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# Improvement of the open wagon for cargoes which imply loading with a “hat”

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**Abstract**. The goal of the article is to evaluate the possibility of improving the design of an open wagon body in order to improve traffic safety when transporting cargoes whose height is beyond the upper belt of the side wall (cargo loading with a “hat”). To achieve it, the authors have proposed a variant of a pull-out bar in a wall rack. In lazy state such bars located inside racks, but during transportation of timber, pipes etc they are pulled out above the wall upper belt to prevent cargo from rolling out. These bars are quite light (mass of one pull-out bar is equal to 3 kg, that corresponds to 36 kg of an additional equipment per a wagon), but they considerably facilitate fixing cargo in an open wagon replacing additional wooden fixing racks. It also makes the transportation more reliable due to elimitation the possibility of skew and jamming of fixing equipment. Strength of the proposed element and the entire wagon side wall is estimated with the finite element method. The proposed bars withstand normative loads, and holes in the upper belt for them do not lead to desrease of the wall carrying capacity.

## 1. Summary

A sufficient amount of rolling stock influences the economic performance of the railway companies, and the technical condition of wagons influences the traffic safety. It is ensured not only by keeping the infrastructure and rolling stock in good working condition, but also by securing transported cargoes. Modern rolling stock should include new solutions that aim to increase the strength, dynamic performance, as well as to improve the design of the wagon in order to increase its versatility [1-4]. There is the highest level of demand for universal open wagons intended for transportation of coal, ore, timber, rolled metal, and other bulk and piece cargoes that do not need protection from precipitation. In works [5-10] it is pointed out the need to improve the rolling stock structures in order to increase its reliability and versatility.

## 2. Literature review

For transportation of a certain nomenclature of cargoes, such as timber, the additional fastening elements (wooden struts, wire ties) are used to fix cargo in a universal open car. When transporting boxes in several tiers, the height of the protruding above the upper belt part of the box should be no more than half its height, and the center of gravity of the protruding box should not overtop the upper belt, Figure

1a [11, 12]. Most wagon models have a body height above rail heads from 3295 mm to 3800 mm. So, the situations can happen, when it is necessary to select the model of wagons according to the height of the body or to use additional means of fastening cargo for transportation. For timber transportation, round wooden posts with diameter of 120–140 mm in the lower cut, at least 90 mm in the upper one, and at least 100 mm at the level of the upper belt are additionally used. Wooden struts are passed through the timber claps and secured to the lower linking device by several threads of wire with diameter of at least 5 mm. Opposite racks should be tied with wire of diameter at least 6 mm laid in several threads, Figure 1b [11, 12].

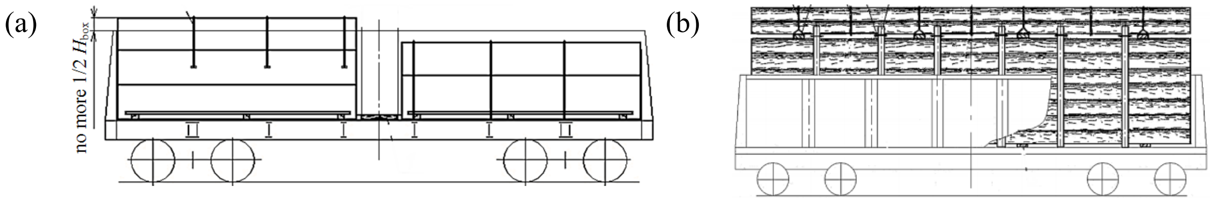



**Figure 1.** Placement and fixing cargo in an open wagon.

**Figure 2.** Transportation of timber in open wagons.

The main disadvantages of transportation of timber in the universal rolling stock (flat and open wagons, Figure 2) consist in the high consumption required for the transportation of equipment, its selection, complexity and risk of loading and unloading [13]. The data [14] show that at sites with intensive transportation of timber the number of detachments of wagons with timber cargo is up to 80 % of the total number. The main reasons for detachments of these wagons are misalignment of the wooden posts and the displacement of the cargo.

### 3. The pull-out bar in the side wall rack

To solve the above-mentioned problem of transportation in open cars cargoes loaded with a “hat”, the authors proposed a telescopic pull-out bar shown in Figure 3. The cross-section of the bar consists of two welded angles No. 40 or square pipe. The weight of one bar is about 3 kg, or 36 kg per car with 12 pull-out bars in side walls. More bars can be installed in open wagons with racks in end walls.

