FEM ANALYSIS IN DESIGN OF EXTENDABLE CENTRAL BEAM FOR A SEMI-TRAILER

Grzegorz KOSZALKA1,* - Andrzej NIEWCZAS2 - Hubert DĘBSKI3 - Mariusz GOLEC4 - Maciej KACZOR5 - Leszek TARATUTA6

1,2,3 Lublin University of Technology, Mechanical Engineering Faculty, Lublin, Poland
4,5,6 Wielton S.A., Wieluń, Poland

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Abstract: The paper presents the process of design of central beam of a semi low-loader for the transportation of oversized load, especially wheeled and tracked machines. The FEM analysis played an important role in the design of the beam, which is critical for the strength of the trailer. The designed trailer can carry oversized and heavy loads due to extendable in length and width load platform and 4 axle lines. An important advantage of the trailer is its versatility and the fact that in a not extended state it meets the regulations for standard trailers and can carry loads without a special permission.

Key words: semi low-loader, transportation of machines, supporting structure, stress analysis, FEM

1. INTRODUCTION

The aim of the presented project was to design and prepare the production of a new low bed semi-trailer for transportation of oversized loads, especially heavy machines for civil engineering, agriculture, military purposes, steel constructions, tanks and other oversized equipment.

The assumption was made that the characteristic feature of the trailer would be the solution that allows for the transportation of oversized loads with its extendable in length and width deck and that the trailer would meet all the requirements of a standard vehicle when not extended. Such solution improves the functionality of the trailer creating possibilities to adapt the length and width of the trailer to the size of the load. If it is not necessary to extend the deck to fit the size of the load or the trailer is unloaded, its dimensions meet all the requirements of road code regulations. It is extremely important for the users, because they do not need to apply for an administrative permit and pay a special fare for the drive of the trailer if it is not loaded or if the load is of a standard size and weight.

In the course of research and development works, the following procedures were performed: the analysis of different solutions of specific sub-assemblies and the whole trailer from the point of view of their functionality, reliability, safety and production costs; the estimation of maximum loads and working out a draft project; the preparation of discrete models and carrying out FEM calculations; the evaluation of the results of the FEM analysis and modification of the design.

Apart from the design of the supporting structures of the trailer, works were done in other fields. The influence of suspension type and the number of steering axles and wheel turning angels on the traction properties of the vehicle for various trailer lengths was studied. On the basis of these, the trailer axles, the suspension and tires were selected. The breaking, pneumatic and hydraulic systems were chosen and their necessary adaptations were made to fit them in the trailer. At the same time, the effect of different load fixing systems and other solutions influencing road safety were also studied. The results of these studies were used in the design and arrangement of lashing provisions, side protections and other auxiliary gears of the trailer.

Using the results of the research, the design of the trailer was created and the prototype of the trailer was built. The prototype was then tested in accordance with the method worked out. The experiments allowed for the evaluation of traction and functional properties of the new trailer. The problems that appeared in the course of tests were instantly analyzed and the necessary corrections to the design were made.

The present article discusses the part of works describe above relating to the design of the central beam of the trailer.

2. INITIAL PROJECT OF THE BEAM

Having analyzed various concepts, central beam was chosen to be used. The proposed solution was based on thin-walled box of rectangular cross section consisting of two separate parts. Such solution permits the easy extension of length and ensures good stiffness of the whole structure. The change of length is realized by sliding of the front part in and out of the rear part. The outline of the solution proposed is presented in Fig. 1.

The basic rear part is supported by axle assembly and serves as a support for the front part. The front part is connected with a gooseneck containing a coupling plate, where this part of the structure can be supported by the fifth wheel of a semi-trailer truck.

