ABSTRACT. The present work considers the problem of long loads fastening to the couple of two flatcars. 3D model of the coupled platforms loaded by rails was created with the help of MSC ADAMS means. The analysis has been performed for the two worst transportation conditions: turnout pass and moving in the turn. Also the stress-strain state analysis of “wooden pad – spike nail” system was performed in the environment of ANSYS. The obtained computational results can be used for improving the existing technique of long loads fastening on the two coupled flatcars.

KEY WORDS: long loads; couple of two flatcars; computer modeling

1. Introduction

Rails and other long loads on the two coupled flatcars are often transported by railways. Such loads are fixed with cables, straps, pads and wooden bars. Really, in practice wooden parts of a tie down are destroyed and strapping cables are weakened while transporting. As a result the flatcar and the cargo can be damaged. This situation is caused by the inertia forces when a train passes a turnout at high speed or enters the curves of 350–500 meters radius. Due to the tie down failure there is a need to re-fix the loads while transporting to the station of destination.

The main purpose of the research work was to establish the causes of the tie down damages while transporting of long loads and to provide recommendations for their effective fastening to the couple of two platforms by analyzing rail transportation as an example.
2. Problem formulation

Rails placed on two coupled flatcars with base 9.72 m have mark R65 and their length is 25 meters (Fig. 2). According to [1] two metal and two wooden transverse pads are put on the floor of each platform under the rails. Metal pads should be heavily lubricated, placed between wooden ones and fixed by wooden bricks. Metal pads designed to best slipping of rails during the entrance to the turn and moving through the turnout. Rails are placed in four tiers as Fig. 3 shows. Usually, the lower tier is rigidly fixed at both ends by hammering of spikes in a wooden brick from the left and right side of the tier.

Fig. 2. Placement of R65 marked rails: 1 – slide block; 2 – pad; 3 – slide block (rail); 4 – nail; 5 – rail lining; 6 – wooden brick; 7 – thicker layer pad; 8 – layer pad; 9–11 – tie down; 12 – moulding; 13, 14 – spike nail; 15, 16 – strap; 17, 18 – tie down; 19 – rail lining
Computer modeling of long loads transporting on the two coupled flatcars

Fig. 3. Placement of rails in tiers

Passing through the marshalling hump is not allowed for coupled flatcars. But the practice shows that after some time of transportation the wooden pad brakes from one side of the lower tier of rails. This fact leads to deformation of strapping wire threads and to the disturbance of the tiers equilibrium state. As a result, there is a need to refasten cargo during delivery to the destination station. The peculiarity of this long load is the absence of holes for bolted joints. Therefore it is difficult to tie down the rails to each other within each tier. Total cargo weight is 110 tons. The system consists of two four-axial 13-401 flatcars of 13.4 meters length. The bottom tier is separately tied down to the flatcar by cables. The other tiers are also connected by cables both among themselves and with the bottom tier.

At the present time calculation of forces perceived by fastening elements should be made by the technique described in [1]. Along with the mass of cargo this technique takes into account the following forces and loads: longitudinal horizontal inertial forces during the movement (speedup or slowing-down/braking of the train), collision of cars during the maneuvers and shunting from inclined surfaces; transverse horizontal inertial forces arisen during the movement of the car and its movement along curved and transition points of track sections; vertical inertial forces caused by the acceleration during the oscillation of a moving car; wind load and friction forces (longitudinal friction forces and transverse friction forces).

The formulas for evaluating the above-mentioned forces do not take into account the interaction between the platforms in the couple during the crossing the turnout and the entrance to the turn. Also the existing technique doesn’t consider the fact that during transportation all these forces don’t reach their maximal value at the same time. Besides, the above-mentioned technique doesn’t take into account the relative linear and angular displacement of the flatcars during movement. The complexity of the calculation scheme causes difficulties while creating mathematical models. So, only computer modeling of long loads’ transportation can help to obtain real results in comparison with the existing technique use.
3. Computer modeling of flatcars

3.1. 3D computer model creation

Computer modeling was performed in engineering package MSC ADAMS. Platforms, rails, pads and bricks were modeled as rigid bodies. Flexible tiedown elements were replaced by springs, which had the same thickness and stiffness. One end of the long load was rigidly fixed. The second end of the long load was fixed against movement in the lateral direction only by strapping. So, this end could change its position relative to the longitudinal axis of the flatcar floor. The connection between platforms was also simulated by springs having the necessary stiffness and damping coefficients corresponding to the automatic coupler mechanism.

![Computer model](image)

Fig. 4. Computer model: a) tiers of rails; b) placement of rails on two flatcars

The motion of loaded coupled flatcars was analyzed. The results showed that the dynamics of rails linked into the tiers corresponds to the dynamics of solid bodies. So, further calculations were done based on a simplified model where the tiers of rails were replaced by rectangular parallelepipeds of the appropriate mass. The movement of the coupled flatcars loaded with rails through the marshalling hump isn’t allowed by railway requirements. So it was carried out the dynamic analysis of the model for two cases: entrance in the curve of a small radius (350 meters) with 5 m/sec velocity and passing the turnouts at 20 m/sec.

3.2. Computational results

One of the objectives in current research was to determine the maximum displacement of the bottom tier in comparison to its initial position on the wooden pad. In other words it was necessary to obtain the maximum deviation the bottom tier longitudinal axis from the longitudinal axis of the flatcar. For this purpose one end of the bottom tier was rigidly fixed but the other end could move freely in the transverse direction. The calculations showed that the maximum displacement of the bottom tier is about 11.5 cm (Fig. 5).
Thus, when the spikes are placed in wooden pads at a distance of more than 12 cm from the nearest rail the strikes of rails on the spikes will not occur. It should be considered that at the specified spike displacement the distance between the spike and the end of the wooden pad reduces. This fact can cause cracking and breaking of the wooden pad.

3.3. The stress-strain analysis of wood pad with hammered spike nail

To find out the features of "wood pad – spike nail" interaction the finite element model of such system was created in ANSYS. It includes the wood brick considered as an orthotropic material. The brick has a crack in the middle, where the spike nail is placed. The 10–node tetrahedral 3D finite elements were used for the simulation. In order to provide the best approximation of displacements and stresses in the contact area the finite element mesh was thickened. Areas of possible contact of wood and spike surfaces were modeled as plane contact elements. Figure 6 shows a fragment of the obtained finite element model.
Figure 7 shows the distribution of equivalent Von Mises stresses in the section plane which is normal to the longitudinal axis of the spike nail. The obtained results allowed to see the crack opening along the fibers of the wood and showed the presence of high contact stresses in the boundary regions between the surface of spike nail and the wooden pad. On the basis of the computational results the dependence of stress values in the wooden pad on the spike nail diameter can be found for all wooden and metal elements used for long load fastening to the couple of two flatcars.

4. Conclusions

1 The computational results have shown that the rails wouldn’t hit spike nails and the cargo integrity would be ensured if spike nails are placed at a distance of more than 12 cm from the first tier rails. However, the displacement of the spike nail on the above-mentioned distance can lead to cracking and tearing of wooden pad.

2 The stress-strain state analysis the wooden pad with hammered spike nail was performed. The obtained computational results have shown that the crack opening along the fibers of the wood and showed the presence of high contact stresses in the boundary regions between the surface of spike nail and the wooden pad. The computational results can be used for other wooden-metal systems analysis

3 The results can be applied for make recommendations for long loads fastening ways improvement.

REFERENCES