Light_Sport_Aircraft, wing design elements and resistance calculus for a new 3D model applied for flaps control

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Abstract. The aim of the paper is analyze of a new linkages used in Light_Sport_Aircraft control, flaps control, on bases of the aerodynamics, structural modelling of linkages with Multibody System method (MBS) and resistance calculus of wing. In virtual prototyping of the aircraft, these linkages have to be modelled by a minimum number of bodies (MBS min). In this paper is described one concrete mechanical flaps control. This will be the bases for virtual modelling and prototyping of these subsystems as parts of the whole product (airplane).

Keywords: mechanical systems, multibody systems, structural modelling, kinematic analysis, aircraft, Flaps

1. Introduction
The aircraft control motion (roll, pitch, and yaw) during the flying by appropriate systems is made. The name and location of these systems are given in figure 1 - for a small airplane [10]. Their auctioning is made from the pilot usually by intermediate of mechanical transmissions (linkages, cams, etc). In design process of an aircraft (very complex product) one of the main steps is virtual prototyping. Previously published research offers many solutions for flight dynamics and control applied for big aircraft. [1, 16]

This means that a unitary modelling of all the subsystems for LSA is necessary.

The aim of this study is MBS method applied for Light_Sport_Aircraft flaps control.

In this paper an appropriate algorithm is described and also applied for concrete mechanical system. This will be the bases for dynamic modelling of these subsystems as parts of the whole product (airplane).

Figure 1. Light_Sport_Aircraft and Wing profile with Forc.
During a straight and uniform horizontal flight, the following forces act on the plane (figure 1):
- following the direction of the X axis: the traction force T, Thrust and the force of resistance at the forward Fx appear;
- after the direction of the Z axis: appears the lift force Fz and weight G.

2. Theory

Wing aircraft and tail surfaces from, Light_Sport_Aircraft, represent two most important lifting surfaces.

From subsonic flight, (see. figure 1), speed and pressure [9], are

\[ p_\infty + \frac{\rho V_\infty^2}{2} = p_{loc} + \frac{\rho V_{loc}^2}{2} \]  

And

\[ \Delta p = \frac{\rho V_\infty^2}{2} \left( 1 - \frac{\rho V_{loc}^2}{V_\infty^2} \right) \]  

Where

\[ p_{loc} \text{ and } V_{loc} \]  represent local wing parameters into disturbed area, and
\[ p \text{ and } V \]  represented parameters from un-disturbed area, \( \rho \) is density of the fluid.

We define, Pressure_Coefficient (see in figure 1)

\[ Cp = \frac{\Delta p}{p_d} \text{ where } p_d = \frac{\rho V^2}{2} \text{ is dynamic pressure} \]

So

\[ Cp = \left( 1 - \frac{V_{loc}^2}{V_\infty^2} \right) \]  

We define Lift_Force

\[ F_z = (\Delta p_{extrados} - \Delta p_{int\_rados})S \text{ where } \Delta p = \frac{C_p \rho V_\infty^2}{2} \]

\[ F_z = (C_p_{extrados} - C_p_{int\_rados})\frac{\rho V_\infty^2}{2}S \]  

Final

\[ F_z = C_z \frac{\rho V_\infty^2}{2}S \text{ where } C_z = (C_p_{extrados} - C_p_{int\_rados}) \]  

Where “Cz” is Lift Force coefficient.

We define Total Aerodynamic Force, R (see figure 1).

\[ \vec{F}_z + \vec{F}_x = \vec{R}, \text{ where } F_x \text{ is Drag Force} \]
3. Concrete linkage
In this section are presenting the 3D model for a new Flap control mechanism.

Figure 2 shows the 3D model for a new Flap control mechanism.

When the lever 1 is actuated, the movement is transmitted to the component elements 1-9 of the two identical kinematic chains on the left and right of the lever.

Flaps 9 increase the aircraft's lift at critical moments (take-off, landing).

![Figure 2. Light_Sport_Aircraft – FLAPS_control_3D_Model.](image)

![Figure 3. Un-equipped_Wing.](image)
In figure 3 is presented an unequipped wing with flap and aileron.

In figure 4 is presented a equipped wing with flap and aileron.

Figure 5 presents a 3D model of flap.

Figure 6 presented a 3D model of wing equipped with flap and aileron.

Figure 7 presented linkage from figure 2, modeled with as MBS min having 6 bodies, five geometrical constraints type R and four geometrical constraints type SS. The input body is body 2 and the output bodies are the ailerons 4 and 6. Mobility M =1.
Figure 6. 3D Model of Wing equipped with Flap and Aileron.

