

Design of a prototype frame of an electrically driven three-wheel vehicle

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Abstract. The article deals with the design of the frame, which will serve to build a new prototype three-wheel vehicle with ecological drive. The proposed frame will be made of aluminum to reduce the weight of a three-wheel vehicle. The new design will allow for optimal distribution of individual parts of an electric vehicle. The 3D model of the frame is created in the CATIA program. The static load calculation will be realized in the ANSYS program.

Keywords: frame vehicle, three-wheel vehicle, structural analysis, modal analysis

1 Introduction

The frame is the basic supporting part of each conveyor and its job is to ensure the exact position of the individual components and not to damage them. The frame of each vehicle carries almost all types of load and therefore the requirements of the vehicle frames are very demanding. When designing a frame, the main requirement is the safety and also the purpose of the construction. In addition to these conditions, when shaping the frame of a given conveyor, its shape, dimensions and material must be taken into account so that the resulting design meets all the strength conditions. The frame of the vehicle must ensure a trouble-free operation of the vehicle with a view to a high degree of safety, and when constructing the frame, care must be taken to its aesthetics and economy.

The design of the vehicle frame is a specific task requiring interdisciplinary understanding of the problem, more demanding if it is an unusual vehicle with elements of an innovative solution such as the E3 – cycle. In designing the E3 – cycle frame, several factors have to be taken into account: innovative solutions to change direction at higher speeds through mechanical control, electromobility and hence increased demands on frame load, safety, manufacturability, etc. To make it easier to distinguish from other three-wheel vehicles, the newly designed tricycle called E3 – cycle.

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2 E3 – cycle frame design

The construction design of the E3 - cycle frame idea goes out of the frame of the three-wheeler electric motorcycle Kyburz Classik designed for the transport of immobile people. In terms of legislation, the vehicle was designed to be grouped into a group of AM vehicles with a cylinder capacity of up to 125 cm³ or an electric motor output up to 4 kW with the launch of the original three-wheel electric scooter.

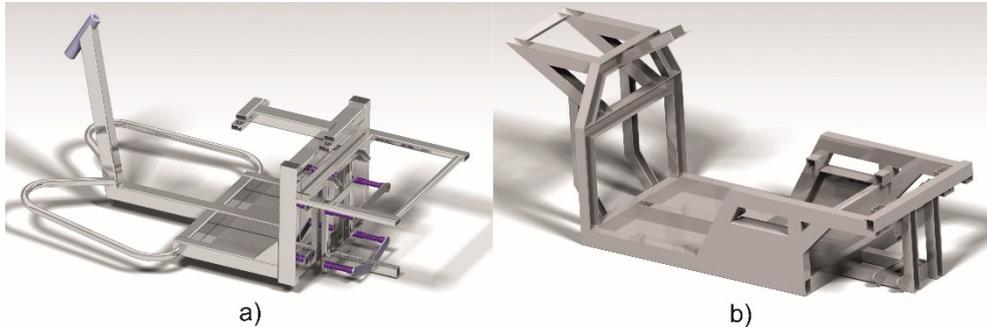


Fig. 1. Frame comparison a) Kyburz Classik frame, b) E3 – cycle frame

The largest shape difference between the original frame and the E3 – cycle frame is evident from Fig. 1, where in the original solution the front fork was placed by means of bearings directly in the tricycle frame. Fig. 1 a). Front of the E3 – cycle frame Fig. 1 b) is specially designed to be able to install a linear guide and a transmission mechanism which is part of the safety-enhancing mechanism in the course of a bend at higher speeds. In addition to this change, two L-shaped brackets have been added to the front with a steering column mounted on the steering wheel.

The central part of the frame is adapted for the insertion of batteries and the necessary electronics. In the original frame, a 12 volt gel battery can be installed. In the E3 frame, a footwell space has been created, allowing for the use of 12V gel batteries or lithium batteries. In addition to this design, the seat frame was reduced by 150 mm in the central part of the frame and therefore the center of gravity of the passenger seat itself. All of these design improvements improve driving performance, reduce weight and increase mileage.

At the rear of the E3 frame, the drive unit of the tricycle is located to accommodate this part be able to mount the engine, the differential gear, the springs etc..

The frame E3 is made of aluminum alloy (AlMgSi) material AW6060 with a strength $R_m = 215$ MPa and a slit with $Re = 140-160$ MPa. When creating the frame, emphasis was placed on making the most of standardized aluminum profiles. The frame of the original tricycle was made of steel. This material change has made it possible to reduce the weight of the E3 frame by up to 40 kg, which also has a positive effect on the range and the vehicle's driving characteristics.

