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ULTRA-LIGHT VEHICLE FOR DISABLE PEOPLE

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Abstract

The paper presents a study on concept of ultra-light vehicle created by innovatory technology with laminate panels what provided low weight of self-supporting body and in consequences low vehicle weight. The usage of panels with aluminum honeycomb core and glass fiber based skins allows creating large flat surfaces for interior and vehicle body without any additional treatment. Glued panels with aluminium core make closed, rigid structure of self-supporting body with relatively low weight. Independent suspension system which components are made of carbon fiber also guarantees low weight. Vehicle is powered by two electric motors BLDC type with power of 2 kW each, and they are placed in rear wheels. Low vehicle weight has important meaning, particularly for electric vehicles and its range. Presented vehicle belongs to L6-e category and does not require any licenses for driving. The vehicle is dedicated for disable people on wheel chairs. The fundamental problem for disable people on wheelchairs is getting inside a vehicle without any help. Proposed solution at the conceptual vehicle allows for getting the wheel chair inside the vehicle by the use of lower part of the rear door and the wheel chair play a role of the vehicle seat. Such solution also makes that the level of physical disability has no influence on auxiliary devices used for vehicle driving.

Keywords: *ultralight vehicle, electric vehicle, laminates panels, vehicle for disable people*

1. Introduction

A rapid growth of urban, ecological and electrical vehicles has been noticed recently. However, none of such vehicle was commercially successful, primarily due to the price, but they made contribute to development of vehicle bodies and chassis design as well as drive and energy storage systems. The other issue was the adaptation of urban vehicles for physically disable people. In majority of such vehicles automatic transmissions are used, usually CVT, what helps disable people driving vehicles. However, problem of vehicle boarding with wheel chair remains still unsolved. Considered concept of the vehicle presented in this work was the assumption that the wheel chair is used as a vehicle seat and the only thing that has to be solved is getting in and out of vehicle (Fig. 1). In existing solutions (Fig. 2) or concepts (Fig. 4.) wheel chairs are able to get into the vehicle by prepared ramp beforehand or by lowering, like in urban buses, the whole vehicle or the rear (Fig. 4). Proposal of Devida Gandini and others from University of Brescia with pneumatic suspension is project, which should provide high comfort during getting into the vehicle and getting off. Furthermore, the amount of necessary free space for this activity is much smaller than by using ramps.

Fig. 1. Concept of getting the wheel chair into the vehicle (7)

Fig. 2. Vehicle Kenguru (1)

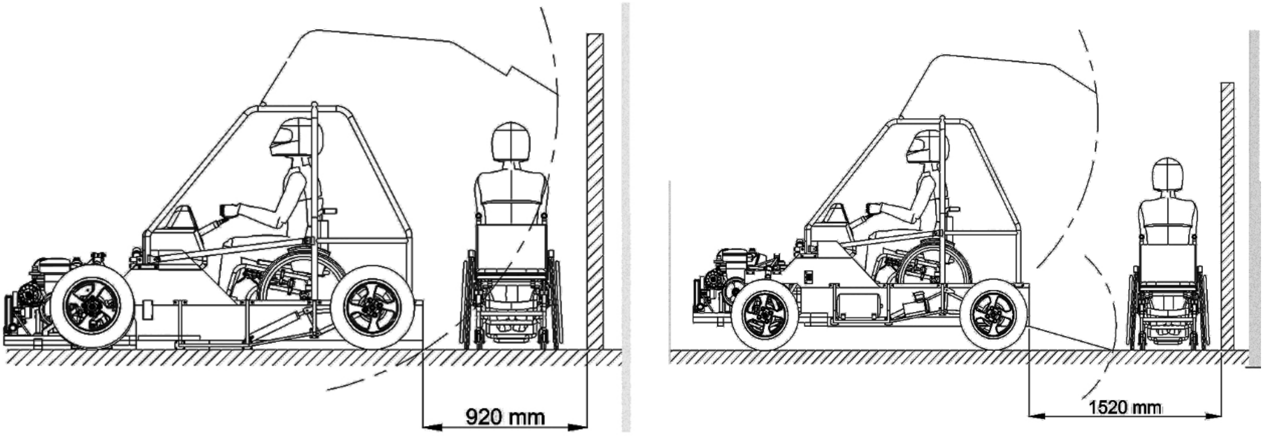

Fig. 3. Concept of vehicle with pneumatic suspension (5)

There is still interest of vehicles for physical disable people in which wheel chair is also vehicle seat what is confirmed by the project of new vehicle prepared in 2013. Additionally the vehicle should have possible highest efficiency of drive system considering specific way of their using, mostly on short distances. Energy consumption for such vehicles depends on theirs weight. An example of ultrahigh vehicle is design of Hochschule für Technik in Rapperswill in which the vehicle structure is a flexible central beam to which aluminium body is fixed. The total weight for this vehicle is surprisingly low and without batteries is 200 kg.

