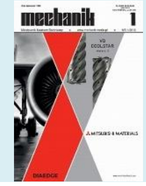

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# Modeling of a timber transport trailer using the Inventor program

## Modelowanie przyczepy do przewozu drewna z wykorzystaniem programu Inventor

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**The article presents the results of the modeling of a forest trailer for the transport of logs. Modeling was aimed at creating a base structure and developing trailer modules with a load capacity of 12, 14 and 16 tons. The design of the trailer frame as the load bearing element is described. With Inventor, trailer strength analysis has been performed, including the distribution of cutting forces, bending moments and displacements. On this basis, it was possible to make conclusions about the functionality of the structure and the direction of optimization. In addition, the design process has allowed Inventor to be tested as an advanced design tool combined with endurance analysis.**
**KEYWORDS: timber transport trailer, 3D modeling, strength analysis**

The solid model of the trailer is shown in fig. 1. The carrier element is a double frame (*1*) made of a rectangular profile. The chassis is made of beams (*2*) equipped with two braked wheels (*3*). The load part is limited by the front cover (*9*). Between the cowl and the rotating tiller (*5*), controlled by hydraulic cylinders (*6*), the oil tank (*4*) is located. Its upper surface is the platform for fixing the loading crane. Stabilizing pawls (*7*) are fixed on the side surfaces of the tank, disassembled and folded by means of actuators (*8*). Protection against transverse displacement of the load consists of stanchions (*10*) fixed in sleeves welded to the external surfaces of the frame side members.

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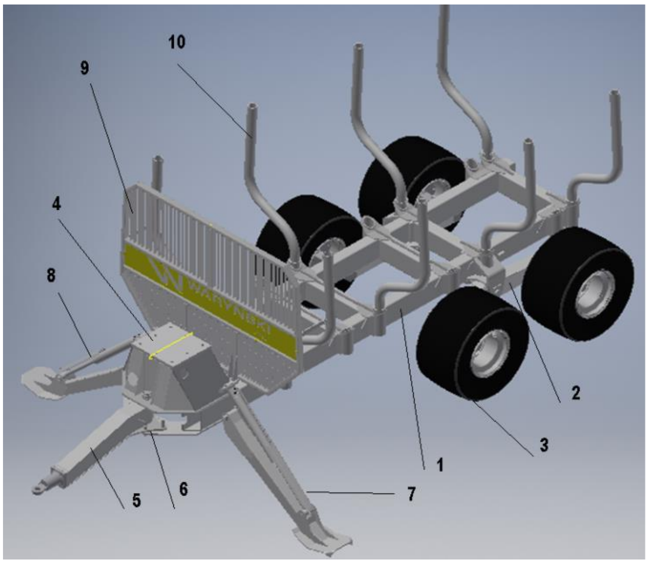


Fig. 1. Solid model of a forest trailer: *1* – frame, *2* – axle beam, *3* – road wheel, *4* – hydraulic oil tank, *5* – drawbar, *6* – drawbar power, *7* – paw, *8* – paw actuator, *9* – partition, *10* – stanchion

### Design restrictions

- The construction first of all must be durable – resistant to fatigue loads. Forest vehicles during operation are constantly subjected to loadings varying in terms of direction and value, resulting from: uneven distribution of cargo in the cargo space, unevenness of the terrain (wheels on both sides of the trailer can move on surfaces of different heights), forces braking and acceleration.
- Research shows that the most frequent cause of cracks occurring in structures subjected to variable loads over time is the phenomenon of material fatigue [1]. The thickness of the sheets or the size of the profiles used to build the trailer frame depends mainly on the fatigue strength of the material

– this is particularly important in the case of welded structures.

- The fatigue strength of welded joints from ordinary S355 structural steel is comparable to high strength steel, e.g. S700 [2]. Although the yield stress of high-strength steel is 100÷200% higher compared to structural steel, due to the low fatigue strength of welds, the weight of the trailer can be reduced by at most 20÷30%.
- It is necessary to ensure adequate rigidity of the structure to prevent vibration and loss of stability (so-called buckling phenomenon).

