DESIGN AND CALCULATION OF A CONTROL SYSTEM FOR AN SMALL AIRPLANE WITH TAKE-OFF WEIGHT TO 2 000KG

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Thesis deals with the design of control system for aircraft with maximum take-off weight of 2,000 kg. Thesis deals about the current state of the aircraft control system. Thesis is dealing with the direct control system. It explained information and description of direct control system. There are also described the basics and terms used in this issue. In the next stage the design of an control system with a description and appropriate documentation is made. In the next stage of this thesis the bonding material analysis and calculation of the control system are made. Design and calculation are made according to official regulations CS-23. The work is accompanied by pictures and technical description of the proposed construction.

K e y w o r d s. Design, strength calculation, material analysis, ailerons, elevator, rudder

1 INTRODUCTION

The outline control system is one of the most important parts of the aircraft structure. In sports, training, and small transport aircraft is used mainly for easy of mechanical systems direct control. Almost particularly when the aircraft can meet with indirect control. My task was to design the primary control system aircraft. In the introduction describes the preliminary proposed new concept aircraft is further evaluated by analysis of the current situation, which includes distribution, requirements and main parts control system. Another chapter is a concrete proposal control system for ensuring the control of roll, pitch and yaw of the aircraft. In short, the proposed approach to the control that balance rudder tabs to play in the summer a very important role. In conclusion, this work describes the analysis of the proposed materialstructure and strength calculation of some parts of the control system.

2 ANALYSIS OF THE CURRENT

2.1 Characteristics of new aircraft

Proposed new airplane based on existing types of aircraft and our desired properties and characteristics are:

- Weight, which should not exceed 2000 kg,
- Flight speed of about 400 to 500 km / h,
- Range up to 2000 km,
- Capacity: 1 pilot, 4 to 5 passengers,
- Drive Unit, TP 100 turboprop engine performance of 180 kW.

The analysis of the selected four planes around the same parameters which have a new airplane. There are basic technical parameters mentioned aircraft EM-11 Orka, Diamond DA42-NG, Partenavia P.68 and aircraft L 200 Morava. For all of these aircraft are used for direct mechanical control. In some cases, can be incorporated into the control system, auxiliary power and control members of that balance areas can be electric.

2.2 The control of aircraft

Control plane is used to control the aircraft. It consists of the main control system by which rudders are controlled longitudinal, lateral and directional control and secondary control system that controls flaps, speed brakes, retractable landing gear, controls the front chassis legs. [5].

2.3 Requirements for control system

General requirements:
- Low weight, strength, toughness, durability and simplicity.

There is also the other special requirements:
- Ensuring the necessary deviations,
- Immediate response to helm the pilot pulse,
- The possibility of regulatory controls in cab
- Removal of dead movements,
- Protection and control transfers from accidental damage.

2.4 Distribution control system

It is usually divided into control, so that lateral and vertical rudder pilot controls the rudder arms and legs. They are two completely independent systems. Accordingly, we divide the control of:
- Hand and foot.

Depending on the type handlebar control manual is divided in:
- Lever and RC.

Under construction:
- Mechanical, electrical and hydraulic.

2.5 The control of mechanical systems

Mechanical control systems transmit impulses from the pilot to control the area by mechanical means. The control system can be divided into a part which is located in the cockpit and on the outside of the cockpit. In the cockpit there are basic controls such as gear lever and pedals.

The direct control consists of several elements. In the simplest case, these are different types of levers, linkages, pulleys, ropes, guide and insurance member and setting elements. Transfer deviations handlebars at the helm of mechanical systems, secured either by a rigid link draft sensing led flexible rope or cable, or a combination thereof. Managing a small group of aircraft consists of the following parts [4]:

- handlebars (single, double)
- leading control,
- power system.

Power Systems

For aircraft with direct control power are members of the horizontal and vertical rudder, ailerons, which are attached to hinges. As of airframe structures can be attached to two or more of the hinges.

