Primary control of the light sport aircraft

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ANNOTATION

SOMMER,T.: Primary control of the light sport aircraft: thesis. Praha: CTU – Czech technical university, faculty of mechanical engineering, aerospace department, 2012, Supervisor: Malásek, T.

This thesis discusses longitudinal and crosswise primary control of light sport aircraft, kinematics project of this route, the elimination of their mutual influence. This thesis contains determination load of primary control, strength analysis of single elements of primary control.

INTRODUCTION

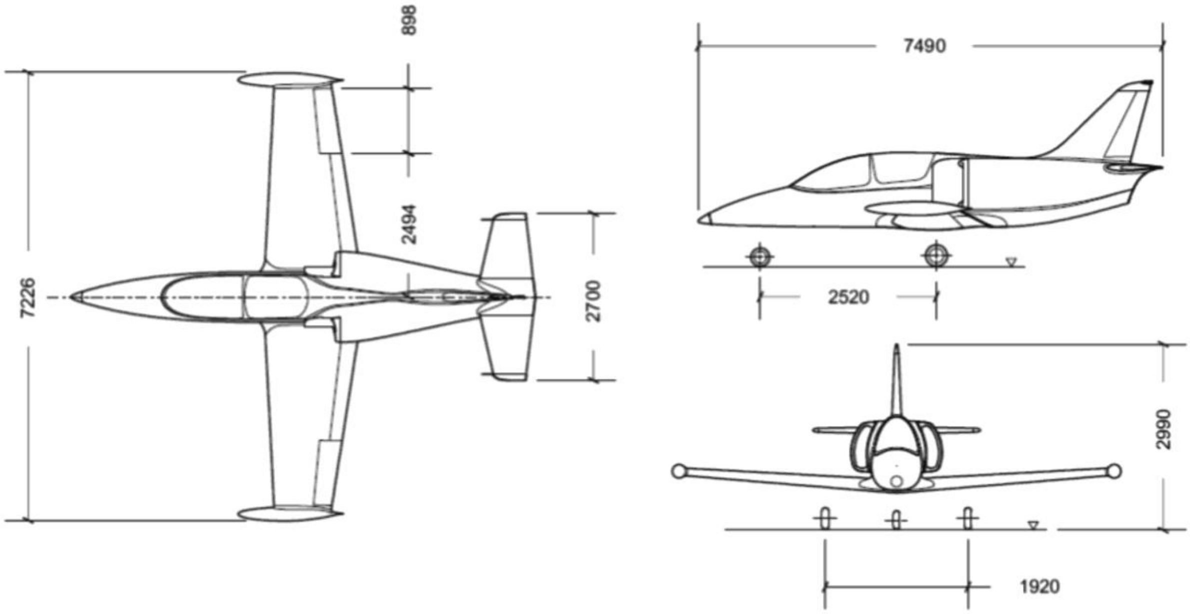
The theme of this work is kinematics design and design construction solution double longitudinal and crosswise control of the primary routes for tandem light sport aircraft UL-39. This airplane is proposed by Institute of Aerospace Engineering, Czech Technical University in Prague for building regulations primary UL 2, secondary CS-VLA.

Technical description of aircraft UL-39

UL-39 is designation for light sport aircraft. It is conceived as single engine, two-seat, self supporting low-wing, all composite construction with non-conventional "flow" drive. The aircraft has a conventional tail arrangement and is equipped with retractable landing gear tricycle nose type. The aircraft is proposed for operation in category ULLa (Ultralight aircraft aerodynamics controlled), in compliance with building regulation UL-2. But it is also monitored compliance with the requirements of the CS-VLA. UL-39 aircraft is based on a light jet trainer aircraft Aero L-39 type C.