Fig. 4. Concept of vehicle Equal1 (3)

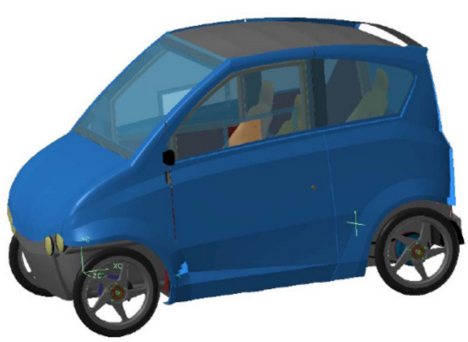

Fig. 5. Ultra-light electric vehicle with central flexible beam (6)

A concept of electrical vehicle was also prepared at Cracow University of Technology. The body of the vehicle is self-supporting structure made of composite panels. The usage of composite panels is relatively new approach and in known solutions is limited to supporting structures (Fig. 6). The usage of composite panels with smooth surfaces allows for significant reducing finishing treatment of interior and vehicle body. During designing process attentions was paid on possibility of creating vehicle body without special equipment and tools. The vehicle body could not limit the vehicle functionality and interior should provide wheel chair movement without any collisions independently from the wheel chair type. The prototype of the vehicle was build and initial test were performed.

Fig. 6. Supporting structure and complete ultra-light vehicle (2)

2. Vehicle concept

The main objective of the vehicle concept was the assumption of vehicle function over its form. This assumption determined the dimensions of the vehicle and form of interior. The appearance of the vehicle could not be of course irrelevant taking into account the tendency to not distinguishing people with disabilities from others (Fig. 7).

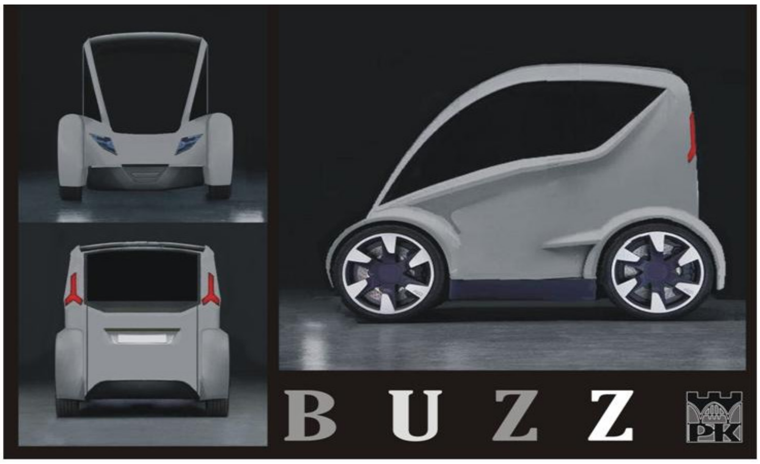

Fig. 7. Concept of external appearance for disable people Buzz (7)

The solution that was selected is a self-supporting monocoque type body built entirely with honeycomb panels with an aluminium core (4). Such panels have very low weight. They consist of outer skins, which are fixed to honeycomb core made of aluminium. The skins can be made of many types of fibres such as glass, aramid or carbon. For the purposes of the project, it was decided to choose the skins made of fibreglass. One of the feature of honeycomb panels is high strength. The structure made of such panels has additional advantage, which is high-energy absorption. Another advantage is possibility of relatively easy connecting and creating 3D structures. These panels have also possibility for machining with traditional tools for steel or wood, what is important when the structure have to be created in medium level workshop.

Fig. 8. Model for ergonomic test made of paperboard (7)

At the next step, full-scale model made of paperboard was created (Fig. 8) which was later used for ergonomic test in order to verify assumptions for available space. The model also allowed for assessment of interior availability, and in the consequence setting the position of rear door and length of the ramp. During the further work, the model of vehicle body was created in CAD system (Fig. 9).