During design work, additional restrictions were imposed resulting from the provisions of the Highway Code regarding the following construction units:

- durability and dimensions of the drawbar and hitch dependent on the weight of the towed trailer,
- a two-wire braking system conditioning proper braking performance,
- maximum overall dimensions of the trailer enabling its entry into traffic on public roads,
- Axle pressure with tires on the road surface, not exceeding the limit values on public roads.

**Description of the research object**

The base frame (fig. 2) is a welded construction, built from stringers (*4*) and cross beams (*7*). For its construction, rectangular profiles 200 × 120 × 8 were used. On the extension of the crossbeam axes, on the outer surfaces of the stringers, staple fastening sleeves (*5*) are welded. In the rear part of the frame, before the last crossbar to the chassis members, the mounting beam (*6*) is welded to the axles. Each beam is mounted independently on the frame side member. A rotary anchoring was used on bolts in bronze sleeves. The stringer outlets are not welded. This is due to the fact that in the case of transporting long sections of wood, it is possible to install the so-called an extension frame (fig. 3).

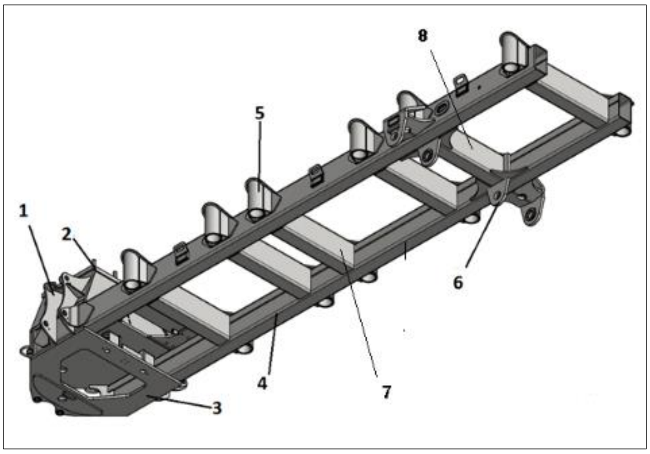



Fig. 2. Trailer frame: *1* – support mounting, *2* – tank base, *3* – rotation plate, *4* – base frame longitudinal, *5* – fixing of bent stanchions, *6* – axle beam mounting brackets, *8* – axle beam the running

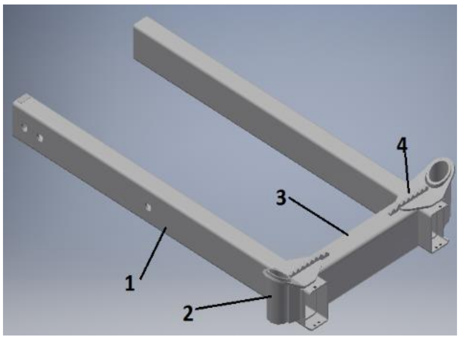
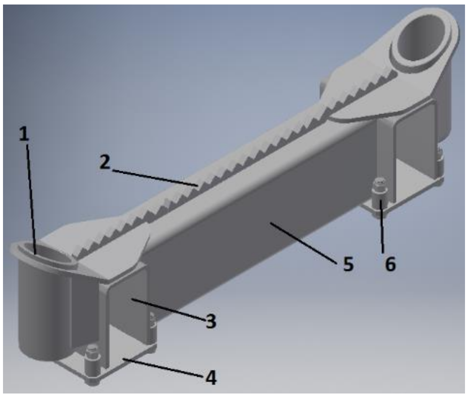



Fig. 3. Extension frame: *1* – extension beam, *2* – stanchion mounting, *3* – crossmember, *4* – toothed rack

The extension frame is a structure made of 190 × 110 × 8 rectangular profile. Three technological holes have been made, in which threaded sleeves are mounted. They are used to adjust the extension of the extension frame from the base frame and to secure it. In addition, toothed bars are welded on the crossmember which prevent the first layer of the cut tree from sliding.

