EAN 2020
58th conference on experimental stress analysis

Design of the Composite Frame of the Zero-Generation Commercial Electric Vehicle

ŠEVČÍK L.[1,a]

[1]Deparment of Machine Design, Faculty of Mechanical Engineering, TUL – Technical University in Liberec, Studentská 1402/2, 46117 Liberec, Czech Republic

[a]ladislav.sevcik@tul.cz

Keywords: Special Electro Vehicle, Composite Frame, Topological optimisation, Frame Design

Abstract. The project "Modular Platform for Autonomous Chassis of Specialized Electric Vehicles for Freight and Equipment Transportation" solves commercial electric vehicle designed for field work. The aim is to move the car autonomously in the nature. Car performed the assigned tasks, and use augmented realities - call Microsoft Windows Holographic HoloLens - for orientation. Originally, the chassis had eight engines, each wheel was individually driven and steered. However, this was not managed in real time. In this way, the electric vehicle was adapted to only one driven axle and two steering wheels. This arrangement is already managed in real time. On paved terrain, an electric car should indicate 800kg of cargo including its own weight. The content of the paper is a design of composite frame. The starting point for optimization is the existing duralumin frame. This has been topologically optimized in terms of dimensional possibilities and mounting of vehicle units and equipment. The frame is glued from composite boards. The boards are made by pressing of composite carbon fibres with acrylic resin. Bonding will be done with Cyberbond adhesive. Cybercryl acrylic adhesives are methyl - methacrylate based and designed for structural bonding of engineered thermoplastics, thermosets, nylons, composites, fibre coat and metal in any combination. Ideal for applications that require high tensile and peel strength. A commercial electric vehicle with a duralumin frame is currently being tested and a frame glued with composite boards is being prepared.

Introduction

Within 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 and terrain recognition. Furthermore, the project solves the composite frame of this commercial electric vehicle. The frame load capacity is up to 300 kg. The aim is to create a frame by topological optimization to meet the requirements for geometry and fastening of elements, torsional yield and load capacity and deformation. The frame type is a self-supporting composite glued from planar shaped plates. The calculation was solved in CAD program CREO by topological optimization and ANSYS WORKBENCH solvers. The starting point for optimizing was a duralumin machined frame.

Default aluminium alloy frame

The basic shape of the zero-generation vehicle is shown in Fig. 1. The battery and control electronics are located inside of the frame. But battery and electronic was removed for frame, as be better its visibility. The car drives is 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. 2.

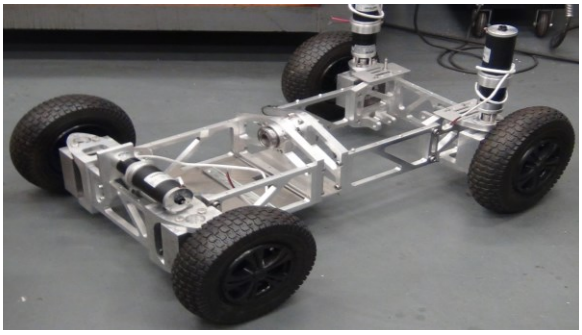


Fig. 1: Frame with wheels and drives

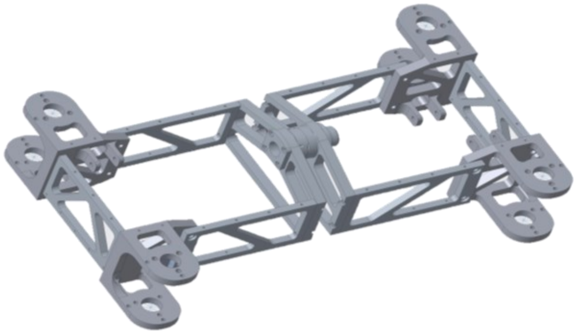


Fig.2: Dural frame ALMgSi alloy

The calculation was carried out by attaching the frame to the wheels. The points were supported, but allowed axial displacements due to frame deformation. The force 8000 N was entered at the hinge in the center of the frame. This is the worst case scenario that 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 AlMgSi6, Young's modulus E = 7.1e10 Pa, poison number ν = 0.33, specific gravity ϱ = 2770 kg/m^3, frame volume V = 5.59e6 mm^3, frame weight m = 15.5 kg, R_m = 380 MPa, $R_{0,2}$ = 210 MPa.