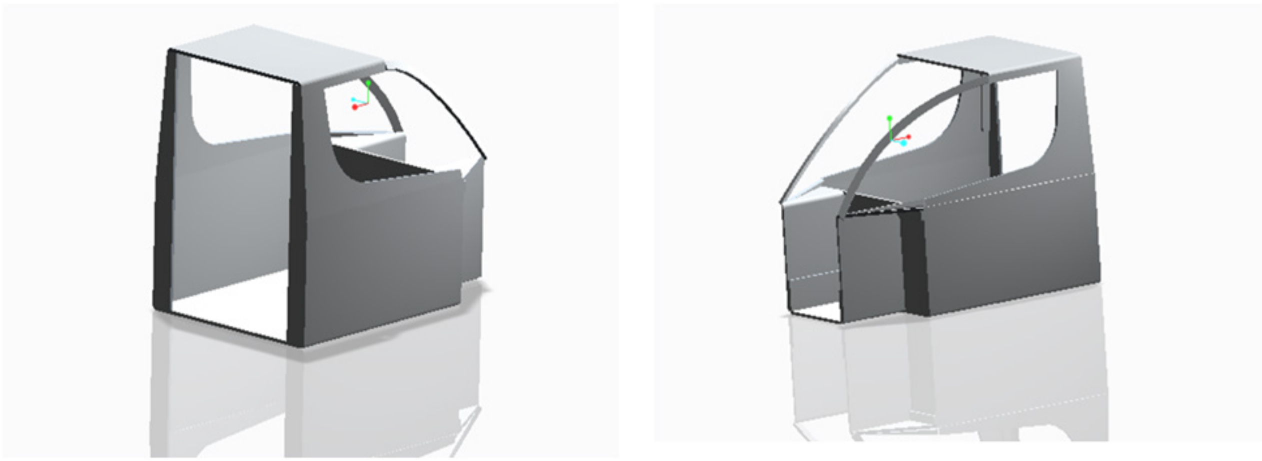

Fig. 9. Final model of the vehicle body (7)

The vehicle body has the following dimensions:

length – 1900 [mm],
width – 1200 [mm],
height – 1440 [mm].

The batteries are placed in the front of the vehicle so that the floor of the passenger compartment will be flat over the whole length, which makes the using vehicle easy. Fixing points for components like suspension are used as metal plates (steel or aluminium) laminated to the vehicle structure. Created vehicle body is presented on Fig. 10.

Fig. 10. Vehicle body (7)

The vehicle has independent suspension system, which components are made of carbon fibres. Front suspension consists of two swing arms with not equal length and they are fixed to vehicle body nonparallel with the use of steel plates. The length of swing arms provides small changes in wheels distance and inclination angle during suspension operating. For the sake of using wheel chairs, the suspension deflection was ± 50 mm. Suspension system was created by the use of components, which are available on the market. Concept of suspension system was presented on Fig. 11.

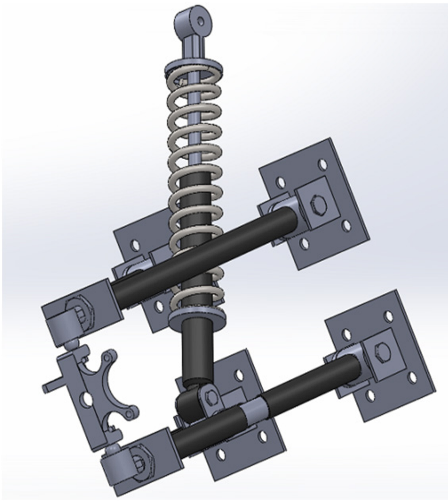

Fig. 11. Front suspension (7)

The way of fixing suspension components to vehicle body is presented on Fig. 12. To avoid local deformation of composite panels of steel plates were used. The vehicle has independent suspension system and the components are made of carbon fibres.

Fig. 12. View on front suspension (7)

For the sake of capacity of available space inside the vehicle the rear suspension are swing arms parallel to vehicle axis (Fig. 13). Additionally a beam, which connects swig arms on both sides, is used to avoid deflection of vehicle interior structure.

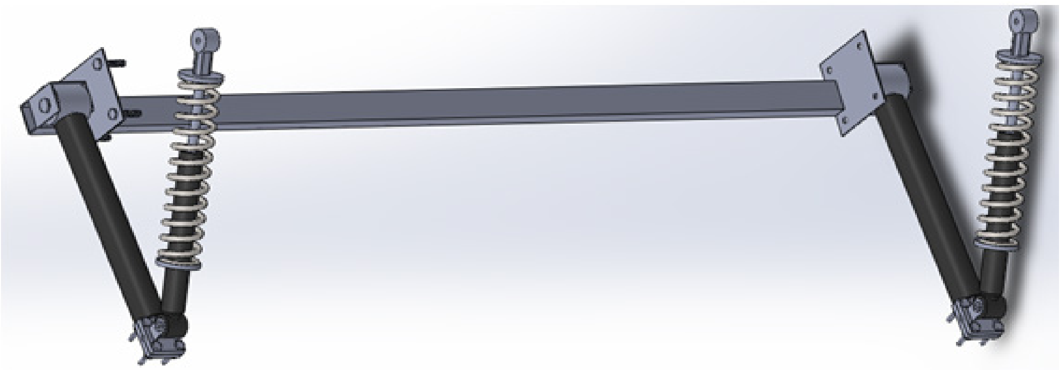

Fig. 13. Concept of rear suspension (7)

A vehicle with installed BLDC electric motors in rear wheels and tooth steering gear is presented on Fig. 14. A typical steering system was applied what allowed to minimize necessary actions for turning of steering wheel in comparison to typical for such vehicles motorbike steering systems.

