PROTECTIVE ELEMENTS OF AGRICULTURAL ELECTRIC VEHICLES

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Abstract
In the paper, there is a procedure for calculation of strength solutions of protective electric vehicle structures according to EU Regulation No 1322/2014 for agricultural and forestry machinery frames for ROPS "Tractor". The design of the protective elements is made of welded high strength steels.

Key words: *electric vehicle; protective elements; stress transcendent calculation.*

INTRODUCTION

The aim of the research was to design a welded ROPS construction of high-strength sheets to comply with the European Directive, with minimum weight.
The design optimization and the strength calculation of the ROPS frame of the agricultural electric car is carried out according to the EU Regulation No 1322/2014 for agricultural and forestry machinery frames for ROPS "Tractor". Values of the maximum static forces to be applied to the ROPS, acting in the vertical and kinetic energy directions in the longitudinal and lateral directions (see Tables 1 and 2), calculated according to EU Regulation 1322 / 2014 for ROPS "Tractor" for electric vehicle, 2x2 chassis.

Tab. 1 Mass of electric vehicle

Chassis type	2x2
Vehicle storage weight	1200 kg
Vehicle maximum storage weight	1400 kg
Vehicle reference weight- max. technical weight	2600 kg

Note: The vehicle reference mass M is the weight chosen by the manufacturer to calculate the input energy and pressure forces to be used in the tests. It shall not be less than the weight without weight and shall be sufficient to ensure that the weight ratio does not exceed 1,75.

Tab. 2 Load variants

Load type	Value
Min. the amount of energy absorbed by the longitudinal loading E (IL1) = 1.4M	3640 J
Min. the amount of energy absorbed at lateral loading E (IS) = 1.75M	4550 J
Vertical loading force at back F = 20M	52000 N
Vertical loading force at front F = 20M	52000 N
Min. energy at longitudinal loading in opposite direction E (IL2) = 0.35M	910 J

Dimensions of force spreaders, the length of the distribution element for the longitudinal and transverse loading of the frame can be min. 250 mm and max. 700 mm by multiples of 50 mm, the height is always 150 mm. Load locations according to EU regulations are shown in Fig. 1.
For longitudinal loading from the rear (in the direction of travel), the point of application of the force is 1/6 of the width of the frame from the edge, closer to the operator's seat (driver), in the 400 mm task.
With regard to the optimized top frame design, the length of the longitudinal load carrier is E (IL1) 600 mm.

For longitudinal loading from the front (opposite the direction of travel) the force is at a distance of 1/6 of the width of the frame W from the edge on the opposite side of the top of the frame, further away from the operator's seat (driver 400 mm). The length of the longitudinal load carrier E (IL2) is 700mm. For lateral loading E (IS), the power point is determined by the position of the clearance zone, precisely by the position of the seat reference point (SIP) by the operator (driver). In the solved task, the point of loading of the side load is only 119 mm from the front edge of the frame and therefore the distributor has the shortest possible length, ie 250mm - see Fig. 1.

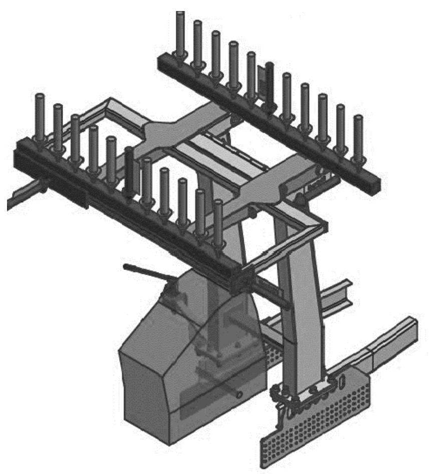

Fig. 1 Design of ROPS "Electro mobile into the field" - loads and their position in tests

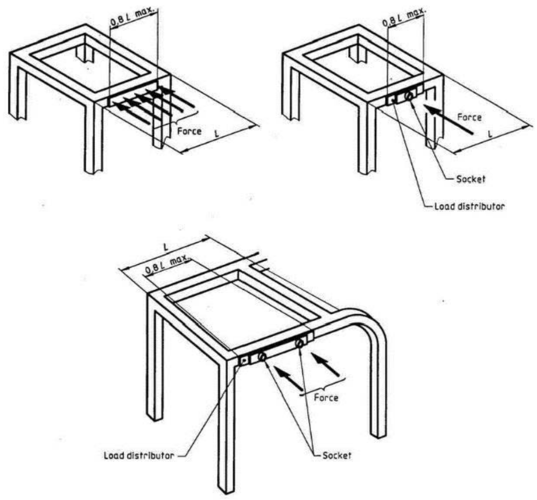

Fig.2 Position of lateral force application according to EU Regulation No. 1322/2014

The vertical loading (pressure test) is performed on the rear and front sides of the protective frame with a force of F = 20M by means of a pressure beam (not part of the ROPS frame), which is pressed against its protective frame by two hydraulic cylinders connected by universal joints. The position of lateral force application according to EU Regulation No. 1322/2014 is in fig. 2.

