Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 150 (2016) 150 – 154

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Industrial Engineering, ICIE 2016

Justification of a Rational Design of the Pivot Center of the Open-Top Wagon Frame by means of Computer Simulation

D.Ya. Antipin*, D.Yu Racin, S.G. Shorokhov

Bryansk State Technical University, 7, Bulvar 50 let Oktyabrya, Bryansk, 241035, Russia

Abstract

The study of the strength and fatigue life of a welded load-bearing structure of the open-top wagon body was carried out by methods of mathematical simulation. The causes of occurrence of crack-like defects in the pivot center of the wagon were detected. Options to improve the load-bearing structure of the pivot center of newly manufactured open-top wagons and repaired wagons with defects were proposed. For the modified design of the open-top wagon pivot center conception complex calculations were made that confirmed its efficiency.

Peer-review under responsibility of the organizing committee of ICIE 2016

Keywords: Solid mathematical modeling; finite element method; open top wagon; pivot center; strength; fatigue life; crack-like defects

1. Introduction

During the operation of the universal open-top wagons of 12-9085 model in the pivot area of the frame fatigue damages in the plates of pivot boxes were detected in the form of cracks. In this regard there was a need to find the causes of damage, to develop design and technological activities to repair and to strengthen of pivot center of wagons with defects and to create an advanced design ensuring durability and fatigue life of the pivot center.

An analysis of contemporary approaches to the study of strength and fatigue life of bearing structures of freight cars showed that the most rational from the point of view of labor intensity, material costs, time of the study, as well as ensuring the accuracy and validity of obtained results is a computer simulation confirming the adequacy of its data by the field experimental data [1-6].

* Corresponding author. Tel.: +7-4832-56-04-66; fax: +7-4832-56-04-66.
E-mail address: shorsg@yandex.ru

Peer-review under responsibility of the organizing committee of ICIE 2016
doi:10.1016/j.proeng.2016.06.738

2. Test Method

At the first phase of the study the evaluation of the open-top wagon body bearing structure dynamic load in the operation was performed by methods of solid-state computer modeling. As a tool for research the software for simulation of dynamics of systems of bodies, "Universal mechanism" was used [7]. The simulation examined the movement of loaded and empty open-top wagon on the real irregularities of path in the speed range of 20 to 120 km / h in increments of 20 km / h. The motion of the wagon was considered on straight track sections, curves with radii of 350 – 1200 m and turnout sleepers R65 of mark 1/11. Also shunting collision of the wagon with support weight of 300 tons with speeds up to 14 km / h was considered. According to the simulations results was determined the dynamic forces acting on the load-bearing structure of the open-top wagon body.

The study of support structure strength of the body is made by finite element method in the static and dynamic statement on the basis of the developed detailed dynamical elastic-dissipative finite element models of open-top wagon body. Calculations in a static setting were carried out from the load actions recommended by the normative documents on the design of wagons [8]. In a dynamic setting the calculations were carried out from the action spectra of the dynamic forces obtained from simulation of the dynamics of motion of a open-top wagon. The calculations are performed using the modern industrial software system that implements the finite element method, Siemens PLM Software Femap [9].

The clarification of the stress-strain state of the supporting structure of the open-top wagon in pivot center area were carried out using the method of successive selection and using detailed finite element model of the wagon frame pivot zone [10].

The verification of developed mathematical and computer models were made on the basis of the results of the static and dynamic performance trials.

Analysis of fatigue life is made within cycle of multi-fatigue model using linear hypothesis of fatigue damage summation during transient loading conditions. As source data in the study of fatigue life the results of evaluation of dynamic loads of the pivot area in a dynamic formulation were used, derived using a detailed finite element model.

3. Dynamic loading study of open-top wagon body

Assessment of dynamic loading of open-top wagon is based on developed dynamic solid model of open-top wagon (Fig. 1) that is a body in the form of a perfectly rigid body with real geometric and inertial characteristics connected by the contact elements and rotational joints with subsystems "truck", and special joints to the subsystem "automatic coupling device"[11-13]. In the analysis of the dynamic characteristics of the wagon variants of empty and loaded wagon body were considered. The load in the model presented by absolutely solid parallelepiped, located on the floor of the wagon. The connection of the load with body was modeled using the generalized joint excluding movement of load towards to the body in any direction.

As a result of modeling the spectra of dynamic loads resulting from the interaction of the supporting structure of the body with elements of the chassis and automatic coupling equipment were obtained.

The adequacy of the results obtained in the simulation is confirmed by their satisfactory compliance with the full-scale trials and tests on impact, conducted at the wagon certification.

4. Investigation of the stress-strain state of load-bearing structure of the pivot zone of the open-top wagon body

Analysis of stress-strain state of the open-top wagon body supporting structure is made on the basis of the finite element model, which is a three-dimensional plate-settlement system, formed by three and a four isotropic plate elements with an average size of 30 × 30 mm [14-17]. Modeling of thick cast elements of the wagon body (body pivot bearing, front draft lugs, combined with the socket of automatic coupler, and a rear draft lugs) carried out on 52 thousand of four-, five- and six-sided solid volume elements. The final elements of the schema are combined in 189 thousand units, the number of degrees of freedom of the finite element model was 1 million 134 thousand.

To clarify the stress-strain state in the pivot area of the wagon of the plate finite element, the frame fragment of the wagon mode was separated, comprising center plate arrangement for which a detailed elastic-dissipative finite element model was developed formed from 131 thousand of four, six- and eight- nodal solid elements, combined