Welded and Bolted Frames of Freight Electric Vehicles

Ladislav Ševčík(✉)

Department of Machine Design, Mechanical Faculty, Technical University of Liberec, Liberec, Czechia
ladislav.sevcik@tul.cz

Abstract. In the contribution is made FEM calculation of frames of freight electric vehicles. A comparison is made between welded and screwed frame joints of high strength steel. A strength check was carried out on the basis of the tensile tests of the welded material and a check with screwed version.

Keywords: electric vehicle · FEM · welding · bolt · high-strength steel

1 Introduction

The article deals with a freight electric vehicle designed for operation in the field, e.g. fields, forests, mines, quarries. The freight electric car will be controlled autonomously, it should orient itself in the field. In the case of very complex terrains, such as unpaved deep mud, it can be navigated by the operator.

Solved problem is an electric car with two axles, both are steerable. The truck has a weight of 1600 kg with batteries and runs at a maximum speed of 40 km/h on paved terrain. The maximum load is 1200 kg. So that the entire truck, fully loaded, has a mass of 2800 kg together. There is an effort to reduce the weight of the electric vehicle and increase the load.

Tightening screws and special form holders are either welded see Fig. 1 or bolted to these profiles see Fig. 2. The aim is to find out what are the strength properties of welds made of high strength materials and to compare them with the properties of screw joints. Determine if the structure is suitable.

Each of the variants has its advantages to disadvantages. The advantage of welds is that the parts are directly attached to the superstructure support profiles, they are not supported by the attachment plate. This solution is cheaper and with less weight. The disadvantage is the difficult interchangeability of superstructures on one frame, the accuracy of welding and the technology of high-strength sheet metal welding. The advantage of bolted handles is the variability and choice of materials. The disadvantage of screwed joints is the complexity of assembly, higher weight.

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2 Materials and Methods

The standard tensile testing device FU250 was used to measure the properties of welded parts. The test device is equipped with hydraulically operated jaws for specimens anchoring. The result of the tensile test is the dependence of normal tension σ on the relative elongation ε. So, two quantities - loading force and specimen elongation - need to be measured during the test. The force sensor is a standard equipment of the test device but the external extensometer needs to be used for the elongation measurement. An extensometer based on the incremental length sensor Renishaw was used for this measurement. This sensor measuring accuracy is 0.001 mm. A wide choice of initial length L0 and the sensor destruction resistance during the specimen breaking are the two biggest advantages of this solution. The extensometer digital output cannot be connected to the test device FU250 control system, so the DEWE5000 universal measurement device was used for data record. The extensometer and the force signal from the FU250 control system were connected to this device. The extensometer principal and block scheme is shown in Fig. 3 (Fig. 4).

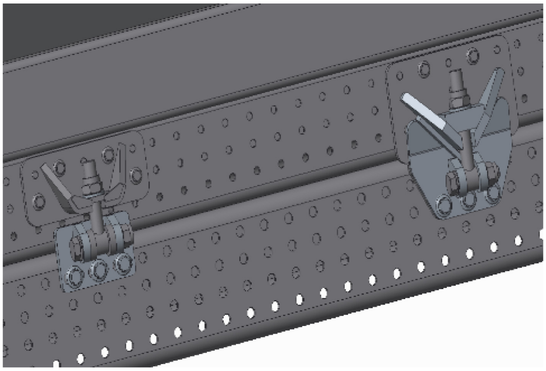

Fig. 1. Welded superstructure frame.

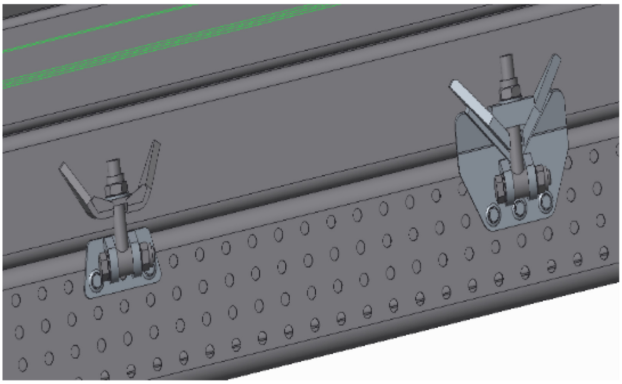

Fig. 2. Bolted superstructure frame.