Basic technical data

Wing span:	7,226 m
Length:	7,490 m
Height:	2,990 m
Max take-off weight (MTOW):	450(resp. 472,5) kg
Empty weight:	~ 290 kg
Maximum amount of fuel:	100 (~75 kg)
Max. velocity in horizontal flight v_H:	272 km/h
Max. design speed V_D:	340 km/h
Design speed maneuvers V_A:	171 km/h
Minimal velocity V_{FS}:	65 km/h



Picture 1

KINEMATICS PRIMARY CONTROL DESIGN

Design individual routes control

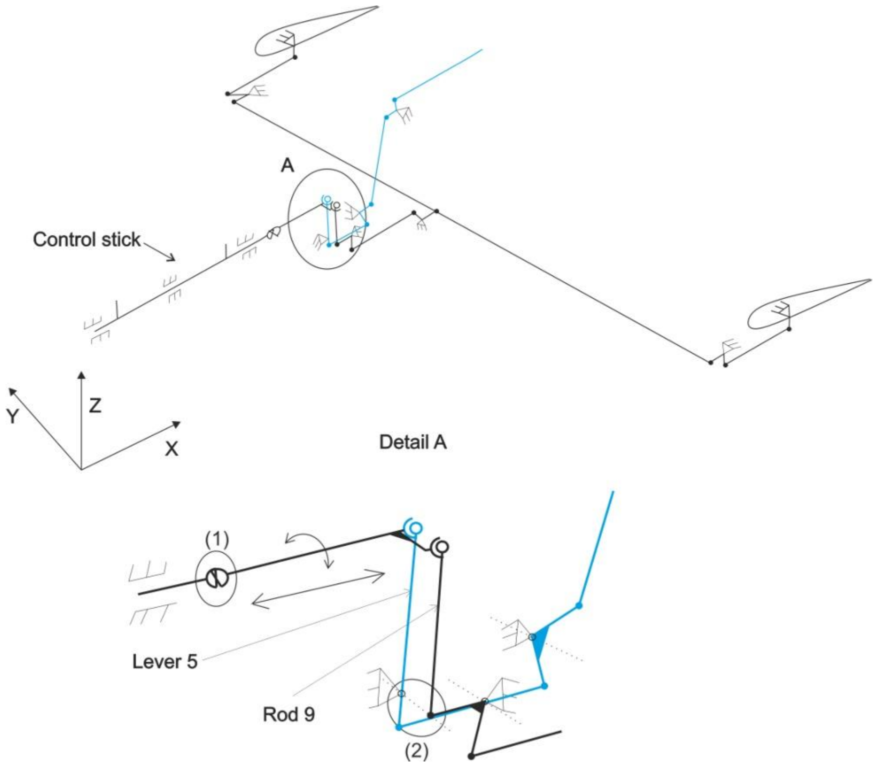
For preliminary simplified calculation of the kinematics of individual routes was voted *"wired"* model in *NX 7.5*. It is proceeded from the specified control parameters. It has been awarded and recommended displacement rudder and control levers, also has been specified model airplane with buildings, which were important for modeling route.
Kinematics was tuned in the superstructure *Motion Simulation*, the most common elements of kinematic relations were *"Revolute"* which were used to attach the levers to the airframe, this binding takes 5 degrees of freedom. *„Universal", „Spherical"* were used to bindings rods. The element *"Universal"* pulls 4 degrees of freedom and can be described as universal joint, the element *"Spherical"* pulls 3 degrees of freedom. The actual use of these features depend on the number of degrees of freedom kinematic system. It was also use the bond *"Cylinder"* to simulate motion of control levers, *"Slider"* with the element *"Cable"* as a simplified behavioral flexi-rod.
This primary design was replaced by real model of the primary control system and it was verified that there are no collisions mechanism or mechanism with the airframe.

Elimination affecting longitudinal crosswise routes

It is proposed to control the aircraft by using an unconventional way. The control is using by side-stick i.e. control lever on the side (usually on the right side of the pilot). Due to its minimal use in the same weight category, it was necessary to propose the system and verify the interaction. It is necessary to provide this conditions: low weight, simple construction and minimal influence of the routes.

Variant A

The control levers are part of the rod that held rectilinear reciprocating motion and it is also allowed to swing (controlling crosswise control). Rod is at its end connected to another rod with universal joint (1). This allows swing in the vertical direction and transfer rotational movement. At the end of the rod, these two movements are separated from each other. The axis of rotation of the lever 5 (2) is the same as the axis of rotation rod 9. This ensures minimal interference displacement aileron deflection the elevator. Other mechanism design is identical to the same category airplanes. That means using rods and levers that ensure differentiation. The chart shows that this variant is not suitable for large positive effect on the routes maximum deflection the control lever. The differences are due to deflections by lever handle 9 and 5 have the same crosswise control deflection the axis of rotation, which is shown in **Picture 2** detail A (2). The axis of rotation is the same only in one case (at zero aileron deflection).



