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Optimization of the structure of the micro electric vehicle deck

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ABSTRACT: Urban mobility has a substantial impact on the air quality of urban areas with high population density and, together with the problems related to traffic congestion, parking and noise pollution, has a relevant effect on the quality of life. Electric vehicles in the form of traditional cars do not resolve all these problems, especially in the urban areas. Therefore, new kind of personal transport devices are gaining popularity: the so-called microvehicles. The most popular electric microvehicles also have some disadvantages. European Commission granted funds for the project aiming to develop microvehicle in which some of the most noticeable shortcomings of microvehicles will be addressed. Demanding functional parameters of the new microvehicle raised the need to use advanced engineering tools in the design process. In the paper, optimization of main deck of the microvehicle is presented. The deck has sandwich-like structure with core made from lightweight material reinforced by skin made from fiber reinforced composites. Advanced genetic optimization algorithms allowed the authors to find optimal structure of the deck, especially in terms of stiffness. As a result, the deck can withstand operational loads and also can act as a replacement for a standard suspension positively influencing the overall weight of the final microvehicle design.

SŁOWA KLUCZOWE: micromobility, optimization, numerical analysis

1. Introduction

Land transport contributes significantly to the emissions of sulphur dioxide and nitrogen oxides as well as to the concentration and deposit of air pollutants [1]. Urban mobility has a substantial impact on the air quality of urban areas, with high population density and, together with the problems related to traffic congestion, parking and noise pollution, has a relevant effect on the quality of life [2].

Pollution and energy problems led to the development of electric vehicles, mainly traditional cars with hybrid engines [3] and, less common, fully electric cars (2.2% of total circulating in EU [?]). The diffusion of these vehicles is progressively increasing, but the main problems that limit their mass diffusion to date are: (i) limited autonomy of fully electric vehicles; (ii) vehicles high cost; (iii) expensive infrastructure at moment limited recharging points and long charging times; (iv) need for parking with charging stations and consequent footprint in the cities.

Analysing the most common types of microvehicles, there are significant differences in terms of charging times, range, power, handling and ergonomics and price as evidenced by tests carried out by the Swiss Touring Club [4]. The most popular microvehicles are e-bikes, e-scooters (as well as monowheels), but all these best candidates to micromobility have some weakness. E-bikes is suitable for long distance, is easy to use but is bulky (also the foldable models) and not easy to integrate with Public Transport. Their costs could be easily over 1,000 €. E-scooter, that is now very popular, is easy to use for everyone, foldable and very practical for transport by Public Transport. Unfortunately, it is not very suitable for long distances and has little ability to deal with steep slopes and rough roads. Even in terms of braking, they do not work well at all. Monowheel compensate most of the weakness of e-scooter with a competitive price, but we can certainly say that, now, it is not the vehicle for everyone since it is difficult to ride. Probably the next generation could use these vehicles as being special shoes, but it does not seem an immediate solution.

In short, all the best solutions suitable for daily use as a means of transport in urban and suburban areas have some weakness.

In 2020 European Commission accepted the project LEONARDO that aims to develop an affordable, safe, easy to manage and cheap to maintain electric micro-vehicle, which does not require parking and is not left on the road or on the sidewalk and that overcomes the limitations of currently available microvehicles [5]. Among number of engineering activities undertaken in order to develop the new vehicle was the task of optimization of the main deck of the vehicle. In this paper, optimization process is described in detail.

2. Experimental tests

The work on suspension-less design started with the testing of deck made from different materials, like bamboo, plywood, FRC etc. All decks were instrumented with accelerometers and mounted on simplified microvehicle. The scooter run thru testing path. The outcomes allowed to assess such parameters like stability and comfort for different deck materials.

3. Optimization of the main board.

Considering previous experience and outcome from experimental tests the choice was made to develop sandwich structure, with outer layers made from fiber reinforced glass composite and core made from PVC.

As it was mentioned, the goal of this study is to find outer layers lay-up with the smallest number of layers (and in effect generating the lowest mass and cost) maintaining stiffness comparable to the bamboo deck. The objective function is formulated in such a way that it contains weighted members depending on the deck's mass, deflection, and stress.

$$f = m \cdot 0.5 + \left| d - \frac{F}{k_{desired}} \right| \cdot 0.15 + \left(\frac{\sigma_{1max} + \sigma_{2max}}{100} \right) \cdot 0.125$$

where: m – mass of the deck in kg, d – maximum deflection in the symmetric case in mm, $k_{desired}$ – desired stiffness of the deck in N/mm, σ_{1max} – maximum equivalent stress in symmetric case in MPa, σ_{2max} – maximum equivalent stress in asymmetric case in MPa.