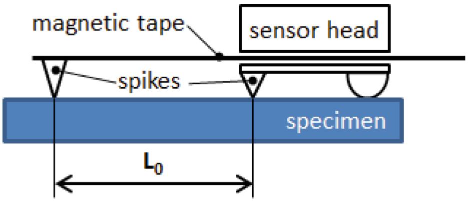

Fig. 3. The extensometer Renishaw principle.

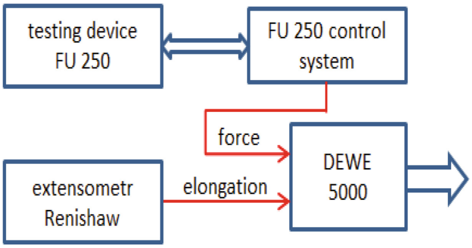

Fig. 4. Measurement block scheme.

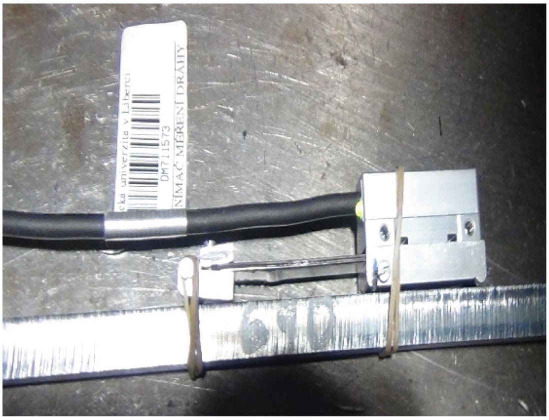

Fig. 5. Samples of welded cut sheets broken.

2.1 Solution Procedure

Two 10 mm thick Simaxx 690QL sheets were welded together and cut into square bars samples approximately 10 × 10 mm [2]. Broken samples are in Fig. 5. Shredder was equipped with extensometer of own production see. Figure 6. It was attached to the rod by elastic elements. Its advantages are in the possibility of attachment to the given square sample and resistance to mechanical damage. See Fig. 6.

Figure 7 shows the installation of a strain gauge on a shredder. The strain gauge was mounted so that the weld was 50 mm in the center of the measured length. It is assumed that the sample to be tested breaks outside the weld under the strain gauge.

This assumption required many tests to be carried out, as few of them would meet this condition.

Figure 7 also shows a broken welded rod in the range of the extensometer, and outside of the weld. Figure 8 shows the measurement result. The welded rod of high strength material was broken under the extensometer outside the welded area. The rod was welded correctly with this rod. It can be seen from the figure that the maximum stress is 950 MPa and the elongation is 15%.

Figure 9 shows the measurement result. The welded rod of high strength material was broken under the extensometer in the welded area. The rod was welded incorrectly on this rod. There was a rupture of the rod at the weld seam and the welded material. It can be seen from the figure that the maximum stress is 850 MPa and the elongation is 2.5%. It can be said that when the weld fails to be technically manageable, the deformation

Fig. 6. Design of extensometer.

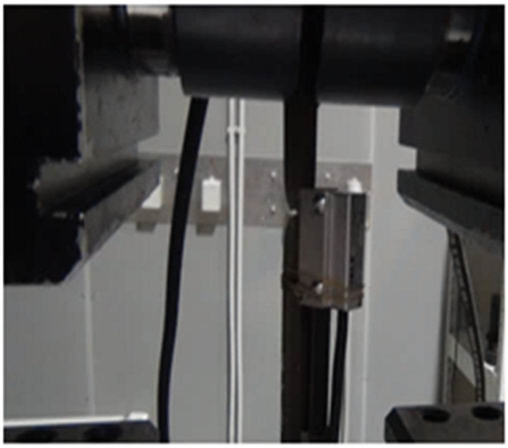

Fig. 7. Fitting of the extensometer.

