EXPERIMENTAL AND NUMERICAL ANALYSIS OF FLAT CARS CONNECTIONS BETWEEN PIVOTING STANCHIONS AND MAIN LONGITUDINAL BEAMS

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***Abstract** – This paper presents experimental and numerical strength analysis of some existing designs of connections between pivoting stanchions and main longitudinal beams of flat cars, pointing out the problem of possible appearance of high contact stresses at some contact surfaces, that might cause some local deformations within plasticity range. Criterion set in the applicable standard requires that two side stanchions fitted to the wagon and positioned opposite each other, shall be able to withstand, without residual deformation, a force of 35 kN acting at 500 mm from the bearing centre of the stanchions in a horizontal direction towards the outside of the wagon. Meeting this criterion and staying inside the limited available space, leaves only minor changes of dimensions of moving parts in a contact as a possible solution of this problem.*

Keywords - Pivoting stanchions, flat car, strength analysis.

1. INTRODUCTION

Elements of connections designed for supporting heavy loads and at the same time for providing relative motion between connecting parts are often subjected to high contact stresses at contact surfaces. This paper presents numerical and experimental analysis of connection between pivoting stanchion and main longitudinal beam of freight flat car type Regns(s)-z manufactured by Railway Vehicles Factory "GOŠA". The scope of this analysis is to find reliable design solution which has relatively lower contact stresses at the contact surfaces.

In Figure 1 is presented exisiting design of the connection between pivoting stanchions and main longitudinal beam on the flat car [1]. Pivoting stanchion is made of steel grade S355. Connection is provided using a bearing pin (figure 2, pos. 1) and U-shaped securing element with cotter pin (figure 2, pos. 2 and 4). In such a way is enabled easy assembling and dismantling of the stanchion in service. Motion stops placed on the outer side of the main longitudinal beam are using as prevention of rotation about bearing pin in locked position.

Fig.1. Side stanchion

Within static strength test of the wagon construction, besides other load cases, strength testing of the connection between pivoting stanchion is

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required according to valid standards [2, 3 and 4]. Pivoting stanchion should withstand force equal to 35 kN at height of 500 mm from the bearing centre in horizontal direction towards the outside of the wagon.

During testing of the side stanchion appeared a problem with U-shaped securing element (figure 2, position 2) which suffered deformation in the plasticity range, jeopardizing safety of the connection (figure 3).

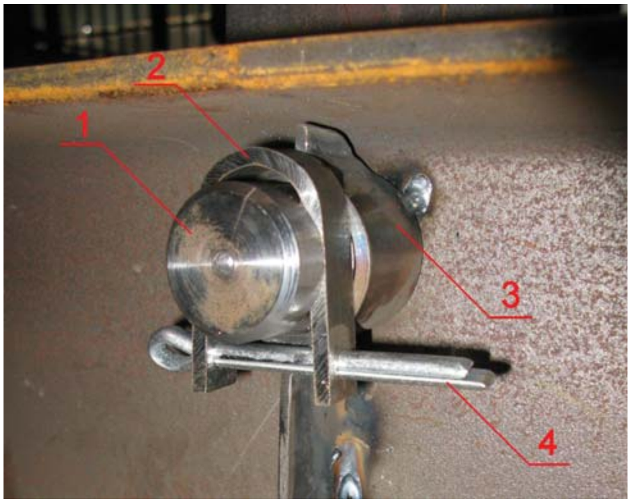

Fig.2. Details of the connection

Fig.3. Deformed U-shaped securing element

To solve the problem, numerical and experimental analysis were performed with the aim to find a solution, which will enable reliable connection between stanchion and car frame.

2. NUMERICAL ANALYSIS

Numercal analysis using finite element method and 3D model with contact elements was performed using commercial software ANSYS, figure 4. Model made in accordance with available technical documentation, provided by manufacturer, has 55465 nodes and 32561 elements. 3D solid elements from the software elements library were used, and for contact modelling special 3D elements (type CONTA and TARGA) were applied. Bilinear isotropic hardening material model of the S355 structural steel was used considering yield strength 355 MPa and tangent modulus 580 Pa.

