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DEVELOPMENT AND DESIGN OF THE SPECIAL VEHICLE FOR THE TRANSPORTATION OF HEAVY WEIGHT CONSTRUCTION MACHINES

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Abstract

A big issue in the construction industry is the transportation of the heavyweight machines from urban areas or production facilities to the construction site and back. Nowadays, low loader trailers are utilized for this kind of transport. They are towed by trucks, where the transport speed is significantly decreased and the ability to reach the construction site is also reduced. To overcome this difficulty, it is necessary to eliminate the low loader trailers from the transportation equipment and use special automotive vehicles. This paper presents the design of one of them. The structure of a standard vehicle with 32-tone gross weight is upgraded to carry and transport heavyweight construction machines. Also, the rear end is equipped with a hydraulically powered ramp for loading the machine onto the vehicle and unloading it off the vehicle.

The stress analysis of the upgraded structure was conducted by the finite element method (FEM) and the optimization was carried out. The stress analysis was done for four different case studies. The stress and the deformation results confirmed the validity of such a design solution for the transportation of heavyweight construction machines.

Keywords*: special vehicle, buildings maschine, transportation, stress analysis*

1 INTRODUCTION

In accordance with the technological development, plants, machinery and means of transport which are used for development of the economic system have significantly evolved[1]. A large number of earth-excavating and other working machines with considerably higher capacities and performance have been developed. However, the consequence is their increased overall dimensions and masses. They also have a restricted radius of motion because their speeds of motion are reduced. Also, due to the increase in their masses, there occurs another problem, i.e. they can cause mechanical damage of roads and considerably slow down the traffic because of their low speed of motion.

For the mentioned reasons, these machines are most often transported by special machines which are called truck trailers. These vehicles have a high carrying capacity, a higher speed than the working machines themselves and a higher radius of motion. However, these machines have their own weaknesses, which, before all, refer to the necessity to provide a traction vehicle for their motion. By attaching truck trailers to the traction vehicle, the total length of the vehicle itself is increased, which restricts its motion and access to the terrain. Also, the height of the vehicle in transport is increased, which can be a problem while passing through tunnels, underpasses, etc. regardless of the type of truck trailer used.

Three most common types of special vehicle for the transport of heavy-duty earth-excavating machines on our market are:

- truck trailers with a semi-trailer,
- truck trailers with a trailer and
- truck trailers with multiple trailers.

All mentioned types have common negative characteristics, i.e. great length, larger radius of rotation and large overall height.

This problem can be solved to a large extent if special vehicles for the transport of heavy loads – without a trailer are used. The structure of such a vehicle is the subject of this paper.

2 TECHNICAL DESCRIPTION OF THE SOLUTION

This paper presents the possibility of elimination of a low loader trailer in favour of using a special automotive vehicle for the transport of large earth-excavating machines. This vehicle is obtained by adding a superstructure to the carrying structure on the chassis of the standard vehicle, in this case vehicle Mercedes 930.20 (trademark Mercedes 3244). The superstructure is designed in such a way that, with small modifications, it can be adapted and mounted on other types of vehicles. The axle distance between the first and second axles is 3900 mm, and the axle distance between the second and third axles is 1350 mm. The base of the chassis of the vehicle is the U-shaped girder whose height is 285 mm, width 70 mm and thickness 8 mm.

The width of the chassis is 760 mm (the distance between the outer edges of the girder).