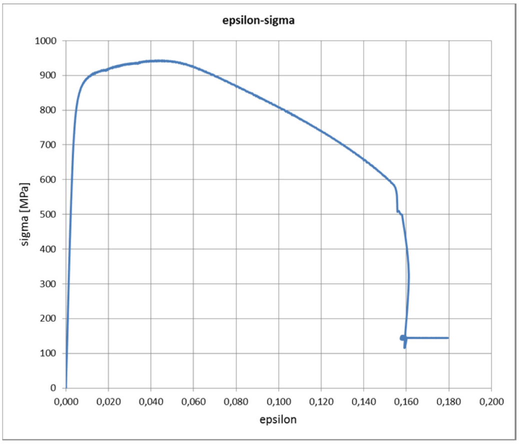

Fig. 8. Material 690 welded, broken outside the weld.

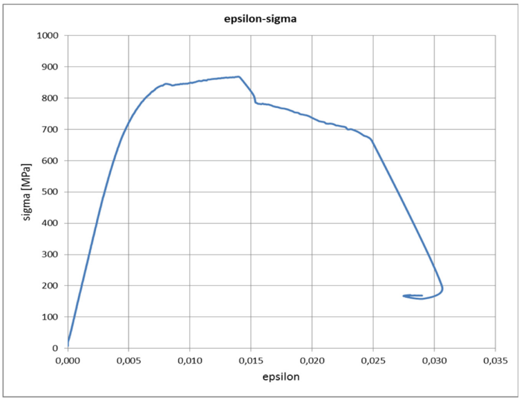

Fig. 9. Material 690, welded, broken in weld – weld made NOK.

ability is substantially reduced. This has a profound effect on the way the structure is constructed. The basis of success is to make smaller weld slags in one weld. Thus, to minimize heat affecting the material to be welded. Heat can transform the structure of high strength sheets. The structure may become coarse and thereby reduce strength. The bigger problem on the basis of performed tests is the quality of the material joining to the weld boundary. Joint quality has a significant influence on the elongation value. It has much less influence on the stress value. This finding is essential for elasto-plastic calculations.

2.2 Standards for Calculating Load Forces of Superstructures

Before carrying out the strength and deformation analysis of the screw and welded supports of the electric vehicle superstructure itself, the calculation of reaction forces and moments at the fixing points was performed. By examining the standards for calculating the storage of various superstructures, it has been found that the strictest standards of loading are for tank trucks. For example EU Regulation for agricultural and forestry machinery frames for ROPS "Tractor". [3] And amending regulation of the European Parliament and of the Council as regards design requirements; General requirements for the approval of agricultural and forestry vehicles [4].

Storing the settings on the frame of the electromobile is statically indeterminate, all elements of the superstructure and frame are flexible. In case the cargo will be transported in the tanker will be according to Art. 5.2 "Fastening the pressure vessel on the car tank" of the standard [5].

Figure 10 shows a schematic diagram of the pressure vessel mounting and the marking of the supports. The pressure vessel and all attachments to the tank truck chassis must be designed and constructed to safely absorb stresses during normal operation, e.g. shocks, vibrations, braking effects, etc. Therefore, the pressure vessel mounting must be designed to cause the forces listed in Table 2 of the "Force affecting the pressure receptacle on the car tank" standard (Table 1).

Where

M is total mass of.

g is the gravitational acceleration.

Note:

(a) the maximum total mass of the tank M = 1 200 kg;

(b) the gravitational acceleration is approximately g = 10 ms-2;

(c) the forces shown in the table are transmitted by a pivot on the towing vehicle and three supports on the chassis frame of the semi-trailer.

The calculation of the reaction forces and moments at the locations of the pressure vessel is provided assuming that the applied forces Fa = 24 kN (longitudinal direction),

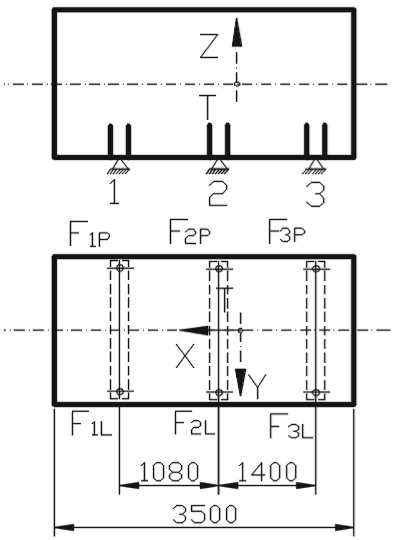

Fig. 10. Layout of superstructure support.

