UDC 629.463.65.001.63

Improvement of upper bundling of side wall of gondola cars of 12-9745 model

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Abstract
The article shows the peculiarities and results of optimization designing of upper bundling of side walls of one of the most widespread models of gondola cars of native production – models 12-9745 to reduce materials consumption during fulfillment of conditions of strength and exploitation reliability.
Suggested aspect of designing may be used for other elements of gondola car bodies and other means of transport machine building.
Key words: OPTIMIZATION DESIGNING, GONDOLA CARS, RECTANGULAR PIPES.

Problem statement and analysis of results of latest researches

According to strategy of railway transport development for the period till 2020, which is approved by Ordinance of the Cabinet of Ministers of Ukraine from December 16, 2009 No 1555-r, one of the priority growth areas for railway transport is the improvement of rolling-stock construction, increase of its economic viability and competition capacity. An important aspect of this task solution is effective usage of constructional capacity of freight cars. Herein in the estimation of specialists more than 50% of common freight traffic in the railway system of SIS countries is fulfilled by gondola cars (www.ukrstat.gov.ua, www.gks.ru), the most part of which is on the edge of operational functionality [1]. Renewal of inventory rolling stock of gondola cars is fulfilled due to their manufacturing at car production facilities of Ukraine and SIS countries and also at reshaping car-repair plants (CRP) of "Ukrzaliznytsya".

Up to date one of the most widespread models of gondola cars of native production is 12-9745 model – basic for reshaped CRP (Darnitskiy CRP, public enterprise “Ukrspetsvagon”, Popasnyanskiy CRP, Striyskiy CRP). Fulfilled comparative analysis of technical-economic values of native and foreign gondola cars [2] showed the presence of improvement opportunity for gondola car construction of the model 12-9745 in the direction of reduction of its materials consumption (tare).

Results of fulfilled research works [1, 2] showed that one of the promising direction of materials consumption reduction of gondola cars construction of the model 12-9745 is mass reduction of upper bundling of side wall. Up-to-date solution of the task requires optimization designing (OD) of upper bundling according to the criterion of minimum materials consumption during fulfillment of strength requirements and maintenance reliability [3-5]. Along with this in the references and scientific-technical literature, devoted to the problems of car-building, there is no data concerning considering and solution of such important task.

The aim of he article and statement of base material.

The article presents the peculiarities and results of optimization designing of upper bundling of side wall of gondola car of 12-9745 model with the aim to reduce materials consumption during fulfillment of strength requirements.

Cross section of existing construction of upper bundling of side wall of gondola car of 12-9745 model is presented in the fig. 1.

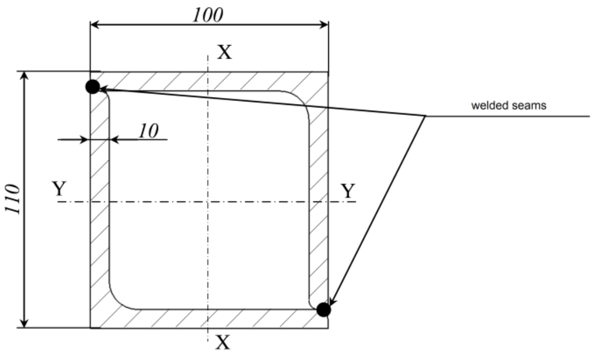

Figure 1. Existing construction of upper bundling of side wall of gondola car of 12-9745 model

General construction of upper bundling of side wall is made of two angle bars *100x100x10-B* (DSTU 2551, steel 295-09Mn2Si GOST 29281), which are welded with each other in the indicated places. Herein mass per unit length of such profile is equal to $m_{un}^{ex} = 30\ kg/m$, total length per car $l_{com} = 26\ m$, section modulus $W_{ex} = 115{,}5\ cm^3$.

Optimization research is directed to the sound choice of profile form of cross section and its corresponding geometrical parameters for reduction of materials consumption of upper bundling under the condition of strength securing.

To solve the task it was carried out exploratory researches [2], in the course of which different geometric forms (for example two welded beam channels, square tubes, curved closed sections) and construction materials were ranging. It was found that for manufacturing of upper bundling it is effective to use curved closed sections of 09Mn2 steel grade. Manufacturing of such profile from the sheet of necessary thickness may be fulfilled under technologies, which were adopted at production capacities and equipment of native CRP. This will provide reduction of prime cost for production of upper bundling and construction of gondola car body in common. With this in view there was fulfilled investigation concerning the choice of effective geometrical parameters of its cross section.

There is cross section of suggested profile in the figure 2, where the main geometrical parameters are: δ- sheet thickness; b – external width of profile and its height – h.

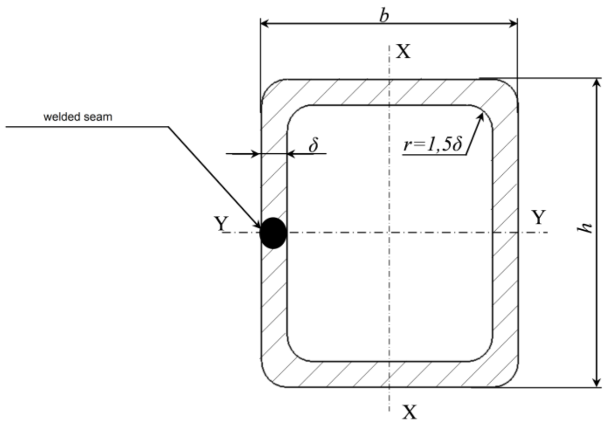

Figure 2. Suggested construction of upper bundling of side wall of gondola car of 12-9745 model.

Final objective of research is the search for parameters (δ^*, h^*, b^*), which will assure the lowest mass of upper bundling of side wall if the condition is fulfilled ($\sigma_{e\max} \leq [\sigma]$).