In the case when short pieces of wood are loaded on the rear part of the trailer, it is possible to attach a sliding beam to the extension frame (fig. 4), which is one with the profiles used for fixing the stanchions.

Fig. 4. Sliding bar: *1* – fixing the stakes, *2* – toothed rack, *3* – mounting hole on the extension frame, *4* – bottom plate, *5* – lateral locking, *6* – threaded bushing




**Strength analysis in Inventor software**

During the analysis of the frame of the welded wagon, bolt supports were modeled, which were fixed in the place where the beams of the axles were mounted and in the places where the support legs were attached. Then, after verification of the working surface on which the logs are loaded, and taking into account the weight of the load (and thus the pressure on the surface), the value of continuous load on the beams of the support frame was calculated.

The stages of strength analysis in Inventor software are:

- selection of construction materials,
- determining the direction of forces,
- definition of appropriate bonds (maintaining a rigid connection),
- definition of supports and their proper arrangement,
- definition of loads with their location.

The analysis was carried out on the basis of obtained ranges of cutting forces, bending moments and frame displacements.

Selected elements related to the visualization of strength analysis are presented in figs. 5–10.

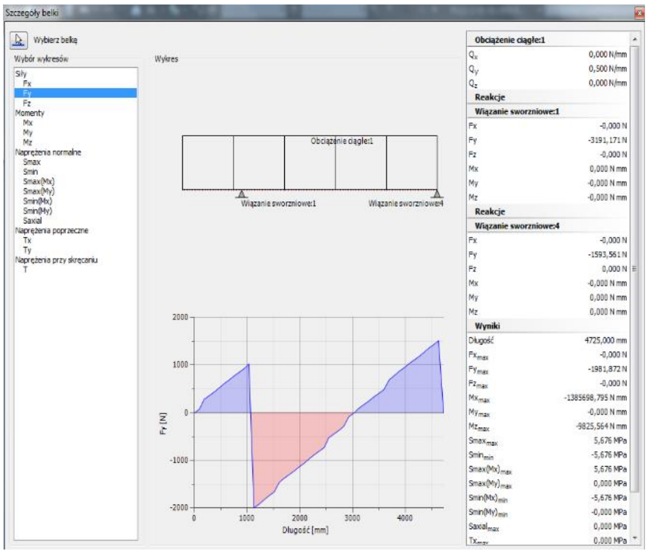


Fig. 5. Diagram of external forces in the direction of the *Y* axis