Table 1. Load values for fixing calculations by standard.

DIRECTION OF FORCE	FORCE
IN THE DIRECTION OF TRAVEL (LONGITUDINAL DIRECTION)	Fa = 2M.g = 24 kN
AT RIGHT ANGLES TO THE DIRECTION OF TRAVEL (LATERAL DIRECTION)	Fb = M.g = 12 kN
VERTICAL UPWARD DIRECTION (SIGN +)	Fg + = Mg = 12 kN
VERTICAL DOWNWARD DIREC-TION (SIGN -)	Fg- = 2M.g = 24 kN

Table 2. Resulting forces and moments in supports.

SUPPORT NO.	**FORCE kN**	**Moment Nm**
$\mathbf{F_{1p}}$	9,2	11500
$\mathbf{F_{1l}}$	11,4	14890
$\mathbf{F_{2p}}$	0,2	2200
$\mathbf{F_{2l}}$	0,5	4510
$\mathbf{F_{3p}}$	5,1	6750
$\mathbf{F_{3l}}$	9,8	9823

Fb = 12 kN (lateral direction), Fg + = 12 kN (vertical upward) and Fg- = - 24 kN (vertical downward) are concentrated in the center of gravity of the entire tank.

For idea, the calculation was made assuming that all the forces Fa, Fb, Fg act at the center of gravity at one time in absolute value.

3 Results

In the CAD system PRO/E CREO 4.0 was created model of superstructure. All the parts which are welded together was design without a gap. The screws were replaced with non-threaded cylinders. The nuts were adjusted to a large screw diameter. The screws were inserted in the holes with standard clearance.

The model was converted to ANSYS Workbench 18.0. The welds were replaced by bonding the surfaces of the parts in contact. A friction bond with a friction coefficient of 0.1 was chosen between the main frame of the truck and superstructure and everywhere was plate connection by bolts. The forces were placed in the center of gravity of the tank geometry [1].

The main frame of the electric car was firmly attached to the bottom surface. Then a linear calculation was performed. The calculation results are based on the assumption of well executed welds. The following figures show calculated results. For the better visibility, are shown in the following figures only the supports 1 and 2 in Fig. 10. Figure 11 shows the deformations of the variant with the screws; in Fig. 12 the deformations of the welded variant are. It can be said that both variants have approximately the same deformation values. The structures will be deformed with a maximum of 5% difference.

Maximum deformations are outside the image on the top of the tank. The smaller deformation about 2 mm shows the welded structure. Figure 13 shows the equivalent stress (HMH) of the bolted structure, the equivalent stress (HMH) of the welded structure in Fig. 14.

The high stress values are given by the singularity at the edges of the weldments and are outside the image area. These values are not in the area of interest of the solution, they are not in the area of attachment of the superstructure.

The equivalent stress between the two variants is different. There are additional preloads in the bolts to ensure frictional force transfer, not shear. The screws tighten the plates to reinforce the structure and distribute the stress more uniformly. Unfortunately,

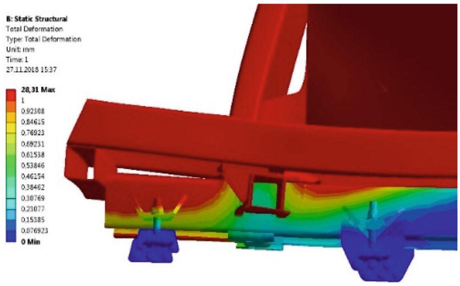

Fig. 11. Deformation of the bolted structure.

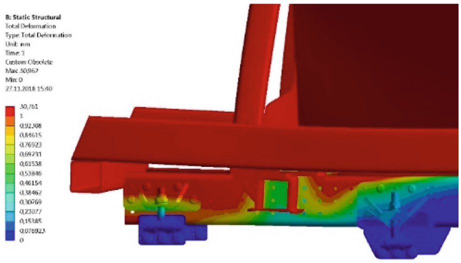

Fig. 12. Deformation of the welded structure.