3 Modal analysis of frame E3 – cycle

In order to determine the integrity, consistency, custom frequencies and their corresponding frame shapes, a modal analysis was created. The generated volume model of the E3 – cycle frame was imported from the CATIA program into the 3D geometry creation program ANSYS SpaceClaim (Fig. 2). Subsequently, a network was created in ANSYS Workbench (Fig.3.b) and a calculation of modal properties of the vehicle frame was started. When calculating the modal properties of the frame, the first 6 custom frequencies were observed on the (Fig. 4). Custom shapes at the first three frequencies are shown in Fig. 5. The

frequencies obtained by numerical calculation have been avoided, thus guaranteeing the compactness of the E3 – cycle frame from the point of view of the modal analysis [1, 2, 3].

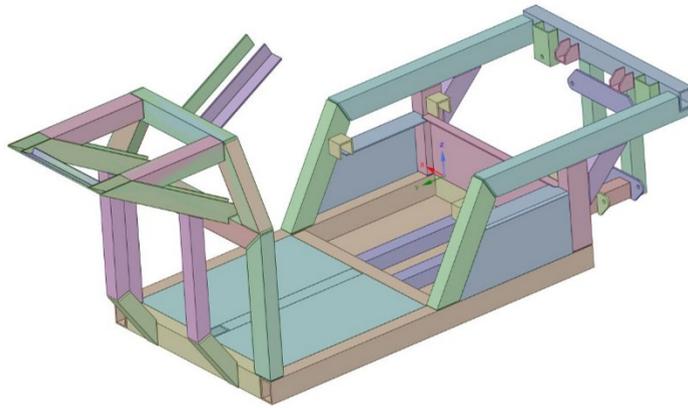


Fig. 2. Import of the E3-cycle frame model into ANSYS SpaceClaim

In the ANSYS SpaceClaim program, the frame model was created using midsurface planes. Creating such a model will simplify, accelerate and provide more relevant results of modal and structural analysis than direct insertion of the CATIA frame model [4, 5, 6]. The midsurface have been assigned thicknesses corresponding to the thicknesses of the given aluminum profiles. This model was exported to the ANSYS Workbench program (Fig. 3a).



