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CALCULATION OF THE ALIGNMENT OF THE AGRICULTURAL AN-2 AIRCRAFT WITH A REPLACING PISTON ENGINE TO TURBOPROP

Abstract: *the article presents calculation of the alignment an-2 agricultural aircraft with a proposed modernizing turboprop engine installation on different conditions like maximum take-off weight with full commercial load and fuel, in case of full refueling, with full commercial load, with an empty airplane without load and fuel.*

Key words: *alignment, engine installation, maximum take-off weight, piston and turboprop engine.*

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РАСЧЕТ ЦЕНТРОВКИ СЕЛЬСКОХОЗЯЙСТВЕННОГО САМОЛЕТА АН-2 С ЗАМЕНЕННЫМ ПОРШНЕВЫМ ДВИГАТЕЛЕМ НА ТУРБОВИНТОВОЙ

Аннотация: *В статье представлен расчет центровки сельскохозяйственного самолета Ан-2, с предложенным усовершенствованным замененным поршневого двигателя на турбовинтовой в различных условиях полёта: таких как максимальная взлетная масса с полной коммерческой загрузкой и топлива, в случае полной заправки, с полной коммерческой загрузкой, а также при отсутствии груза - пустом самолете без нагрузки и топлива.*

Ключевые слова: *центровка, установка двигателя, максимальная взлетная масса, поршневой и турбовинтовой двигатель*.

Calculation of the alignment of the aircraft.

The proposed modification of the An-2 aircraft design with the replacement of a piston engine to a turboprop requires recalculation of the layout or alignment in different flight conditions, since a change in the design elements entails a change in the calculated alignment relative to the base version. In this regard, one of the most important tasks of the airplane configuration is the determination of the center of mass (CM) of the aircraft and its reduction to this position relative to the average aerodynamic chord of the wing in which:

1. In the variant of the most rear position of the CM, the following condition would be ensured:

$$\overline{X}_{m.b.a} - \overline{X}_F = m_{z.per}^{Cy}$$

Where: $\overline{X}_{m.b.a}$ - maximum back alignment;

$\overline{X}_F$ - relative coordinate plane of focus;

$m_{z.per}^{Cy}$ - Permissible degree (supply) of the longitudinal static stability of the aircraft

2. In the variant of the most forward CM position, the conditions for sufficiency of deviation of elevator rudders or a stabilizer would be provided for balancing the aircraft in take-off or landing mode with deflected wing mechanization.

In the first approximation, $\overline{X}_F$ - defined the following dependence:

$$\overline{X}_F = \overline{X}_{Fw.hs} + \Delta \overline{X}_{Fhs}$$

Where: $\overline{X}_{Fw.hs}$ - Coordinate of the aircraft focus without HS ≈ 0,2…0,22

$\Delta \overline{X}_{Fhs}$ - Displacement of the aircraft focus by the presence of HS = 0,18…0,2

$\overline{X}_F \approx 0,4$

Then:

When calculating the alignment, the determining condition is:

$$\overline{X}_F \leq \overline{X}_{m.b.a} - m_z^{Cy}$$

Where: $m_{z.per}^{Cy}$ - Permissible degree (supply) of the longitudinal static stability of the aircraft

m_Z^{Cy} - for subsonic passenger aircraft = – 0,15

$0,4 \leq \overline{X}_{m.b.a} + 0,15$

Then:

The alignment of the aircraft along the horizontal axis is determined –OX (Fig. 1).

As the origin in the calculation of alignment taking fuselage nose, in order to coordinate all the goods have been positive. In this case, the OX axis is usually combined with the construction horizontal (axis) of the fuselage. An alignment sheet is compiled for the calculation of the alignment.

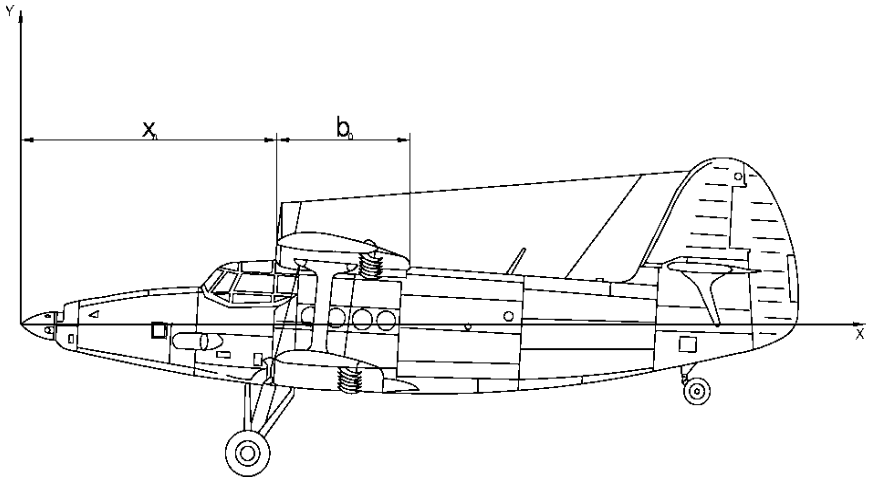

Fig.1 Location of the axes OX and OY in the calculation of the aircraft.

Coordinates of loads are taken from the layout drawing, which is a longitudinal section of the aircraft along the axis of symmetry in scale. In the centering calculations of the first approximation, the masses of the second approximation are taken as the initial masses.