Fig. 14. A vehicle body with suspension system (7)

3. FEM analysis

The assessment of presented ultra-light vehicle body strength was made by finite element method (FEM) in ANSYS Workbench environment. Panels, which the car body was created consists of two skins, which are glass fibre composites and metal core in honeycomb shape. A fragment of honeycomb panel is presented on Fig. 15 (4).

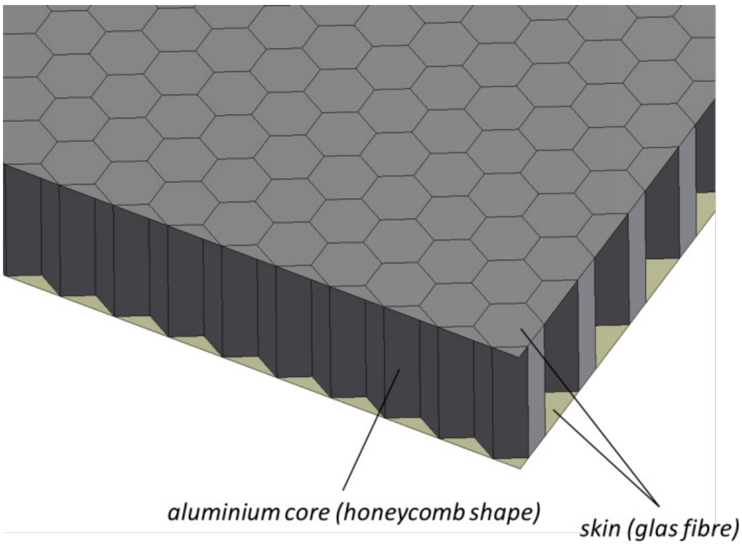

Fig. 15. Aluminum honeycomb panel

The usage of exact geometry in FEM simulations makes difficulties due to the problem with small dimensions of honeycomb in comparison to the overall dimensions of vehicle body. Therefore, an attempt of using equivalent model of honeycomb laminate was undertaken. One of the approach that is presented in available literature is using an equivalent model of honeycomb laminate as a laminate 2D shell elements and the second is the use of 3D solid elements (8), (9), (10). The second approach was applied to evaluate strength of the vehicle presented in this paper.

The real structure of panel was replaced by equivalent model with mixed 2D shell and 3D solid elements. Shell elements were used for modelling panel skins, while solid elements for honeycomb core. Both, shell and solid elements are linear elastic material models, skins were assumed to be elements with isotropic material properties while solids with anisotropic. The equivalent properties of core material were determined according to experimental test and FEM simulations. At the first step, the full scale sample of panel with dimension 100 x 500 was used in bending, compression and tension test, than these results were used to adjust the FEM model and finally to find equivalent mechanical properties of skins element and honeycomb core. The first step was to determine the equivalent skin properties with using exact geometry of honeycomb panel. This model, presented on fig. 16, consists of 2D shell elements for skins and 2D shell elements for aluminium core. The comparison of FEM results and experimental test is presented in Fig. 17.