Picture 2

Dependence aileron on control stick deflection

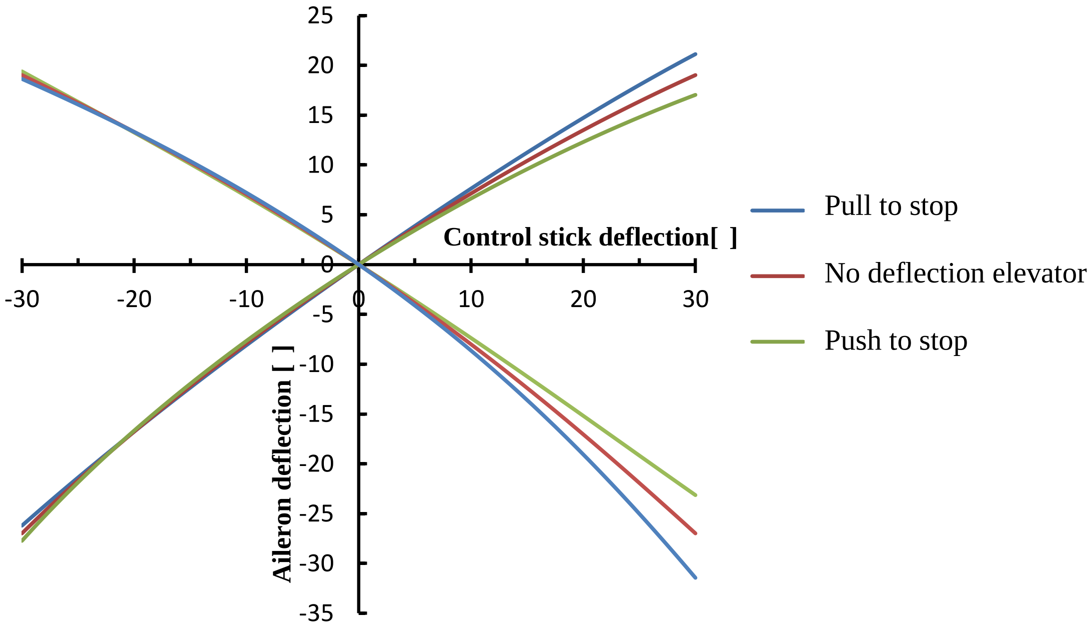


Fig. 1

Variant B

Due to the influence elevator aileron movement must adapt and find a version option with the least influence on individual routes. Option B is to restrict the range of the control levers to ± 25 °.