The hole for pull-out bar is made in the upper belt at the point of its connection with the side wall rack. In idle position the pull-out bar is lowered into the wall rack and locked there. When necessary the pull-out bar is mounted at the desired height and securely locked in this position. The height of the pull-out bar in the working state is limited by the zonal loading gauge. At this stage of design the mechanism for fixing the bar is considered as a threaded rod with a screw-nut. When necessary to increase the height of the body the pull-out bar provide holes for bolt connection to fix the boards.

The theoretical assessment of the strength of the structure was carried out by the finite element method. The main loads on the side walls and pull-out bars are caused by lateral forces such as the inertial force in curved sections of the track and the force of bulk of rolling cargo bursting. These forces relate to III design mode. It is also required to check the strength of the side wall when unloading the wagon with the car dumper (I design mode). The mechanical properties of the material according to [15, Table. 12.1] are given in Table 1. The close analog of 09Г2С grade is the steel grade 13Mn6 (DIN 17145).

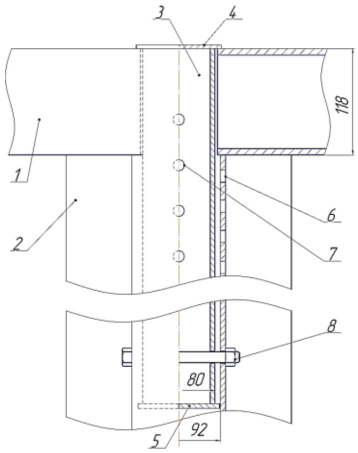



**Figure 3.** The pull-out bar in the side wall rack: 1 – upper belt; 2 – rack of the side wall; 3 – pull-out bar; 4 – patch; 5 – fastening; 6 – openings in the rack (for fixing the pull-out bar); 7 – holes in the pull-out bar (for mounting planks); 8 – fixing rod with a nut.

**Table 1.** Mechanical properties of material.

| Part of a wagon | Steel grade | Stresses, MPa | |
|---|---|---|---|
| | | permissible for I design mode $[\sigma_{\mathrm{I}}]$ | permissible for III design mode $[\sigma_{\mathrm{III}}]$ |
| Side wall of a body | 09Г2Д, 09Г2С[a] | 289 | 195 |

[a]The close analog of 09Г2С grade is the steel grade 13Mn6 (DIN 17145).

**4. The strength of the side wall and the pull-out bar**

The strength of the side wall and the pull-out bar is estimated separately. According to [15] the uniform load $P_1$ (the lateral inertial force of an upper part of the cargo in curved sections of a track) and the triangular load $P_2$ (the cargo bursting force) are applied to the pull-out bar (Figure 4). The height of the protruding part of the pull-out bar is 294 mm. We fix the model displacement at lines $D_1$ and $D_2$, it corresponds to resting on the threaded rod and on the hole in the upper belt.

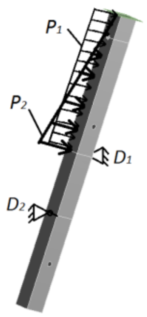



**Figure 4**. Loads acting on the pull-out bar.

We faply a similar load, namely a lateral inertial force and a force of cargo bursting, to the side wall. To the openings in the upper belt (Figure 5) we apply the forces corresponding to the reaction components $R_{xi}$, $R_{yi}$ in the supports $D_1$ and $D_2$ of the pull-out bar ($i$ is the number of the support $D_i$).

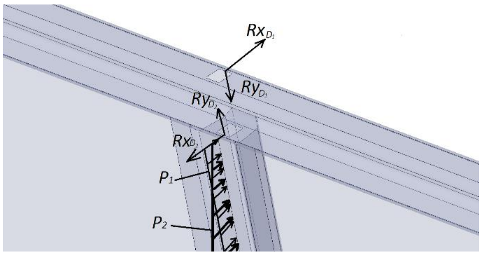



**Figure 5.** Loads of III design mode acting on the hole in the upper belt.

According to [15], for the conditions of unloading on wagons, the side wall of the open wagon was checked by I design mode for simultaneous action of vertical and horizontal loads, evenly distributed along the width of the upper belt at a length of 0.8 m (Figure 6). There a $n$ such spots, each corresponds to a cur dumper clip.