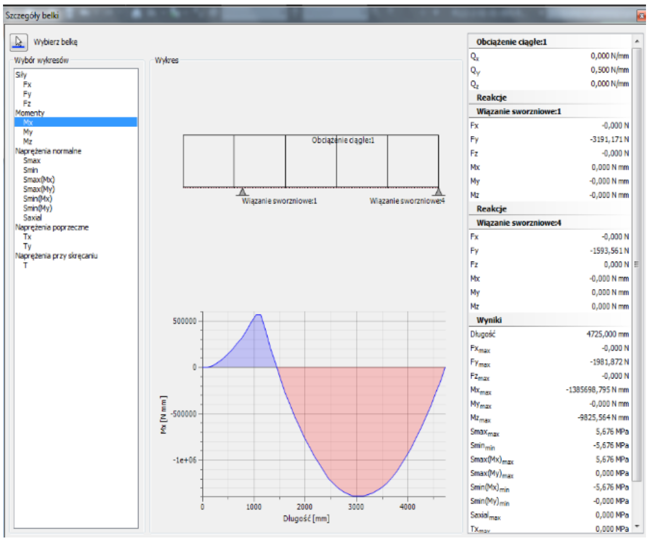


Fig. 6. Diagram of bending moments in the action plane of the *X* axis

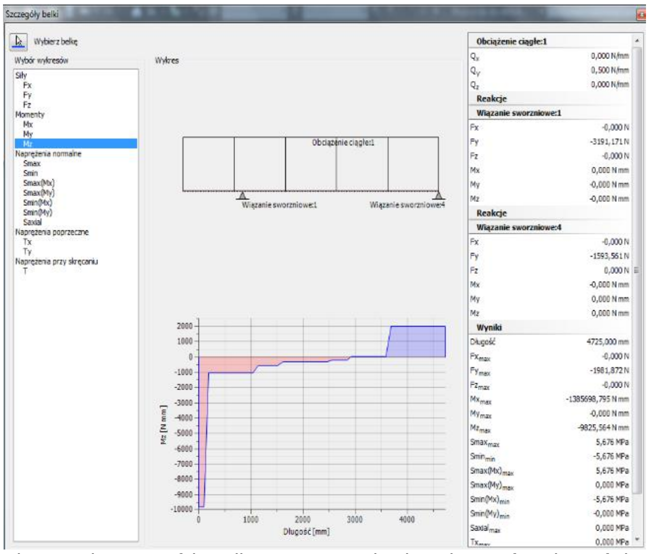


Fig. 7. Diagram of bending moments in the plane of action of the *Z* axis

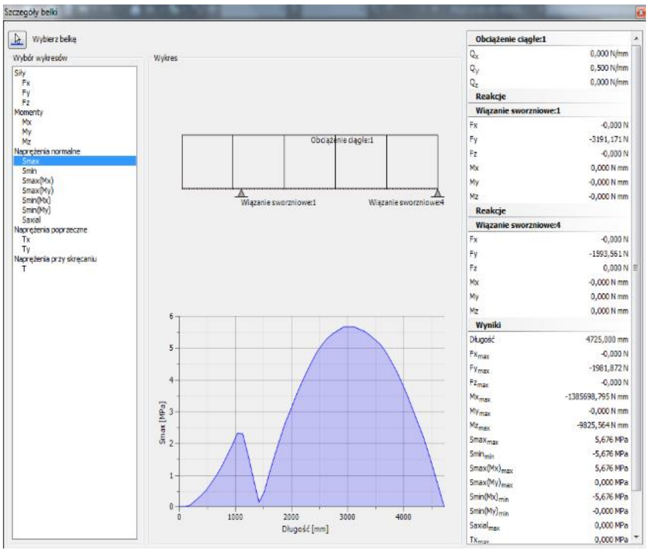


Fig. 8. Distribution of stresses from normal forces

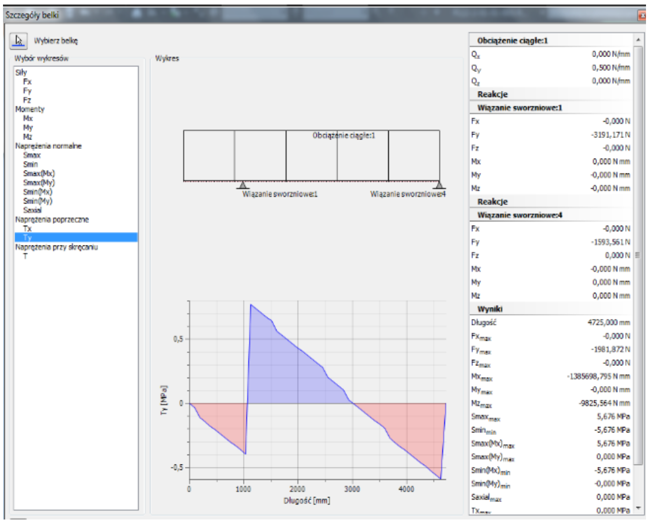


Fig. 9. Distribution of stresses from shear forces

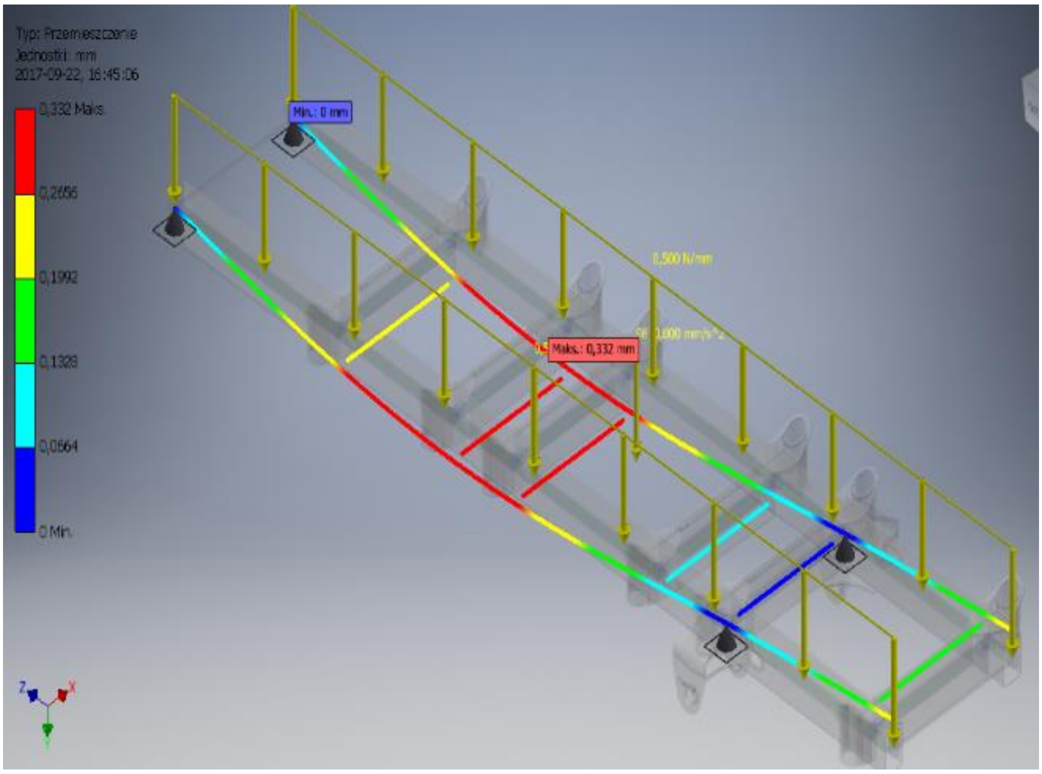



Fig. 10. Visualization of displacements of the trailer frame

Results of strength calculations:

- the maximum displacement of the longitudinal beams of the base frame is approx. 0.33 mm,
- maximum pressures on supports at the mounting location of the axle beams are 320 MPa,
- in the front part of the trailer, in places of support legs, they strain 160 MPa,
- the maximum value of the bending moment occurring in the middle between the front and the axle beams fixing is approx. 138 Nm; a much smaller bending moment occurs in the $Z$ axis – approx. 9.8 Nm,
- maximum normal stresses arise in the middle of both bonds and amount to approx. 5.6 MPa,
- transverse stresses with a maximum value occur in the vicinity of axle beam fasteners and assume a value of approx. 0.75 MPa.

Taking into account the stress and moment diagrams, it can be concluded that the structural solution of the frame with the use of specific materials is oversized. As part of the optimization of the sections of construction elements, smaller shapes (at the same time the weight of the trailer can be reduced) – where the actual stresses have not yet exceeded the allowable stresses. Based on the data from field tests, however, the question should be asked whether the optimization is expedient. The designed structure is very rigid – it has little susceptibility to any displacement. This is an important feature, because during transport of timber, there are variable loads whose values can not be determined unambiguously. An additional advantage of the trailer is the visual effect of sustainability and durability.

## Conclusions

Execution of the 3D model of a timber transport trailer allowed for: carrying out strength analysis, optimizing the structure and generating technical documentation in the form of 2D drawings.

Comparing Solid Edge and Inventor programs used in design works, we can conclude that Inventor has advantages like [3, 4]:

- intuitive menu, simplified editing commands;
- extended capabilities of strength analysis;
- the results of the sustainability analysis with a smaller error compared to the analytical calculations.

During the construction of the trailer model, the following problems were encountered:

- high hardware requirements regarding the processor, built-in memory and monitor;
- the need to define constraints between the individual elements of assemblies, because Inventor does not allow connection by an edge and plane binding;
- the need to simplify the geometry of the frame model in order to perform strength analysis.

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