STUDIES REGARDING THE BASE STRUCTURE BEHAVIOUR OF THE POWERED-HANG-GLIDERS

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Abstract
This paper presents the results of some studies about testing and optimizing of the structure of the powered-hang-glider. To establish the stress distribution, the behaviour of the structure under static and dynamic loading was simulated. The structure was modeled in 3D and the models were analyzed using the finite elements method. Starting from the analysis results, the base structure was optimized in order to obtain a maximum load capacity on a lightweight structure. The theoretical results were used to design the prototype presented in this paper.

1. INTRODUCTION

The advantages of air transportation are beyond doubt, especially in an era when transportation has become more and more congestioned.
The powered-hang-glider meets the essential requirements, such as: a simplified constructive solution, accessibility, easy handling. It's also adequate for a large range of applications: emergency transport, sports and entertainment, training schools for flying, tourism, agricultural services (beware pest control), high-sky observation and evaluation (ecological, agricultural, piscicultural, forestrial, high-tension lines, natural disasters), frontier survey, road traffic control, military activities.
Specific aircraft researches have been intensively developed in many Central and East European countries. The team that proposed this project, is a mixture of researchers coming from the main areas involved (aviation, technology of materials, innovative technologies, structures calculus). This multidisciplinary collaboration resulted in the design and construction of a powered-hang-glider prototype. The prototype has been tested in order to evaluate the capabilities and to optimize its configuration for different types of loading.
This paper will present the results of static and dynamic analysis of the powered-hang-glider base structure.

2. THE DESCRIPTION OF THE STRUCTURE

The powered-hang-glider described in this paper is presented in Figure 1 and includes the following components: 1- the base structure (chassis), 2- the gondola, 3- the engine with airscrew, 4- the surface of the wing.
Moreover, there are auxiliary elements for flight control, orientation, etc.

Fig.1. The structure of the powered-hang-glider

The gondola's capacity was thought as the sum of one or two crew members' weight, force installation weight and board equipment weight. The main part is represented by the strength frame (which will be named *base structure*), the basic support of the undercarriage, the main supports, the force installation, the dashboard and the fixing assemblies. The base structure includes the longitudinal beam and the pylon, made of pipes (material: 2024T6, diameter: 55 mm, wall thickness: 3 mm) joined together as an articulation assembly.

On the longitudinal beam are mounted the console for the front undercarriage support, the chair and the vertical pylon. On the pylon are mounted consoles in order to fix the engine, the chair and the suspending wing assembly. The main undercarriage supports are made of pipes (material: aluminum alloy 2024, diameter: 55 mm), which are finally tied up with stressing cables. At the free end of the support there'll be fixed the axle of the wheel, axle made of steel pipes. The front support is a U-shaped fork with one girder, which function as a maneuver lever. The fork is made by using welded pipes and it's fixed through a vertical lever at the end tubular part of the longitudinal beam. The foot throttle is connected through a cable to the carburetor gas throttle valve and it has a reverse spring. The foot throttle works in parallel with the engine command lever, fixed on the chair frame. The brake's pedal is connected to the cable that joins the brake hangers of the wheel.

The crew's chairs include a metallic frame and a pillow.

The powered-hang-glider is made of different materials: aluminum, steel and composite materials. These materials have the property to take over the loadings generated during the take-off, landing and emergency landing, insuring the pilot safety in case the powered hang-glider overturns in the air.

3. THE PRESENTATION OF THE 3D MODEL

The powered-hang-glider was modeled using known CAD techniques in order to bring forward date about the structure's behaviour according to various loading cases.

The model is presented in figure 2.

The engine was modeled only in order to be used in the calculus for behavior analysis and it was approximated by exterior surfaces. This way, the loadings due to airscrew rotation, engine mass and other parts masses, can be estimated with a higher precision. In this phase, the most important objective is the study of the powered-hang-glider base structure's behavior.

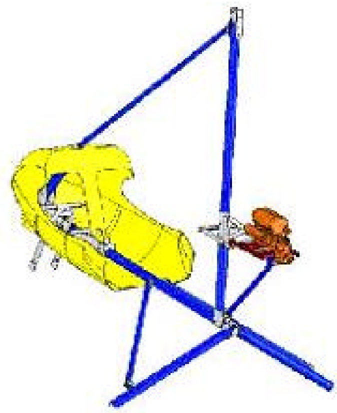


Fig. 2. The 3D model of the powered-hang-glider

The simplified model of the base structure and the meshed model are presented in figure 3.