In doing so, we take:

1. The position of the center of mass of the wing (0.4 ... 0.42) · b_a
2. The position of the center of mass of the fuselage is 0.5 · L_f
3. Center of mass of fuel - in the center of the fuel side wing area on a planned projection.
4. The mass of pilots is 160 kg.
5. Center of mass equipment and control - 0,5 · L_f

The alignment of the aircraft is calculated for the following main options:

1. The maximum permissible take-off mass is the total commercial load and fuel.
2. Airplane with full refueling, but without commercial load (ferry variant).
3. The aircraft with full commercial load without fuel (landing version).
4. Empty aircraft without load and fuel (parking option).

As a result of calculations, it is necessary to have:

$$\overline{X}_{m.b.a} = 0,23 \ldots 0,27$$

If this value is not obtained, then it is necessary to mix the wing with respect to the fuselage and the alignment of the aircraft is determined again.

After calculating Σmi xi and Σmi, we obtain the coordinate of the center of mass:

$$x_T = \frac{\sum (m_i \cdot x_i)}{\sum m_i}$$

The value of the centering is determined by the formula:

$$\overline{X}_T = \frac{X_T - X_a}{b_a}$$

Where: X_a - the distance from the origin to the beginning of the b_a

1. For maximum take-off weight with full commercial load and fuel.

Table 2 Airplane alignment list.

Name of the masses of groups.	m_i	x_i	m_i x_i
	dN	m	dN*m

1. Wing.	1309	5,088	6660,192
2. fuselage.	424,5	6,36	2699,82
3. Horizontal stabilizer.	95,4	10,812	1031,4648
4. Vertical stabilizer	39,5	10,812	427,074
5. The rear landing gear.	40,4	10,812	436,8048
6. The main landing gear.	229,1	2,544	582,8304
7.Power plant.	417	1,272	530,424
8. Equipment and control systems	371,4	6,36	2362,104
9. Fuel.	906,7	5,2	4714,84
10. Commercial load	1500	5,406	8109
11. Service load	160	2,544	407,04
Amount.	5493		27961,594

CALCULATION:

$$X_m = \frac{27961,594}{5493} = 5,09 \text{ м}$$

$$\overline{X}_m = \frac{5,09 - 4,53}{2,4} = 0,23$$

2. In case of full refueling, without commercial load (ferry variant).

Table 3 Airplane alignment list.

Name of the masses of groups.	m_i	x_i	$m_i\ x_i$
	dN	m	dN*m
1. Wing.	1309	5,088	6660,192

2. fuselage.	424,5	6,36	2699,82
3. Horizontal stabilizer.	95,4	10,812	1031,4648
4. Vertical stabilizer	39,5	10,812	427,074
5. The rear landing gear.	40,4	10,812	436,8048
6. The main landing gear.	229,1	2,544	582,8304
7.Power plant.	417	1,272	530,424
8. Equipment and control systems	371,4	6,36	2362,104
9. Fuel.	906,7	5,2	4714,84
10. Service load	160	2,544	407,04
Amount.	3993		19852,594

CALCULATION:

$$X_m = \frac{19852,594}{3993} = 4,97м$$

$$\overline{X}_m = \frac{4,97 - 4,53}{2,4} = 0,184$$

3. With full commercial load, but without fuel (landing option).

Table 4 Airplane alignment list.

Name of the masses of groups.	m_i	x_i	$m_i\ x_i$
	dN	m	dN*m
1. Wing.	1309	5,088	6660,192

2. fuselage.	424,5	6,36	2699,82
3. Horizontal stabilizer.	95,4	10,812	1031,4648
4. Vertical stabilizer	39,5	10,812	427,074
5. The rear landing gear.	40,4	10,812	436,8048
6. The main landing gear.	229,1	2,544	582,8304
7.Power plant.	417	1,272	530,424
8. Equipment and control systems	371,4	6,36	2362,104
9. Commercial load	1500	5,406	8109
10. Service load	160	2,544	407,04
Amount.	4586,3		23246,754

CALCULATION:

$$X_m = \frac{23246{,}754}{4586{,}3} = 5{,}06\,\text{м} \quad \overline{X}_m = \frac{5{,}06 - 4{,}53}{2{,}4} = 0{,}224$$

4. With an empty airplane without load and fuel (parking option).

Table 5 Airplane alignment list.

Name of the masses of groups.	m_i	x_i	$m_i\ x_i$
	dN	m	dN*m
1. Wing.	1309	5,088	6660,192
2. fuselage.	424,5	6,36	2699,82
3. Horizontal stabilizer.	95,4	10,812	1031,4648

4. Vertical stabilizer	39,5	10,812	427,074
5. The rear landing gear.	40,4	10,812	436,8048
6. The main landing gear.	229,1	2,544	582,8304
7.Power plant.	417	1,272	530,424
8. Equipment and control systems	371,4	6,36	2362,104
9. Service load	160	2,544	407,04
Amount.	3086,3		15137,754

CALCULATION:

$$X_m = \frac{15137,754}{3086,3} = 4,9 \text{ м} \qquad \overline{X}_m = \frac{4,9 - 54,53}{2,4} = 0,156$$

As the center of mass of the aircraft, we choose the value obtained when calculating the first variant with the maximum admissible take-off mass - full commercial load and fuel.

Therefore, X_m = 5.09 m

The obtained calculated results and comparative characteristics allow qualitatively and quantitatively assess changes in the aircraft centering on different flight conditions, as well as continue research on the feasibility of further modifying the design of the An-2 aircraft.

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