22nd International Conference
ENGINEERING MECHANICS 2016
Svratka, Czech Republic, 9 – 12 May 2016

STRENGTH CONTROL OF THE STANCHION OF POLE TRAILER

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Abstract: *The Paper is focused on assessment of strength of the stanchion of the bunk. It describes measurements of the specimen consists of two bunks to answer distribution of forces along stanchion and its increase during inclination of the specimen about 30°. For better understanding of force distribution along stanchion more measurements with pure loading up logs in the specimen were performed too. Results of experiments were subsequently used as inputs for setting the load for analyses. For determination of strength of the stanchion construction was used FEM. Parts of stanchions were subjected to both static linear and nonlinear analysis.*

Keywords: Stanchion, Pole trailer, Tilting platform, FEM

1. Introduction

Manufacturers of lorries, trailers and semi-trailers are trying to offer products with the highest utility value. They try to offer products with the largest loading area or volume or with the lowest curb weight according to the restrictions given by rules of law. Manufacturers must search new solutions and design for their products and optimize them. Big range of calculations is necessary to make to develop new successful product.

Department of Transport Means and Educational and Research Centre in Transport (ERCT) of University of Pardubice were asked by company Hořické strojírny spol. s r.o. to make FEM analysis of their new prototype of a stanchion of bunk. But there was no knowledge about input load. It was possible to make theoretical model, but load (wooden logs) is usually a lot imperfect opposite to idealized model. And here was a question what is the load distribution on the stanchion in reality. This gap in knowledge about straining of the stanchion did not allow making any strength analyses and so it was necessary to undergo experiment with real wooden logs. This experiment should explain forces straining the stanchion which would be able to use as an input for strength analyses.

2. Experiment

It was important not only to find straining of the stanchion by simple loading up the bunk. The question was also what happens, when the centrifugal force on the logs is applied. This supposed to make a driving test in a circle or to replace the centrifugal force by another type of a force. The advantage of driving test is in its description of response on real conditions during driving the truck. But at the same time is also its disadvantage - it is important to measure kinematic and dynamic parameters of the vehicle, it is necessary to ensure safety when driving limits are attacked, costs are higher and so on.

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From this reason we decided to use possibilities and technologies of our laboratory in ERCT. In the laboratory of transport means – road vehicles is situated tilting platform for determination static threshold of a car rollover and also for determination of height coordinate of center of gravity of a car. It suggested itself to use this platform for simulation centrifugal force by using the part of gravity during tilting the platform.

For experiment was prepared specimen consisted of two whole bunks and auxiliary frame as a holder of bunks. Auxiliary frame was also used for fixation the specimen to the tilting platform. Measuring part was one of four stanchions. It was equipped by ten force sensors and five strain gauges along active length of the stanchion. These were protected by safety shields hung on stanchion and enabling force transmission from logs to the stanchion. The specimen was loaded with logs of total mass of 9 tons and length of 4 meters.

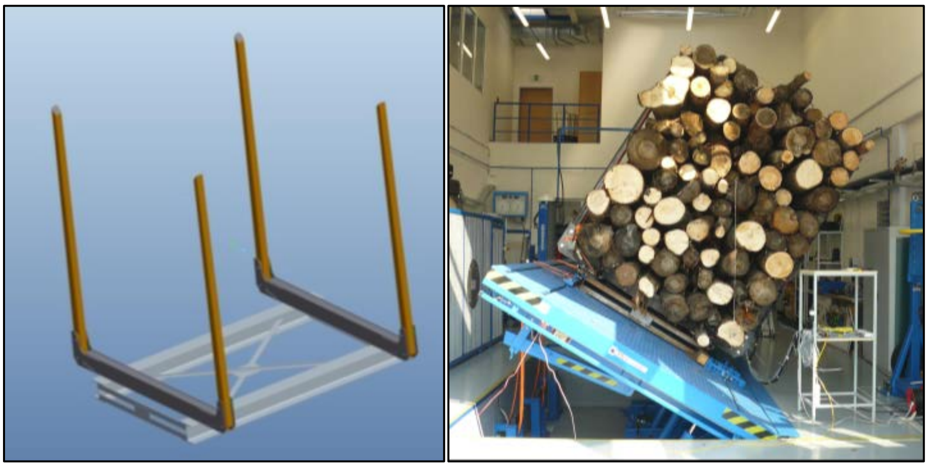

Fig. 1: CAD model of empty specimen and tilted specimen on the tilting platform (Pokorný et al., 2014)

Specimen with logs was fixed on the tilting platform in laboratory and during one month several times tilted up to 30°. Value of tilt angle of 30° was chosen according prescriptions relating to stability of tank trucks. For pole trailers is not similar prescription defined. This value of tilt angle is too big, that is not possible to reach it on real pole trailer during common driving without rollover. Such overstated value enabled to create safety space in straining of stanchions and took into account also some lateral dynamic effect.