Leading control

Transfer of control is used to transmit motion from the hand and foot levers to control the rudder of the aircraft. The transfer of control control surfaces of aircraft used three types of mechanical transmission.

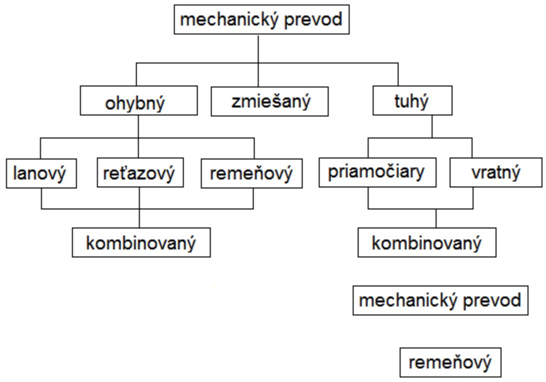

Figure. 1: Distribution of mechanical transmission

3 PROPOSAL FOR CONSTRUCTION CONTROL SYSTEM

The control system must be designed to ensure the simple technique of piloting. The control channels must be independent of each other (eg rotation of the steering control must not affect the elevator). The aircraft will be equipped with dual control the rudder and elevator and ailerons. Elevator control is transferred and the steering wheel and steering column forward or backward. Aileron control is performed by turning the steering wheel. Rudder is controlled by two pedals. The control control are used either rod, rope, or a combination thereof.

The structural design must respond regulation CS-23, the control levers and pedals are designed so that their movement was a logical connection with the movement of aircraft. This greatly facilitates training with piloting [5]. Counterbalance the elevator control tabs, rudder and ailerons are located on the front control panel. The twin-engine aircraft must be balancing tabs designed so that in case of failure in any part of the primary control ensure safe flight and landing with longitudinal and directional trim.

3.1 The load control system

Forces from the pilot used for design purposes, shall not exceed the maximum forces prescribed in CS 23rd. The proposal must be tailored to suit the system operating conditions that include seizure control surfaces, ground gusts and inertial forces in the control and the friction. In the design of the elevator, rudder and aileron must be used to compute a curtain moment multiplied by the factor 1.25 [1].

3.2 Control elements of the lateral control

Managing aileron is controlled wheel located on the steering column (Fig. no.1). At the end of a pole attached to the flange bolts. The pillar is welded to angled lever which transmits motion to the rod connecting the two steering wheels. It is transmitted by the movement of the lever, which is stored in the reservoir and tube anchored to the hull structure

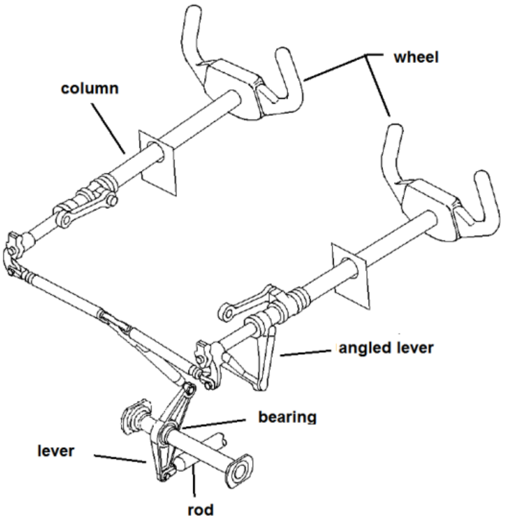

Figure. 2 Transfer of control of the steering rod in the trunk

From there the movement is driven by a system of linkages, which are interconnected by means of the guide lever.

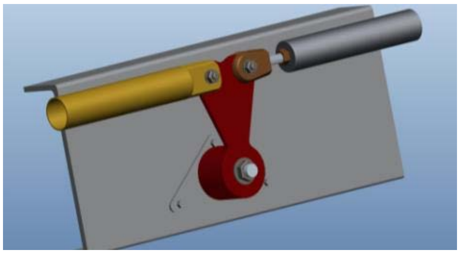

Figure. 3 The guide lever is placed in the trunk of her small nose

Rod on one side and welded fork on the other hand, a floating plug that you can use to reset the length of the rod. Forks are screwed to the body and stretched them, you can set the control stiffness. As material for the rod I chose aluminum alloy 2024-0. In the upper torso in a place where the wing is attached, is placed angular lever movement dividing into right and left wings.

