wjert, 2017, Vol. 3, Issue 3, 493 -504 *Original Article* ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 4.326

PROBLEMS IN FLIGHT DYNAMICS AND ITS SOLUTIONS

Ahmed Soliman M. Sherif*

Researcher, Novosibirsk State Technical University, Department of Aircraft and Helicopter Construction, Russian Federation.

Article Received on 04/04/2017 Article Revised on 26/04/2017 Article Accepted on 17/05/2017

***Corresponding Author**
Ahmed Soliman M. Sherif
Researcher, Novosibirsk State Technical University, Department of Aircraft and Helicopter Construction, Russian Federation.

ABSTRACT

The mechanics of the flight studies the forces acting on the aircraft in flight, and the reaction of the aircraft to the action of these forces. All aircraft are equipped with a control system that allows the pilot to maneuver and release forces from the control levers on each of the three axes. The aerodynamic moments required to rotate the aircraft are usually realized by deflecting control surfaces that change the curvature of the profile. Control surfaces are located as far as possible from the center of gravity in order to create the maximum control moment.

KEYWORDS: Coefficient of aerodynamic lift, the angle of inclination of the trajectory, aerodynamic drag coefficient of planning, the angel of decline associated with the aerodynamic efficiency, the angle of trajectory planning.

Usually there are three independent control systems and three control surfaces

- A rudder that controls the movement around the normal axis;
- Elevator, which controls the movement around the transverse axis;
- Ailerons that control the movement around the longitudinal axis

(differential spacing of the spoilers is also used).

One surface can participate in the control in two axes

- Elevons - a combination of elevator and ailerons;
- The handle of the V-shaped tail, combining the functions of elevator and rudder direction;

- Differential stabilizer. When both halves work synchronously - pitch control, when separately - by roll.

The control moment is created by creating an aerodynamic force on the corresponding surface.

The magnitude of this force is determined by the velocity head (~V^2High-speed pressure) and the angle of deflection of the surface.

The control aerodynamic force can be created

- Deflecting the trailing edge, which will lead to a change in the curvature of the profile;
- Turning the whole surface;
- Reduce the lifting force and increase the resistance by tearing the flow with an interceptor.

When the curvature of the profile (wing, stabilizer or keel) changes, the aerodynamic force changes on it. The figure shows the effect of the aileron deflection on the lift factor of the wing section.

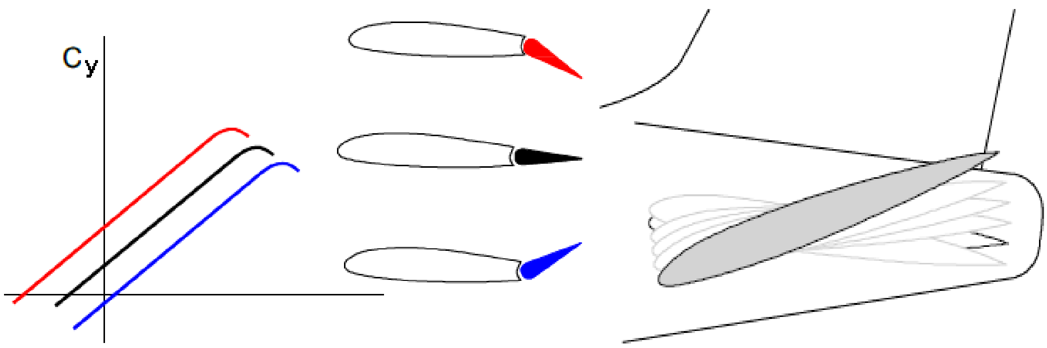
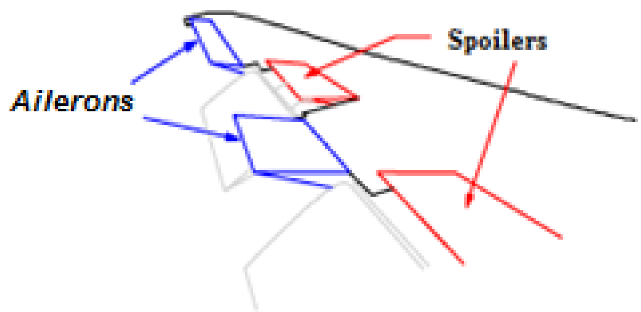


Fig 1: Angle of attack.