The goal of optimization is minimization of the function f.

In the present work, authors decided to use two arbitrary chosen optimization techniques to find optimal lay-up of FRC. The first is the application of genetic algorithms. The second approach uses response surface methodology (RSM).

4. Optimization results

The idea behind RSM approach is to find a function describing response of the objective to the change of design variables. Once the function is found, it is assumed that extreme of this function within the decision space makes the solution of the optimization problem. Calculated response surface is shown in Fig. 2.

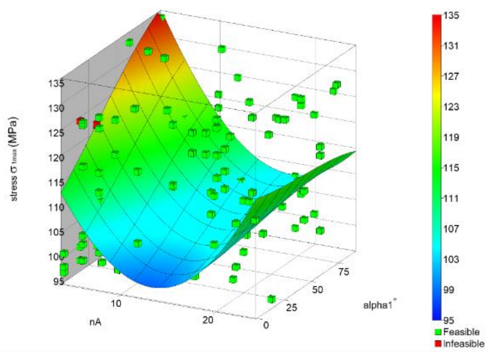

Fig. 2 Response surface calculated for the problem

The Space Filling algorithm used in the analysis randomly moves the design points so as to optimize the maximin distance criterion using so called simulated annealing.

Example of cloud of design points created by generic algorithm is shown in Fig. 3.

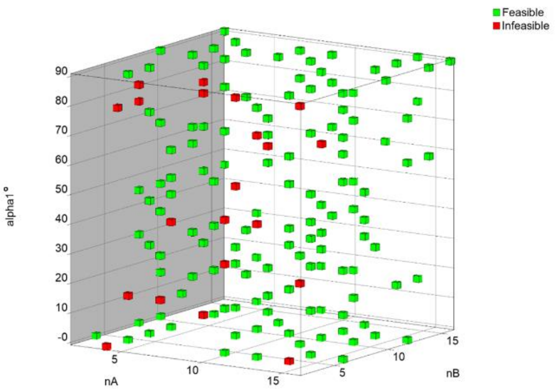

Fig. 3 Design points created by generic algorithm.

Genetic optimization proved to give better results. Simple sensitivity studies allowed to make sure that both in case of steering parameters and design assumptions the obtained final deck layout is functional and efficient. It has similar stiffness as bamboo deck used in the tests, but a significantly lower mass (0.4 kg compared to about 0.6 kg). The optimal design is shown in Fig. 3.

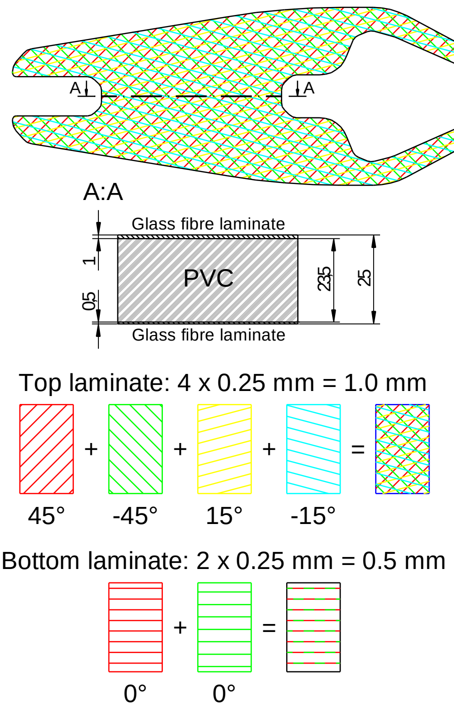

Fig. 3. Optimal deck design

5. Conclusions

In the article, optimization of sandwich structure of e-scooter is presented. Advanced optimization tools led to the development of a deck that can replace suspension systems and therefore simplify scooter design, minimize its weight and price.

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[3] registrations in EU / EFTA January-September 2019 equal to 6.7%, plug-in hybrids and hybrids, source ANFIA: 092019_UE-EFTA_Focus Vehicle Market Alternative Power Supply-1.pdf.
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