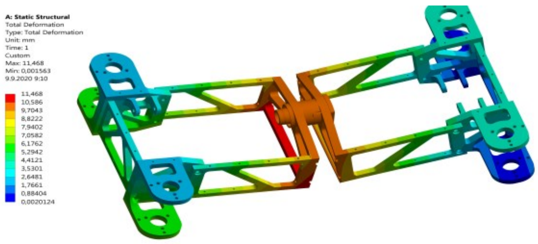


Fig. 3: Total frame deformation

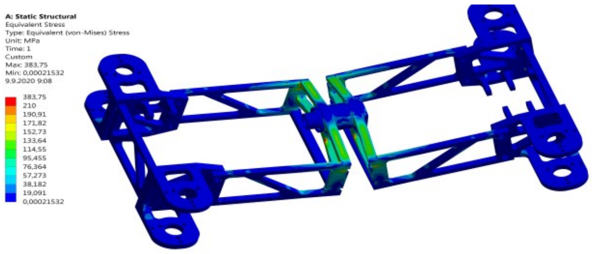


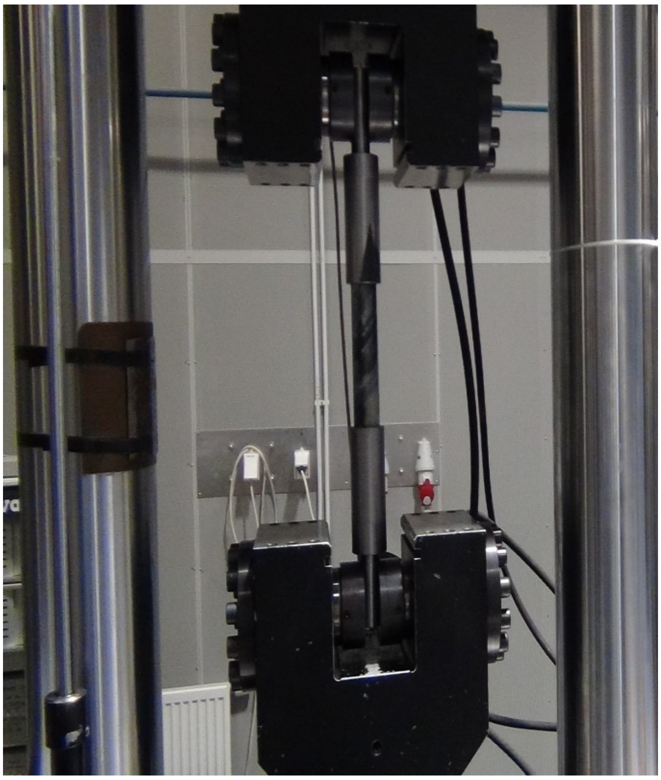
Fig.4: Reduced frame tension

FEM calculation solver was used as static structural analysis with the elastic material model and small deflections. The calculation resulted in a maximum deformation value of 11,5 mm for a given load of 3000 N. Furthermore, the approximate value of equivalent stress in the carrier parts 380 MPa.

Glue by methacrylate

The frame is designed from five glued boards with topologically optimized ribs. These boards must be glued together in the largest possible area and in places with low tensile stress. The joints should be particularly stressed by shear stresses. For the calculations it was necessary to determine the values of the glued joint, especially in shear. A glue with a sales designation was used Cybercryl - methyl-methacrylate based and designed for structural bonding of engineered thermoplastics, thermosets, nylons, composites, fibre coat and metal in any combination. The shear strength of the joint of the steel and composite plate is stated by the manufacturer as 28 MPa. Since this value may be vary, we have tried to create an optimum bonded composite pipe joint and verify the shear stress value. The composite pipe of Fig. 6 was inserted into a steel pipe and sealed with glue. The joint was loaded on the shredder, Fig. 5. Several measurements were made. The average value was determined from five measurements.

The measurement results depend mainly on the surface roughness, a mean value of 1.6 µm was chosen, further on the quality of degreasing of the surface before gluing and especially on the glue thickness. There was a gap to make thickness of glue less than 0.1 mm. The glue was applied to both parts of the joint and the parts slid together. In a few hours the glue had hardened.



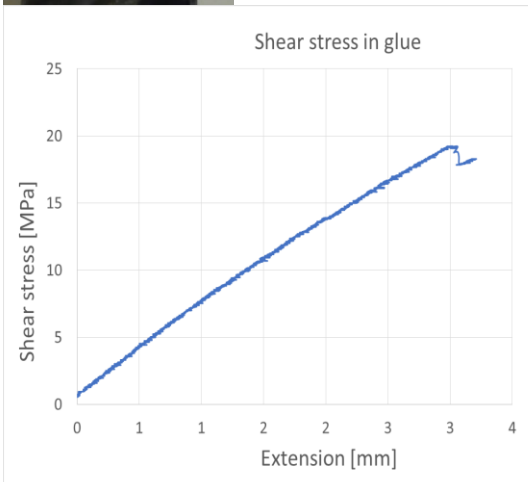


Fig. 5: Loaded joint test   Fig.6: Composite tube   Fig 7. Shear stress

The shear stress in the adhesive surface was calculated from the measured tensile force and the adhesive bonded area. The resulting value of the measured shear stress is shown in Fig. 7.