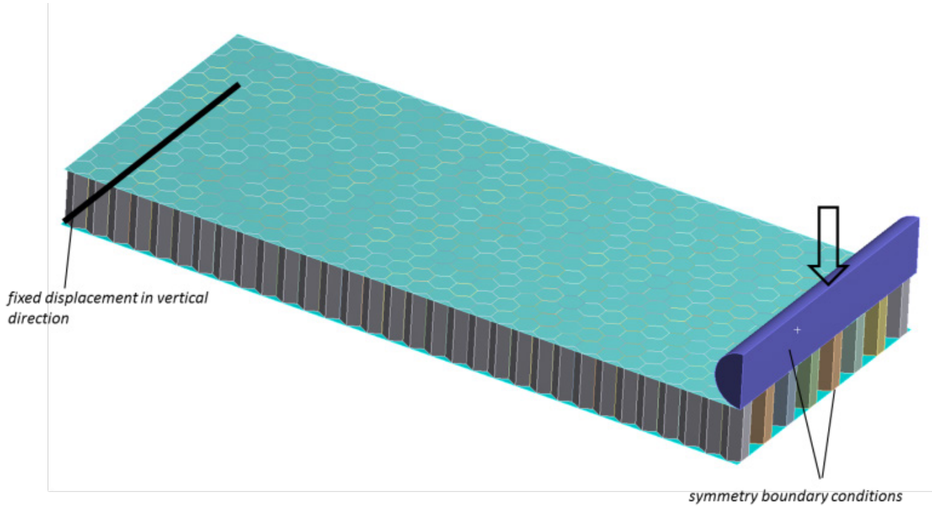

Fig. 16. The FEM model of three point bending test

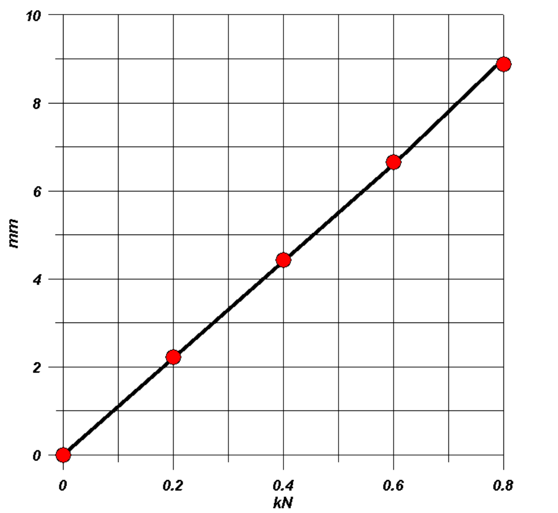

Fig. 17a. Bending test (FEM:dots, experiment: line)

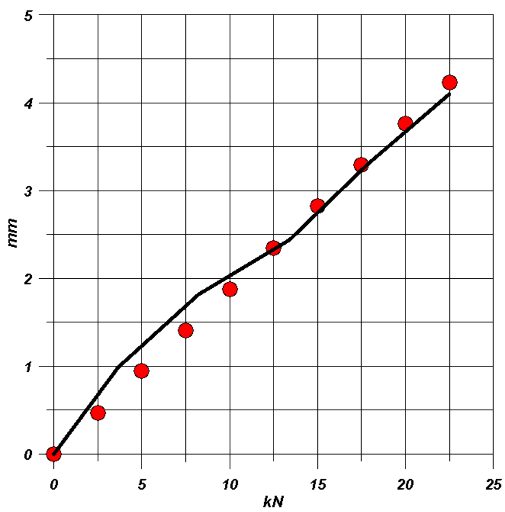

Fig. 17b. Tension test (FEM: dots, experiment: line)

At the next step, FEM model with the equivalent core properties was created. In this model, the honeycomb core structure is replaced by homogenous solid elements with anisotropic material properties. Created model is presented on Fig. 18. The equivalent model of honeycomb core is anisotropic model which is described by adequate Young modulus (E_1, $E_2 = E_1$, E_3) and Poisson ratio (ν_{12}, $\nu_{13} = \nu_{23}$, ν_{23}), the model was assumed to be linear elastic.

