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Experimental Stress Analysis

DESIGN AND EXPERIMENTAL VERIFICATION OF LANDING GEAR FOR ULTRALIGHT AIRCRAFT

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Abstrakt: The goal of the paper is to describe design and structural analysis of landing gear for ultralight aircraft. Design satisfies all conditions of today's directives for the aircraft of ultralight category. Design was verified on experimental model. Experiment was realized by the methods of photoelasticimetry.

1. Introduction

Landing gear belongs to the main parts of aircraft. Development of landing gears began with ski and float landing gears, then through non-retractable landing gears equipped by wheels with wire strings, disc wheels, retractable landing gears and today's undercarriages on big aircrafts and space shuttles, which are able to absorb huge kinetic energy during landing.

2. Types of landing gears

Purpose of landing gear is:

- to allow moving of aircraft on ground, water surface or snow;
- to damp impacts and to absorb part of energy during loading;
- to damp impacts which arise during moving of aircraft on rugged terrain;
- to ensure good stability and control of aircraft on ground, water surface and snow;
- to prevent rotations and uncontrolled movements during taxing [9].

In Fig. 1 are seen various tapes of landing gears from various points of views. This division can be considered to be a guide for decision what type should be used for a given aircraft [8]. In order to gain low weight of ultralight airplanes, it is necessary to use the simplest solution with respect to height strength and the highest level of safety [3].

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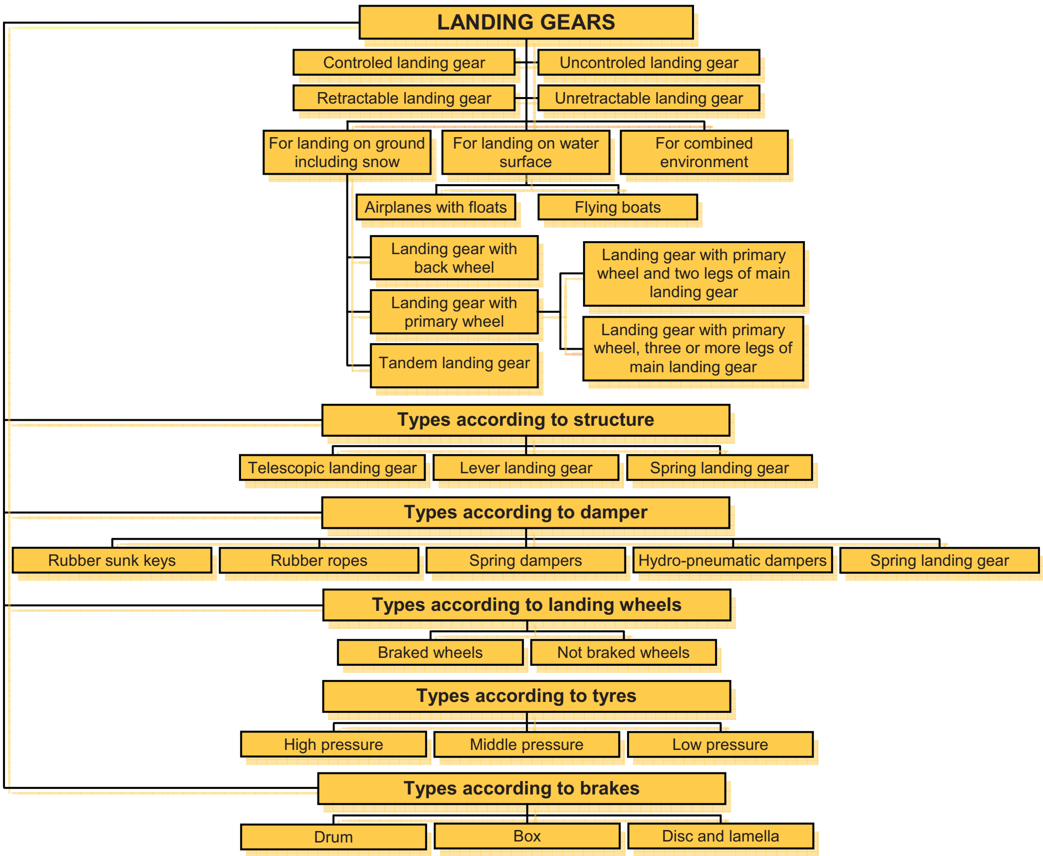


Figure 1: *Types of landing gears.*

3. Specification of loading

3.1. Weight of aircraft

According to [1] and Directive of State Airplane Inspection No. *3/96*, the ultralight airplane is an airplane that has starting mass maximally *480* kg (two seats) and *300* kg (one seat).