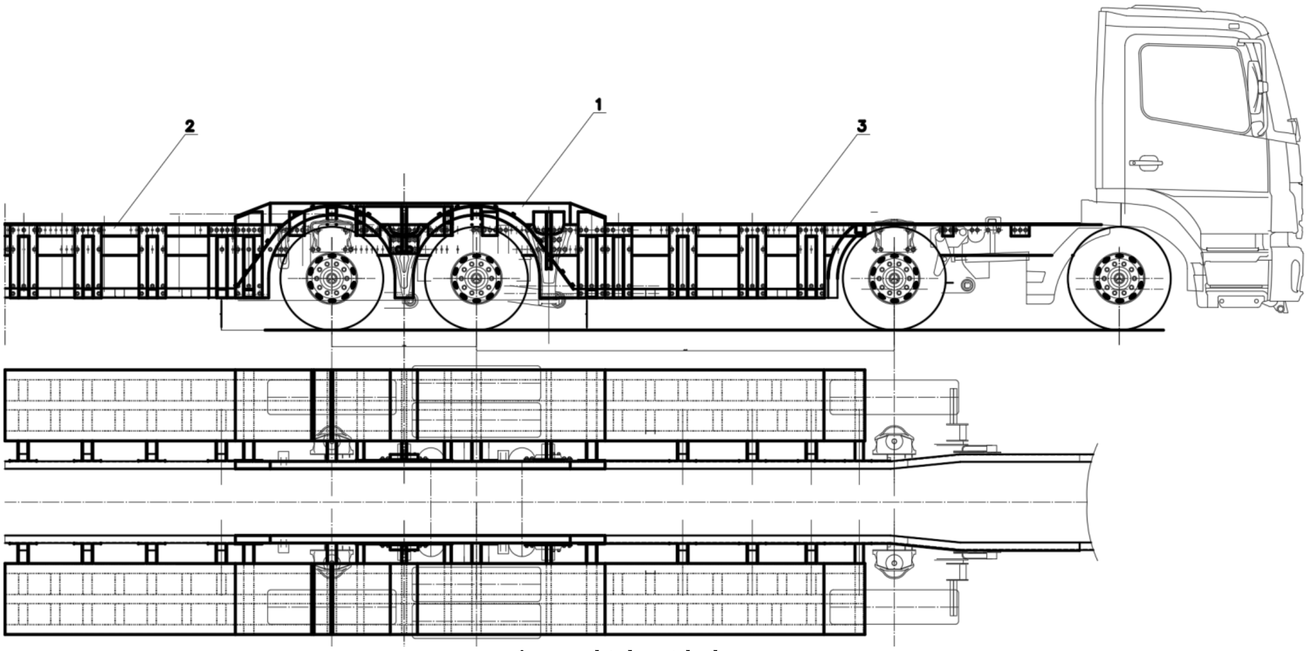
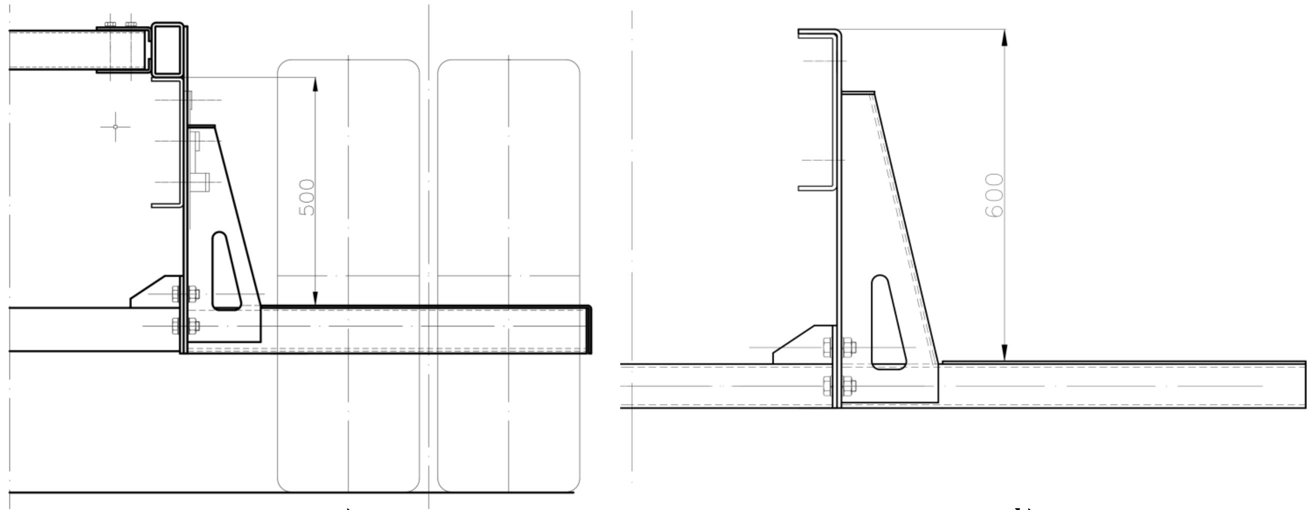


