Research Regarding Design and Material for an Electrical Car Charger Shell

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In the recent years, the electric vehicles have drawn great attention worldwide as a feasible solution for clean transportation. The charging infrastructure for electric vehicles is expanding throughout the world, encouraged by large investments from the automotive industry, to reduce carbon emissions. The purpose of this paper is to design the shell of an electrical vehicle charger by using polymeric composite materials. The manufacturing technology is proposed and the analysis of the product behaviour during the wind action in extreme conditions is presented. The paper includes studies and research regarding the design, the manufacturing and the simulation for the action of wind upon the product's walls. The simulations are performed for the actual used material (ordinary sheet steel) and for the proposed composite material in order to compare the results. The composite material seems to be an adequate solution for the electric charger shell.

Keywords: composite material, electric car charger shell, simulations, static loadings

In these days due to the environment pollution and with increasing the oil price, the electrical vehicles are getting to be more interesting than they were several years ago. The electric vehicles have drawn great attention worldwide as a feasible solution for clean transportation. The charging infrastructure for electric vehicles is expanding throughout the world in order to reduce carbon emissions. Worldwide there are 3 types of electric vehicle chargers available on the market: Level 1 chargers (120 volt), Level 2 chargers (240 volt), Level 3 chargers or DC fast charging (3 phase) [1]. Nowadays, all these chargers have shells manufactured from metal sheet.

In the last years, it was observed a trend of changing the metallic materials with plastic or composite materials. Usually glass-fibre reinforced polyester composite materials are used instead of metallic materials due to their low density, high strength, and high rigidity. Because of their mechanical properties, glass-fibre reinforced polyester composite materials are used in wind turbine blades, in air, sea and land transportation, where are subjected to a cycle loading during the service condition [2, 3].

The use of reinforced composite materials in the wind turbine blade industry had as a consequence the elaboration of many studies regarding the mechanical properties and investigations of the fatigue behaviour. In industrial applications, most materials are subjected to cyclic loading and deformation using the tensile strength. For this reason, the usability of these materials can be decided in a better way by knowing their fatigue behaviour [3-7]. Abd Allah et all [5] studied the flexure fatigue behaviour of aligned E-roving glass reinforced polyester composite rods. In order to clarify the effect of mean stress on the behaviour of the Stress Life Diagram (S-N diagram) of glass fibre reinforced polymer composites, they conducted constant deflection flexural fatigue tests on standard unidirectional glass fibre reinforced polyester pultruded rods, using a 25 Hz frequency of the testing machine. U.A. Khashaba [6] conducted a research about rotating bending fatigue tests on unidirectional glass fibre reinforced polyester composites and the failure of the composite rods have been examined using scanning electron microscope. W. Van Paepegem [7] presents an investigation of the fatigue performance of plain woven glass/epoxy composite materials and of the numerical modelling of composites' behaviour under fatigue.

Taking into consideration the previous researches in the field, the purpose of this study is to redesign the shell of an electrical vehicle charger by changing the material, the manufacturing technology and to analyse its behaviour during the wind action, in extreme conditions.

This paper is part of a larger research that is focused on the behaviour and properties of different thicknesses and structure for the shell manufactured from composite material (made of glass fibre - one of the most used materials in the composite materials industry- and epoxy resin). The changing of metals with reinforced polymers is due to their low weight and electrical conductivity since their mechanical strength is high. That makes the reinforced polymers very attractive to be used for manufacturing charger shells. In the paper one of the cases studied by the authors is presented.

Experimental part

Material and methods

One objective of this paper was to redesign a shell for an electric car charger made of composite material. In order to build the 3D model of the part, SolidWorks 2017 software was used. The new shell which is presented in figure 1 is designed to replace the old electric car chargers models made from metal sheet, currently available on the market. This necessity appeared on the market due to the superior mechanical features that the polymeric composite materials offer comparing to metals.

In this research all the components of the shell have the wall thickness of 2 mm.

The material proposed for the front door is epoxy resin reinforced with bidirectional glass fibre with a fibre volume fraction of 62.5%. Epoxies have very good strength and stiffness properties being also resistant to solvents and alkalis. Epoxies are also well known for their excellent adhesion, chemical and heat resistance and relevant electrical insulating properties. They have very low shrinkage (≅1%), which is perfect for products that are going to be part of an assembly.

