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Structural Improvements in a Tank Wagon with Modern Software Packages

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Abstract

For transportation of dangerous goods rail transport uses tank wagons. Structural changes can contribute to reduction in the maximum stresses, and as a result, to improvement in technical and economic characteristics of a tank wagon. In order to investigate the stress-strain state of a tank wagon the finite element model was built, its adequacy having been checked by results of analytical calculations and experiments. It has been applied for numerous researches to find the most effective bracket support structure by comparing it to the existing structure. The laws of stiffness change in radial direction and the laws of contact pressure change have been demonstrated. The improved structure has been checked by a load spectrum according to normative documents.

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Keywords: tank wagon, barrel, finite element method, support structure, stress-strain state, equivalent stresses, contact pressure

1. Introduction

Dangerous goods are transported in tank wagons which provide safe and high-quality delivery of petroleum products to customers [1, 2]. Operational environment of transport modes requires high standards in capacity of

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existing and new tank wagon structures. The forecasting and elimination of vulnerable zones and a longer life cycle of tank wagons should take into account new achievements in capacity, reliability and durability researches [3, 4].

The researches provided by leading companies in the field of rolling stock testify that stresses exerted by support pressure amount to 70–90% out of the maximum stresses in the tank of tank wagons [5–7]. The observations have shown that cracks on the surface of liquid tanks in support areas begin to intensively appear after 10–12 years of operation [8, 9]. Typically, the cracks are of fatigue nature.

At present the wagon structure has taken full advantage of width and height, therefore a further increase in body space is only possible due to extension that results in increased tare weight and decreased carrying capacity at the same axial loads.

$$P \le q_o m_o - T\,, \tag{1}$$

where P is the wagon carrying capacity; q_o is the admissible axial load of the wagon; m_o is the number of wagon axles, T is the tare weight.

As $q_o m_o$ can not exceed its maximum value, a further increase in carrying capacity is only possible due to a lower tare weight.

Structural changes aimed at re-distribution of loads and stresses in vulnerable zones can contribute to reduction in the maximum stresses and, as a result, to improvement of technical and economic characteristics of a tank wagon.

2. Development of the computational finite element model of a tank wagon

Nowadays the finite element method is one of the most efficient multiple methods of research into capacity and stress-strain behaviour of tank wagons [10, 11]. A computational finite element model was developed for investigation into stress-strain state of tank wagons. The tank was built by rotating a generatrix around the axle through the centers of heads. The tank hatch is a cylindrical surface and the hatch cover is a circular plate. An outlet for the drainage device is built by rotating the generatrix around the axle through the tank centre in vertical plane. To calculate hollow cases one can use a number of simple lamellar quadrangle finite elements. Yet these elements cannot be used to describe the geometry of compound profile structures, so triangular elements are used. Application of triangular elements makes it possible to clearly describe the geometry of a compound profile structure. Therefore, to build a computational model it is necessary to use triangular finite elements in the tops of heads and hatch covers, in places where the hatch and outlet for drainage device join with the tank shell. For every basic frame element one can notice that the thickness of an element is much smaller than its basic dimensions, thus it is reasonable to design the frame's supporting parts with flat finite elements. Thus, each beam of the frame, bracket support and middle mounting foot are made of sheets the thickness of which correspond to the dimensions of the elements. The wooden beams of the bracket supports are presented as octagonal three-dimensional elements. In places where the compound frame elements cross and join, triangle finite elements are used. In places where the tank rests on the wooden beams binodal finite elements were introduced, namely, a one-sided linear connection for simulating free movement of the tank relative to the beams in the plane perpendicular to the generatrix and a one-sided frictional element for sliding the tank along the generatrix. Furthermore, in the place where surfaces touch and friction appears the union of movements is applied for all nodes in pairs in all directions except the direction of sliding. By the finite element method the computational diagram was obtained by dividing the model into three-dimensional eight-nodal lamellar quadrangular and triangular finite elements [12]. This division generated 86174 elements and 82479 nodes (Fig. 1).

LIRA software was used for calculation by static and impact loads.

In order to check the adequacy of the method the calculation results were compared to analytical and experimental data [13, 14]. The inaccuracy of the results obtained for the model and experimental results does not exceed 10–12%.