Fig. 1*Vehicle with the superstructure*



a) ***b)***

Fig. 2*Appropriate cross sections of the vehicle superstructure*

The complete structure of the superstructure (Figure 1) consists of three segments: central part of the structure (Fig. 1, position 1), rear part of the structure (Fig. 1, position 2), front part of the structure (Fig. 1, position 3).
The appearance of the vehicle with the carrying structure of the superstructure for the transport of heavy-duty earth-excavating machines is shown in Figure 1.

The connection between the carrying structure of the superstructure and the main chassis is separable.

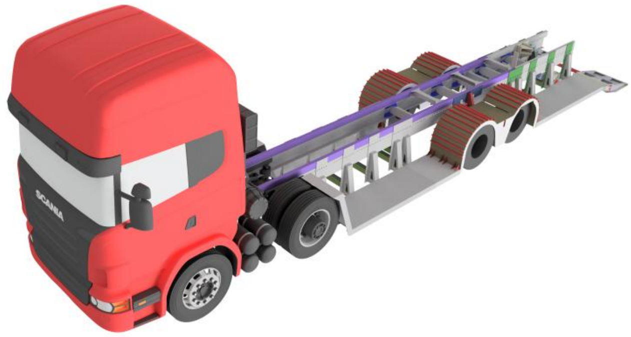
The main element of the carrying structure for all three segments is the carrying plate which is joined to the chassis of the vehicle by bolts. The openings on the carrying plate are adapted to the already existing openings on the chassis of the vehicle. In the lower part, the carrying plate is joined to the structure of the platform along which the vehicle being transported moves. This connection is strengthened by profiled reinforcements which are mutually joined by welding (Figure 2).

The lower part of the structure is additionally loaded on pressure, so that the reinforcement is achieved by means of cross beams which connect the left and right sides of the carrying structure. The cross beams are connected by separable - bolted joined.

3 CALCULATION OF THE CARRYING STRUCTURE OF THE VEHICLE SUPERSTRUCTURE

3.1 Loading of the structure

The model of the structure is created in Autodesk Inventorsoftware, and the stress analysis is performed by the finite element method in Ansys. Tetrahedral finite elements with 10 nodes are used for the creation of the model. The model is formed of 440119nodes and134601elements[3].
The appearance of the model is shown in Figure 3.



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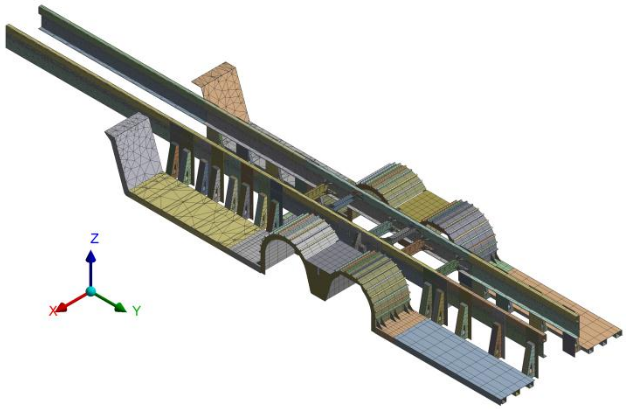

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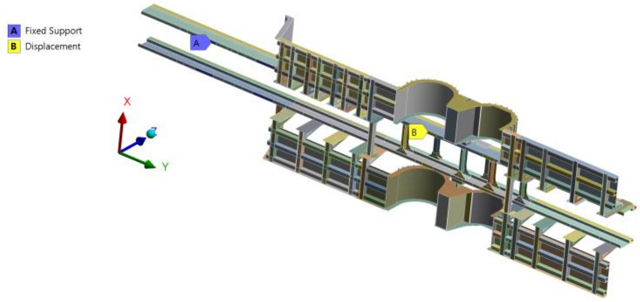