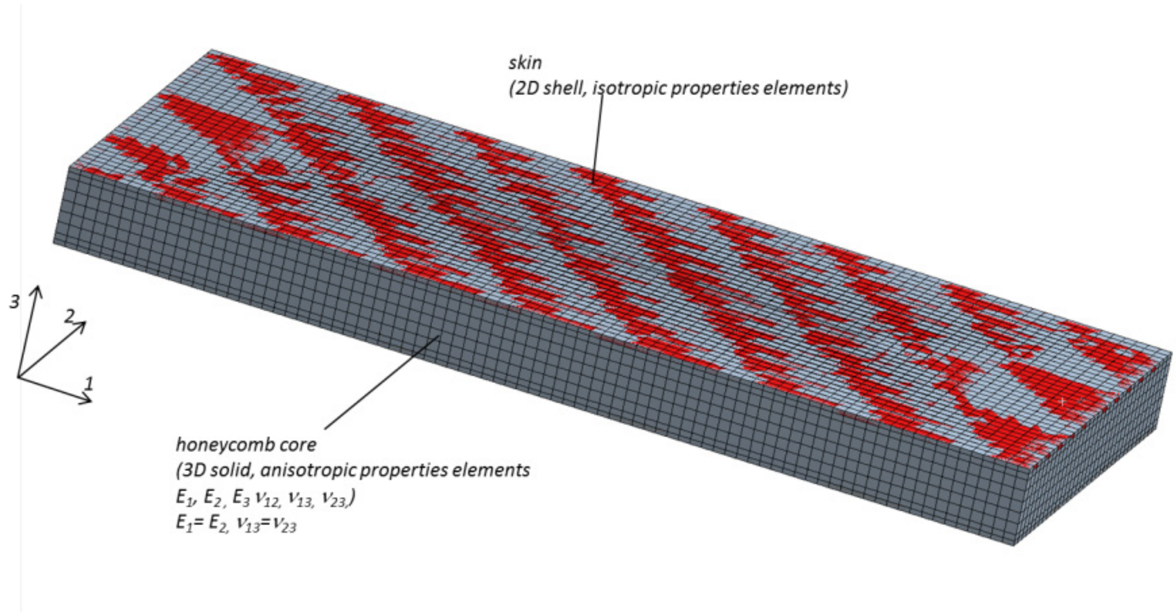

Fig. 18. The FEM model with equivalent model of honeycomb core

Comparison of test and FEM results is presented on Fig. 19. As the properties of skin and honeycomb elements were obtained, the full model of vehicle body was created (Fig. 20). Created model consists of vehicle body structure as well as a simplified model of vehicle suspension for front and rear axis. Created FEM model allowed conducting simulation test to evaluate vehicle body strength under defined conditions. The exemplary results for uniform vertical load (200 kg) are presented on Fig. 21.

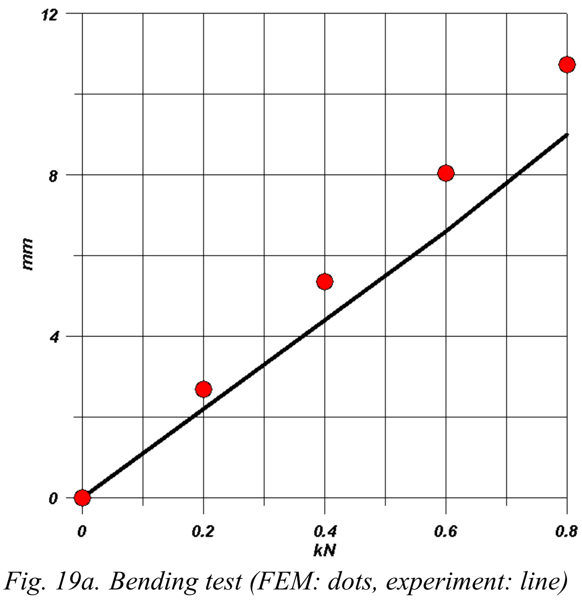

Fig. 19a. Bending test (FEM: dots, experiment: line)

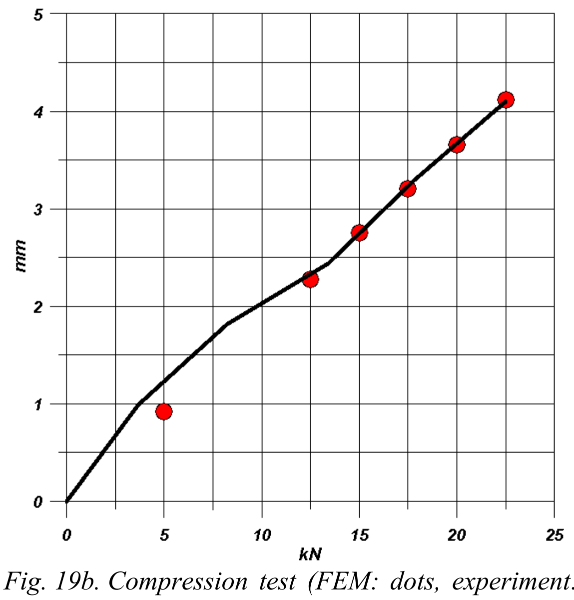

Fig. 19b. Compression test (FEM: dots, experiment: line)

It has to be mentioned that presented approach does not allow evaluating stress value in laminate structure but it may be used as for obtaining input data for detail analysis of critical part of the vehicle body. Such might be connections of panels and fixing points for suspensions system. Presented in this paper model is ready for conducting global/local FEM simulation (Fig. 22) with using various honeycomb panels models: global with equivalent solid core model and local with exact honeycomb shape.