Fig. 3. a) Import of the model into the ANSYS model, b) Frame model network

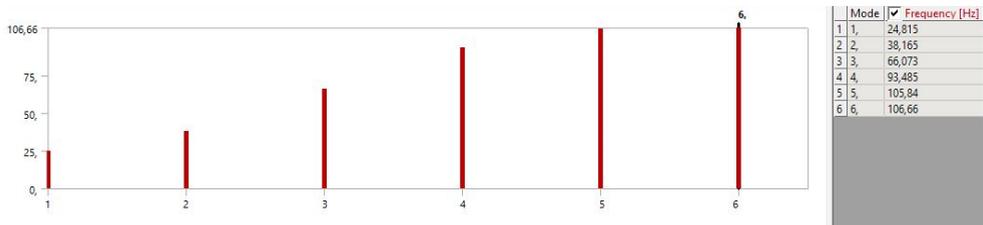


Fig. 4. The first 6 custom E3 - cycle frame frequencies

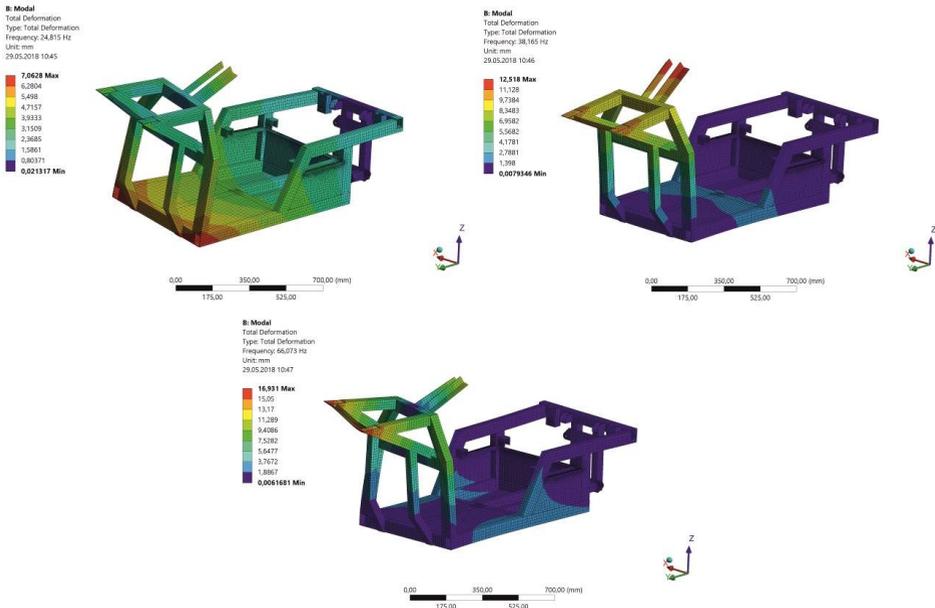


Fig. 5. Custom shapes of the first 3 custom frequencies E3 – cycle frame

4 Structural analysis of the E3 – cycle frame

The static analysis was performed to determine the overall rigidity and load-bearing capacity of the frame construction. The analysis revealed the locations where stress concentrations, size of tensions and displacements occurred due to the action of load forces. The static analysis was necessary to consider the two border states [7, 8, 9]. The first condition occurs when the tricycle is in motion or in the straight line, and does not act on the transverse forces generated by the movement in the arc on its frame. The second boundary condition occurs when the curve crosses with the intended 0.5 g of transverse acceleration.

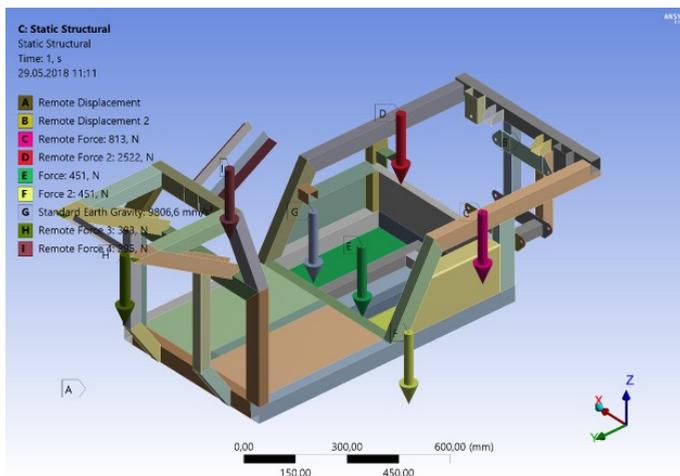


Fig. 6. Boundary conditions of E3 – cycle frame in static or direct movement

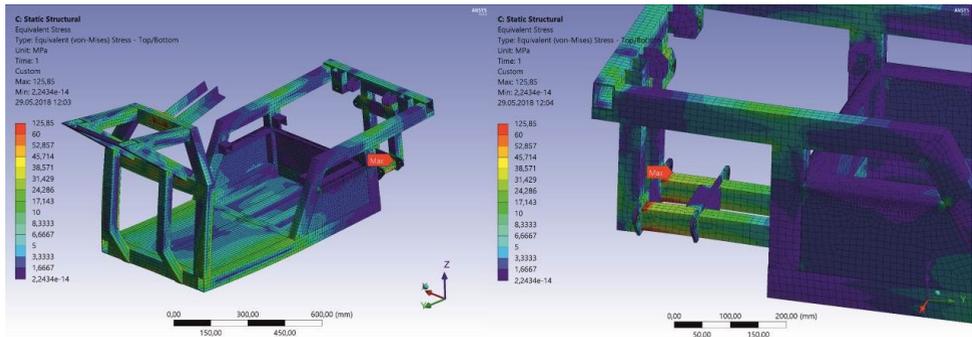


Fig. 7. The resulting stress in numerical computation of the non-moving or direct moving E3 – cycle

The numerical calculation of the load-bearing frame of the vehicle was due to the stress concentrations in the rear of the frame (Fig. 7), where the drive unit E3 – cycle is located. The voltage at this location reached 125.85 MPa.