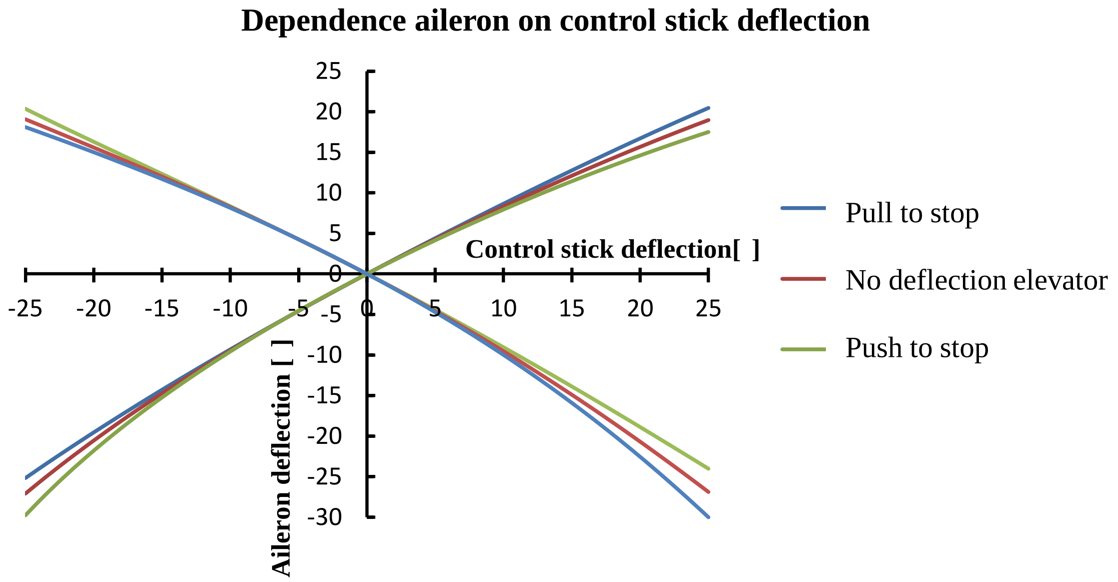
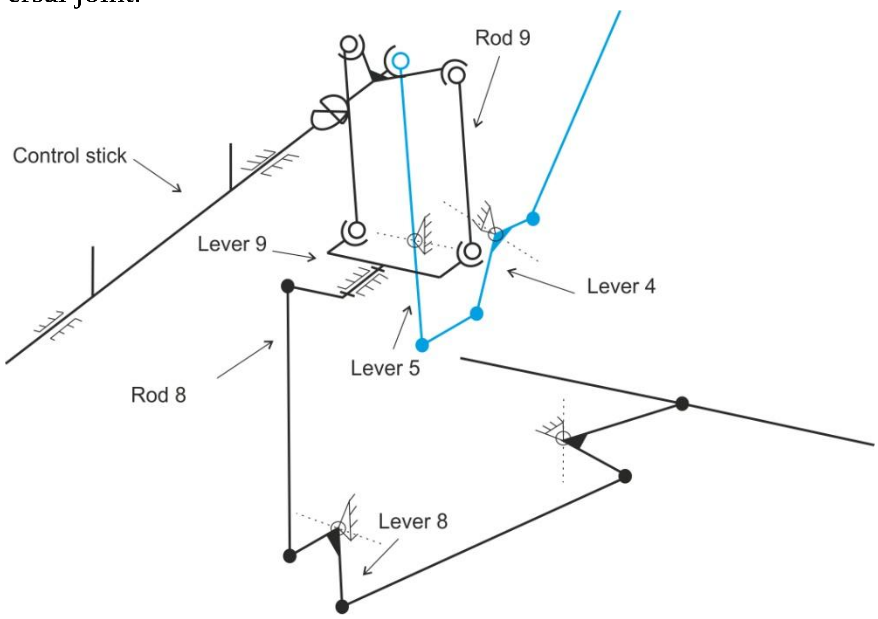


Fig. 2

Variant C

The universal joint is used. The axis of rotation lever 9 has been changed. The axis of rotation of the lever 9 and the control levers are parallel. Rod 9 and lever 5 is at zero crosswise control deflection have the same axis of rotation. The advantage of this variant is that the crosswise control influence is symmetrical.

From previous versions is apparent that this arrangement is preferable, but it is still necessary to modify mechanism. To eliminate influence routes is necessary that the axis of rotation of the control lever and the lever 9 are identical. It is impossible to ensure the smallest swing rod from the universal joint.