For the proposed landing gear is considered mass *480* kg.

3.2. Safety coefficient

Safety coefficient has to cover and compensate inaccurate assumptions used during computation, inaccuracy of computation, production tolerances and influences of technology (imperfections and inaccuracy of production). If not stated differently, the safety coefficient is $k=1{,}5$.

3.3. Determination of loading

For determination of loading is considered the most critical case, i.e. that the whole maximal starting mass of airplane is not distributed regularly to all wheels of landing gear, but it is acting only to one wheel. In that case is the loading force F_{CELK} equal to product of maximal starting mass m, gravitational acceleration g and safety coefficient k, so that for $k=1{,}5$ is the force $F_{CELK}=7064$ N.

These data and configuration of characteristic properties of material (Fig.2) produced input for strength computation of landing gear by the finite element method in system

CosmosWorks.

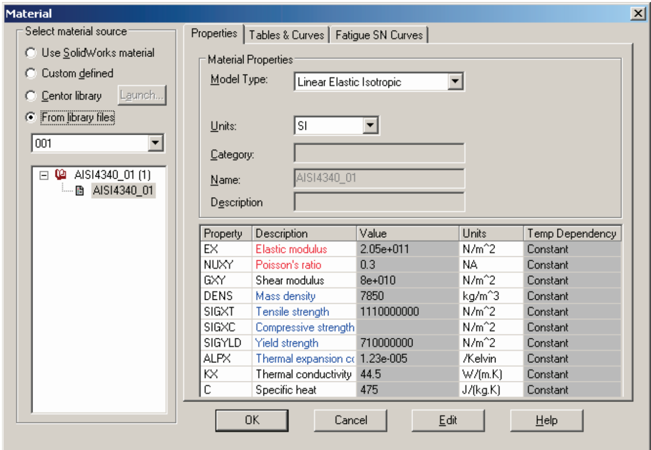


Figure 2: *Characteristic properties of material.*

3.4. Methodology of computation

For the computation was created simplified model of a whole system. Landing gear leg is a cantilever beam with certain physical properties. It is fixed on the one side and loaded by force F_{CELK} on the other side. By the computation is solved static state, i.e. there are not considered dynamical loads that arise during taxing, takeoff, or landing. There are also not considered loadings in the location of beam fixing. All computations are provided only for part outside of airplane bodywork.

3.5. Proposal of basic dimensions

The base geometric dimensions of landing gear leg are chosen according to dimensions of real airplanes *ULL*. All dimensions are given in Figs. 3 and 4 and they are in millimeters. The dimensions of used cross-sections are given in Table 1. In case of variable cross-section is in upper part of the table given cross-section B-B and in bottom part cross--section A-A, while the change of cross-section width along landing gear leg is linear.

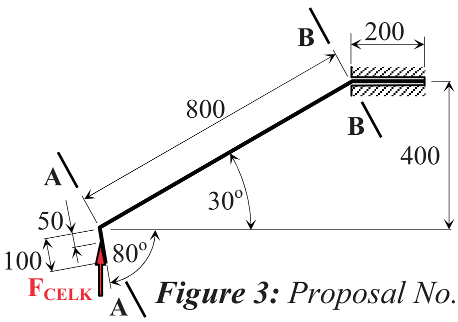


Figure 3: *Proposal No. 1.*

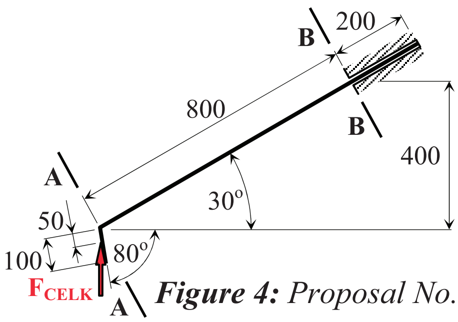


Figure 4: *Proposal No. 2.*

3.6. Strength computations

Strength computation is realized by the finite element method [4] in system *CosmosWorks*. The method compares allowed equivalent stress with the von Mises stress that was gained from simulation of loading of 3D model. Allowed stress was chosen according to used material $\sigma_D = 7{,}1.10^8$ Pa. In Figs. 5 to 13 are given results of 3D model simulations.