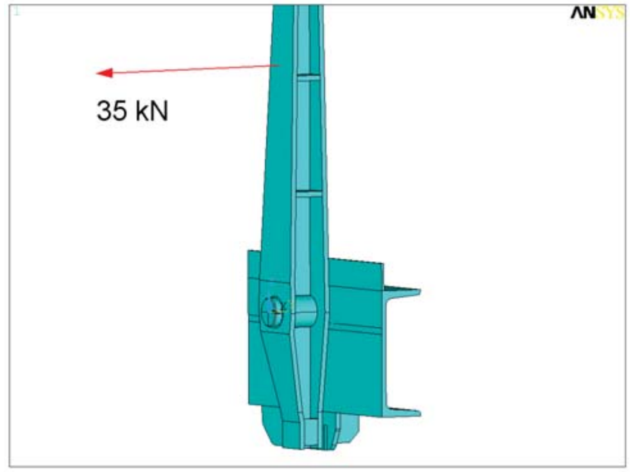

Fig.4. Model of the stanchion connection for FEA

In figure 4 is presented model of the connection between stanchion and the main longitudinal beam with marked required load case.

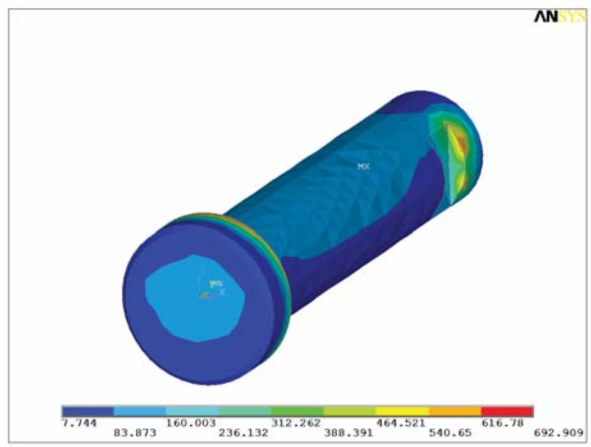

Fig.5. Von Misses stresses of the bearing pin in MPa

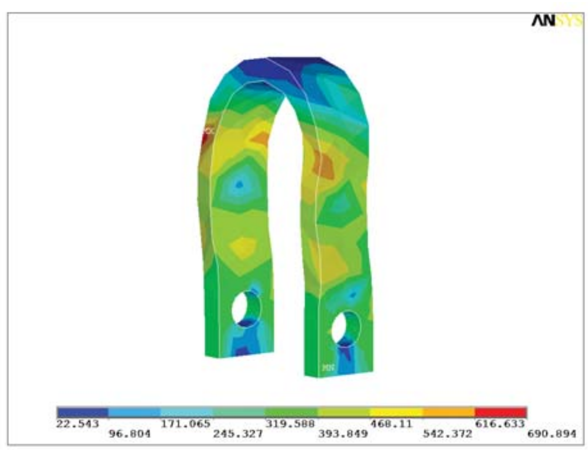

Fig.6. Von Misses stresses of U-shaped securing element in MPa

In figure 5 and 6 could be noticed that the maximum calculated stresses are above yield strength for steel grade S355 which is equal to 355MPa. Stress value of 690MPa, which appeared in some regions of the securing element implies on permanent deformations within plasticity range which may affect funcionality of the connection between stanchion and the main longitudinal beam. Cause of appeerences of such high contact stresses are small contact surfaces between bearing pin and stanchion, figure 5.

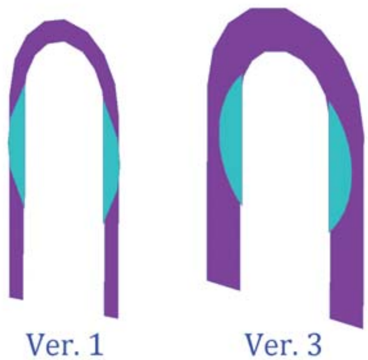

Fig.7. Contact surfaces in case of version No. 1 and version No. 3

Considering the fact that design is already built on several cars, selected connection securing principle was impossible to change. Possible solutions and modifications of the existing design were focused on increase of the contact surfaces between the parts in contact. In figure 7 is presented contact surfaces on existing version No. 1 and modified version No. 3.