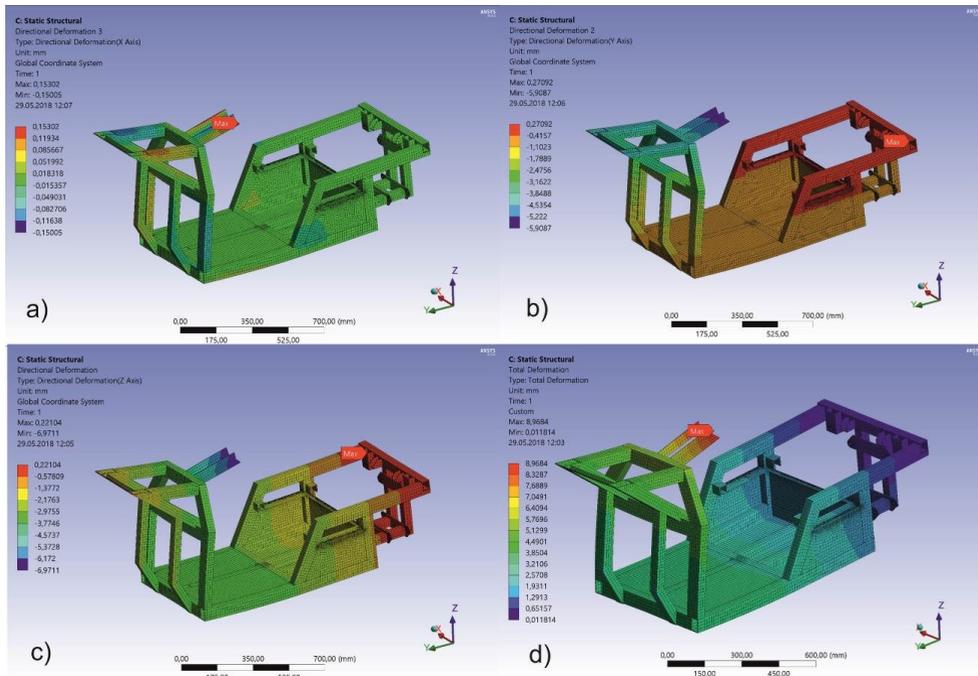


Fig. 8. Deformations in individual axes and overall deformation of the frame in the direct moving

Sliding in individual directions (Fig. 8) are informative and offer us a picture of the overall stiffness of the frame construction. The largest deformation takes place in the z axis. This deformation also manifests itself in total deformations and is caused by a considerable distance of the L end profile from the lower part of the tricycle frame. The maximum value of the deformation is 9 mm. In the structural analysis, the most important task was to correctly determine the boundary conditions so they correspond to the state in the most realistic way. Marginal conditions when considering a non-moving or forward-moving tricycle (Fig. 5) were considered as follows: A – Bonding representing the front wheel, B – the attachment of the rear wheels, C – The weight caused by the weight of the drive unit (41.5 kg), D – Load due to the weight of the passenger (120 kg) E, F – load caused by the weight of the battery (23 kg), G – gravitational acceleration, H – load due to the weight of the patent mechanism

(20 kg), I – load caused by the weight of steering column and steering wheel (15 kg). In the calculation, a double value of all loads was considered with respect to safety factor $k = 2$ (-).

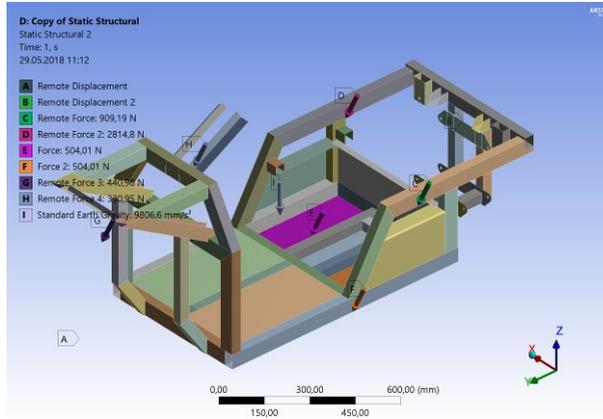


Fig. 9. Marginal conditions when passing through the arch

Boundary conditions when considering moving tricycle in a curve with a peak lateral acceleration of 0.5 g (Fig. 9) were considered as follows: A – Bonding representing the front wheel, B – the attachment of the rear wheels, C – Load caused by the weight of the drive unit (41,5 kg), D – Load due to the mass of the passenger (120 kg) weight of the seat (8,5 kg), E, F – load caused by the weight of the battery (23 kg), I – gravitational acceleration, H – the weight caused by the weight of the patent mechanism (20 kg), G - the weight of the steering column and the steering wheel (15 kg). In the calculation, a double value of all loads with respect to safety factor $k = 2$ (-) was taken into account and the resulting load forces were the resultant between vertical gravity acceleration and transverse acceleration resulting from the curve travel [10].