Controlling aerodynamic force can be created by turning the entire surface entirely. This scheme is often used for pitch control with the help of a one-way stabilizer. The elevator in this case is absent.

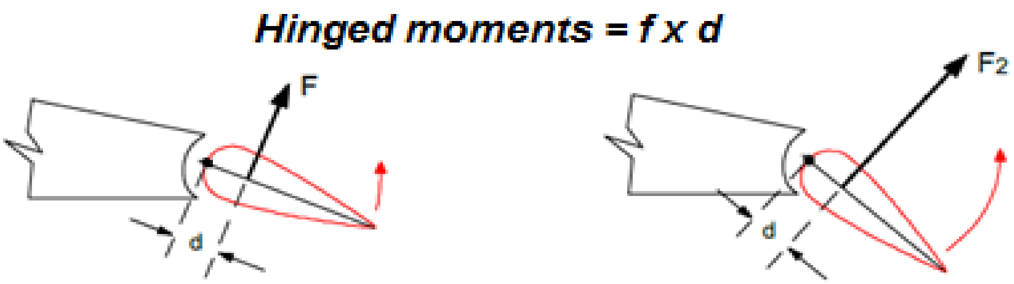
1. INTRODUCTION

Spoilers are devices for reducing the lift force of the wing profile, by breaking the flow over its upper surface. They are used to controlling the roll, rising on that wing, where the ailerons are deflected upwards, and like air brakes, rising on both hemispheres synchronously.



Hinged moments

The aerodynamic force acting on the control surface tends to rotate this surface relative to the axis of rotation in the direction of the force. The moment of this force will be equal to the product of the force on the arm from the center of pressure to the axis of rotation. This moment is called the hinge moment. The magnitude of the force is determined by the surface area, velocity head and angle of deflection of the surface.



To deflect the control surface to the required angle, the pilot must overcome the hinge moment by applying force to the control lever in the cab. Thus, the amount of force on the control lever is determined by the hinge moment from the steering wheel (non- booster control).

2. Initial data of the Research

Problem Number I

For glider, flying at a height of H = 1 km and has a G = 500 kg f;

$$S = 12\ m^2;\ C_{x0} = 0.015\ ;\ \lambda_{ef} = 14\ :$$

1) Determine the value of C_y and V (speed glider) steady decreasing at an angle of inclination of the trajectory $\theta = -5\,°$;
2) Determine the value of C_y and V (speed glider) steady decreasing at an angle of inclination of the trajectory θ_{min};

3) Determine the minimum vertical upstream speed $V_{y\,min}$, necessary for horizontal flight glider.

Problem Number II

Determine the minimum angle of planning when engine thrust P ≈0 proper planning speed of the aircraft TU-124 at a height of H = 2000 m, if it is known that the aircraft drag coefficient at this mode is equal to 0.042, the effective extension wing $\lambda_{ef} = 6.15$, and the specific load on the wing mg/s = $304\ \frac{kg}{m^2}$.

Problem Number III

Determine the derivative C_y^{α} and the angle of zero lifting force α_0 of the aircraft, if at $\alpha = 0^{\circ}$, $C_{ya} = 0.05$ and at $\alpha = 4^{\circ}, C_{ya} = 0.43$.

Problem Number IV

Aircraft at altitude of H = 0 has a velocity V_0 , How many times is it necessary to increase the speed at altitude of H =10 km, if the weight of the aircraft G and the lift coefficient force of C_{ya} remain the same.

Problem Number V

Prove Mathematically and Graphically that, the required thrust does not equal to the force of resistance for the aircraft and the car?

Problem Number VI

The Heavy-weight of the aircraft is $\overline{P} = \frac{P}{G} = 0.2$, K=10, V= 200 m/s.