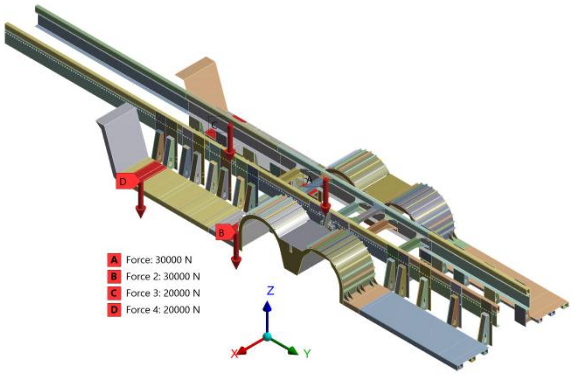
c)

Fig. 3Model of the structure

In the analysis by the finite element method, those parts which are not of importance for the analysis (front part of the vehicle, with the cabin, drive motor, etc.) are eliminated. The influence of the eliminated part is taken through the corresponding supports.
Three characteristic positions of the vehicle which is being transported are adopted for calculation:

1. the transported vehicle is at the front part of the structure (Figure 4a),
2. the transported vehicle is at the rear part of the structure (Figure 4b),
3. the transported vehicle is both at the front and rear parts of the structure (Figure 4c).

The loading of the structure depends on the mass of the vehicle as well as on the carrying structure which is mounted as the superstructure.



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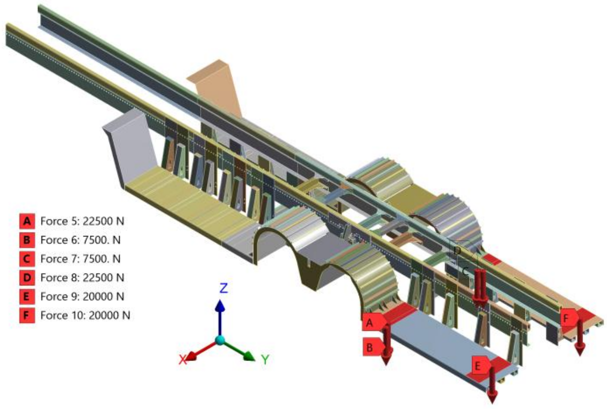

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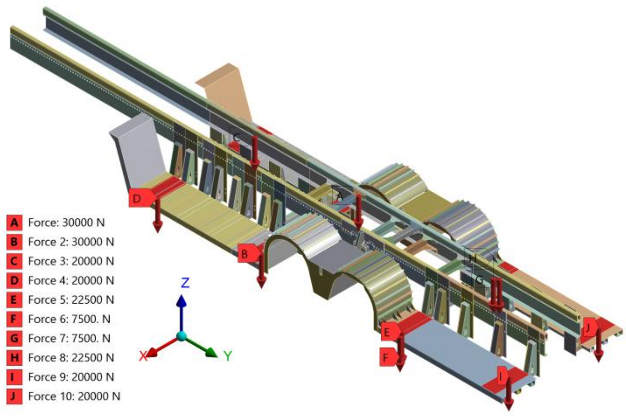


c)

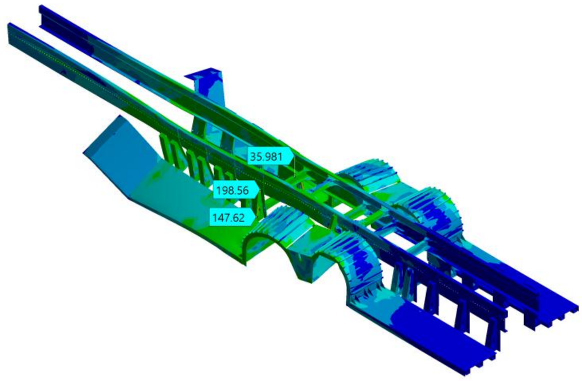
***Fig. 4**Characteristic cases of the loading of the structure*

The permissible gross mass of the mentioned vehicle is 32 tonnes. As the mass of the vehicle with the carrying structure is about 14 tonnes, the mass of the vehicle which is being transported must not exceed 18 tonnes. This value corresponds to the mass of special vehicles of earth-excavating machinery which are being transported.