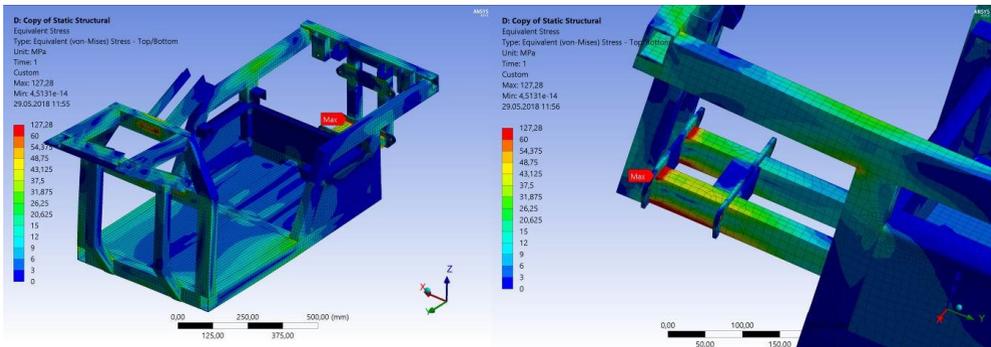


Fig. 10. The stress created in the E3 – cycle frame when passing through the arch

As in the previous case, the stress concentrations at the rear of the frame E3 – cycle (Fig. 10). In this case, the maximum voltage was 127,28 MPa. The difference between the first and second calculations was about 2 MPa. After a thorough analysis of the numerical calculations, a location was determined which, on frequent use of E3-cycle, will be regularly checked.

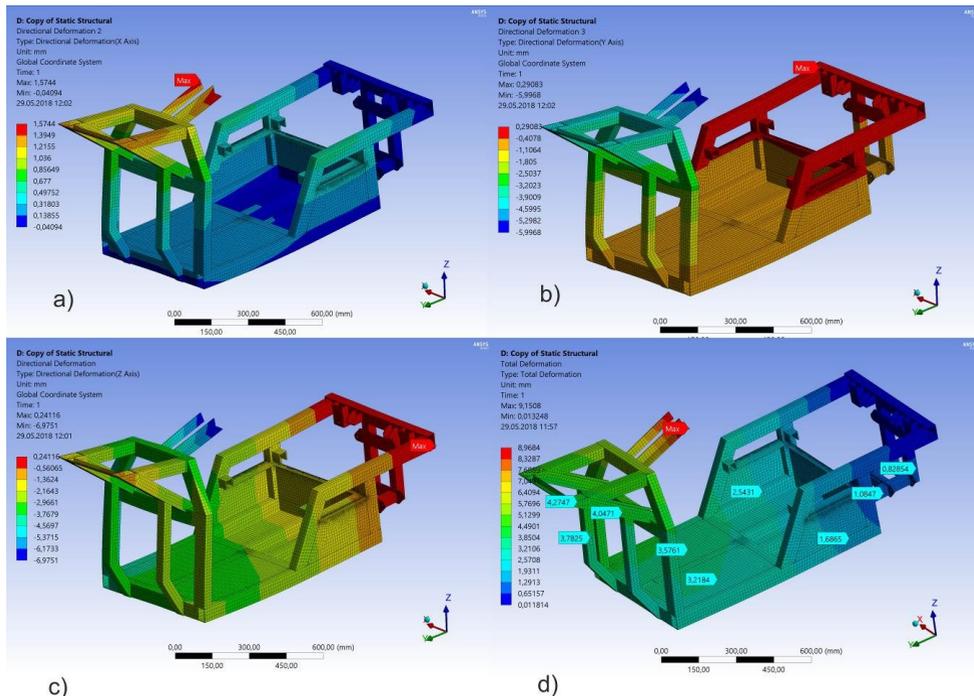


Fig. 11. Deformations in individual axes and total deformation of the frame when passing through the arch

5 Conclusion

The aim of this article was to design an electric tricycle frame on which a special mechanism is installed, which in an innovative way increases the tricycle's stability when crossing the curve at higher speeds. The design of the E3 - cycle frame was created in accordance with technical regulations and design principles with a knowledge-based implementation based on previous simulations. Numerical strength analysis has examined all possible states that may occur when using E3 – cycle. The E3 – cycle does not include devices that cause excitation vibration to resonate the system and thus damage the E3 – cycle frame, which guarantees the strength and structural integrity of the frame. After all the necessary calculations and analyzes, we proceeded to produce the prototype of the frame (Fig. 12). At present the frame is installed in the E3 - cycle prototype.

With this research and development subjects deals other publications too [11-21].



Fig. 12. Manufactured E3 – cycle frame

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