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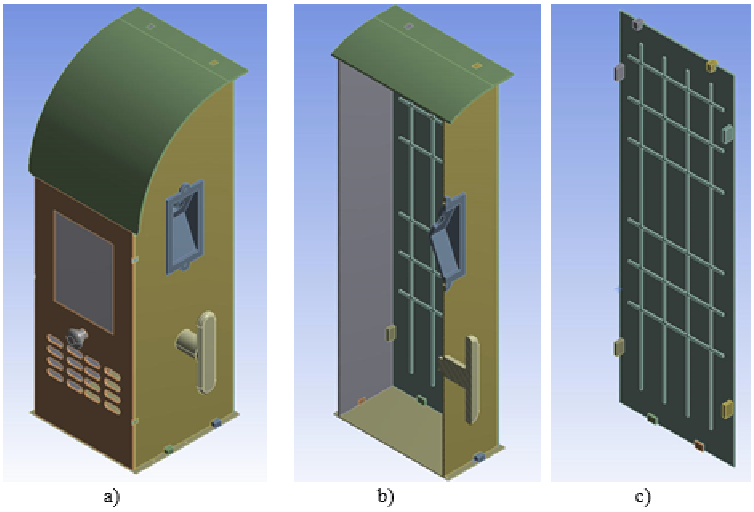


Fig. 1. Model Assembly: a) isometric view; b) section view c) back plate

For the manufacturing, Resin Transfer Moulding technology was chosen, as high volume fibre fraction laminates can be obtained with very low void contents. This technology offers safety and proper environmental control while the resin is transferred into the mould. It is also used for obtaining uniformity for the walls thickness which is very important for a proper behaviour in time [8]. If the shell is made of only one piece it would be very complex, and the mould would need high manufacturing costs and a long production time. Considering this, a simplified shape was considered by making each shell's walls individually. This solution will generate lower manufacturing costs and will reduce the required time for removing the part from the mould.

The back plate will be made from the same material; this component has an important role in the shell stiffness, so it was designed with many ribs which are used to fix the inner components of the electric car charger and to increase the stiffness of the wall.

The right plate of the shell is designed to fix a frame (in order to support the plug-in) and held the feeding cable. The frame is fixed on the shell with two special self-locking screws in the upper and bottom side. The element that will sustain the feeding cable will be fixed with screws and screw nuts.

In order to study the behaviour of the shell during the wind blowing, ANSYS software was used. This software is used to analyze the influence of different pressures on shell's walls and helps to improve the design of the product in order to reduce the costs of manufacturing. As the wind can blow from all directions, 8 main directions were considered as presented in figure 2.

For simulation, loading conditions and fixing conditions (with 6 screws) were required. The mechanical properties of the material were taken from a previous study made by one of the authors [9]. In order to obtain the mechanical characteristics, the authors prepared a plate obtained by using Resin Transfer Moulding technology, with initial dimensions of 250 x 250 x 2 mm and samples were cut from it. An epoxy resin, type Epiphen RE 4020 / DE 4020, was used for the matrix. The mixing ratio of the parts (in weight) is 100:30, according to the manufacturer recommendations. For reinforcement 4 layers of bidirectional balanced glass fabric by 300 g/m^2 were used and the calculated fibre volume fraction is 62.5%, which is very close to the maximum value of 65% that can be realized with this technology. The composite material was cured at 20°C for 24 hours. The obtained mechanical characteristics were used for simulation as input data. The simulations were made for the proposed composite material and also for a metallic material (S355 of 2 mm thickness).

Considering the recommendations from the scientific literature [10], the pressure of 1000 N/mm^2 was used for the loading conditions. The loadings on the support for the feeding cable and the weight of all internal components on the back plate were also taken into account. Figure 2 presents the loading directions for pressure used for the simulations and loading conditions for the weight of other components (cable and internal components of the charger). In point A was considered the weight of the internal components, in point B the plug in of the feeding cable and in point C the weight of the feeding cable.

Results and disscusions

Following the analysis, the values of deformations and stresses were determined. As can be seen in figure 3, the results obtained for sheet steel S355 show that the maximum stress is 226.39 MPa - figure 3a, in the case when the wind is blowing from P1 direction and the maximum deformation is obtained in the case of P1 direction (6.5286 mm) (fig. 3b).

