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ONE VIEW ON THE OPTIMIZATION OF THIN-WALLED CANTILEVER CHANNEL-SECTION AND Z-SECTION BEAMS

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Abstract

An approach to the optimization of the thin-walled cantilever open section beams subjected to the bending and to the constrained torsion, whose consequencesis are particularly evident in the case of thin-walled profiles, is considered. The problem is reduced to the determination of minimum mass i.e. minimum cross-sectional area of structural thin-walled channel-section and Z-section beam elements for given loads, material and geometrical characteristics. The area of the cross-section is assumed to be the objective function. The stress constraints are introduced. A general case when bending moments about two centroidal axes and the bimoment are acting simultaneously is derived, and then some particular loading cases are considered. A method of solving the optimal relation of the parts of the considered cross-section is described. Applying the Lagrange multiplier method, the equations, whose solutions represent the optimal values of the ratios of the parts of the chosen cross-section, are derived. The obtained results are used for numerical calculation.

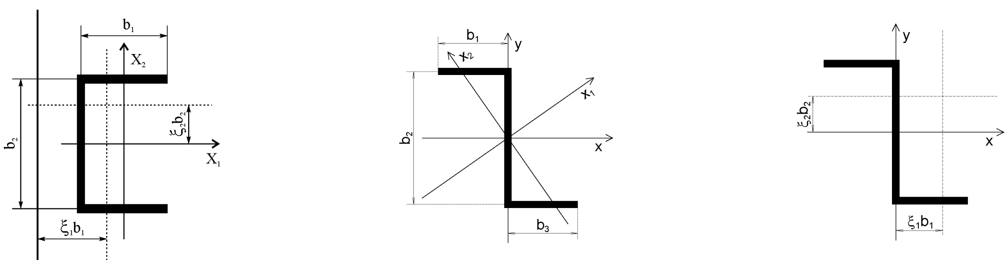
Key words: optimization, thin-walled beams, objective function, stress constraints.

1. Introduction

There are a number of works, where the problem of optimization of various sectional solve Lagrange multiplier method [1-3].

2. The problem definition

It is assumed that the loads are applied in two longitudinal planes, parallel to the longitudinal centroidal axes.



a) b)

Figure 1. Cross-section: a) channel-section; b) Z-section

In the considered problem the cross-sectional area will be treated as an objective function and the constraints treated in the paper are the stress constraints. The aim of the paper is to determine the minimal mass of the beam or, in other words, to find the minimal cross-sectional area *A* for the given loads and material and geometrical properties of the considered beam (Fig.1). The normal stresses are caused by the bending moments and by the bimoment *B* that appears in the case of constrained torsion.

3. Results and discussion

Applying the Lagrange multiplier method to the vector which depends on two parameters b_i (i = 1, 2), the system of equations will be obtained

$$\frac{\partial}{\partial b_i}\left[A(b_1,b_2)+\lambda\varphi(b_1,b_2)\right]=0,\quad \mathrm{i}=1,2, \tag{1}$$

where λ is the Lagrange multiplier and $\boldsymbol{\varphi}$ represents the constraint functions corresponding to the given stress. After the introduction of the expression for the bimoment into the equations (1), the equations can be reduced to the equations whose solutions give the optimal values of the ratio $\frac{t_i}{b_i}\neq const,\ \mathrm{i}=1,2,3$. The solutions are in the form of the eighth order for the considered channel-section beam, and in the form the sixth order for the considered Z-section beam.

4. Numerical example

Considered cantilever beams fixed at one end are subjected to the bending moments. After the numerical calculation, it was concluded that greater saved mass of the material was obtained for Z-section than for channel-section. Also, the calculation showed that if the distance of the loading plane from the shearing plane is increased, the optimization of the cross-section is less necessary to be done.

5. Conclusions

Accepting the cross-sectional area as the objective function and the stress constraints as the constrained function, it is possible to find the optimal relation between the dimensions of the web and the flanges of the considered thin-walled profiles in a very simple way. Particular attention is directed to the calculation of the saved mass using the proposed analytical approach. It is also possible to calculate the saved mass of the used material for different loading cases. The aim of the paper was the optimization of thin-walled elements subjected to the complex loads, and it may be concluded that the paper gives the general results permitting the derivation of the expressions that are recommendable for technical applications.

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