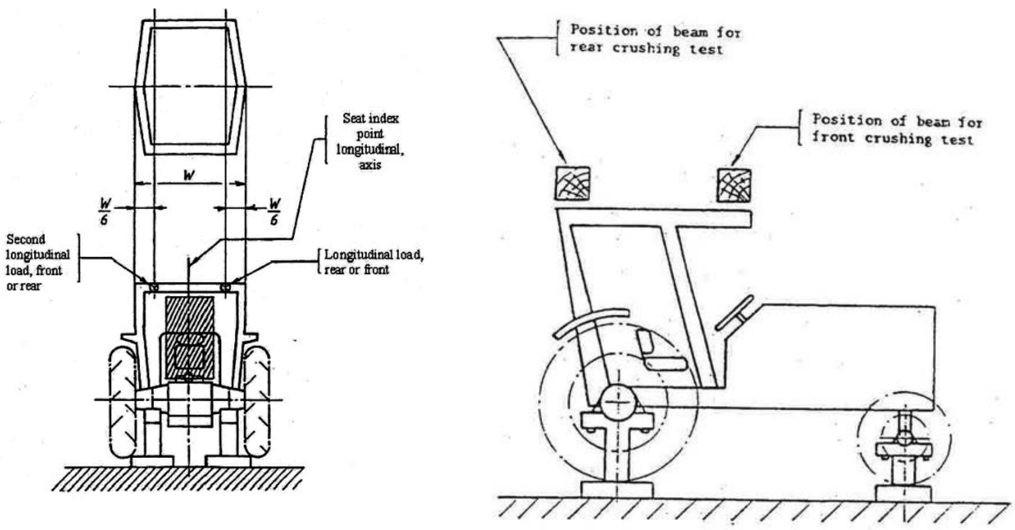

Fig. 3 Positions of longitudinal forces from the rear (in the direction of travel) and from the front (in the opposite direction)

Back and side view, Fig. 3, show loads of electric tractor according to EU Regulation No. 1322/2014. The structure of the protective frame must be such that after the deformations from the gradually loading forces the hatch operator area is not affected.

MATERIALS AND METHODS

High-strength steel S690QL, strength limit 770 - 940MPa, yield strength 690 - 790MPa was used for the main welded vertical beams of the lower frame (webs) and hinged top part of the frame.
Mechanical properties of steel are according to SIJ Acroni certificate.The FEM calculation was based on the tensile test data of the material (*Xiaolin & Yijun, 2019*). Nonlinear calculation respected measured data see. Fig. 4. The device is tested by loading forces in three directions gradually over time. Load first in the direction of travel, then from top and on the end from side. The device deforms plastically. It is then unloaded but partially deformed. As a result of the positive evaluation, the permanent deformation of the device does not reach a certain space.
Furthermore, the loading procedure (tests) according to the standard for the calculation of operator protection during overturning and the size of welds, in particular at welding points, was entered. The plastic and elastic deformations and stresses were calculated in gradual loading by individual tests in Ansys Workbench 17.2, module transient structure. The project scheme is shown in Fig. 5. In linear static structure were counted deformation and stress separately for each load. In transient structural the loading was linked to the previous one from tab. 2. Force from energy calculate by nonlinear gradual system in software.

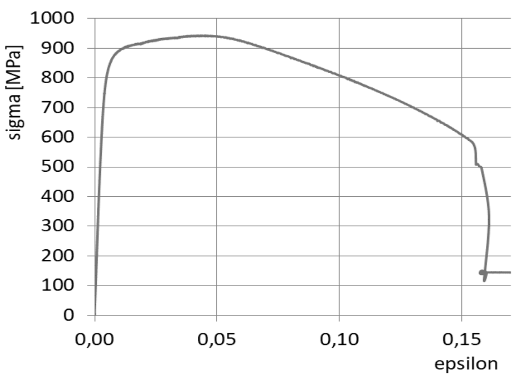

Fig. 4 Material S690 QL welded

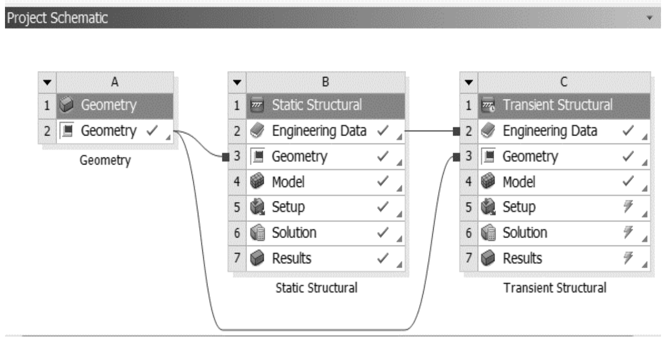

Fig. 5 Project scheme

In transient structural the loading given by energy was linked from the static calculation. Steps followed gradually by tab. 2. It only tests one frame per standard load, which probably won't happen in car crush.