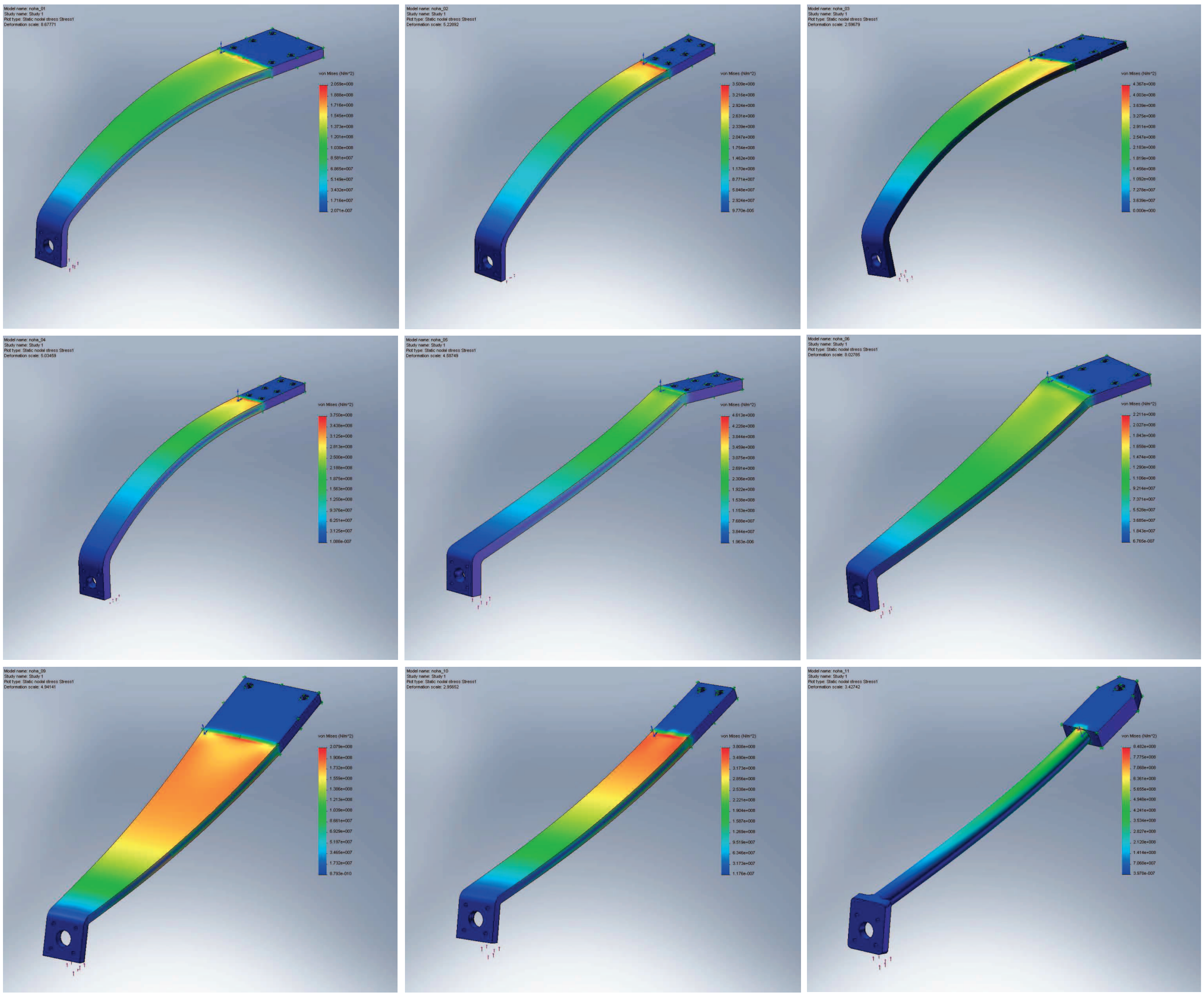


Figure 5-13: *Equivalent stresses for variant 1 to 9.*

4. Comparison of proposed designs

By the simulation of 3D model of landing gear leg in system *CosmosWorks* were computed equivalent stresses according to *von Mises* and these were further compared with allowed stress σ_D.

