Design of Load Carrier Composite Reinforcement of Zero Generation of an Electric Car Frame

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Abstract. The aim of the article is to report the methods of solving the construction of the electric car frame. The electric car is designed for movement in the field. This is a functional model marked generation 0. The electric car should move in the field according to the specified trajectories with a load of up to 300 kg. The frame of the electric vehicle consists of aluminium alloy workpieces carrying wheels and four shaped sidewalls. One of the side panels was replaced by a composite part – by a fibre-reinforced plastic. Loading of the sidewall was monitored during operation. The side composite panel is made of welded duralumin, complemented by glass-epoxy composite. The composite part is composed of an epoxy matrix and glass fibre reinforcement (GFRP – glass fibre reinforced plastic). The reinforcing fabric has a plain weave. Holes and threaded holes were made in the aluminium inserts for mounting boards on the frame and mounting the electric vehicle units. Simulations of the behaviour of this sidewall and measurements during the operation were performed. Calculations were performed from both strength and deformation points. The result of calculations and measurements is that the composite sidewall designed in this way can be used for a given load of 300 kg.

Keywords: Electro Mobile · Composite Frame · Fibre-reinforced Plastic

1 Introduction

The paper deals with the design of the supporting frame of a zero generation electric car see Fig. 1. The electric car is composed of a duralumin milled frame. The aim is to design a solution for a frame composed of composites with fibres reinforcement. The design is optimized with respect to weight, strength and deformation. Modern design methods such as topological optimization are used. This contribution belongs to the project "Modular Platform for Autonomous Chassis of Specialized Electric Vehicles for Freight and Equipment Transportation". The frame for the zero generation vehicle was solved. This vehicle will be tested for basic functions, especially autonomous driving

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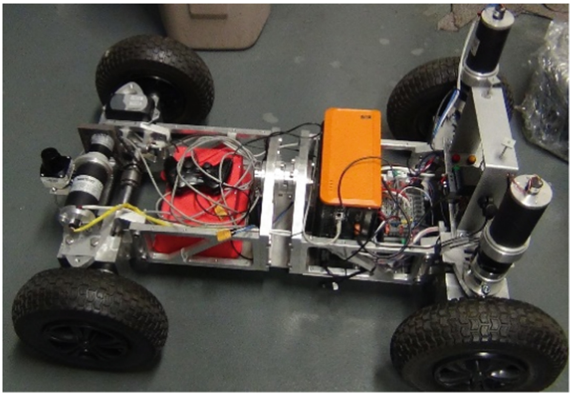

Fig. 1. Electric mobile "0" generation.

and terrain recognition. Furthermore, the project solves the composite frame of this commercial electric vehicle. The frame load capacity is up to 800 kg. The aim is to create a frame by topological optimization to meet the requirements for geometry and fastening of elements, torsional yield, load capacity and deformation.

2 Materials and Methods

2.1 Default Aluminum Alloy Frame

The basic shape of the zero-generation vehicle is shown in Fig. 2. The battery and control electronics are located inside the frame. On picture battery and electronic was removed for the frame, as to be better its visibility. The car drives are 1200 W stepper motor, and the front wheels drive two stepper motors with encoders. The car has no brakes, and in case of sudden need of braking, turns the wheels against each other.

The starting point of the optimization was a torsion-yielding assembled frame made of machined duralumin parts see Fig. 3.

The force 3000 N was entered at the hinge in the centre of the frame. This worst-case scenario can occur with uneven load distribution. Except for the hinge, all the parts of the frame parts were taken together as unmountable - glued together. Physical values for the calculation were as follows: frame material $AlMgSi_6$, Young's modulus $E = 7.1$ E10 Pa, poison number $\mu = 0.33$, specific gravity ϱ $= 2770$ kg/m^3, frame volume $V =$ 5.28 106 mm^3, frame weight $m = 15.5$ kg.

2.2 Design of Glass Composite Frame

First, topological optimization was performed. This took place under conditions of a 35% reduction in the volume of material. Materials: glass fibre reinforced plastic, casting, dividing plane in the middle of the plate shape. Boundary conditions - through bearing - fixed binding, blind bearing loaded with a force of 800 N, i.e. ¼ of the total load.

Figure 4 shows the result of topological optimization [1]. It was not possible yet to make the shape in Fig. 4 from composite material. This shape is very complex. Figure 5

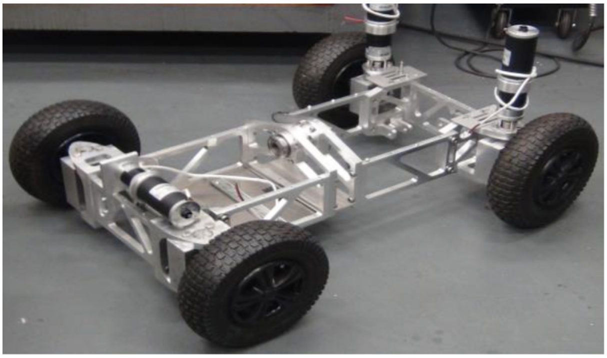

Fig. 2. Frame with wheels and engines.