3.2 Stress and strain analysis

The values of stresses and strains for all three cases of loading are presented in Figs. 5-7.

The carrying structure is made of steel S355, whose module of elasticity is E=210 GPa; - Poisson's ratio: ν=0.30; - yield criterion: von Mises - initial yield stress: σy=355 MPa.



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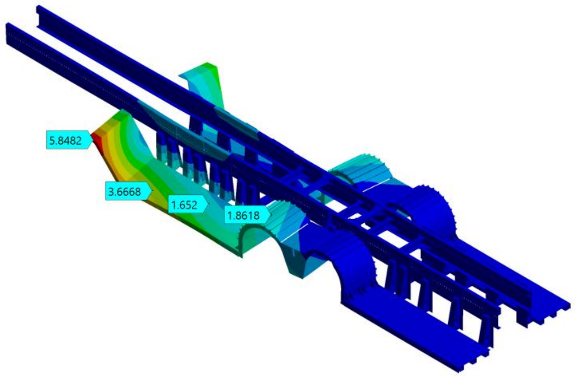

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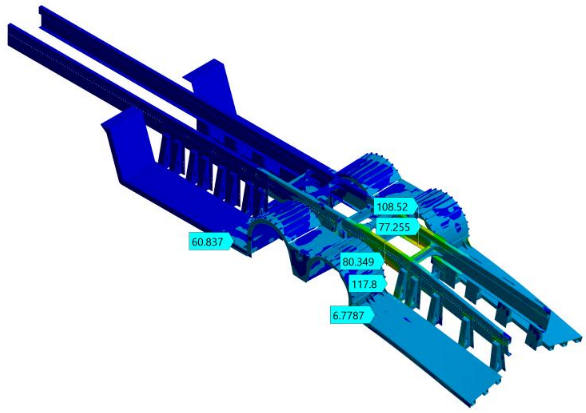
Fig. 5*Values of stresses a) and strains b) for the first case of loading*



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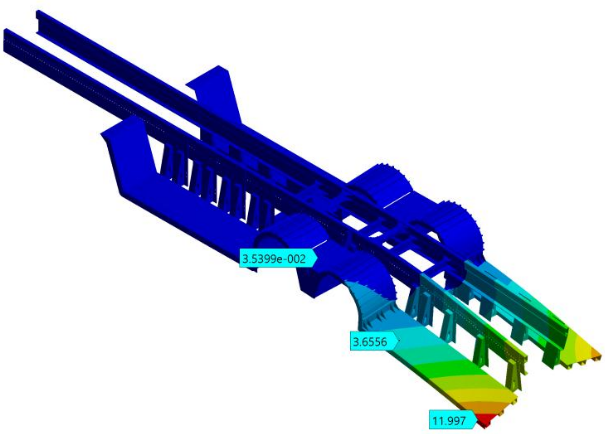

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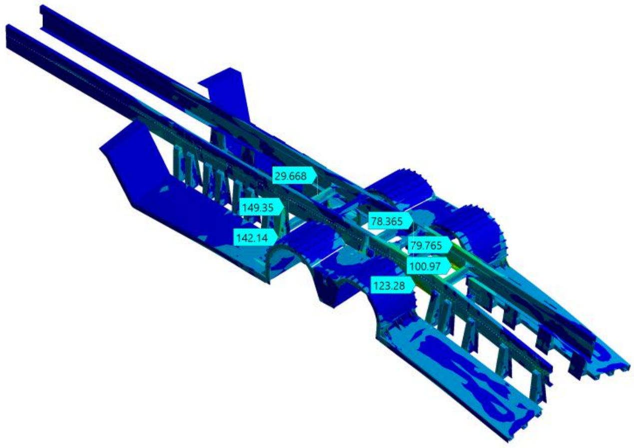
Fig. 6*Values of stresses a) and strains b) for the second case of loading*