The calculated vertical force, in Newtons, per plot was determined by the formula:

$$q = \frac{P}{n}, \tag{1}$$

where $P$ is the gross weight of the wagon;

$n = 8$, i. e. there are 4 dumper clips per wall.

The lateral force is equal to $0.25q$.

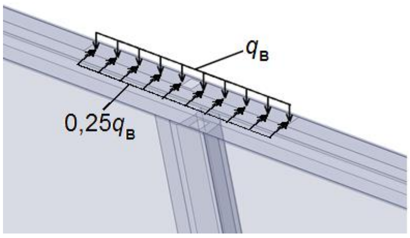



**Figure 6.** Loads on the hole in the upper belt acting during unloading on a car dumper.

Wall gravity is also taken into account.

Calculation carried out with the software package MSC.Patran/Nastran. The geometric model was meshed into finite elements with edge size of 10–50 mm for the side wall and 10 mm for the pull-out bar (Figure 7).

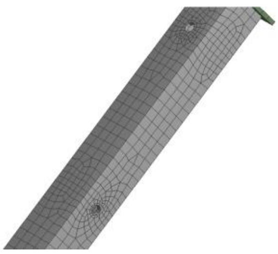
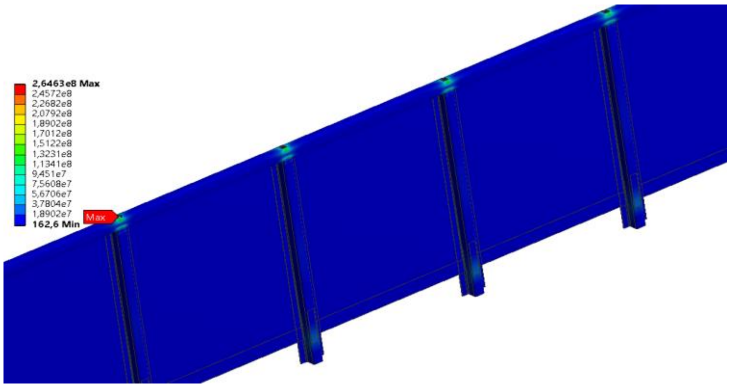
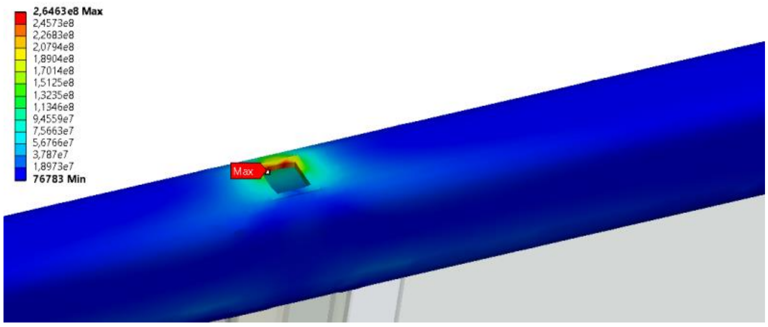


**Figure 7.** The part of a finite element mesh.

The equivalent stresses in the pull-out bar and in elements of the side wall under the loads of III design mode and in the side wall during unloading with the car dumper are shown in figures 8–10 and in Table 1.




(a)




(b)

**Figure 8.** Stresses (von Mises) in the side wall when pull-out bars are used, Pa: (a) III design mode (general view); (b) the upper belt.