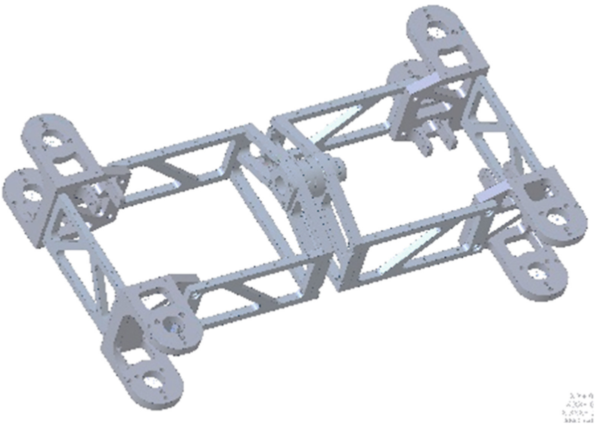

Fig. 3. Frame AlMgSi alloy.

presents an alternative solution - a composite sidewall in the shape of a plate with metal reinforcement at frame shape. The board is composed of two layers of glass fabric. The fabric has a plain weave, area weight 390 gm^{-2}, sett in the warp direction is 400 m^{-1}, sett in the weft direction is 340 m^{-1}. The matrix of the composite system is composed of EPOXY 531 resin and TELALIT hardener, a weight mixing ratio of 100: 27. The matrix has standard mechanical properties.

Composite boards are possible to produce by pressing a special semi-finished product - prepreg [2, 3] or using other technologies according to type of fibre reinforcement. Values for calculating the glued joint were determined by measurement [4]. In calculations, the x-axis is the longitudinal axis of the car. Mechanical values of glass fibres used with values $E_x = 1.2$ E11 Pa, $E_y = 8.6$ E9 Pa, $E_z = 8.6$ E9 Pa, $\mu_{xy} = 0.27$, $\mu_{yz} = 0.4$, $\mu_{xz} = 0, 27$, further specific density $\varrho = 1490$ kg/m^3, frame volume $V = 2.31$ 10^6 mm^3, frame weight $m = 3.44$ kg.

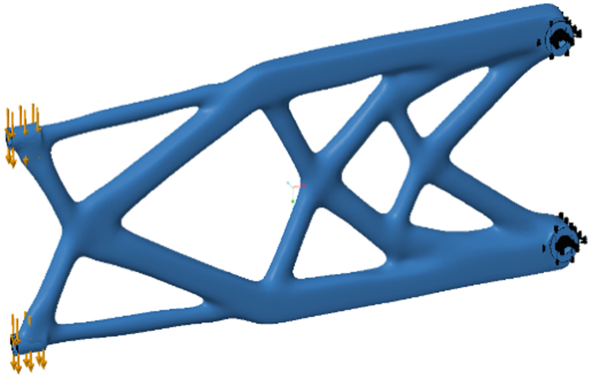

Fig. 4. Composite frame, topological optimization.

Fig. 5. Duralumin frame with GFRP.

3 Results and Discussion

3.1 Results of Aluminium Alloy Frame

The calculation resulted in a maximum deformation value of 11 mm for a given load of 3000 N. Furthermore, the approximate value of equivalent stress in the carrier parts was 394 MPa (Figs. 6 and 7).

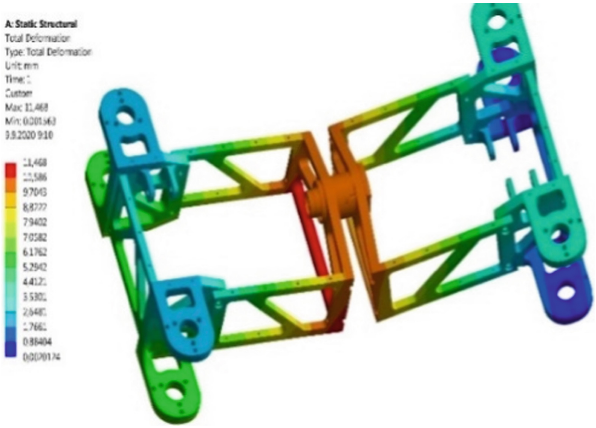

Fig. 6. Total frame deformation.

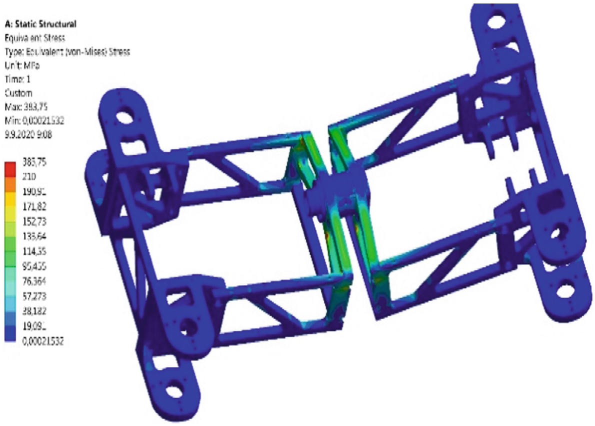

Fig. 7. Reduced frame tension.

3.2 Results of Glass Composite Frame

The calculation resulted in a maximum deformation value of 11 mm see Fig. 8, for a given load of 3000 N. Furthermore, the approximate value of equivalent stress in the carrier parts is 183 MPa see Fig. 9.

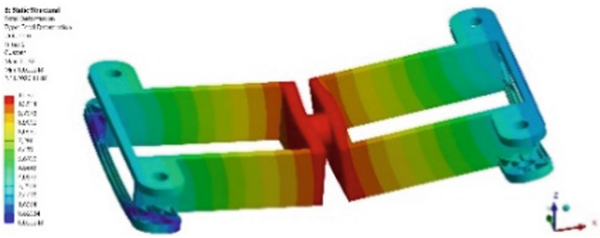

Fig. 8. Total frame deformation.

Fig. 9. Reduced frame tension.

4 Conclusions

The current solution electro mobile construction uses a duralumin frame. Topological optimization of the sidewall was performed. However, it was not used due to insufficient production equipment. A plate construction with a reinforcing metal frame was used for the composite solution.

The designed fibreglass sidewall has five times lower weight. At the same load (according to the mathematical model), both designs have the same maximum deformation of 11 mm. The stress in the composite solution is approximately two times lower.

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