*Correspondence Author’s Address: Lublin University of Technology, Mechanical Engineering Faculty, Nadbystrzycka 36, Lublin, Poland, g.koszalka@pollub.pl
The design circumstances had a decisive influence on the external dimensions of the beam. The width of the rear part of the beam was limited by possibility of using of axles with steered twin wheels. The height of the beam was limited by the want to obtain the lowest possible position of the load deck. Taking all these limitations into account, the external dimensions of the rear beam were established and it was assumed that they could not be modified. The parameter that was supposed to influence the strength of the beam was the thickness of the walls. The external dimensions of the front beam were supposed to result from the assumed dimensions of the rear part and their role was to ensure the proper cooperation of front and rear parts of the beam. The modification of the elements of the rear part of the beam entailed the change in the external dimensions of the front part. It was initially decided, on the basis of technological and economic aspects, that the beam would be made of steel for which the yield strength was 360 MPa.

3. NUMERICAL MODEL AND BOUNDARY CONDITIONS

On the basis of initial strength calculations, the basic dimensions of the beam were assumed, and then the preliminary design was made (Fig. 2). Being aware that design details such as holes, material joints, etc. have influence on local material stress, the project was subjected to the detailed FEM analysis.

4. THE RESULTS OF FEM ANALYSIS

Numerical calculations were made with the used of Abaqus/Standard software. The calculations made were defined as a non-linear geometrical problem which was solved by the program with the use of iterative Newton-Raphson method. Because the calculations were not aimed at defining the border carrying capacity of material or the effects of local plastic deformations, linear
characteristics of materials were used in the models. Such assumption is generally accepted in engineering analysis as it gives well enough results in the range of suspected structure loads.

The results of numerical analysis for the two least favorable loads applied to the structure are presented in Fig. 4. The results allowed for the evaluation of the initial design. The equivalent stress according to Huber-Mises-Hencky criterion and contact pressure – in the zones of contact between the front and rear part of the beam – were considered in the evaluation.

The analysis of the HMH stress distributions allowed for locating the most endangered areas of the structure. The highest stresses, considerably exceeding the yield stress of the material, were located in the area where the front inner beam passed into a gooseneck (Fig. 5). Because of the area of contact between the front and rear part of the beam a high contact pressure was also present in that zone.

In order to assure the proper cooperation conditions between the rear and front parts of the beam, special sliding pads were fixed in the front area of the rear part of the beam (Fig. 1). Their role was to increase the contact area that led to reduction of local contact pressure.

5. THE MODIFICATION OF THE DESIGN

The presence of very high HMS stress located in some areas of the structure entailed the changes in the initial design of the beam. The largest modifications were made in the area presented in Fig. 5. It was decided that the location of the technological holes would be changed and reinforcing plates would be added in the front part of the beam (Fig. 6). Additional ribs reinforcing the gooseneck were also added (Fig. 7).

Fig. 4. The HMH stress distribution in the beam model folded (upper) and extended (bottom)

Fig. 5. The HMH stress distribution in the area of the highest stress

Fig. 6. The plate reinforcing the beam

Fig. 7. Additional ribs reinforcing the gooseneck
The incorporated changes in the design significantly improved the distribution of stress (Fig. 8). After a series of modifications dangerous concentrations of stress were eliminated from all parts of the beam and final design was accepted.

6. CONCLUSION

FEM calculations played an important role in the process of the trailer design, especially supporting structures. Presented in the paper method of modeling of the central beam allowed for detailed analysis of the distributions of stresses and deformations for different cases of external loads. It was exceptionally helpful and allowed for avoiding design errors that could lead to a failure during trailer service.

The work described in this paper was a part of the project that resulted in the design of the very universal semi low-loader for transporting oversized machines and heavy loads up to 40 tons. The length of the trailer can be easily adjusted within 5 m in steps of 0.5 m, and the width of the deck can be broadened by means of outriggers by 0.51 m. Moreover, the trailer, depending on the requirements of the customer, can be equipped with 3 or 4 axles, including a lifted and a self-tracking axles, an air suspension with height control, double range landing legs, and hydraulically operated, width adjustable ramps enabling loading of self-propelled land machinery. The trailer meets rigorous requirements concerning active and passive safety: it is equipped with ABS, EBS, side protections, and appropriate marking and lights.

The design was implemented to production and several trailers have already been sold so far (Fig. 9). Positive opinions of the users prove the correctness of the design.

REFERENCES