The result of tests was an average shear stress of 19 MPa. The manufacturer's reported values could not be achieved. This is probably because our joint did not have the required adhesive thickness over the entire joint area.

Design of carbon composite frame

Composite boards are produced by pressing a special semi-finished product - prepreg [1,2]. The ribbed elements are an optimized rib system. Values for calculating the glued joint were determined by measurement [3,4]. In calculations, the x-axis is the longitudinal axis of the car. Mechanical values of ACRYL AND CARBON fiber used with values $E_x = 1.2e11$ Pa, $E_y = 8.6e9$ Pa, $E_z = 8.6e9$ Pa, $\nu_{xy} = 0.27$, $\nu_{yz} = 0.4$, $\nu_{xz} = 0.27$, further specific density $\varrho = 1490$ kg/m^3, frame volume V = 2.31e6 mm^3, frame weight m = 3.44 kg and Rm = 850MPa. The results of the calculation are shown in Fig. 8 and Fig. 9.

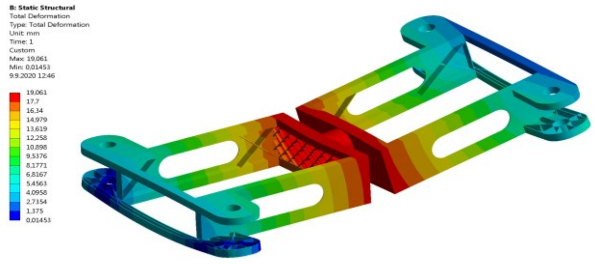


Fig. 8: Total deformation of the composite frame

Fig.9: Reduced stress in the composite frame

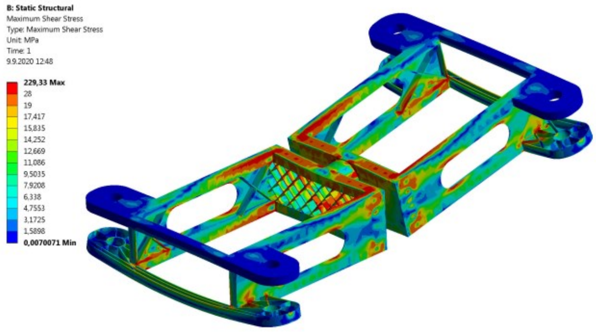


Fig.10: Maximum shear stress in the composite frame

The result of the calculation was a maximum deformation value of 19 mm for a given load of 3000 N. Furthermore, the approximate value of equivalent stress in the carrier parts was 450 MPa. The maximal shear stress, see Fig.10, reaches a maximum value of 230 MPa. At the bonding surfaces of the individual composite parts, the shear stress is lower and does not exceed 30 MPa.

Conclusion

The proposed composite frame for a given contract load shows 8 mm more deformation, same maximum of stress and 4.5 less mass. Since the frame was made by machining of duralumin blanks, the price difference between the frames will not be large.

The frame was glued from several composite boards. The boards were glued by Cybercryl - methyl methacrylate. Shear stress measurements in the adhesive were made. An average shear stress of 30 MPa was achieved. In fact, the shear stress value may be higher, since in reality the composite sheets will stick together. However, the measurement was done by gluing the steel and the composite. The steel was chosen for attachment to the blasting machine.

ACKNOWLEDGMENT

The result was obtained through the financial support of the Ministry of Education, Youth and Sports of the Czech Republic and the European Union (European Structural and Investment Funds - Operational Programme Research, Development and Education) in the frames of the project "Modular platform for autonomous chassis of specialized electric vehicles for freight and equipment transportation", Reg. No. CZ.02.1.01/0.0/0.0/16_025/0007293.

References

[1] O. Grimes, Design and Finite Element Analysis of a Composite Monocoque Chassis for the Shell, Eco Marathon Car Project, Coventry University 2012

[2] C. Kirby, Formula SAE Monocoque Design and Validation Using a Foam Core and Carbon Fibre Skins, South Dakota School of Mines and Technology 2007

[3] M. Biron, The Plastics Industry Economic Overview, Thermosets and Composites - Material Selection, Applications, Manufacturing and Cost Analysis, 2014, pp. 25-103.

[4] A. Elmarakbi, A. Wheatley, D. Warren and S. Das, Advanced Composite Materials for Automotive Applications, Chichester, UK: John Wiley & Sons, 2014.