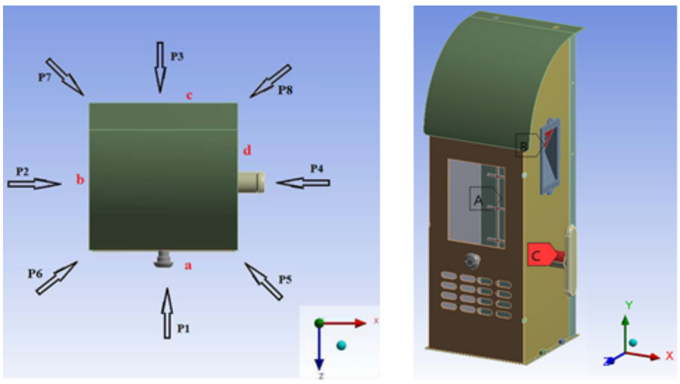


Fig. 2. Presure directions and weight loading conditions

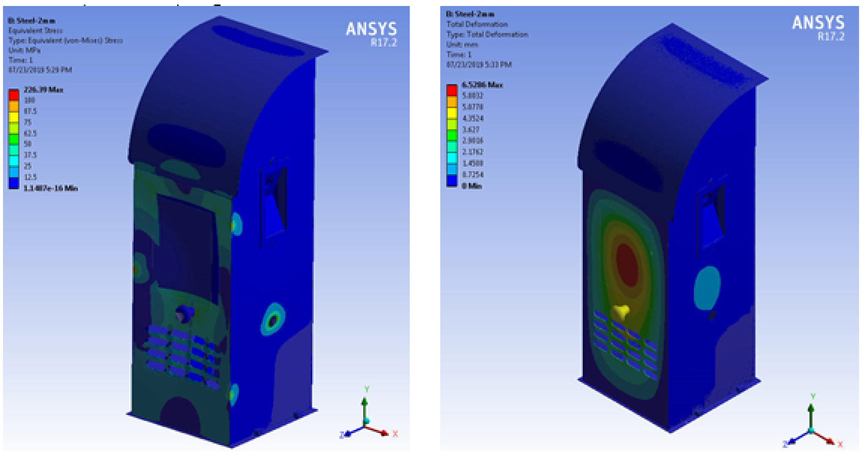
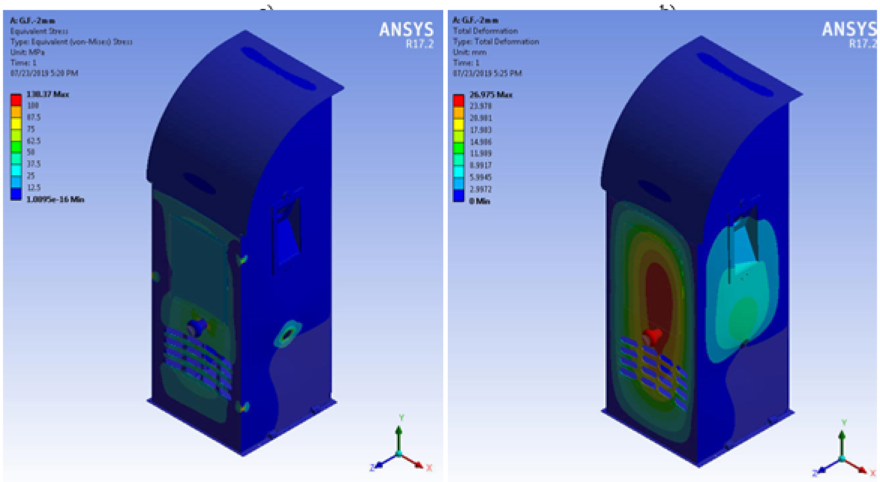


Fig. 3. Maximum values for steel sheet material: a) Equivalent stress; b) Deformation



a) b)

Fig. 4. Maximum values for composite material: a) Equivalent stress; b) Deformation

For the proposed composite material, in figure 4 the maximum von-Mises stress values and deformations are presented, both obtained for the case when the wind is blowing from P1 direction.

As can be observed from figure 4, in the case when the wind is blowing from P1 direction, the maximum Stress is 138.37 MPa, with 64.734 MPa more than in the case when the wind is blowing from P4 direction, when the lowest stress value is obtained. The maximum deformation for the composite material was obtained in the case of P1 direction (26.975 mm) and the minimum deformation in the case of P2 direction (6.8366 mm).

In table 1 and figure 5 there are presented the maximum stress values for the two analysed materials, for all the considered directions. Knowing the admissible values for steel (355 MPa) and for composite material (162 MPa [9]), it can be seen that all the obtained stresses are lower for all the wind directions. Also it is clear that the maximum stress values appear on the same faces for both materials. The faces that are more affected are the front door (a) and the right plate (d) (fig. 2). For the front door it can be considered that, for the composite material, as the holes disturb the resin flow, the impregnation is poor, so high stresses will occur under wind conditions as a

Table 1

MAXIMUM OBTAINED EQUIVALENT STRESSES [MPa]

Material	Wind Direction							
	P1	P2	P3	P4	P5	P6	P7	P8
Steel Sheet	226.39	66.704	69.636	66.098	87.232	86.149	68.639	68.762
Composite Material	138.37	74.067	76.521	73.636	106.310	102.460	73.916	74.147