The version No. 2 of the design included increase of the securing element thickness from 5 to 12 mm and increasing of the diameter of the bearing pin head from 55 to 60 mm. Thus increasing of the the areas of the contact surfaces towards the outer side. Performed FEA showed that contact stresses between bearing pin head and stanchion were decreased and are below yield strength. Stresses at the contact surfaces between securing element and bearing pin were also decreased but were still above yield strength.

Since the second version did not show satisfactory improvement, in the third version (version No. 3) besides increase of the bolt head diameter, thickness of the securing element was increased to 13 mm and, groove on the bearing pin was deepened from 6 to 7 mm. Thus the contact surfaces were increased towards the inner side.

With one such solution maximum stress value obtained using FEA on very edge of the contact surfaces was 370MPa. This value is insignificantly above yield strength of the steel grade S355. As a side-effect by deepening of the groove, cross section area of the bearing pin was reduced. FEA showed that this modification does not jeopardize bearing pin function i.e. stresses of the bearing pin body were increased for less than 10% and were still far bellow allowable value.

Since the experimental results are decisive for approval of the design, after numerical analysis test of the connection was performed.

3. EXPERIMENTAL VERIFICATION

Test was performed in the laboratory conditions in the workshop of the Railway Vehicles Factory "GOŠA" [1]. Three versions of the design of connection between pivoting stanchion and main longitudinal beam of Regns(s)-z wagon were tested.

Fig.8. Measurement equipment

Test was performed according to requirements defined in [2] by applying pressure force between the two opposite stanchions at 500 mm above pivoting centre (figure 8). Force equal at least 35 kN was produced using hydraulic cylinder (position 1) placed in series with force transducer (position 2). Pressure in the cylinder was achieved using hand hydraulic pump and permanent deformations of the stanchions were measured using displacement transducer (position 3).

Fig.9. U shaped securing elements after testing

Fig.10. U shaped securing elements after testing

Version No. 2 with increased thickness of the securing element showed relatively lower surface damage, while version No. 3 with improved U-shaped securing element and replaced bearing pin with the aimo of increasing of the contact surfaces between bearing pin and securing element showed minor surface settlement of all contact surfaces. It should be mentioned that surface damage of the version No. 3 in figure 9 and 10 is a result of a force equal to 50 kN and not under required 35 kN. The reason for that was to check additional safety margin of the connection design. Version No. 2 and No. 3, besides minor surface damage did not suffer other damage which may jeopardize function of the connection between the pivoting stanchion and the main longitudinal beam. Measured deformations of the stanchions using displacement transducer for all three versions of design (if appropriately fastened) were within accuracy range and were less than 1 mm, measured at the point of application of the required load equal to 35 kN.

4. CONCLUSIONS

The scope of this paper was to propose a way for overcoming the problem noted on the connection between pivoting stanchion and the main longitudinal beam of Regns(s)-z wagon. Used methods for solving the problem were based on numerical analysis using FEM and experimental research on a full scale object. Based on the obtained results could be concluded that all three version of the design are exposed to high contact stresses between the contact surfaces. Level of deformations are such that for the version No.1 after repeated number of loads equal to maximum force 35 kN, may eventualy produce unfastening of the U-shaped securing element i.e of the connection as a whole.

Permanent deformations of version No. 2 design may not produce failure of the connection. Only minor increase of the gap between the elements may appears.

Connection formed using design version No. 3 is significantly reliable comparing to previous two versions and permanent deformations are insignificant.

Based on the previous stated could be concluded that reliability of the connection between pivoting stanchions and the main longitudinal bemas could be significantly improved by increasing of the contact surfaces between elements in relative motion and by using materials having better mechanical properties and appropriately heat treated. In earlier phase of design development, possible solution of the problem could be selection of different design principle, which is less sensitive to contact stress appearance.

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