RESULTS AND DISCUSSION

The design of the ROPS was changed until it was simulated that it would be distorted outside the area of Fig. 1 and Fig.3 after all tests in Tab. 2 of the device. Furthermore, the condition was that the plastic deformation in welds would not be greater than 3%. The device will be most stressed at the attachment welds, so the stress and strain results after all tests are shown in the following figures.

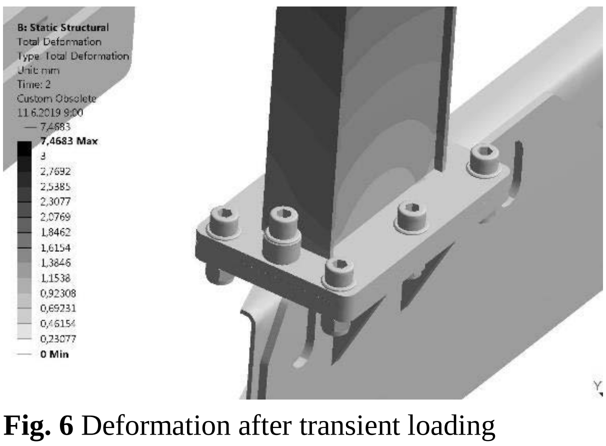

Fig. 6 Deformation after transient loading

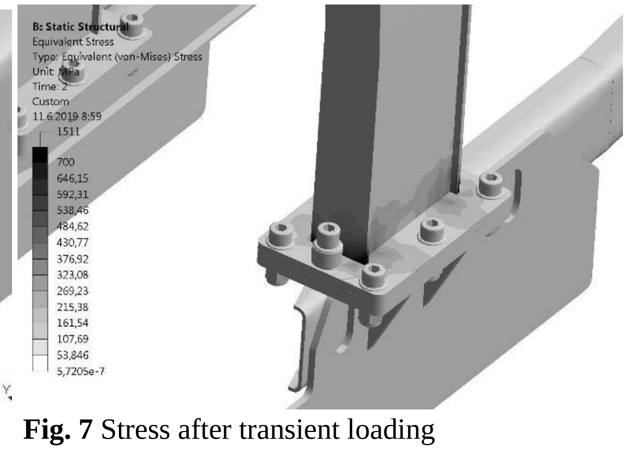

Fig. 7 Stress after transient loading

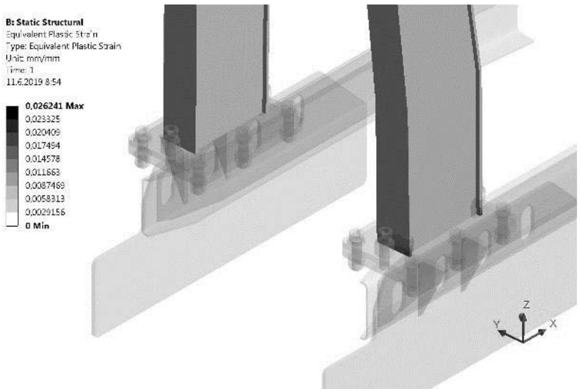

Fig. 8 Equivalent plastic deformation is 2%

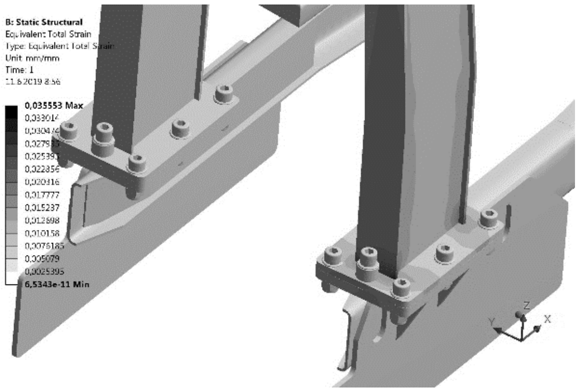

Fig. 9 Elastic and plastic deformation is 3.6%

Taking into account the post-test deformation and stress of transient loading, see Fig. 6, 7. Result of equivalent plastic deformation and elastoplastic deformation are in Fig. 8, 9. The required maximum 3% plastic deformation ensures sufficient space for the operator under the protective cover after its plastic deformation. It is important that the elastic and plastic deformation does not exceed 5% in total for the attachment to the electric car. Since the maximal deformation value in Fig. 9 is 3.6%, the design will be on the safety side and can corrected quality of welds (*Xiaolin & Yijun, 2019; Parrish, 2014*).

CONCLUSIONS

As predicted, the resulting load capacity of the electric car frame made of welded high strength plates will depend on the technology of the welds. The welds must be formed sequentially from several layers so that recrystallization does not occur due to the thermal load. The weld tensile test in Fig. 4 shows a 15% total deformation. However, the strength value of the material decreases after 5%. The required 3% plastic deformation and 2% elastic deformation are in the area of maximum possible stress. The design was designed for this value based on simulations. Practical testing after production will be verified.

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