1) Determine the slope of the trajectory θ, the vertical component of the velocity V_y.
2) Estimate, Which will have a greater impact on the increase of θ :
   a) an increase of K by 10%;
   b) an increase of P by 10%?

3. Solutions

Decision for Problem Number I

1) The equations of motion of a glider in steady planning:

$G * Sin\theta - X = 0$

$Y - G * Cos = 0$

planning speed

$$V_{Plan.} = \sqrt{\frac{2 * G}{\rho * S * \sqrt{C_{Y\ Plan.}^2 + C_{x\ Plan.}^2}}} ;$$

The angel of decline associated with the aerodynamic efficiency

$$tan\ \theta = \frac{1}{K}\ , tan\ (-\ 5°) = -\frac{1}{K}\ \ => -\ tan(5°) = -\frac{1}{K} ;$$

$$\therefore K = \frac{1}{tan\ \theta} = \frac{1}{tg\ 5°} = 11.4 ;$$

$$K = \frac{C_y}{C_x} = \frac{C_y}{C_{x0} + \frac{C_Y^2}{\pi * \lambda_{ef}}} = \frac{C_y}{0.015 + \frac{C_Y^2}{\pi * 14}} = \frac{C_y}{0.015 + 0.0227 * C_Y^2} = 11.4 ;$$

Coefficient of aerodynamic lift $C_Y^2 - 3.86 * C_y + 0.66 = 0$;

$$Cy_{\ I,II} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} ;$$

$$Cy_{\ I,II} = \frac{3.86}{2} \pm \sqrt{\left(\frac{3.86}{2}\right)^2 - 0.66} = 1.93 \pm 1.75 ;$$

Cy_{I} = 1.93 + 1.75 =3.68

Cy_{II} = 1.93- 1.75= 0.18 (Acceptable)

Aerodynamic drag coefficient of planning by the formula

$$C_{x\ Plan.} = C_{x0} + \frac{C_{Y\ plan.}^2}{\pi * \lambda_{ef}} = 0.015 + \frac{0.18^2}{\pi \times 14} = 0.0157$$

planning speed $V_{Plan.} = \sqrt{\frac{2*G}{\rho*S*\sqrt{C_{Y\ Plan.}^2+C_{x\ Plan.}^2}}} = \sqrt{\frac{2\times500\times9.81}{1.112\times12\times\sqrt{0.18^2+0.0157^2}}} = 63.8\frac{m}{s}$

2) The minimum angle of inclination of the trajectory of sustainable planning will be at the maximum aerodynamic quality:

Then; $\theta_{min} = arctan\ \frac{1}{K_{max}} = arctan\frac{1}{27.1} = 2.1°$;

$$K_{max} = 0.5 * \sqrt{\frac{\pi * \lambda_{ef}}{C_{x0}}} = 0.5 * \sqrt{\frac{\pi \times 14}{0.015}} = 27.1;$$

$$C_{y\ K_{max}} = \sqrt{C_{x0} * \pi * \lambda_{ef}} = \sqrt{0.015 \times \pi \times 14} = 0.81.$$

Coefficient of parasitic drag when θ_{min}

$$C_{y\,K_{max}} = 2 * C_{x0} = 2 \times 0.015 = 0.03$$

planning speed

$$V_{Plan.\theta\,min} = \sqrt{\frac{2 * G}{\rho * S * \sqrt{C_{Y\,Plan.}^2 + C_{x\,Plan.}^2}}} = \sqrt{\frac{2 \times 500 \times 9.81}{1.112 \times 12 \times \sqrt{0.81^2 + 0.03^2}}} = 30.1\,\frac{m}{s}$$

3) The minimum vertical upstream speed required for steady level flight the glider will be at glider flight at maximum aerodynamic quality:

Horizontal flight speed of the glider

$$V = \sqrt{\frac{2 * G}{\rho * S * C_{y\,K_{max}}}} = \sqrt{\frac{2 * 500 * 9.81}{1.112 * 12 * 0.81}} = 30.1\,\frac{m}{s}$$