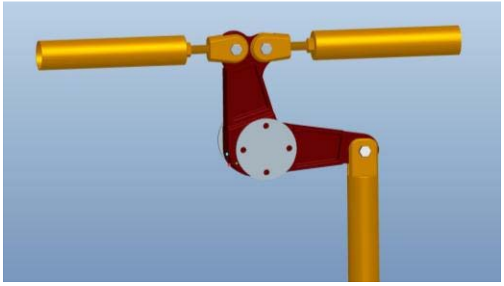

Figure. 4 angled lever in the control aileron [author J. Košík]

3.3 Analysis load system control

To calculate the various parts of control is necessary to first determine the input load (torque curtain) and geometric ties that determine the ratio of the load across the system. The forces in control levers will depend on the aerodynamic forces acting on the rudder, ie will vary depending on the speed, altitude and times, as the rudder angle (and hence a force in the control levers) will answer aload. Specifically, I have dedicated my work in analyzing and calculating the forces on the rod and lateral control levers.

3.4 Managing counterbalance tabs aileron

Each wing is equipped with an adjustable-colored, which prevents flapping wings. Balancing pitch is controlled by balanced action facet located on the trailing edge of the wings, more to the inside of the wings and moving always in the opposite direction of the wings and serve to reduce the load force on the handlebars. I suggested manual control only counterbalance the tabs left wings with aileron actuator. Pilot in cockpit movement of the steering screw (Fig. 5), which is located immediately near the rudder control and the resulting movement of balancing tabs. For checks and inspections shall be of such rollers, stretchers easily accessible through the openings or removable panels. The guide wire element is 4 mm thick placed in Bowden's case and guided by pulleys to the front wing actuator.

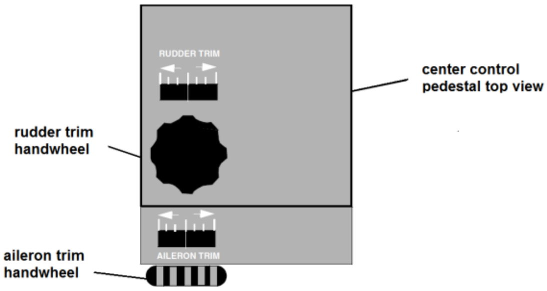

Figure. 5 Location of controls in the aircraft cabin

3.5 Control elements of the longitudinal control

Elevator control is transferred and the steering wheel and steering column forward or backward. Steering column elevator is stored in the control aileron pillar. The movement is transmitted via angular lever rod connecting the steering wheel, the lever also stored on ball bearing, which is anchored to the tube. From there the movement is led through to the link draft sensing lever that controls the elevator. Rod is attached to a guiding policy levers and fixed totheairframe structure. The movement of the steering column is limited longitudinal pole screws, which are strongly associated with the construction of the hull. Stop in the direction of suppressing the spring.

3.6 Managing the elevator counterbalance tabs

Managing the elevator trim tabs are designed electrically. The control panel in the cockpit is a control that adjusts position to counterbalance the deflection pads.

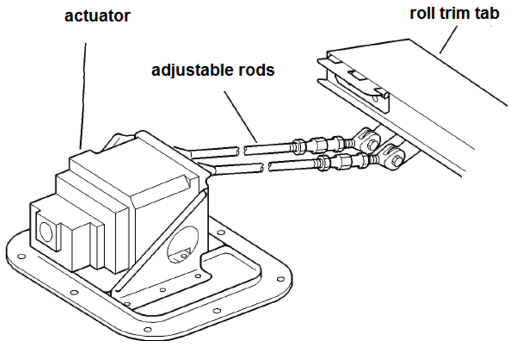

Figure. 7 Detail tabs counterbalance control tower control surfaces [4].

