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Computational assessment of hinge deformation of the tilting sidewall of the truck body

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In the current era of forensic expertise in the field of transport and accident analysis, software (hereinafter sw) based on algorithms of Multi-Body-Systems (MBS) dominates for the solution of dynamic simulations (especially vehicle collisions). Representatives of such software in Europe are, for example, PC Crash or Virtual Crash. Both software excel in sophisticated graphics, which, unlike previously used analytical solutions with a number of complex equations, allow litigants to create a much more realistic picture of a court case solution, which otherwise often causes considerable difficulties for non-technical judicial staff. However, both of these software work mainly with rigid non-deformable bodies, which can often lead to incorrect results.

Fig. 1. Tipper body with spring mechanism, opened sidewall

The paper deals with the search for the mechanism of damage to the hinge of the tilting sidewall with the spring mechanism of the tipper body, Fig. 1, for the purposes of litigation between the vehicle operator and the body manufacturer. Although the problem could probably be solved using analytical procedures, in our case, a nonlinear variant of FEM with a PAM Crash solver is used to solve the dynamics of the body sidewall movement in the gravitational field. This approach, which is rarely used in similar cases, will provide the parties to the dispute with a completely objective view of the whole matter, while making it possible to monitor the distribution of stresses and deformations in the sidewall at individual moments of tilting.

The applicant's view, which in the present case is the vehicle operator, supported by an expert opinion, states that the damage to the sidewall should have been due to the inertial effects of the bulk load (sand) on the body when the tipper (TATRA T-815) was driving in arcs.

Therefore, this load condition was also analyzed in two body loading modes, when on the one hand bulk material (sand of average humidity and density) was poured into the body at a pour angle of about 35°, Fig. 2A, up to a payload of 13.6 t. This case can be seen as one of the borderline cases where the sidewall of the body is loaded with sand to a minimum height of 35 cm. The second of the limit cases then represents the state when the sandy surface is aligned in the body to a rectangular cross-section, Fig. 2B. In this case, the sidewall is loaded with sand up to a max. height of 78 cm. If the height of 78 cm was exceeded (the total height of the sidewall is 90 cm), the payload of the vehicle would already be exceeded. The pressure distribution of the bulk cargo at the bottom of the body and the sidewall can be considered similarly to the hydrostatic pressure of liquids.

The following 3 operating states (modes) were analyzed, which are based on traditional empirical approaches:

1. standing in a gravitational field 1.0 g
2. driving in an arc of 0.3 g in a gravitational field of 1.0 g
3. tilting the sidewall in the gravitational field 1.0 g, Fig.3.