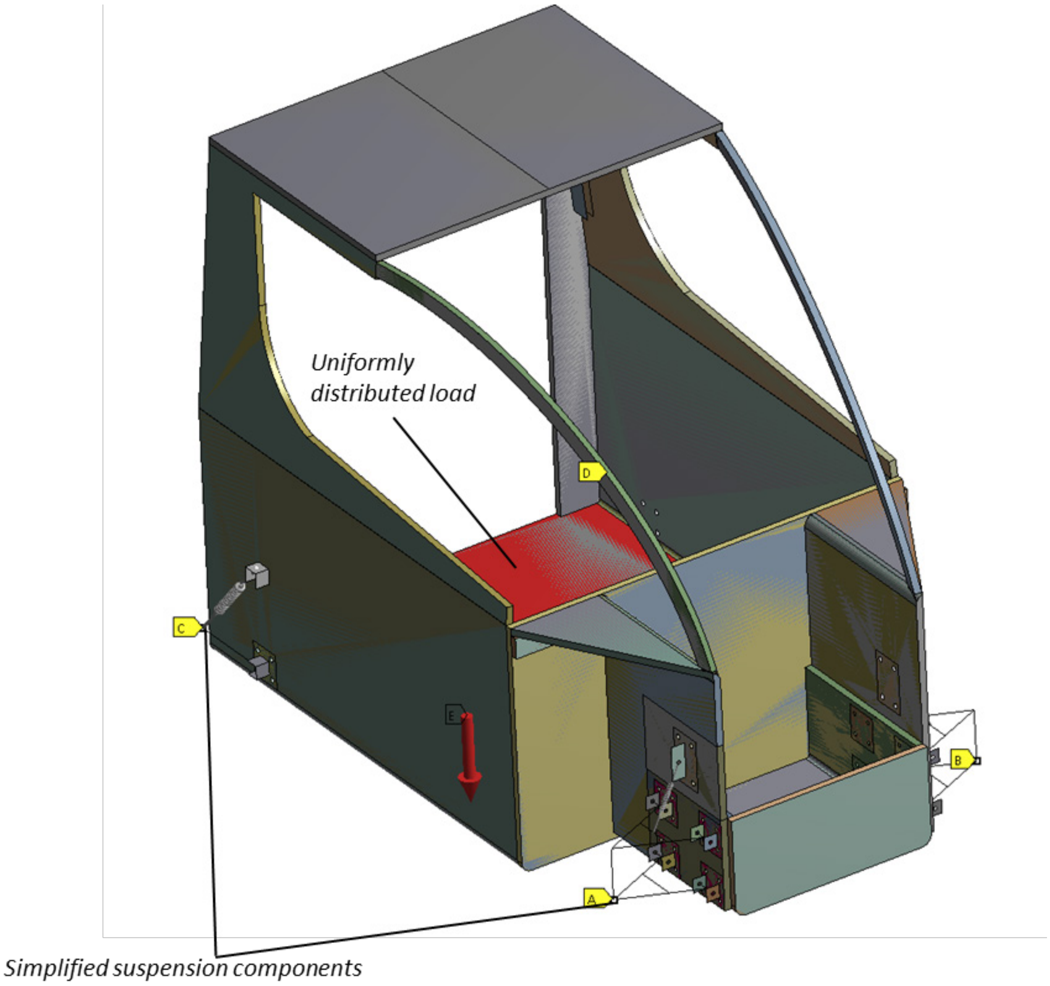

Fig. 20. The FEM model of vehicle body for uniformly distributed vertical load of 200 kg