This experiment simulated increase of straining of a stanchion during action of lateral or centrifugal force. In addition more measurements with repeated loading and unloading of logs were realized outside laboratory – both on specimen but also on a real trailer. These experiments should show usual distribution of forces along the stanchion and also extremes in this distribution.

Results of experiments showed, that general distribution is very difficult to determine. Distribution of forces straining the stanchion was stochastic and even summary of these forces was with wide dispersion (difference between two extremes of sums was over 6700 N). Increasing of straining of the stanchion owing to tilt the platform of 30° was around 44% that was little bit less compared to theoretical calculations (according calculations it should be around 50%) (Voltr O. & Pokorný J., 2015).

3. FEM analysis of bunk

Bunk consists of two main parts: stanchion and main beam called as a crossbeam. FEM analyses were focused primarily on a stanchion (material with R_e=900MPa) and connection parts between stanchion and crossbeam (materials with R_e=355 and 900 Mpa).

3.1. FEM analysis of stanchion

Computational model of stanchion was idealized opposite to real stanchion. Model of stanchion was proposed as a thin-wall shell. Cross-section of stanchion was taken into account as closed and linearly variable along whole length. At this model and phase of analyses were not taken into consideration parts forging lock between stanchion and crossbeam. For creation the mesh was used shell triangular element. Nearly whole model consists of element mesh of element size of 12 mm. Only in areas accordant with positions of strain gauges on real measuring stanchion was element mesh refined to element size of 5 mm. Boundary conditions were defined as fixation of lower end of stanchion. This increased safety of analyses. Input load was implemented in accordance with experiment.

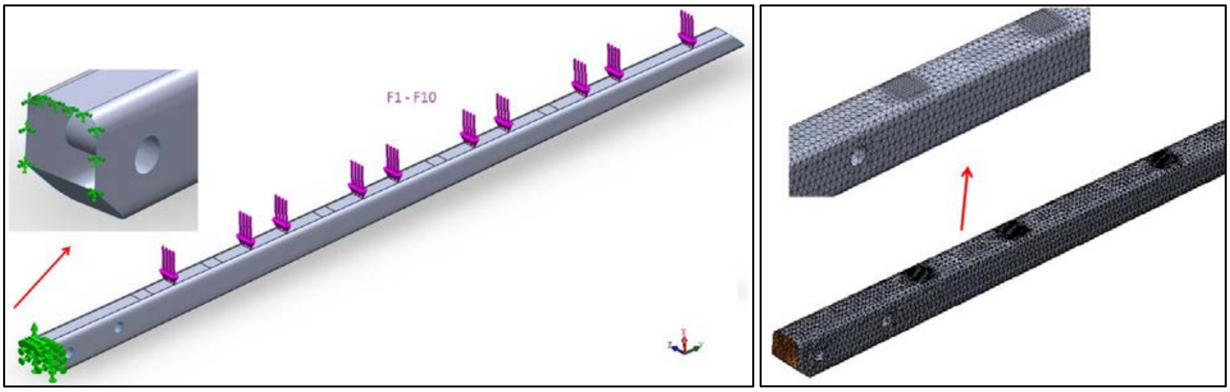

Fig. 2: Boundary conditions and distribution of load forces; mesh (Voltr O. & Pokorný J., 2015)

For validation of this model were used values of strain obtained from experimental strain gauge measurements. Three load cases from experimental data were chosen for this purpose. All of them generated maximal bending moment on the stanchion. Validation process was successful. Accuracy of results was obtained with relative error up to 15% (Voltr O. & Pokorný J., 2015).

Following analyses were focused on extreme loading of the bunk – up to its loading limit. In our measurements loading limit was used only from around 60%. According to experience and prescript of producer is impossible to fully use this limit. Because there was no experimental data for this case of loading, the straining of stanchion was necessary to predict. Used estimation was very rough, because we did not obtain general distribution of forces from experiments as was mentioned hereinbefore. For estimation was finally used rate between mass of load and resulted force acting on a stanchion. This was applied on the two load cases with the highest load on a stanchion.

These estimated loads on a stanchion were used for analyses. Results for estimated load of stanchion in normal position (without acting lateral or centrifugal force = tilt angle 0°) were safely to yield point. With applying additional load by tilting on angle of 30° got one predicted load case on the yield point of material in a wider area above fixation. Such stress is pseudo-elastic stress and for further analyses of stanchion behavior is important to make fully nonlinear analysis on more detailed and more accurate model.