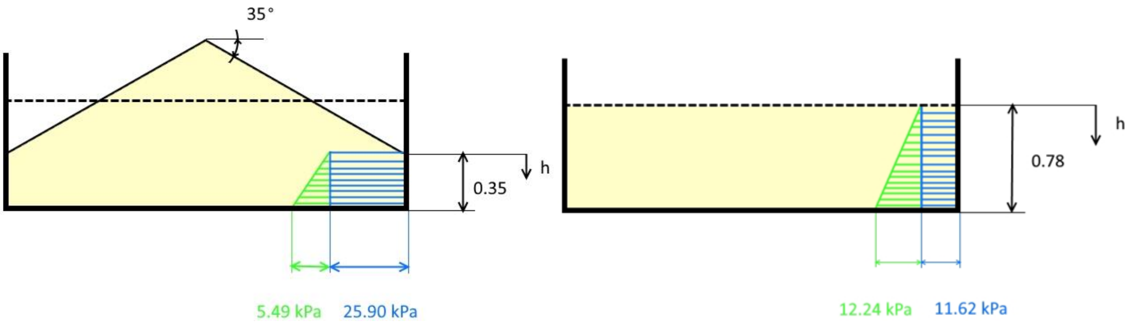

Fig. 2. Pressure distribution A) for a pour angle of 35 ° B) for a flat surface

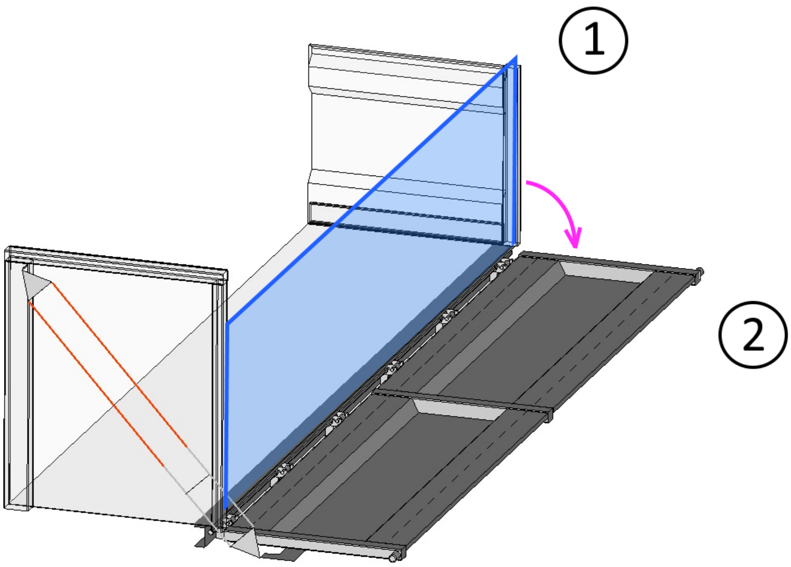

Fig. 3. The principle of the sidewall tilting

Modes 1 and 2 were chosen as conservative modes (depending on the distribution of the surface layer of sand on the body of the tipper). At the same time, in mode 2, conservative results are achieved with a relatively high acceleration factor of 0.3 g when driving in a curve, as it is clear that this limit value will only occur exceptionally in real traffic. For mode 2, friction between the loading area and the bulk load (sand) is not considered, which further increases the degree of conservatism of the results.

On the other hand, operating state number 3 - tilting of the sidewall is solved with an empty body, Fig. 3, when the sidewall is not loaded by any sand. The results can be seen as rather optimistic, when the dynamics of tilting the sidewall, especially in the lower position with stops will cause significantly less tension in critical places than in the case of a body loaded with sand. In real operation, the sidewall will be loaded by the own weight of the bulk load, which will increase the kinetic energy of the released sidewall at the moment of contact with the hinge stops and thus the stress in critical areas will reach significantly higher values.

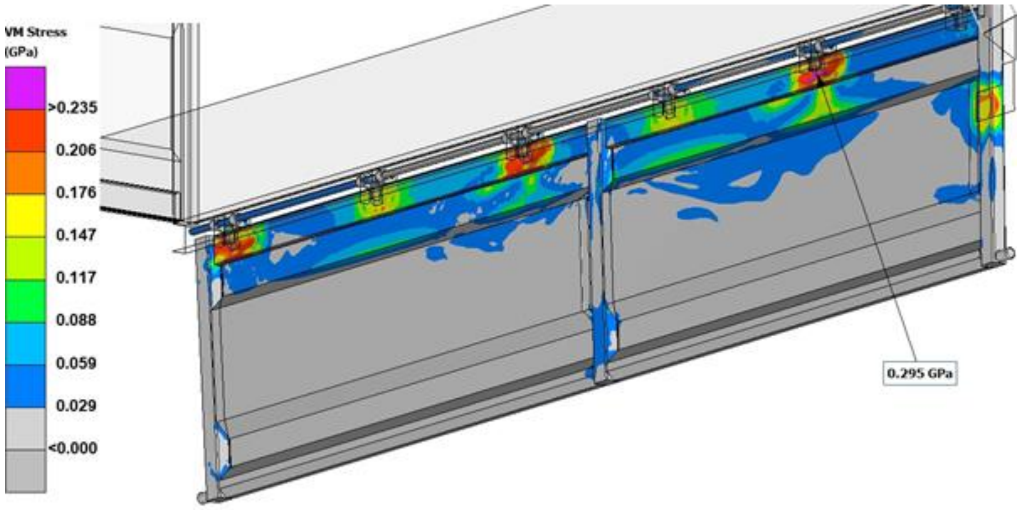

Fig. 4. Tilting of the sidewall in the gravitational field 1.0 g - residual stress, overall view from below, scale VM 0-235 MPa