3.7 Control elements of the directional control

Proposal directional control is handled through a mixed transfer (Fig. 8)

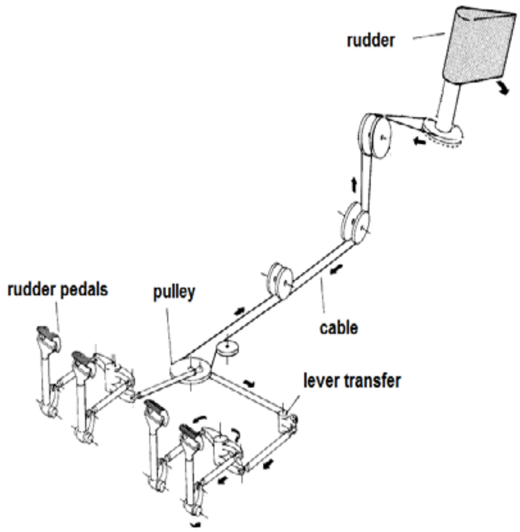

Figure. 8 control System to control the rudder with ropes stretches and [5].

The pedals are connected from the stem, which is connected through a pulley on the rope transfer (Fig. 9). Ropes are guided in the guide pulleys to the rudder.

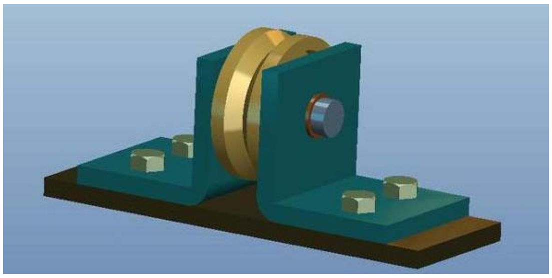

Figure. 9 The guide pulley ropes [author J. Košík]

The system is designed to prevent dangerous changes in cable tension throughout the range ofmotion under operating conditions. Control cables form a closed circuit and is necessary for each circuit was equipped with its own, easily accessible stretchers. Directional control pedals are designed as adjustable on the ground. Lock is released by pulling the lever, pedal, which is the Pedal.

3.8 Managing counterbalance tabs rudder

Control trimtabsrudder is mechanical. The control screw is attached using the pin through the shaft and ball bearings fixed on the front control panel.

4 MKP ANALYSIS OF SELECTED PARTS CONTROL SYSTEM

Case no. 1

The graphical environment for Mechanica I simulate the load lever guide. In the analysis I used the most power that enters the eye stick. The calculation showed the maximum stress 42 MPa which is negligible voltage to the maximum allowable tensile material.

Case no. 2

Stress link draft sensing power at the maximum tension and compression has a very low voltage (up to 6 MPa).

Case no. 3

The angular movement of the lever rozvadzajúcej link draft sensing the wings were also detected low voltage. Angled handle meets the strength requirements. The angles and dimensions of the lever according to the model I chose.

Case no. 4

The strucuture is designed to eliminate as far as possible point of stress concentration and thus prevent fatigue fractures with alternating stress in service.

5 STRESS AND MATERAIL ANALYSIS

Materials must meet the approved r equirements to ensure sufficient strength andrelia bility.

Rod

Sections link draft sensing I chose the shorter distance tube 20 mm, length 1000 mm and for a greater length of 25 mm, length 1500 mm. The wall thickness in both cases is 1.5 mm. Link draft sensing material is alloy 2024-0.