Picture 3

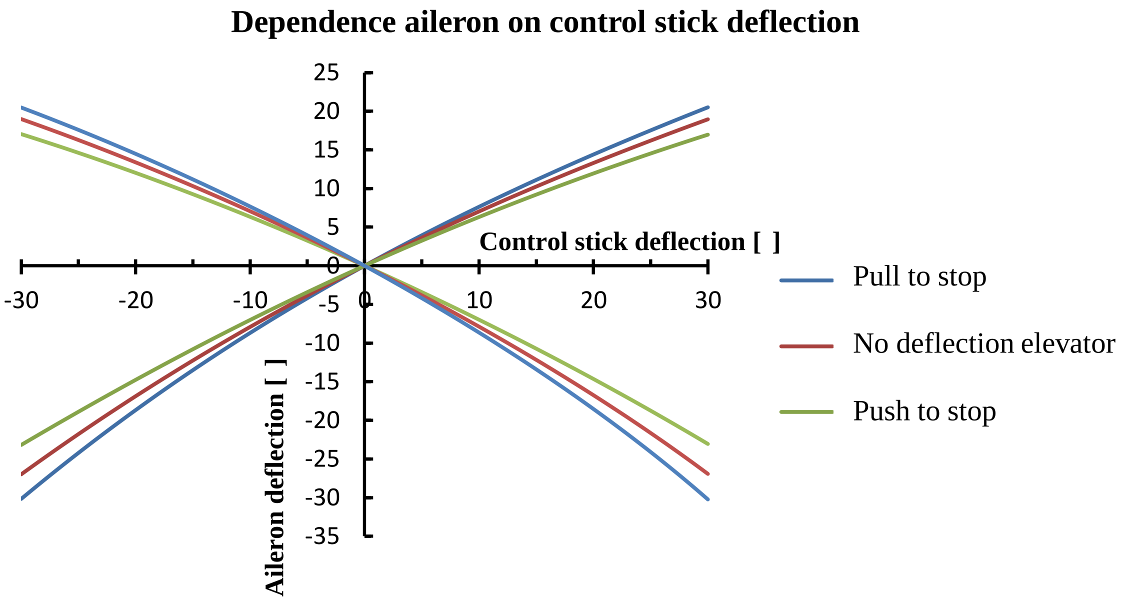
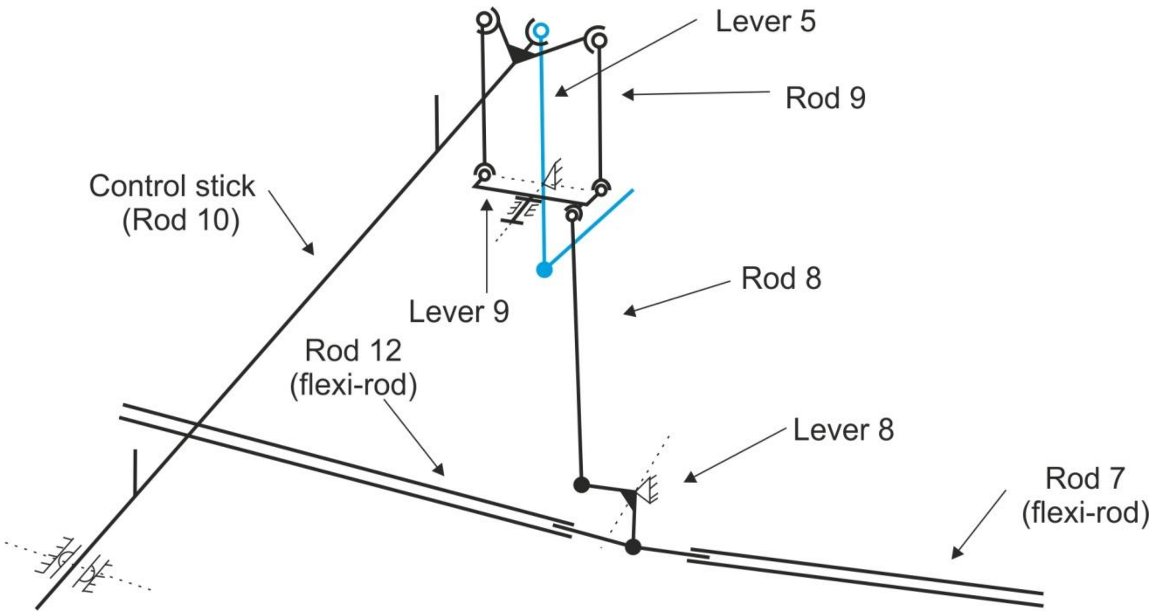


Fig. 3

Variant D

Option D is modification of option C. The universal joint was removed. There is one rod which leads from control stick. Its swiveling movement ensures rocker bearing. Increased to arm and swing angle lever (up and down) is minimized. Increased control lever operation to ± 40 °.

Of all the proposed options, this option is most appropriate. To reduce weight and simplify construction mechanism is changed to use only one rod 9. Influence of crosswise control is minimal. A large arm of the crosswise direction control influence decreased to approximately 1 °.