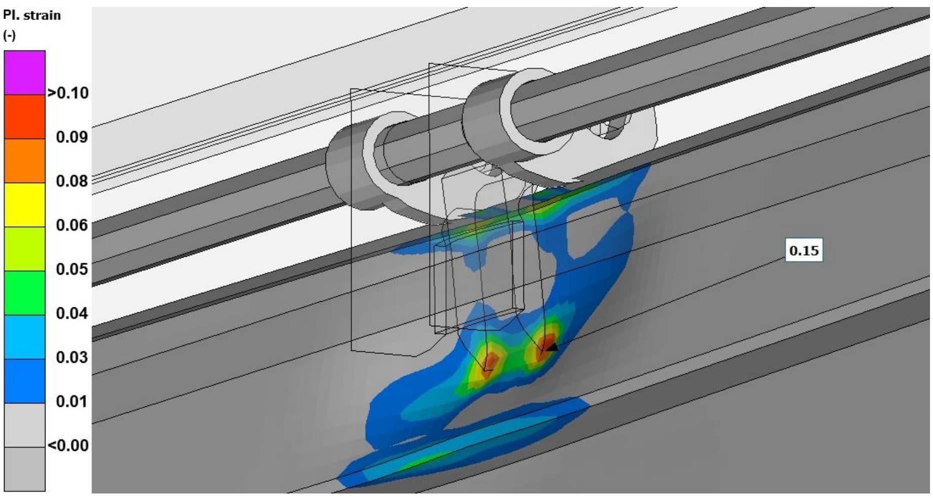

Fig. 5. Tilting of the sidewall in the gravitational field 1.0 g - moment at max. deformation - detail of the hinge with the highest plastic deformation, plastic deformation scale 0-10%

In the given task, in modes 1 and 2, negligible plasticization of the material was found in the places of the side hinges (max<0.5%). In the third mode, local plasticization of the material was found to reach a value of up to 15%, when the yield strength of the material used was exceeded in 5 of 6 hinges. Such behavior would, in the case of frequent repetition of the analyzed load, lead to the so-called low-cycle fatigue of the structure (up to a maximum of 10,000 similar cycles). However, in none of the critical points of the structure did there be a damage or fracture with a subsequent collapse of the sidewall.

Summary

FEM model of the assembly of the side of the body of the truck - tipper according to Fig. 1 assembled from approx. 234 thous. elements with a nominal size of 5 - 8 mm was analyzed for 3 selected load cases representing selected operating modes of a fully loaded vehicle, including the body sidewall tilting mode. The means of nonlinear FEM solver PAM-Crash Explicit v. 2019 were used for the analysis.

The used nonlinear solver and the used elasto-plastic material model make it possible to evaluate the behavior of the structure also above the yield point of the used metallic materials.

The aim of the analysis was to determine the stress distribution with the possibility to determine the places with maximum stress values and to assess the character of deformation in the places of attachment of the hinges of the sidewall of the vehicle body in individual operating modes.

The simulations of operating modes 1 and 2 did not show the occurrence of significant plastic deformations causing permanent deformation of the sidewall structure of the tipper. In operating mode 3 - tilting of the sidewall by free fall in the gravitational field, a stress of 415 MPa was found in the places of welding of the hinges to the lower profile of the sidewall due to the impact of the hinge, exceeding not only the yield strength of S235. The maximum plastic deformation found here reaches 15%. This operating mode can therefore be considered as the cause of damage to the body side.

The maximum values of stress and plastic deformation for individual operating modes are recorded in Table 1.

Table 1. Values of max. stress and max. plastic deformations found on the sidewall

Operating mode		max. VM stress	max. plast. deformation
		[MPa]	[%]
1.	stojící vozidlo v gravitačním poli 1.0 g	151	0
2.	průjezd obloukem 0.3 g v gravitačním poli 1.0 g	237	0.5
3.	spuštění bočnice v gravitačním poli 1.0 g.	415	15