The angle of trajectory planning

$$\theta_{min} = arctan\,\frac{1}{K_{max}} = arctan\,\frac{1}{27.1} = 2.1°$$

The minimum vertical speed $V_y = V * Sin\,\theta = 30.1 * Sin\;2.1° = 1.1\;\frac{m}{s}$

Decision for Problem Number II

$$tan\theta_{min} = \frac{1}{K_{max}};\, K_{max} = \frac{0.5}{\sqrt{C_{x0} * A}};\, A = \frac{1}{\pi\lambda_{ef}};$$

$$C_{xa} = 2C_{x0}\;at\;\theta_{min}$$

$$\therefore C_{x0} = \frac{C_{xa}}{2} = 0.021$$

$$C_{Y\,most\,advantageous} = \sqrt{\frac{C_{x0}}{A}} = \sqrt{C_{x0} * \pi * \lambda_{ef}} = \sqrt{0.021 \times \pi \times 6.15} = 0.636$$

$$K_{max} = \frac{0.5}{\sqrt{\frac{0.021}{\pi \times 6.15}}} = 15.166$$

$$\therefore tan\theta_{min} = \frac{1}{15.166} = 0.06$$

$$\theta_{min} = arctan\,0.06 = 3.77° \approx 3.8°$$

$$V_{Plan.} => \sqrt{\frac{2 * G}{\rho * S * \sqrt{C_{Y\,Plan.}^2 + C_{x\,Plan.}^2}}}\;;$$

$\frac{G}{S} = 304 \, {}^{kg}/_{m^2}$; $\rho = 1.007 \, {}^{kg}/_{m^3}$ *Then,*

$$V_{Plan.} => \sqrt{\frac{2 * 304}{1.007 \times \sqrt{(0.636)^2 + (0.042)^2}}} = 30.77 \frac{m}{s} = 110.79 \, km/h$$

$$V_{sr.}(speed\ reduction) => \sqrt{\frac{2G * Cos\ \theta}{C_y * \rho * S}} = \sqrt{\frac{2 \times 304 \times Cos\ 3.8^\circ}{0.636 \times 1.007}} = 30.77 \frac{m}{s} = 110.79 \, km/h$$

$\boldsymbol{Result}$: $V_{Plan.}$ $(Planning\ Speed) = V_{sr.}(Speed\ Reduction) at\ zero\ thrust.$

Decision for Problem Number III

The derivative C_y^α is defined by the formula:

$$C_y^\alpha = \frac{\Delta C_{ya}}{\Delta \alpha} = \frac{0.43 - 0.05}{4 - 0} = 0.095 \ Gradian^{-1}$$

Where, ΔC_{ya} is the change in the lift coefficient force of the aircraft C_{ya}, when the angle of attack α is changed from $(0^\circ \div 4^\circ)$;

$\Delta \alpha - Change\ the\ angle\ of\ attack.$

"The calculation is made for a degree measure of the angles of attack, if the angles are assumed in radians, then the value of C_y^α must be multiplied by 57.3"

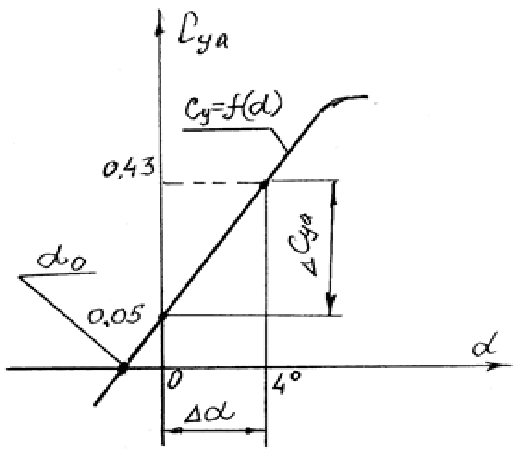


Fig 2: The calculation scheme for the solution of Problem III.