In the suggested set of designing of upper bundling of side wall may be considered as the task of multidimensional constrained optimization [2]:

$$m^{up.bun.}(\overline{X}) \rightarrow \min$$
$$\overline{X} \in D_x \in D \qquad (1)$$

where $m^{up.bun.}$ – mass of upper bundling of side wall (main criteria index);

$\overline{X}$ – vector of controlled variable parameters , the components of which are - δ, h and b, their variability intervals determine the area of feasible solutions D, where feasible region D_x is shown by functional limitations*[σ]*.

Taking into account that the value $m^{st.t.}$ is determined as the product of profile mass per unit length on its length ($m^{up.bun.} = m^{up.bun}_{un} \cdot l$), during corresponding stages of research it makes sense to consider it as main criteria index. Herein to simplify calculations, the value of allowable section modulus, which is equal to W_{ex} is taken as functional limitation. Preliminary calculations allowed to fix the following variability intervals of controlled variables: *h=100…140 mm; δ=6…10 mm* (taking into account the requirements of overall profile of rolling-stock there was taken b = const = 100 mm). Mathematical notation of defined problem of OD of upper bundling of side wall of gondola cars of 12-9745 model takes the form of:

$$m^{up.bun}_{un}(h^*, \delta^*) = \min$$
$$h^*, \delta^* \in D_x \in D \qquad (2)$$

where h^*, δ^* – optimum value of parameters h, δ wherein the lowest mass per unit length of upper bundling, which is determined at the level of acceptable decisions D_x, is provided. Common area of acceptable decisions D is determined by variability intervals of variable parameters:

$$D = \left\{ h, \delta \,\middle|\, _{100_{mm} \le h \le 140_{mm};\ 6_{mm} \le \delta \le 10_{mm}} \right\} \qquad (3)$$

Feasible regions:

$$D_x = \left\{ h, \delta \,\middle|\, _{W \ge 115.5 cm^3;\ 100_{mm} \le h \le 140_{mm};\ 6_{mm} \le \delta \le 10_{mm}} \right\}$$

(4)

Proved choice of optimal values of geometrical parameters of cross section of investigated element is fulfilled on the base of conjoint analysis of corresponding generic mathematical models (GMM) of the $m^{up.bun}_{un} = f(h, \delta)$ and $W = f(h, \delta)$ forms, which were obtained with the usage of methods of mathematical planning of experiment [2].

Obtained GMM for controlled values are presented below:

$$m^{up.bun}_{un} = 1.599 \cdot 10^{-14} - 4.441 \cdot 10^{-15} \cdot h + 15.42 \cdot \delta + $$
$$+ 3 \cdot 10^{-16} \cdot h^2 - 3.084 \cdot \delta^2 + 1.542 \cdot h \cdot \delta;$$

(5)

$$W = 24.9278 - 5.2126 \cdot h - 17.064 \cdot \delta + 0.27156 \cdot h^2 -$$
$$- 32.4135 \cdot \delta^2 + 14.63 \cdot h \cdot \delta;$$

(6)

Validity check of obtained GMM proved their ability to be used in further researches concerning determination of efficient geometrical parameters of cross section of construction element under consideration. With their application there was being built secondary graph [2] with isolines of corresponding fixed values of controlled indexes $m^{up.bun}_{un}$, W, which is presented in the figure 3.

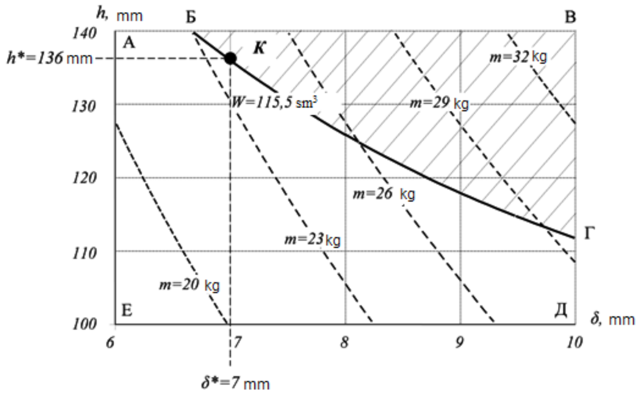

Figure 3. Secondary graph for determination of optimal parameters of cross section of new profile of upper bundling of side wall

- - - - - - $m^{up.bun}_{un} = f(h, \delta)$

——— $W = f(h, \delta)$

Feasible region:

$$D_x = \left\{ h, \delta \,\middle|\, _{W \ge 115.5 sm^3;\ 100_{mm} \le h \le 140_{mm};\ 6_{mm} \le \delta \le 10_{mm}} \right\}$$

Package treatment of isolines $m^{up.bun}_{un}$, W allowed to distinguish shaded region of feasible solutions D_x and chose K point, coordinates of which determine search value of experimental variables *h* = 136 mm, δ* = 7 mm.* Results of fulfilled calculations showed that for set values mass per unit length of upper bundling of new construction will be $m^{up.bun}_{un}$ *= 24kg/m* (m^{ex}_{un}*= 30kg/m)*, and section modulus *W = 115.81 cm³* *([W] = 115.5 cm³).*

Practical implementation of suggested technical solution concerning construction improvement of side wall is equivalent to the reduction of gondola car tare of 12-9745 model up to 150 kg. This allows to transport extra 9 tons in train formation with 60 gondola cars.

Conclusions and recommendations for further usage

The results obtained speak for practicality of implementation of suggested approach concerning optimization of designing of elements of native gondola car body construction to reduce materials consumption. Its practical realization will provide achievement of essential economic effect while their manufacturing and exploitation.

Suggested approach may be used for other body elements and gondola car constructions.

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