Numerical modeling and sensitivity of aerodynamic characteristics to shape and material properties of paraglider

M.Sc. Paulina Maślanka

Supervisor
Professor Ryszard Korycki, D.Sc.; Ph.D

ABSTRACT

Paragliders are devices intended for gliding; typically, their wings are of an elliptical outline (in the orthogonal projection). They are made of upper and lower panels, and ribs, which are woven fabric materials connected by seams. Therefore, the wings do not have any rigid elements applied. The other basic elements of the paraglider are: lines, risers, harness.

The topic regarding development of the paragliders is an interesting field from the point of view of science, i.e. materials engineering, aerodynamics and flight mechanics. The dissertation is focused on numerical modeling and sensitivity of aerodynamic characteristics to shape and material properties of a paraglider.

The laboratory tests were performed on 10 different woven fabrics in the sense of material composition, as well as general, structural and mechanical characteristics.

The analyze of paraglider/parachute fabrics shows that they are characterized by good relation of strength to the surface mass and low air permeability. All the considered samples are PA 6.6 fabrics coated with polyurethane resins or silicone/polyurethane. Based on the SEM records, the paraglider/ parachute fabrics are manufactured using multifilament yarns and are characterized by rip-stop weave. The functional groups characteristic for the analyzed samples were indicated by the Fourier Transform Infrared Spectroscopy.

Three of the analyzed fabrics were selected to be subjected to the UV, thermal and mechanical ageing.

The greatest influence on mechanical properties has ageing caused by the UV radiation. No significant influence of freezing on the mechanical properties of the considered samples is observed. The flexing damage has the greatest influence on the air permeability change among all considered aging factors.
The obtained laboratory results could be introduced to the further steps of the research.

In the next steps a multistage algorithm was introduced; it concerned the numerical analysis in the terms of CFD (Computational Fluid Dynamics) and FEM (Finite Element Method) Structural calculations performed on a model of a traditional recreational paraglider wing in the sequence: (1) study of the initial influence of air permeability on aerodynamic

characteristics with applying of the *porous media* tool; (2) recalculating of the flow over paraglider after applying the more accurate permeability results, i.e. with the consideration of the actual pressure drop acting on the material during the flight; (3) study of the stress, strain and deformation in the materials covering paraglider; (4) determining the impact of deformation on the aerodynamic characteristics of paraglider.

Based on the obtained CFD results it can be concluded that air permeability increase has an impact on the paraglider's aerodynamic characteristics decrease. The best characteristics presented paraglider covered with an air-impermeable material.

The pressure distribution acting on the paraglider covering materials was obtained based on the CFD calculations and the value of the assumed load factor. Deformation and strain in the considered materials decrease with increasing of tensile strength of a material and/or decreasing of pressure acting on a material.

Safety factors of the considered materials not subjected to degradation range between around 4 – 6. However, the structural calculations show that the values of the factor can significantly decrease, when materials subjected to ageing are analyzed.

The CFD re-calculations shows, that the deformation caused by pressure acting on a material has a significant influence on the decrease on the aerodynamic characteristics of a paraglider.

The multistage optimization allowed to determine the influence of material properties on the aerodynamic characteristics of paraglider and can be a useful tool to select the covering materials advantageous to the considered constructions and assumptions.

The next section of the dissertation is focused on introducing a single cover paraglider model. Model of the paraglider wing covered only with the upper brits has a significant importance from the view of packing volume and mass of the final product. The aerodynamic characteristics and material behavior on the proposed geometry are advantageous.

The last part describes initial calculations estimating the safety factors of seams and lines, as well as the heat transfer through the harness. The topics are introduced as fields for the future development.

Each element of the paragliding system is characterized by different behaviors, which require separate physical and mathematical descriptions. Assembling all the parts creates a complex model, which has completely different characteristics than those resulting from partial models. The construction, description and solution of this model is a very complex problem, far beyond the scope of doctoral dissertation.