To calculate the zero lift angle, we will write the formula for determining the lift coefficient of the aircraft on the linear part of the dependence $C_{ya} = f(\alpha)$:

$$C_{ya} = C_y^\alpha * (\alpha - \alpha_0)$$

Hence, we determine the angle of zero lift:

$$\alpha_0 = \alpha - \frac{C_{ya}}{C_y^{\alpha}} = 4 - \frac{0.43}{0.095} = -0.53^{\circ}$$

Where, $\alpha = 4^{\circ} - is\ the\ angle\ of\ attack\ of\ the\ aircraft;$

$C_{ya} = 0.43 - is\ the\ lift\ coefficient\ of\ the\ aircraft\ at\ \alpha = 4^{\circ}$.

Decision for Problem Number IV

When the altitude of the flight is increased, the density of air decreases, so that for constant weight and A constant lift factor, it is necessary to increase the flight speed.

For the altitude at H = 0 we have;

$$G = C_{ya} * \frac{\rho_{H=0} * V_{H=0}^2}{2} * S;$$

Where, $C_{ya} - is\ the\ lift\ coefficient\ force\ at\ altitude\ of\ H = 0;$

$\rho_{H=0} = 1.225 \frac{kg}{m^3} - is\ the\ air\ density\ at\ the\ altitude\ of\ H = 0;$

$V_{H=0} - the\ speed\ of\ flight\ at\ the\ altitude\ of\ H = 0;$

$S - is\ the\ wing\ area\ of\ the\ aircraft.$

For the altitude at H =10 000 m we have;

$$G = C_{ya} * \frac{\rho_{H=10000} * V_{H=10000}^2}{2} * S;$$

Where $C_{ya} - is\ the\ lift\ coefficient\ force\ at\ altitude\ of\ H = 10000;$

$\rho_{H=0} = 0.413 \frac{kg}{m^3} - is\ the\ air\ density\ at\ the\ altitude\ of\ H = 10000;$

$V_{H=10000} - the\ speed\ of\ flight\ at\ the\ altitude\ of\ H = 10000.$

When we equate these equations, the weight of the aircraft does not change.

$$\left[C_{ya} * \frac{\rho_{H=0} * V_{H=0}^2}{2} * S\right] = \left[C_{ya} * \frac{\rho_{H=10000} * V_{H=10000}^2}{2} * S\right];$$

Or

$$[\rho_{H=0} * V_{H=0}^2] = [\rho_{H=10000} * V_{H=10000}^2];$$

Whence, we get;

$$\frac{V_{H=10000}}{V_{H=0}} = \sqrt{\frac{\rho_{H=0}}{\rho_{H=10000}}} = \sqrt{\frac{1.225}{0.413}} = 1.72$$

$\boldsymbol{Result}: The\ flight\ speed\ should\ be\ increased\ by\ 1.72\ times.$

Decision for Problem Number V

The required thrust equal to the force of resistance for an aircraft and a car is determined by the formula:

$$P = X = C_x * \frac{\rho * V^2}{2} * S$$

Where, $C_x - is\ the\ coefficient\ of\ aerodynamic\ resistance;$

$C_x - can\ be\ taken\ as\ 0.05.$

$\rho - is\ the\ density\ of\ air;$

$\rho - can\ be\ taken\ to\ be\ 1.225\ \frac{kg}{m^3}$

$S - is\ the\ calculated\ area. For\ an\ airplane\ and\ a\ car\ we\ take\ 40\ m^2$

In this case we obtain:

$$P = X = C_x * \frac{\rho * V^2}{2} * S = 0.05 * \frac{1.22 * V^2}{2} * 40 = 1.22 * V^2$$

Let's perform a trial calculation:

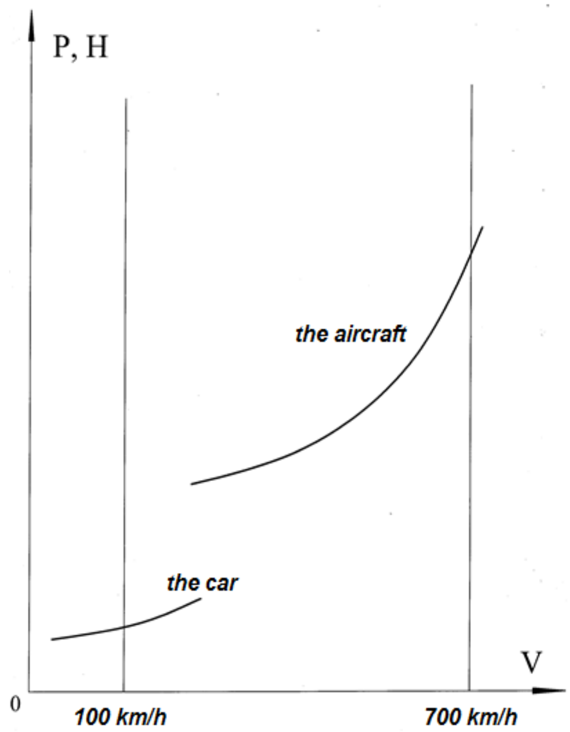
The car	The aircraft
$-On\ Speed\ 50\ \frac{km}{h}$	$-On\ Speed\ 600\ \frac{km}{h}$
$P = X = 1.22 \times 13.9^2 = 236\ N.$	$P = X = 1.22 \times 166.7^2 = 33889\ N.$
$-On\ Speed\ 100\ \frac{km}{h}$	$-On\ Speed\ 650\ \frac{km}{h}$
$P = X = 1.22 \times 27.8^2 = 943\ N.$	$P = X = 1.22 \times 180.5^2 = 39747\ N.$
$\Delta_{Car} = \boldsymbol{V}_{100} - \boldsymbol{V}_{50} = 943 - 236 = 707\ N.$	$\Delta_{Aircraft} = \boldsymbol{V}_{650} - \boldsymbol{V}_{600} = 39747 - 33889 = 5858\ N.$

Result:

The ratio of the required thrust for the car and the aircraft at the same speed increased by $50\frac{km}{h}$.

$$\therefore \frac{\Delta_{Aircraft}}{\Delta_{Car}} = \frac{5858}{707} = 8.3$$

As we see at high speeds, the increase in resistance is much higher than at low speeds. Hence, the curvature of the right side of the curve is sharper in the plane than in the car, since the airplane is moving at higher speeds than the car.



Decision for Problem Number VI

With a steady set of heights, the equations of motion of the aircraft have the form:

P - X - G*sin θ = 0

Y - G*cos θ = 0

Where, P- is the thrust of the engine;

X- is the drag force of the aircraft;

G- is the weight of the aircraft;

Y- lift of the aircraft;

θ - is the angle of inclination of the trajectory Moving to the horizon.

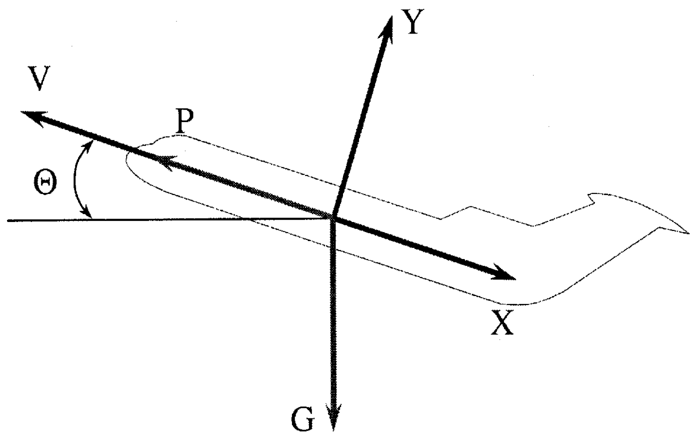


Fig 3: The scheme of forces at climbing.

The aerodynamic quality of the aircraft is determined by the formula using the second equation of motion

$$\mathrm{K} = \frac{Y}{X} = \frac{G * \cos\theta}{X} \; Or \; \mathrm{X} = \frac{G * \cos\theta}{\mathrm{K}};$$

$$\mathrm{P} - \frac{G * \cos\theta}{\mathrm{K}} - G * \sin\theta = 0;$$

$$\bar{P} - \left(\frac{\cos\theta}{K} + \sin\theta\right) = 0;$$

$$\bar{P} - \left(\frac{\cos\theta}{K} + \sin\theta\right) = 0.2 - \left(\frac{\cos\theta}{10} + \sin\theta\right) = 0;$$

$$f = \left(\frac{\cos\theta}{10} + \sin\theta\right) = 0.2$$

θ	5.7°	5.8°	5.9°
f	0.1988	0.2005	0.2023

Thus, the angle of inclination θ = 5.8°.