Picture 4

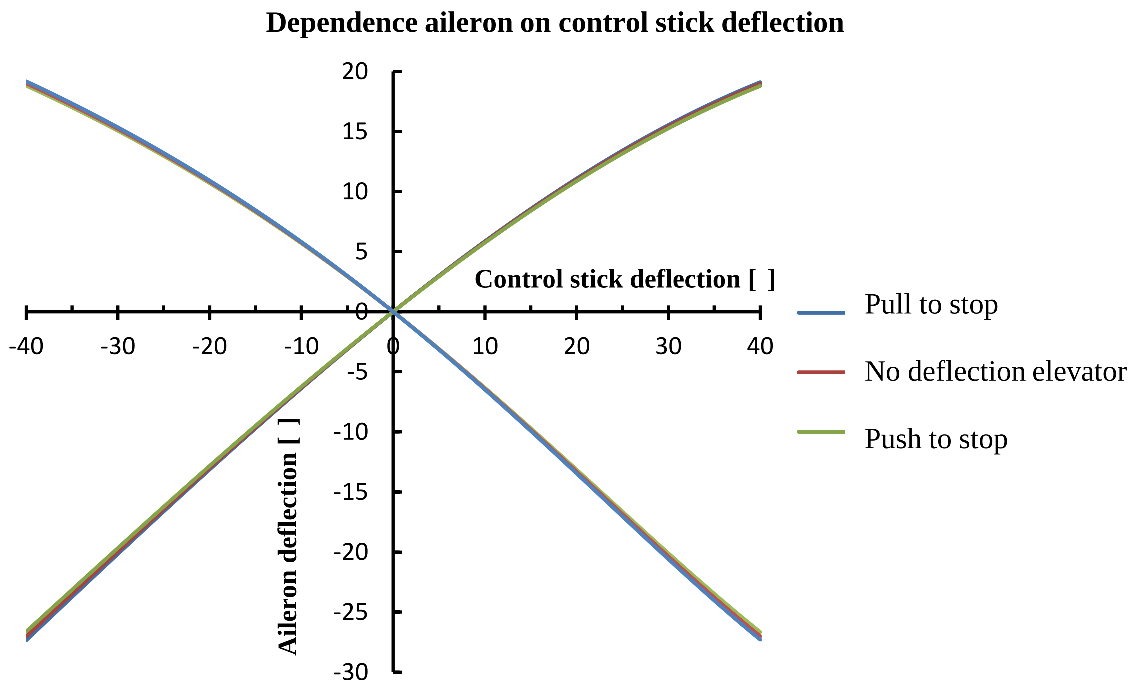


Fig. 4

DETERMINATION OF FORCES IN THE CONTROL ELEMENTS

The construction must be able to transfer loads without permanent deformation. Ultimate load of the design shall be transferred at least 3 seconds, during this time it can't cause a malfunction. Strength requirements are determined by the operating loads (the maximum expected traffic load) and ultimate load multiplied by prescribed safety factors. Compliance with the strength of the construction must be shown for all combinations, which establish the build standard (UL 2, CS-VLA).

Model of control routes created in NX 7.5, was loaded with forces which were calculated in routes control. Control forces were determined from the hinge moment. Hinge moment was determined from the angle of pitch and airspeed, hinge moment coefficient and surface rudder. Hinge moment coefficient was determinated from line chart. The hinge moment was substituted in the principle of virtual work, the control forces were determined.

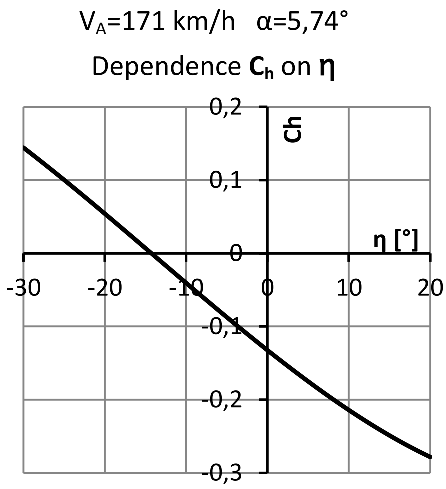


Fig. 5

STRENGTH CHECKS

Strength checks were carried out both analytically and using FEM calculations.