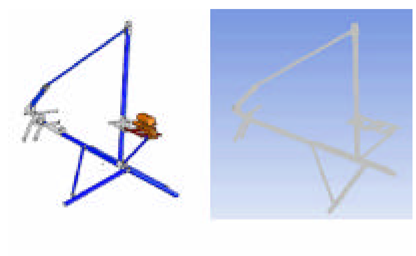


Fig. 3. The calculus model

The structural optimization process is based on theoretical research with finite elements method.

4. THE RESEARCH RESULTS REGARDING THE POWERED-HANG-GLIDER'S BASE STRUCTURE

4.1. Static behaviour analysis

The stress on the powered-hang-glider base structure varies according to many factors, such as: flight conditions, flight parameters, flight trajectory.
International norms settle the main values for the simulation parameters and for the calculus. The modeled structure analysis is made for the take-off phase, for the landing phase, as well as for extreme flying conditions.
In this paper are mentioned only the simulation results based on the flight condition. The other phases will be described in other articles.
The loadings taken into account are those determined by the weight of the components and transported masses (passengers, fuel, equipments, etc.), propulsion forces generated by the engine, as well as maximum inertial forces, which appear under extreme flight conditions. The structure was considered fixed at the joint point with the wing structure (the upper most point of the model).
The study of the static behavior hints to the structural displacement under the established loading conditions and the stress components where the parts joint.
In order to get precise results, the contact surfaces between the base structure components were carefully modeled. The base structure includes pipes, made of

aluminium alloy, mechanically assembled and welded steel pipes, fixed with screws on the aluminium frame. This solution was confirmed by the good results of the optimization process. The purpose was to get a lightweight structure with a good behavior for static and dynamic loading. The engine support and the undercarriage are made of welded steel pipes.

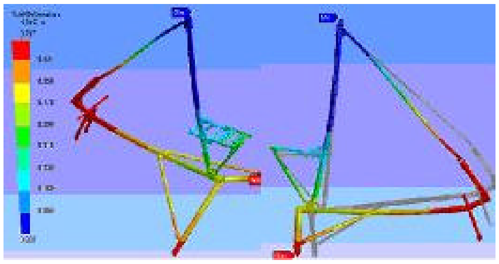


Fig. 4. The static displacements range for the powered-hang-glider' s structure

Figure 4 shows the values range determined through the finite elements analysis. An increased value of the structure displacements can be observed. The maximal displacement value rises up to 7,17 mm. The results show that there is a solid-rigid rotation going on around the wing articulation. There is no displacement because the base structure is highly flexible and all joints are modeled as articulations. Those are used, according to the international aircraft norms, to reduce the stress in joints and to increase the flight safety.

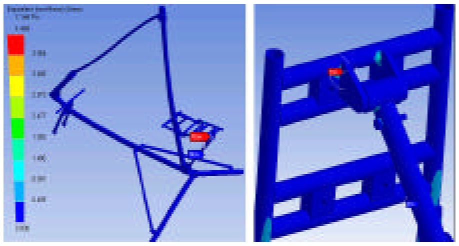


Fig. 5. The equivalent stress distribution

In figure 5 we can observe the equivalent stresses distribution, determined by Von Mises criteria. Stress distribution is quite uniform and bellow the value of 50 MPa, except for the small areas, where the engine frame is welded. Taking into account that the frame is made of steel pipes, static loadings have no effect on the structure's behavior.

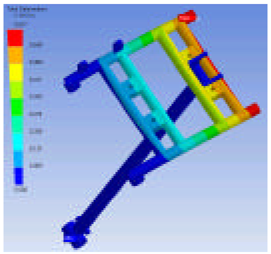


Fig. 6. The displacement distribution over the engine's frame

Nevertheless, the welded frame of the engine was considered for further researches to increase its safety.

The loading values were increased and the connection joints to the entire structure were considered to be fixed. The displacements resulted are shown in figure 6, while the equivalent stress values are presented in figure 7.