We can simplify the function f, taking $\cos\theta = 1$ due to the smallness of the slope angle of the trajectory.

$$\left(\frac{1}{10} + \sin\theta\right) = 0.2$$

$$\therefore \theta = \arcsin 0.1 = 5.74°$$

As we see a simplified solution, has an error of about 1% compared to the exact solution.

Vertical component of speed $V_y = V * \sin\theta = 200 \times \sin 5.8° = 20.2 \text{ m/s}$

Increase K by 10% K =11.

$$\theta = \arcsin 0.1091 = 6.26°$$

Increase Thrust-to-weight ratio by 10% $\bar{\mathrm{P}} = \mathbf{0.22}$

$$\theta = \arcsin 0.12 = 6.89°$$

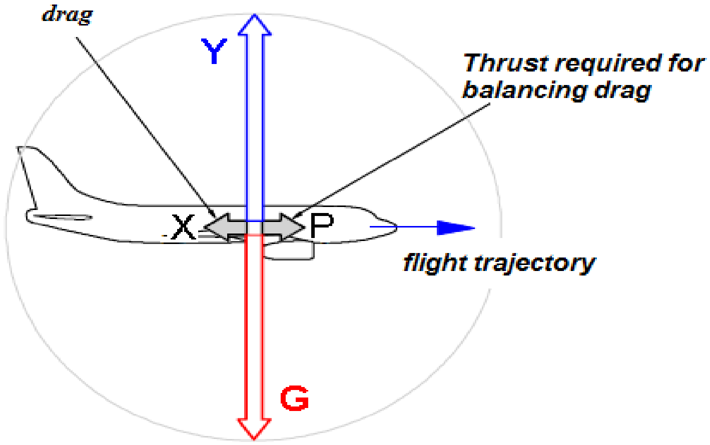
$\boldsymbol{Result}: To\ increase\ the\ angle\ of\ inclination, it\ is\ more\ effective\ to\ increase\ the\ thrust\ by\ 10\%$

4. CONCLUSIONS

1. In order for the aircraft to move uniformly and rectilinearly, the following conditions must be met:

- The sum of all forces directed upwards should be equal to the sum of all forces directed downwards,
- The sum of all forces forward is to be equal to the sum of all forces directed back, and
- The sum of all the moments must be zero.

If these conditions are met, the aircraft will be in a state of equilibrium.



2. In a rectilinear horizontal flight, four forces act on the plane - lift, gravity, traction and drag.

- Gravity is applied at the center of gravity and directed vertically downwards. Gravity is also called the weight of the aircraft.
- Lifting force is applied in the center of pressure (CP), is located in the symmetry plane of the aircraft and is directed at right angles to the flight path (the direction of the incoming air flow).

3. In this Research, I assume that the thrust is directed in the direction of the flight path (although this is not entirely true), and the drag is in the opposite direction.
4. The condition for uniform horizontal flight is the equilibrium of these forces. The lifting force must be adjusted to match the current weight of the aircraft, and the engine's thrust is selected to compensate for drag.
5. Horizontal empennage (stabilizer and elevator) is designed to create the force necessary for balancing the pitch moments arising from the displacement of pressure centers and gravity.

REFERENCES

1. Mkhitaryan AM Flight Dynamics. (2nd edn.), Mechanical engineering press, Moscow, 1978.
2. Salenko SD, Obuhovsky AD, Flight Dynamics. NSTU press, Novosibirsk, 2014.
3. Ostoslavsky IV, Strazheva IV, Flight dynamics. The trajectories of the summer-enforcement apparatus. Mechanical engineering press, Moscow, 1969.
4. Bochkarev AF, Aeromechanics aircraft. Mechanical engineering press, Moscow, 1985.