5.1 Calculation of the screw is moved

I chose the lever Al alloy 2024- T351. The lever is stored in the design of ball bearing and the rod is connected via the screw nut. The screw and nut are made of steel 11500th In the calculation I used the most power that enters the stem.

$$\sigma_{otl.} = \frac{F}{l \, . \, d} \leq \sigma_{D\ otl.} \qquad (1)$$

$\sigma_{otl.} = 54{,}97$ MPa,

$\sigma_{otl.} < \sigma_{D\ otl.}$ meets ($\sigma_{D\ otl.} = 500$ MPa),

5.2 Calculation of the shear bolts

$$\tau_s = \frac{2F}{2 \, . \, \frac{\pi \, . \, d^2}{4}} \leq \tau_{Ds} \qquad (2)$$

$\tau_s = 69{,}99$ MPa

$\tau_s < \tau_{Ds}$ meets ($\tau_{Ds} = 265$ MPa).

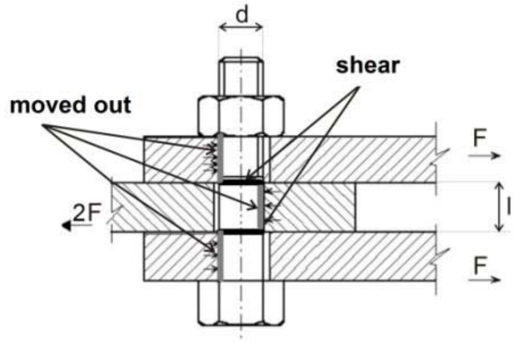

Figure. Screw 10 is moved and loaded in shear [by J. Košík]

5.3 Critical loss of strength stability

Calculated by the formula:

$$F_{krit.} = c \,.\, E \,.\, J \,.\, \left[\frac{\pi}{2}\right]^2 \qquad (3)$$

$$\sigma_{krit.} = \frac{F}{S} \leq R_e \qquad (4)$$

$$S = \frac{\pi . D^2}{4} - \frac{\pi . d^2}{4} \qquad (5)$$

$\sigma_{krit.}$ = 23,53 MPa ≤ 96 MPa MPa (for L =1500 mm)
$\sigma_{krit.}$ = 33,38 MPa ≤ 96 MPa (for L =1000 mm)

The calculated values wecan conclude that the critical loss of stability is high enough and is designed safety rod. Critical loss of voltage stability are lower than the yield shear strength aluminum alloy Al 2024th The proposal complies.

5.4 Materials

Dural 2024

Due to its high strength and good resistance to fatigue ratio, the lowest weight isoften used in the aerospace industry. Round tubes are used as the rod is usually produced by cold.

Steel

The design aircraft is used to make the most exposed parts (chassis, suspension fittings of wings). Although has a relatively high density (7.8 kg/dm3), but superior strength (up to 1800 MPa), high modulus (210 GPa), good fatigue properties andwell tolerated load.

Steel 11500

Overall non-alloy steel with the required mechanical properties used for static and dynamic stresses components and produce from it screws, pins, machine parts, rivets, chains, boltsand nuts

6 CONCLUSION

When designing the control system must be met strength, manufacturing ando perational requirements. Itshould always try to fin d the best solution, beca sethe extent of compliance can lead to excessive complexity of the design the main part of this thesis was the construction of the proposal itself. At the beginning of this section describes a brief overvi ew of the proposed system. Next I willaddress sp ecific design of lateral, longitudinal and directional control of aircraftcontrol surfaces and trim. With the development of aircraft systems and growing requirements forreliability, security, easy of ener gy use in new construction materials.

BIBLIOGRAPHY

[1] Evropská agentura pro bezpečnost letectví Certifikační specifikace pro letouny kategorie normálni, cvičná, akrobatická a pro sbeřnou dopravu CS-23. 2009. s. 44-50

[2] PETRÁSEK, Miloslav. Konstrukce letadel III. Univerzita obrany v Brně, 2002. s. 7-17

[3] MERTL, Vlastimil. Konstrukce a projektování letadel, VUT v Brně, 2000. s. 96-103

[4] DAŇEK, Vladimír.: Konstrukce a projektovanie letadel III - Základy projektování letounu. VUT v Brně, 1982. s. 11-17, 128

[5] TUMA, Jiří: Všeobecné znalosti letounu DRAK A SYSTÉMY. Praha: FTO VS ŘLP ČR, s.p., 1999, s. 44-61

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