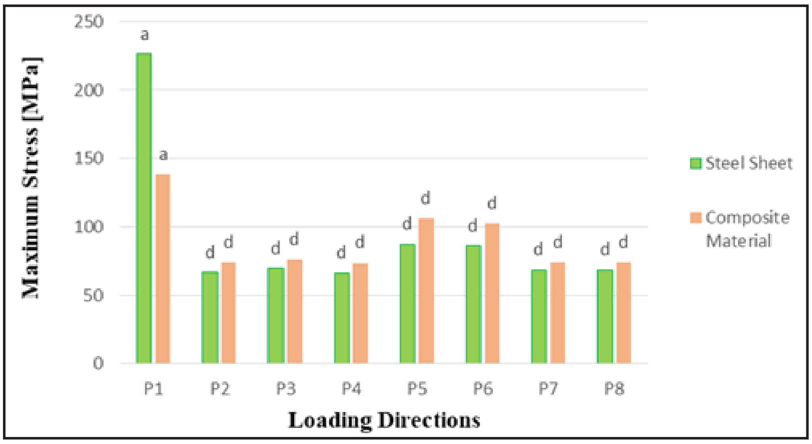


Fig. 5. Maximum stress for the most affected faces (face a, face d)

Table 2
MAXIMUM OBTAINED DEFORMATIONS VALUES [mm]

Material	Wind Direction							
	P1	P2	P3	P4	P5	P6	P7	P8
Steel Sheet	6.5286	0.4261	1.3677	0.4399	2.0636	2.0847	1.0385	1.0378
Composite Material	26.975	6.8366	8.4148	7.888	14.354	14.403	7.6948	7.5019

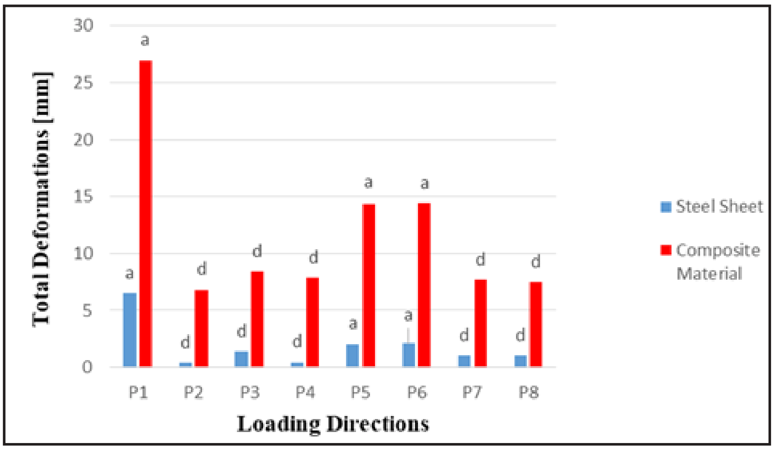


Fig. 6. Maximum deformations for the most affected faces (face a, face d)

consequence. For the plate from the right, where the support for the feeding cable is located, the simulations are influenced because the weight of the feeding cable was taken into account.

Table 2 and figure 6 present the maximum deformations for the composite and steel material, for all the considered wind directions. The maximum deformations appear for both materials in the front door because of the many holes design of the shell. Comparing the results for the two analysed materials, it can be seen that, the deformations for the composite material are much higher than for the steel, due to elastic properties of it and with a poor design, as no ribs are provided around or between the ventilation holes.

Considering the deformations, the same faces of the shell are affected by the wind blowing as for the maximum stress: the front door (a) and the plate from the right (d). This fact is due to the shape and the role of the components. The front door must have the ventilation holes for cooling the equipment and the right plate must sustain the support and the feeding cable.

It was also determined the weight of the shell for both materials. In the case of sheet steel, the shell has 61.28 kg and 25.78 kg in the case of composite material and this is another reason for using a polymeric composite reinforced material for manufacturing.

Conclusions

Considering an electrical charger station, the shell was redesigned and its manufacturing technology was changed because a composite material was used. The new shell was designed to replace the old electric car charger models made of metal sheet, currently available on the market. The material proposed is an epoxy resin reinforced with bidirectional glass fibre and the product is manufactured through RTM (Resin Transfer Moulding) technology.

The results obtained from the simulations showed that the maximum equivalent stresses and deformations for both analysed materials appeared in the front door and in the plate from the right. The maximum Equivalent (von Mises) stresses that were determined through simulation are lower than the maximum admissible values, suggesting that the shell will resist in the case of extreme conditions. This new design will be more suitable for manufacturing the electric car charger shells made from composite material, that will resist even if the wind will blow with 120 km/h (no damage of the structure will be produced).

An important advantage of using polymer based composite is the weight of the shell that can be reduced (with 57.93% in the case presented) and this is another reason for using a polymeric composite reinforced material for manufacturing.

In order to reduce the maximum deformations and for a higher stiffness for shell made of the composite material, it is necessary to place ribs on the two faces of the shell that are mostly affected. For the product analysed, on the plate from the back of the shell, ribs were placed and that gives it more stiffness and the deformations under critical conditions are smaller. For more rigidity of the shell, some changes of the design - as placing ribs in certain places - have to be considered.

It can be concluded that considering weight reduction and good mechanical behaviour, the change of the material is a suitable solution for the electric car charger shell.

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