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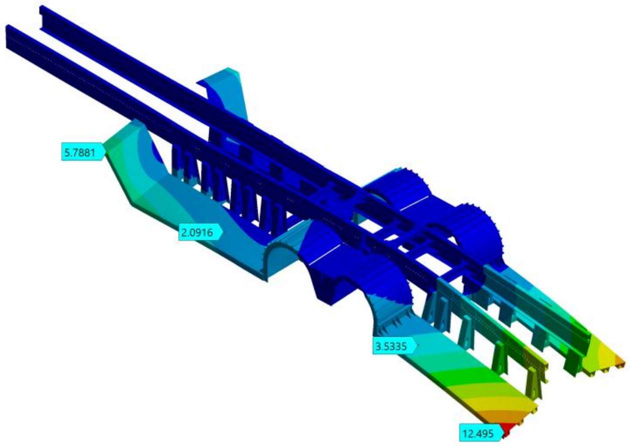

b)

Fig. 7*Values of stresses a) and strains b) for the third case of loading*

In the first and second cases, the load of the structure is Q=100 kN, uniformly distributed at four points, Figure 4a and Figure 4b. In the third case, the load of the structure is Q=200 kN, uniformly distributed at eight points, Figure 4c.

In the first and second cases, the values of equivalent stress are considerably lower than the permissible ones.

In the third case, the stress values are highest near the point where the load is applied at the front part of the vehicle.

The highest values of the equivalent stress are σe=24 MPa.

It should be mentioned that the value of the real load is increased by 10%. On the basis of the analysis, it can be seen that even with these load the stresses are within the allowed limits.

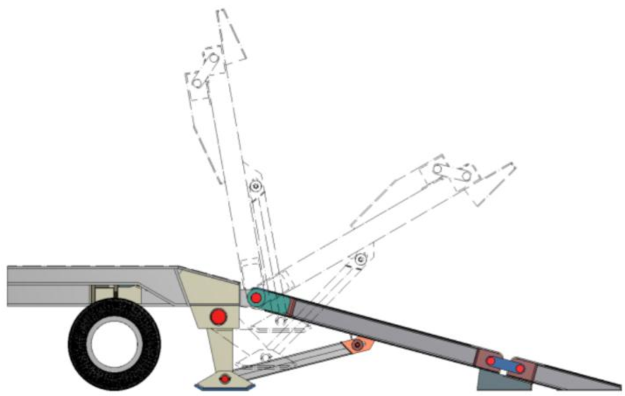

Fig. 7*Loading ramp*

At the rear part of the vehicle, a ramp for loading vehicles is installed [2], [3], [4], [5], [6], [7],and it has its hydraulic drive for lifting and lowering, which considerably facilitates the operation of loading and unloading of the vehicle. During the lowering of the ramp, the hydraulic cylinder brings the supporting leg to the lower working position. The leg is supported on the base, which relieves the rear wheel completely. By installing such a solution of loading ramp, loading and unloading are carried out without manual work of the operator, which considerably facilitates transport.

4 CONCLUSION

The analysis showed that the values of stresses and deformation for the new structural solution for the superstructure of the vehicle for transport of heavy-duty machinery are within the allowed limits, for the selected material of structure.

The new solution consists of segments which facilitate the processes of mounting on the vehicle and disassembling.

The presented solution can also be mounted on another vehicle, but the openings for connecting the plate with the main chassis of the vehicle must be adapted.

The vehicle with the mentioned superstructure can transport heavy-duty earth-excavating machinery to large distances and inaccessible locations at high speeds.

The installation of a self-loading ramp with hydraulic drive excludes the manual work of the operator, which considerably reduces the time for loading and unloading of the vehicle and facilitates the work of the operator.

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