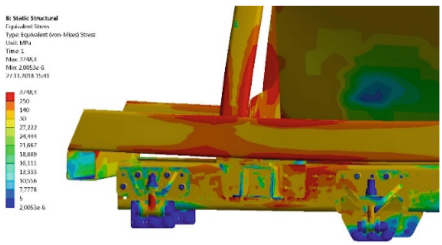

Fig. 13. Equivalent stress of the bolted structure.

even on bolted parts, there are welds that are stressed and so the problems of stress in the welds cannot be avoided.

To assess the possibility of a fault occurring, it is better to decide on the knowledge whether the tension is tensile or compressive. Such an overview can be obtained from the first major stresses, see. Figure 15 - bolted construction or Fig. 16 - welded structure.

The high stress values are given by the singularity at the edges of the weldments and are outside the image area. These values are not in the area of interest of the solution, they are not in the area of attachment of the superstructure.

The figures show that the welded structure in the second support is more tensile than the support of the screwed structure.

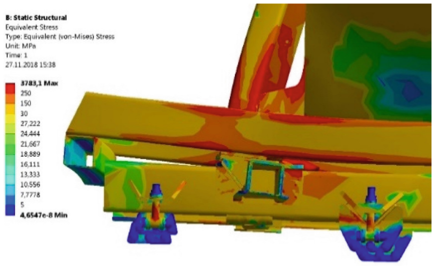

Fig. 14. Equival stress of the welded structure.

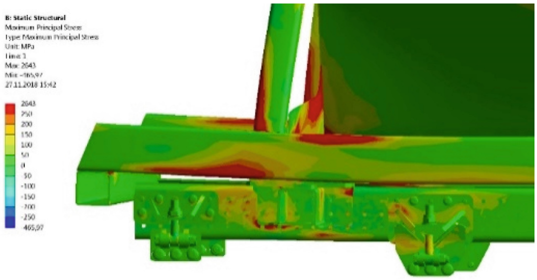

Fig. 15. First main stress of the bolted structure.

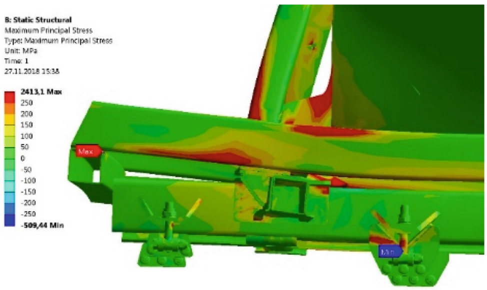

Fig. 16. First main stress of the welded structure.

4 Conclusions

The aim was to assess whether the screwed handles to the superstructure frame have any meaning. The construction is made of high-strength sheets. These sheets have material sheets where the yield strength is above 690 MPa. Welding such sheets does not have certified technology. Every company creates its own procedures. First, the strength of the welds had to be verified. Most of the tests were found to have achieved the required strength. However, the quality of the welds was reflected in the relative damping values. Poorly made welds had 5 times worse ductility.

Furthermore, a model with welds or bolts was created and loaded according to the standard for LPG calculating the pressure tank attachment. The evaluation was performed on the basis of finite element calculations.

Comment:

It can be said that from the point of view the strength behavior of the welded structure and the screwed are the values similar and there is no big difference between them. From my point of view, both variants are suitable.

It will be necessary to use bolts of strength of 10.8, or better and preloaded. The maximum stress value in the bolts was found to be 810 MPa. However, in the group where the screw was found, some screws are less tensile and can be assumed to be replaced after the failure.

There are relatively large moments in the mounts, which are caused by the construction of the hopper attachment. It would be weighed, rework the structure so that the grips are closer to the intermediate frame.

Screws (16 pcs) securing the hopper to the intermediate frame and those between the hopper and the superstructure frame were not solved. However, in these places the tension seems to be higher than in the solved area of the superstructure frame.

In conclusion, both variants are suitable for the given load.

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