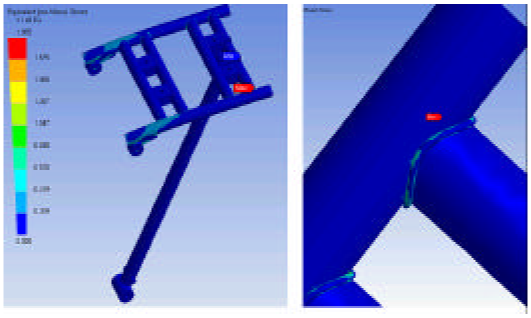


Fig. 7. The equivalent stress distribution over the engine's frame

The maximum displacement value for the engine's frame reaches 0,617 mm. It's determined by the force component due to the engine's impeller, running at flight parameters. Maximum equivalent stress (Von Mises) value is 188 Mpa, much lower than the maximum admitted value. As there are no maximum stress areas over the parts surface or along the beads, components and mainly welded-assemblies were sectioned. In figure 8 are underlined the areas where shear stresses reach maximum values (108 MPa).

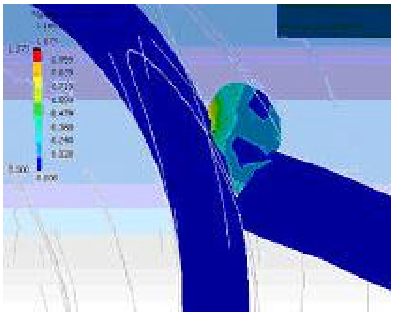


Fig. 8. Section through the bead in the area with the maximum shear strain

The beads represent regions with a negative behavior, due to the longitudinal nonlinear strains. This was the reason they were carefully evaluated. It's also necessary a thermic analysis, but further details will be given in some other articles.

4.2.Dynamic behaviour analysis

The dynamic behavior of aircraft structures is essential. The first stage of dynamic evaluation is the modal analysis. Its results offer information about the eigenfrequencies and vibration eigenmode. The purpose of the optimal design for the aircraft structures is to find products whose eigenfrequencies aren't included in the plane eigenfrequencies values, so that there is no resonance. The mock-up previously presented was used for the modal analysis. The structure eigenmasses and other masses were taken into account. It's well known the fact that an increased value of the total mass determines lower values of the eigenfrequencies.

This is why, different eigenfrequencies will vary according to the structure's loading, results evaluation is performed to obtain the eigenfrequencies areas.

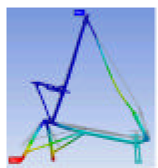
If the eigenvalues are within the range of functioning eigenfrequencies, the aircraft structure’s rigidity will be increased/decreased, this resulting in the increase/decrease of the eigenvalues.

To avoid the effects of the structure’s resonance (very high amplitude vibration) we will design a structure with a high amortization degree, to diminish the vibrations amplitude.

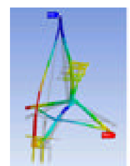
These are rendered as structure deformations as compared to the refference shape (shown as a transparent contour).

The first vibration mode is a front-back oscillatio, around the wing articulation of the powered-hang-glider. This corresponds to an eigenfrequency of 26,027 Hz (1561 rot/min).

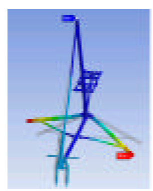
Modal analysis results for the first four modes of vibration are presented in figure 9.



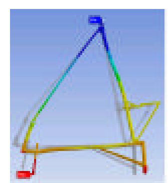
a) Mod 1-26,027 Hz



b) Mod 2 – 57,489 Hz



c) Mod 3 – 60,494 Hz



d) Mod 4 – 76,424 Hz

Fig. 9. The first four vibration modes

As the maximum number of revolutions is 100 Hz (6000 rot/min), the first four eigenfrequencies are within the running eingenfrequencies range, which leads to the conclusions that these are resonance frequencies. Those are the resonance frequencies. The first and the fourth vibration mode are symmetrical and therefore don’t expose the structure to additional loads. More dangerous are the second and the third modes as they are torsional modes around a horizontal truss. If the values of their frequencies are increased, the amplitude can be too high. As an example, for the second vibration mode (f_2 = 57,489 Hz), the maximum amplitude value is lower than 32 mm, without taking into account the amortization. The third mode (f_3 = 60,494 Hz) is characterized by a maximum amplitude of 23 mm, determined under the same condition: no amortization. To reduce the resonance effects (as it cannot be completely avoided) the structure was stiffened with pre-stressing cables, while the configuration of the base structure was preserved.

Further research will inlude tests on the base structure’s static and dynamic behaviour, by using the same prototype that has already made the first flights.

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