Strength check rods

Rods are loaded in tension and buckling. In terms of strength check buckling load condition is more stringent. When the control rod strength is based greatest strength, which stresses the rods for buckling. The calculation of rods was performed by energy method.

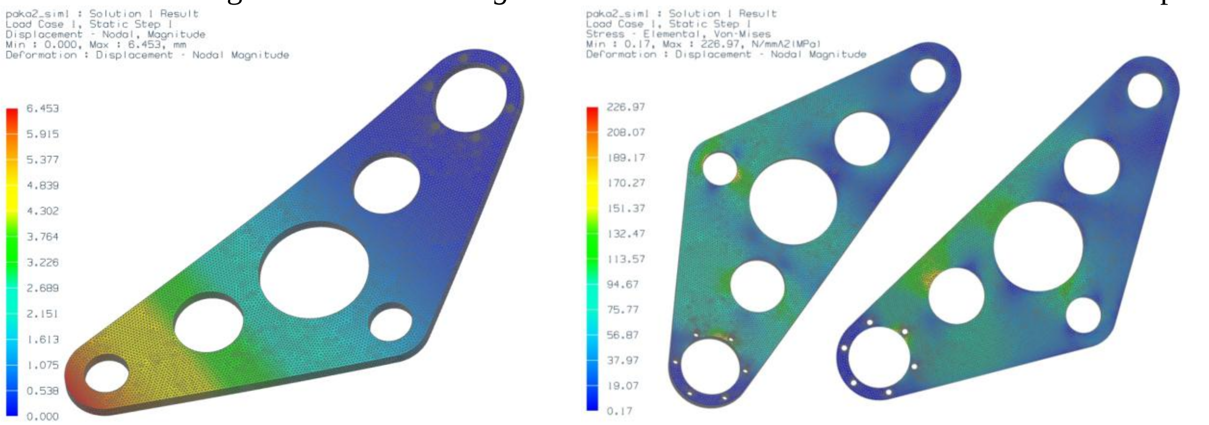
$$F_{Kr}^{E} = \frac{\int_{l} v''^{2}(x) \cdot E \cdot J_{min} \cdot dx}{\int_{l} v'^{2}(x) \cdot dx} \tag{1}$$

$$v(x) = A \cdot \sin\left(\frac{\pi}{l} x\right) \tag{2}$$

Levers strength check

Stress analysis was then performed using FEM analysis in the superstructure Advanced simulation *NX 7.5*. It was an attempt to bring as much stress on the levers in real introduction computed forces raised the safety factor k = 1.5. For the calculation itself was used the opportunity to use a simplified model. For meshing was used the automatic mesh parameters. The element type was chosen *CTETRA (10)* element resembling a pyramid of 10 nodes. Size of one element for more accuracy calculation was 1mm. For these mesh body the feedback control network was necessary created, so each generated mesh was controlled by the shape of the elements. The elements of contact tasks were bound by function *Mesh mating condition*. The characteristics of the material were also given. The calculation was done assuming that the lever is in the field of Hook law.

It was further established store lever and the forces. The most common storage levers were elected *Pinned constraint* (drawing 5 °D), *User defined constraint* (the user defines the properties of ties). Bindings were chosen so that the levers were blocked and behavior after applying forces were closest to the real behavior of loaded lever. The forces have therefore been defined using the element *Bearing* that simulates the real tasks such as contact hole / pin.



Picture 5

CONCLUSION

The aim of this thesis was the design of crosswise and longitudinal control for light sport two-seater in tandem aircraft for category UL. The kinematic design routes was performed. Then these routes were modeled and was strength check of all elements.

Symbol list

A	Constant	[1]
E	Young's modulus of elasticity	[MPa]
F	Force	[N]
J_{min}	Quadratic product of interia	[mm^4]
l	Length	[mm]
v(x)	Deflection function	[mm]

Scripts

^{E}	Energy
$_{KR}$	Critical

Literature

Diploma thesis Primární řízení malého sportovního letounu 2012 Tomáš Sommer