It was found out that the beams of rectangular cross-section are more appropriate than circular cross-section. Problem arose in variant No. 9, where in fixing location the beam has broken. In this case is necessary to solve this part by using variable cross-section, or to choose variable shape of cross-section.

Suitable variants are 1, 2, 4, 6, 7 and 8. These variants have enough reserve of strength and there can be supposed that also for dynamical loading the stresses do not cross allowed levels.

Not very suitable are variants 3 and 5, where the beam during static loading demonstrates appropriate stress, but the strength reserve is small and probably it is not enough for dynamical loading.

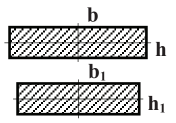
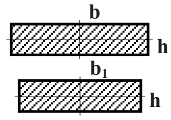
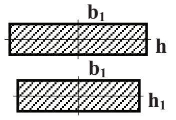
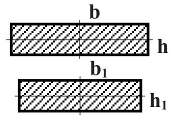
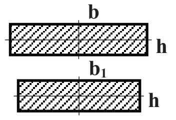
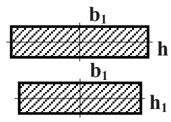
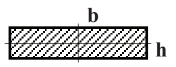
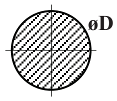
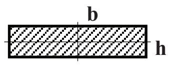
Unsuitable is variant 9 that cannot transfer static loading.

In Table 1 are given possible shapes of landing gears.

From the point of applied material of beam, it is possible to use alloy steels of class 15 and 16, wood, layered composites, or combinations of sandwich materials, e.g. steel and composite materials, plastics, etc.

As further evaluate parameters can be considered: mass of beam, production costs and technology, price and so on [2]. However, the aim of work was to provide evaluation from the point of view of strength.

Table 1: *Comparison of appropriateness of landing gear's cross-section.*

variant	Cross-section		Stress according to *von Mises* [Pa]	appropriatness	Variant	Cross-section		Stress according to *von Misses* [Pa]	appropriateness
	shape	dimensions [mm]				shape	dimensions [mm]		
1		b=200 b_1=100 h=30 h_1=20	$2{,}059.10^8$	suitable	6		b=200 b_1=100 h=20	$2{,}211.10^8$	suitable
2		b_1=100 h=30 h_1=20	$3{,}509.10^8$	suitable	7		b=200 b_1=100 h=30 h_1=20	$2{,}079.10^8$	suitable
3		b=200 b_1=100 h=20	$4{,}367.10^8$	less suitable	8		b_1=100 h=30 h_1=20	$3{,}808.10^8$	suitable
4		b=200 h=20	$3{,}750.10^8$	suitable	9		D=45	$8{,}482.10^8$	untimely
5		b=200 h=30	$4{,}613.10^8$	less suitable					

5. Experimental verification of proposed solution

Proposed solution was verified by experiments, by transmission photoelasticimetry. For this purpose was, on the base of model similarity, created model of real landing gear (Fig. 14). In Table 2 are given material characteristics and magnitude of load force for real structure and model. Material with Photoelastic properties was chosen from catalog *fy Vishay Micro-measurements Raleigh, Photoelastic Division* and material *PL-1*. Magnitude of fringe constant was f_ε was determined by standard procedure [7].

Table 2: *Charakteristics of used material and loading of real structure and model.*

material real	Young modulus $E=2.10^5$MPa	Poisson ratio $\mu=0{,}3$	allowed stress $\sigma_D=7{,}1.10^8$ Pa	loading $F=7064$N for $k=1{,}5$ and landing on one wheel
material model	Young modulus $E=2{,}9.10^3$MPa	Poisson ratio $\mu=0{,}36$	fringe constant $f_\varepsilon=0{,}484.10^{-3}$	loading $F=35{,}32$N

The model with gauge 1:5 was loaded by static force. This force is 200 times smaller than real force given in part 3.

