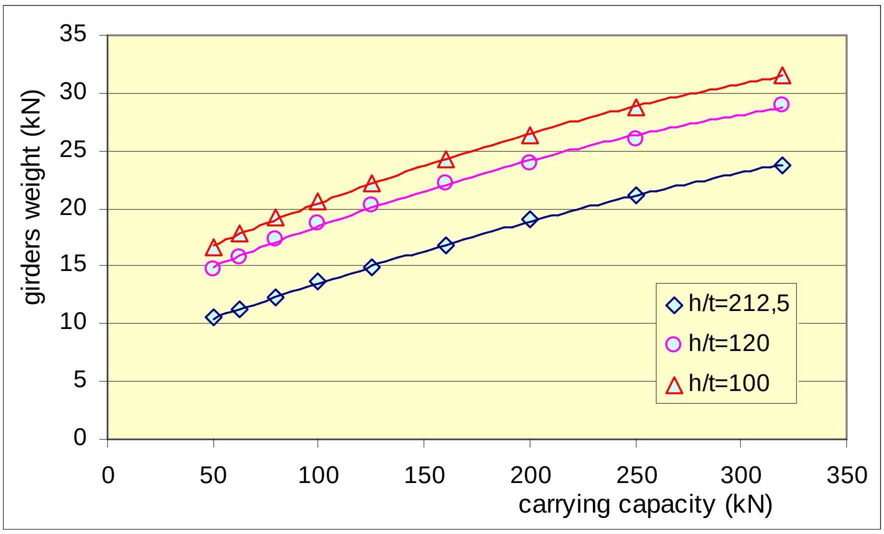

Figure 3. The weight of the girder depending on the cranes carrying capacities for the bridge spread of 16m and allowed deflection of l/1000 for three values of h/t

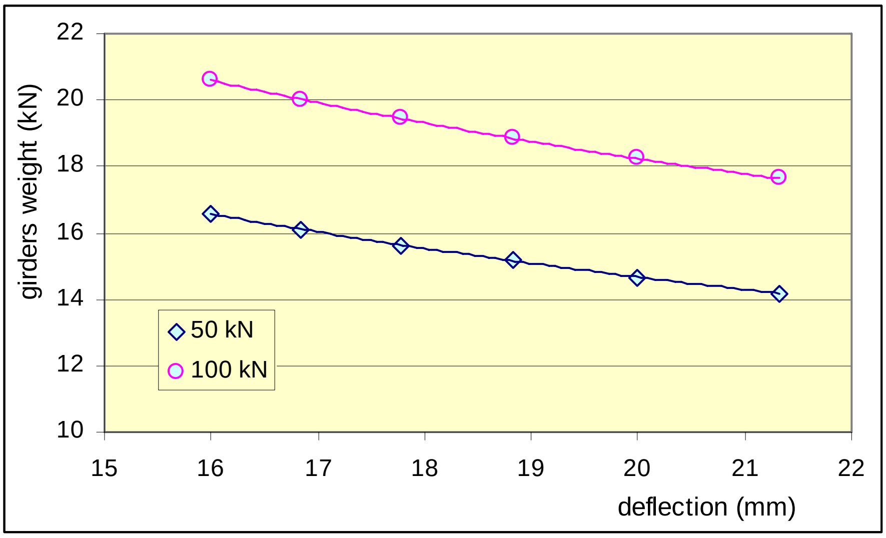

Figure 4. The weight of the girder depending on the girders allowed deflection for the bridge spread of 16m and for the value h/t=100

On Figure 2 can be seen that with small bridge spreads, increasing the (h/t) ratio, the material savings are insignificant, because of the concentrated force F_{kr} high influence in limitation (2), while the most influence on girders weight in examples with higher bridge spreads has the limitation (4).
The calculation is made for the case in which the crane works in the second working group. For the weight estimation of the driving winch expressions [2] are used:

- for the cranes carrying capacity $Q_T = 32 \div 80\,kN$

$$G_V \cong 16 + 0{,}2 \cdot Q_T \qquad \text{... (6)}$$

- for the cranes carrying capacity $Q_T = 100 \div 500\,kN$

$$G_V \cong 28 + Q_T / 16 \qquad \text{... (7)}$$

5. CONCLUSION

On behalf analyses and calculations that are carried out the law for girders (carriers) weight change, depending on his length, cranes carrying capacity and maximum allowed girders deflection is established. The presented procedure can be used for the optimization of box carriers which, as mentioned in the introduction, allows to ensure and to optimize the material costs participation in overall costs in the projects starting phase.

6. REFERENCES

[1] Rašković D.: Teorija elastičnosti, Naučna knjiga, Beograd, 1985.,
[2] Ščap D.: Prenosila i dizala-podloge za konstrukciju i proračun, Sveučilišna naklada Liber, Zagreb, 1990.,
[3] Standardi o stabilnosti nosećih čeličnih konstrukcija: JUS U.E7.081/1986, JUS U.E7.121/1986.,
[4] Parezanović N., Kolar D.: Fortran 77, Naučna knjiga, Beograd, 1991.,
[5] Банди Б.: Методы оптимизации-вводный курс, Перевод с английского. Радио и связ, Москва, 1988.