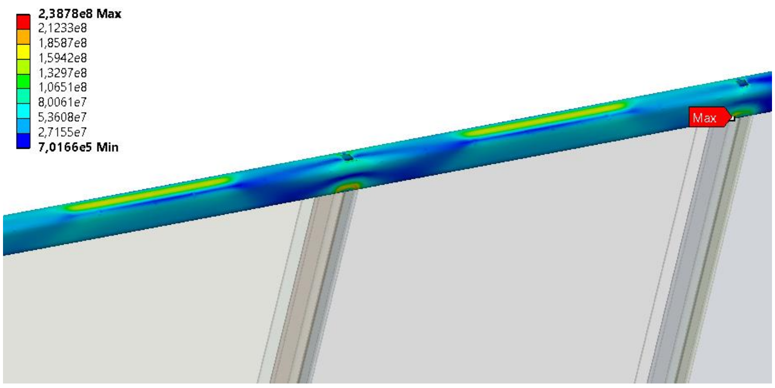



**Figure 9.** Stresses (von Mises) in the upper belt during unloading on a car dumper, Pa.

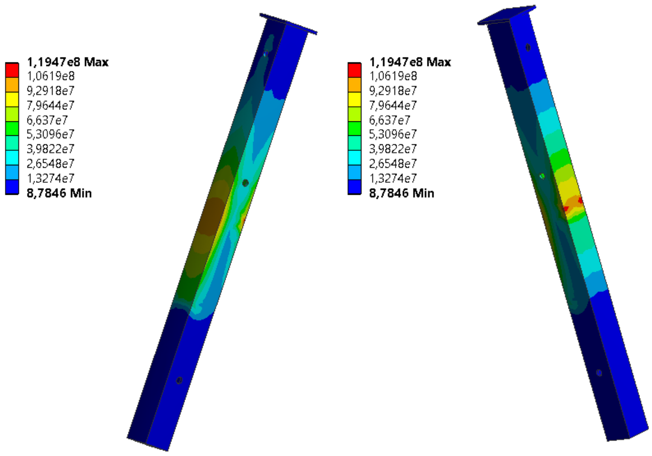



**Figure 10.** Stresses (von Mises) in the pull-out par, Pa.

**Table 2.** Maximum stresses in the side wall and pull-out bars.

| Part of a wagon | Stresses, MPa | | | | |
|---|---|---|---|---|---|
| | III design mode ($[\sigma_{\mathrm{III}}]=195$ MPa) | | | unloading on a car dumper ($[\sigma_{\mathrm{I}}]=289$ MPa) | |
| | below the upper belt | above the upper belt | | upper belt | |
| | | not reinforced | reinforced | not reinforced | reinforced |
| Rack of a side wall | 110 | 87 | 87 | 245 | 245 |
| Upper belt | 63 | 265 | 158 | 238 | 238 |
| Pull-out bar | — | 120 | 120 | — | — |

As we can see, the stress $\sigma = 265$ MPa in the area of the hole in the upper belt, when bar is pull out, is higher than the permissible $[\sigma_{\mathrm{III}}]=195$ MPa. So, this part of the upper bels needs reinforcement. As a reinforcement we offer a patch $54\times54$ mm and 4 mm thick. Stresses is the uppers belt with such reinforcement are shown in Table 2 and Figure 11.

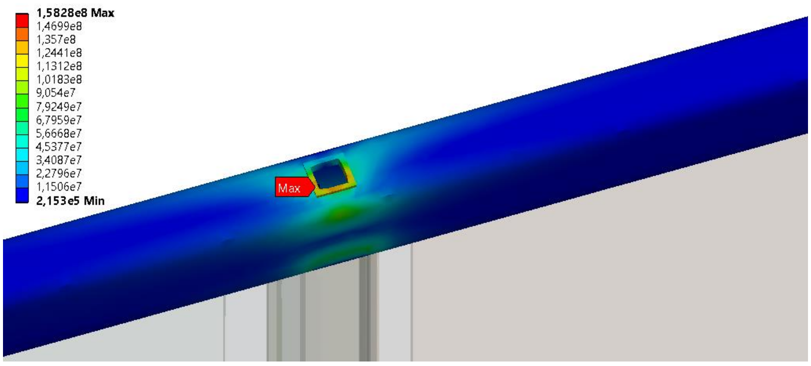



**Figure 11.** Stresses (von Mises) in the reinforced upper belt (III design mode), Pa.

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## 5. Conclusions

The proposed pull-out bar of the semi-wagon increases not only its versatility, but also the safety of transportation when cargo is loaded with a "hat". It can be easily installed from a technological point of view, requires only small alterations of an upper belt and a rack, and does not lead to a noticeable increase in the wagon weight. The performed analysis has shown that the strength both the pull-out bar with selected dimensions and the side wall withstand loads the standard prescribes. The hole in the upper belt should not have sharp corners and requires reinforcement with a 4 mm thick patch. The mechanism of fixing of the pull-out bar needs more detailed consideration. It is advisable to consider the possibility of optimizing the proposed design by selecting the configuration of the cross section of the pull-out bar.

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