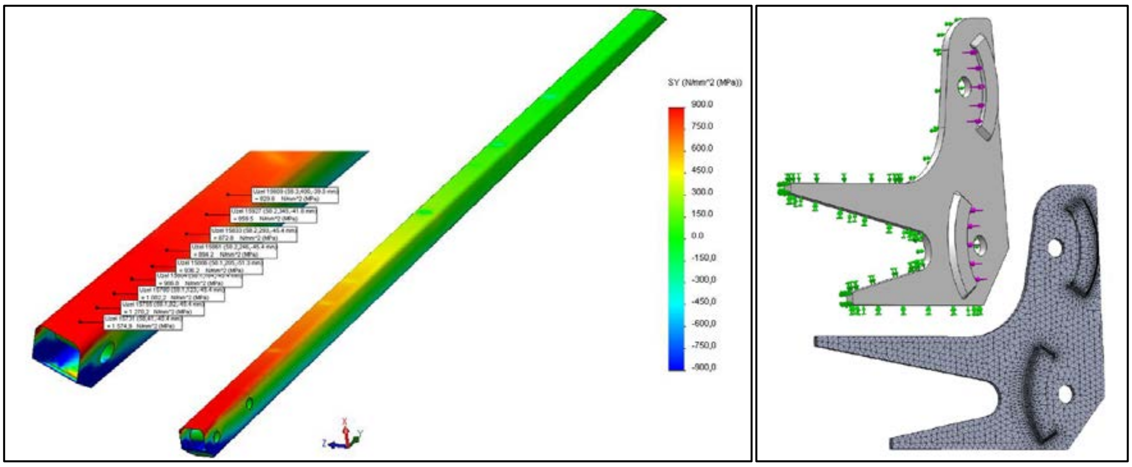

Fig. 3:Results for prediction of the most loaded state, stress on yield point (Voltr O. & Pokorný J., 2015); boundary conditions and distribution of load forces and mesh of ear of crossbeam (Pipek J., 2015)

3.2. FEM analysis of connection parts

Deeper analyses were made for part called as ear (ear of crossbeam – Fig. 3b) connecting stanchion and main beam. This part was chosen by reason of rugged shape, number of welds, and material with lower yield point than material of stanchion and crossbeam.

Models were not such simplified as a model of stanchion – only welds were made as a draft. Boundary conditions were chosen as fixed – according real possibilities of deformation of the ear. Input load corresponded to maximal bending moment calculated from real experimental data. Moment was applied on model as couple of forces acting on contact surfaces of locks. Mesh was created from elements of size 6 mm and in areas of welds was element size reduced to 1 mm.

In the first step was made linear analysis. This analysis showed some of potentially risk areas. In fact, as was supposed, it was areas of welded parts of lock, whereas the upper one was strained more. This part was subsequently analyzed by nonlinear analysis. Opposite part of this lock welded to the stanchion and welded connection between ear and crossbeam were analyzed this way too. This type of analysis enables to determine strength limit state, limit force, loss of stability and problems of fracture mechanics and works with material and geometric nonlinearity. In this case limit force was primary to determine. From each analyzed part was chosen node in the most shifted place and for this was subsequently plotted the graph of dependence between shift and load coefficient λ. Limit force is then calculated according formula:

$$F_{lim} = \frac{\alpha \cdot \lambda \cdot F}{k} \qquad [N], \tag{1}$$

where α is weld coefficient, F is load force and k is safety coefficient (k = 1,5).

In table 1 are shown results of these nonlinear analyses. In the second column are shown limited forces of parts and in the third column are forces for static load (calculated from experimental measurement).

Tab. 1: Results of nonlinear analyses of parts (Pipek J., 2015).

part	F_{lim} [N]	F_{st} [N]
weld - kidney	93600	26250
weld - crescent	73666.7	26250
weld ear - crossbeam	74100	26250
ear of crossbeam	74666.7	26250

4. Conclusions

This article was focused on problematic of strength of the stanchion of bunk. Producer of pole trailers demanded FEM analyses of stanchion and some another detailed parts of the bunk. But experiments had to be done before these analyses, because it was not known straining of the stanchion. Data obtained from experiments were used for validation of models and consequently in FEM analyses. In the case of stanchion it was the aim to make strength control on the heaviest load of stanchion responding the maximal loading limit of the bunk. Additional load in form of lateral force simulating centrifugal force was for this analysis used too. Linear analysis of the stanchion with such extreme and unreal straining showed, that lower part of stanchion is getting on yield limit of material. Further linear and nonlinear analyses of other detailed parts of bunk were made, where the result was the limit force. Analyses showed, that stanchion is well resistant to normal loaded up the bunk by logs and additional lateral forces. Also other parts as lock of stanchion or member connecting the stanchion and crossbeam spent strength requirements.

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