Stresses were measured on the model and the deformations served for computations of maximal stress on real structure (procedure is given in [6]). These are in Table 3 compared with the stresses and deformations determined by *CosmosWorks*.

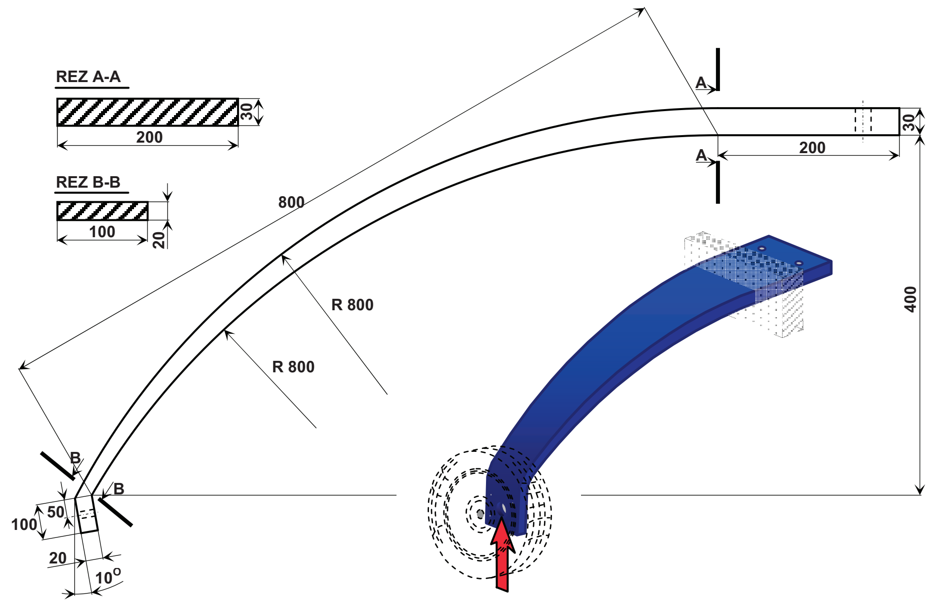


Figure 14: *View to landing gear and its dimensions.*

Model and isochromat fringes of loaded model observed on the transmission photoelasticimeter are seen in Fig.15.

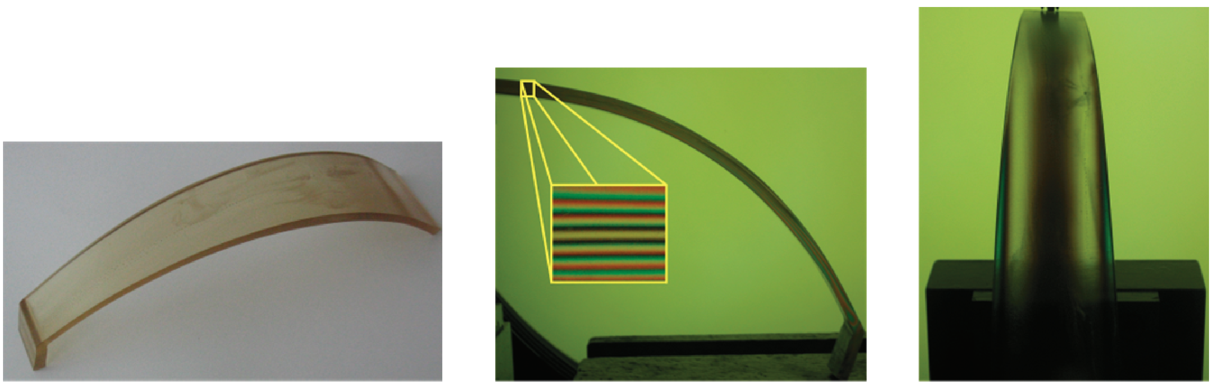


Figure 15: *Model and isochromat fringes.*

Table 3: *Stresses and deformations on the model and on real structure.*

Method of determination of stresses and deformations	stress [MPa]		deformation [mm]
	σ_1	σ_2	
Measured on model	36	12	53,14
Recomputed to real structure	288	96	30,82
Determined by numerical method	280	88,9	32,06

6. Conclusion

After realization of proposed landing gear there will be provided the stage of experimental verification that will simulate real environment. The paper was prepared according to [3].

Acknowledgement

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