Figure 7. Flaps control modelled with min number of bodies.

Table 1: Flaps control (see figure 7)

| Body i | Body j | gc | Location | Number of constraints |
|--------|--------|-----|----------|-----------------------|
| 1-2    | R      | O2  |          | 5                     |
| 1-3    | R      | O3  |          | 5                     |
| 1-4    | R      | O4  |          | 5                     |
| 1-5    | R      | O5  |          | 5                     |
| 1-6    | R      | O6  |          | 5                     |
| 2-3    | SS     | AB  |          | 1                     |
| 2-4    | -      | -   |          | -                     |
| 2-5    | SS     | A1B1|          | 1                     |
| 2-6    | -      | -   |          | -                     |
| 3-4    | SS     | CD  |          | 1                     |
| 3-5    | -      | -   |          | -                     |
| 3-6    | -      | -   |          | -                     |
| 4-5    | -      | -   |          | -                     |
| 4-6    | -      | -   |          | -                     |
| 5-6    | SS     | C1D1|          | 1                     |

\[ M = S (n_b - 1) - \sum r \]
\[ \sum r = 29 \]
\[ n_b = 6 \text{ si } S = 6 \]
\[ M = 1 \]
The input body is body 2 and the output bodies are the flaps 4 and 6. Mobility $M = 1$ (see figure 7).

In a linkage having “$n$” elements number of bodies $n_b$ is:

\[ n_b \leq n \]
\[ n_{b\text{ min}} \leq n_b \leq n \] (7)

$n_{b\text{ min}}$ representing the minimum number of bodies for modelling a concrete linkage [13, 14, 15].

The geometrical constraint imposes restrictions in bodies relative motion. Number of restriction is $r = 1$ and $r = 2$ in the case of planar systems ($S = 3$), respective $r = 1 \ldots 5$ in the case of three dimensional systems ($S = 6$).

The restrictions are imposed by joints or composite joint in planar systems they are: rotation $R$

($r = 2$), translation $T$ ($r = 2$), rotation-rotation $RR$ ($r = 1$), rotation –translation $RT$ ($r = 1$) curve –curve $CC$

($r = 1$) [13]

Between number of bodies $n_b$, number of geometrical constraints ($\Sigma r$) in a concrete space $S$, and mobility $M$ there is the relation [13]

\[ M = S (n_b - 1) - \Sigma r \] (8)

The algorithm for MBS modeling with minimum number of bodies has the following steps:

a. Identifying the bodies, in order:
   - fixed body,
   - input body (bodies),
   - output body (bodies),
   - bodies with more than two connection,
   - bodies with applied forces,
   - other bodies (if necessary).

b. Identifying geometrical constraints:
   - type ,
   - location,
   - number of restriction.
Figure 8. Wing structure – Forces.

Figure 9. Force diagram on an oval frame.

a - general scheme of force, b - effort in tension, c - frame as articulated at the soles in A and B
Figure 10. Force diagram on the half of rib frame from diagram din figure 8, c.

Regarding the ADBC framework from the wing junction in figure 7, to avoid the high concentration of stresses in the casing, an ABB1A1 stretcher heart is mounted between the two input ribs.

This heart acts as a tension between points A and B and, as a result, the diagram of forces in the rib-frame decomposes as in figure 8.

In Figure 8, [4] considering the rib-frame articulated in points A and B. By isolating half of it, we obtain the simple scheme of figure 9.

Taking the moments in relation to point B, we have:

\[ 2h N_0 = \int_{ABC} \rho \cdot q \cdot ds = 2 \int_{ABC} q \cdot d\Omega \]  

(9)

If we consider the flux q = const. and is equal to the maximum flow per contour:

\[ q = \frac{P \cdot S_c}{2 \cdot I_c} \]  

(10)

\[ 2h N_0 = 2q \cdot \Omega_{ACB} \]  

(11)

\[ N_0 = q \cdot \frac{2\Omega_{ACB}}{2h} \]  

(12)

The bending moment at any point S along the frame is:

\[ M = \frac{P}{4} \cdot x - N_0 \cdot z + 2q \cdot \Omega_{ACS} \]  

(13)

The bending moment is maximum at point D.
4. Conclusions

Present research in the multibody dynamics has been developed by computer techniques. Modern industrial design use computer for analyzing rigid multibody systems. Automatic process in this case offers many solution in short time.

This study offers a modern method for analyze LSA flaps control and propose few wing design elements for a new 3D model.

For aircraft design many equations needs simultaneous solutions. Many mechanical aircraft systems work together in different conditions. Performance analysis of this used new applications software. MBS is a modern method for dynamic simulations and virtual prototype.

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