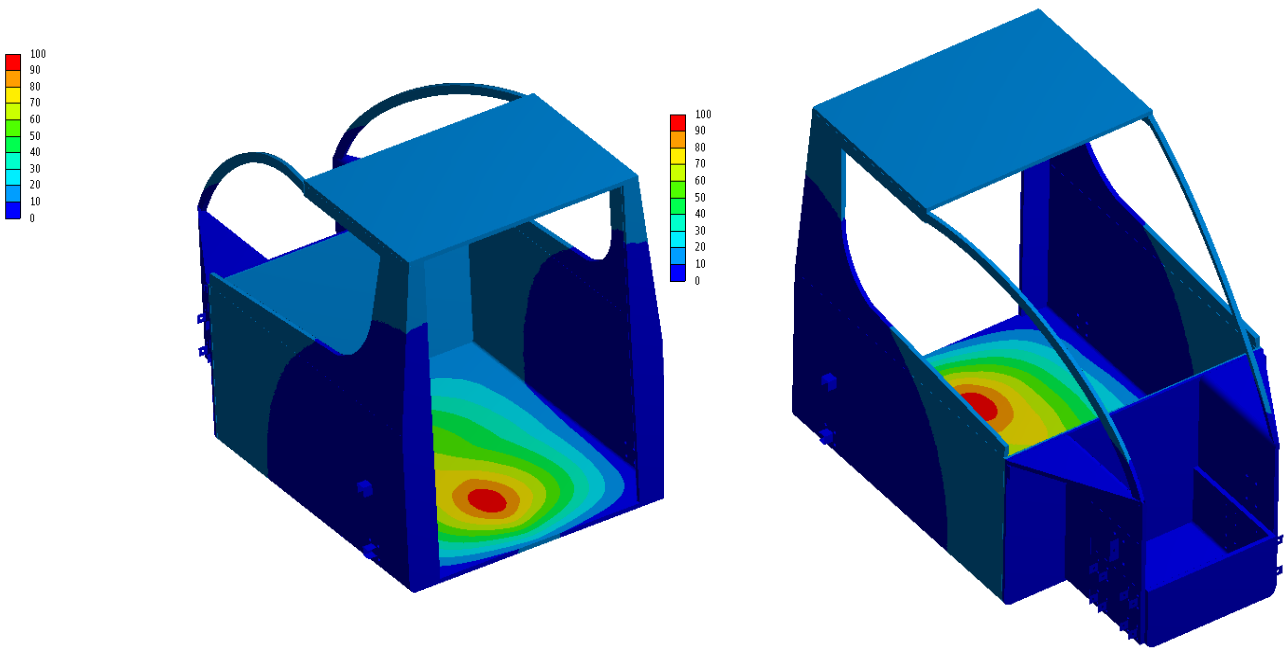

Fig. 21. Vertical displacement in mm

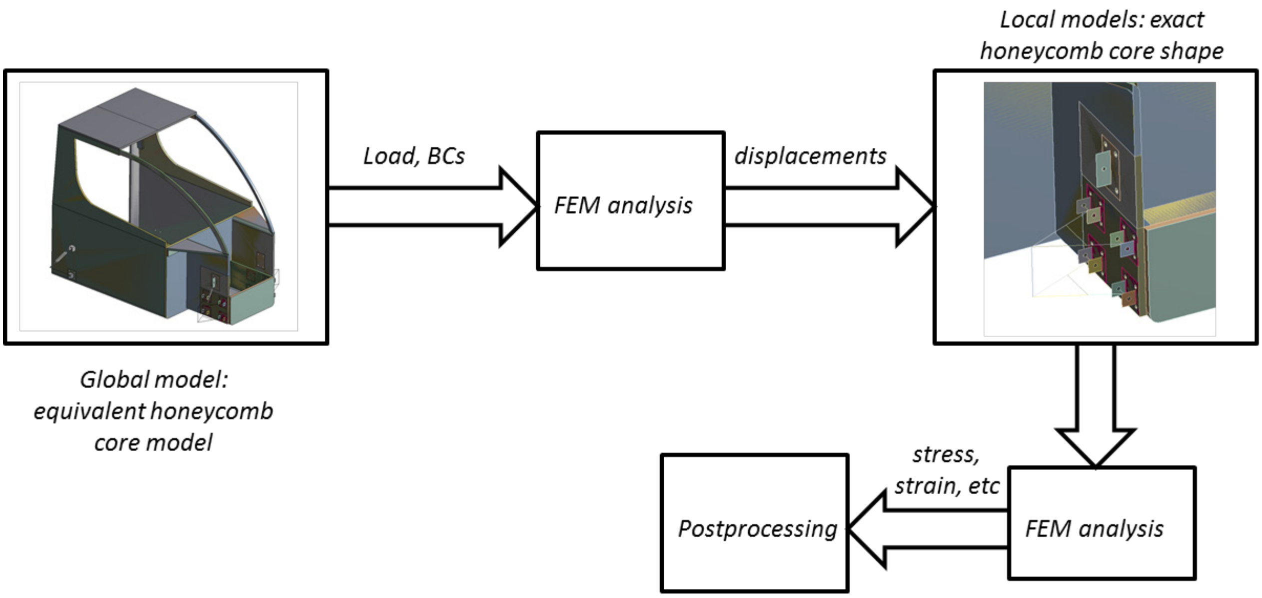

Fig. 22. Global/local FEM analysis with various honeycomb core models

4. The vehicle body appearance

According to set assumptions, the vehicle body appearance should not much vary from present vehicles. Created vehicle structure did not allowed fully follow the concept presented on fig. 7, however, the main feature: monocoque type body was fulfilled. In addition, large windows were used what allowed to obtain very good visibilities (Fig. 15).

Fig. 23. Vehicle for disable people: Buzz (7)

5. Summary

This paper presents a concept of ultrahigh vehicle for people with physical disabilities. At the concept an innovative technology was applied which allowed to minimize weight of the vehicle which is very important issue for electric vehicles. Presented vehicle might be manufactured in medium level workshop. Created vehicle is the prototype and due to implemented innovative technology should be tested to verify the usage of this technology.

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