MINISTRY OF EDUCATION AND SCIENCE OF THE RUSSIAN FEDERATION
SAMARA STATE AEROSPACE UNIVERSITY
(NATIONAL RESEARCH UNIVERSITY)

CONCEPTUAL AIRCRAFT DESIGN

Term Project Example

S A M A R A

2011

Compiler: **Reznichenko Gennadiy A.**

Translated by: **Kancher Galina S**.

Conceptual Aircraft Design = Концептуальное проектирование самолетов [Electronic resource]: Term Project Example / The Ministry of Education and Science of the Russian Federation, Samara State Aerospace University; Compiler G.A. Reznichenko. - Electronic text and graphic data (345 kb). - Samara, 2011. - 1 CD-ROM.

Guide is an example of a term project on discipline “Conceptual aircraft design” for the specialties 160201 “Airplane and Helicopter Construction”, 160901 “Technical Maintenance of Aircrafts and Engines” and for the Masters programme «Designing, construction and CALS-technologies in Aeronautical Engineering» for education direction 160100.68 «Aeronautical Engineering».

Prepared by the Department of Aeronautical Engineering SSAU.

CONTENTS

SYMBOLS

$A_{го}$, $A_{во}$ – volume coefficients of horizontal and vertical tail.

a – speed of sound;

α – wing angle of attack;

B, $\bar{B}$ – landing gear track, relative landing gear track;

b – wing or tail chord;

b_A – mean aerodynamic chord of wing or tail;

$b_о$ – root chord of wing or tail;

$b_к$ – tip chords of wing or tail;

c – thickness-to-chord ratio of wing or tail;

$C_р$ – specific fuel consumption of turbojet engine;

$C_е$ – specific fuel consumption of turboprop/turbofan engine;

C_{xa}, C_{ya} – drag and lift coefficients in the velocity-related coordinate system;

C_{xa0} – zero-lift drag coefficient (C_{ya}=0);

$D_о$ – induced drag ratio;

$D_ф$ – fuselage diameter;

δ – deflection angle of control surfaces and wing high-lift devices;

f – safety factor, the friction coefficient;

g – acceleration due to gravity;

γ – landing gear offset angle;

$\gamma_{дв}$ – engine specific weight;

H – flight altitude;

χ – sweep angle of wing or tail;

K – lift-to-drag ratio;

κ – coefficient;

L – flight range;

l – wing span, tail span;

$l_{разб}$ – the takeoff run;

λ – aspect ratios of wing or tail;

M – Mach number;

m – weight of an aircraft or its part, engine bypass ratio;

N – engine power;

N – aircraft power-to-weight ratio;

$n_р$, $n_э$ – ultimate and limit load factors;

$n_{пас}$ – number of passengers;

P – engine thrust;

P_0 – aircraft start thrust-to-weight ratio;

p_0 – wing loading;

q – dynamic pressure;

ρ – air density;

Δ – air relative density;

S – wing area, tail area;

S – the relative tail area;

η – wing taper ratio, tail taper ratio;

V – flight velocity;

V_y – rate of climb;

$X_м$ – center of gravity coordinate;

X_F – aerodynamic center coordinate;

φ – aircraft overturning angle;

$\varphi_н$ – coefficient to account for thrust change with flight altitude;

$\varphi_{др}$ – engine throttling coefficient;

ψ – aircraft ground angle;

ξ – coefficient to account for thrust change with flight velocity.

ABBREVIATIONS

daN=10N – decanewton;

MAC – mean aerodynamic chord;

TJEA – turbojet engine with the afterburner duct;

BTJE – the bypass TJE;

RE – the reciprocating engine;

TPE – the turbo-propeller engine;

TPFE – the turbo-propeller and fan engine;;

SUBSCRIPTS

в – wave;

взл – takeoff;

во/го – vertical/horizontal empennage;

дв – engine;

зп – landing approach;

к, кон – frame, airframe;

ком – commercial;

крейс – cruise, cruising;

кр – critical, limit;

0 – initial, start value;

об упр – equipment and control system;

отр – airplane takeoff;

наб – climb;

нз – air navigation margin;

пас – passengers;

пос – landing;

пн – payload;

полн – total load;

п, (пот) – altitude limit;

пуст – empty;

р – calculated;

разб – takeoff run;

рейс – flight;

рв/рн – elevator/rudder;

сн – equipment;

су – power plant;

ф – fuselage;

цн – payload;

ш – landing gear;

эк – crew.

1 STATISTICS ANALYSIS

For the development of initial specification, you must first examine the statistical material, for which we choose the five planes of different schemes: the normal scheme.

Boeing 747-400

Boeing Model 747-400 - long-haul passenger aircraft developed by the American company Boeing.

Airbus A330-300 (Airbus A330-300)

A330-300 - A340-300 prototype, but has only 2 engines. Range up to 8980 km.

Airbus A380

Airbus A380 - wide-body passenger jet, created concern «Airbus SAS».

Table 1- Basic Data of the Prototype Aircraft

№	**Aircrafts**	**1**	**2**	**3**	**4**	**5**
1	Airplane model, manufacturer, year and country	Boeing 747-400 Freighter, Boeing, USA, 1989	Airbus A340-300, Airbus SAS, European Union, 1992	Airbus A330-300, Airbus SAS, European Union, 1992	Il-96-400M, Ilyushin EDB, Russia, 2001	Airbus A380, European Union, 2005
2	Crew, people	2	2	2	2-3	2
	Characteristics of the propulsion system					
3	Engine type, number (n), thrust P_0 (daN), power N_0 (kW)	Turbofan PW4062, 4 x 28600	Turbofan CFMI CFM56-5C4, 4 x 15400	Turbofan P&W PW4168A, 2 x 30800	RDD PS-90A-1, 4 x 17400	Rolls-Royse Trent 900 or Engine Allianse GP 7000 4 x 31100
4	Fuel consumption rate C_{p0} (kg/daNh), C_{e0} (kg/kWh)	0,597	0,596	0,591	0,580	0,557
5	By-passratio$m$	5,1	6	6	4,8	8
6	Specific engine weight γ_e, ($\gamma = m_e g$, daN/kW)	0,150	0,1140	0,134	0,183	0,231
	Weight characteristics					
7	Take-off mass m_0, kg	396900	275000	230000	270000	560000
8	Payload (combat load) mass $m_{ком}$, kg	70620	50900	51700	58000	66400
9	Empty airplane mass $m_{пуст}$, kg	181120	130900	122200	123000	276800
10	Fuel mass m_T, kg	145160	94000	5800	123622	251100
11	Specific wing load P_0 , daN/m^2	0,822 0,194	0,815 0,188	0,775 0,225	0,785 0,215	0,881 0,102

12	Weight efficiency $k_{Bo}=\frac{m_0-m_{kom}}{m_0}$ or $k_{kom}=\frac{m_{kom}}{m_0}$	733,5	760,5	636,1	771,4	650.13
13	Thrust-to-weight ratio (power-to-weight ratio) $\overline{P_0}=\frac{10P_0}{m_0g}$; ($\overline{N_0}=\frac{10N_0}{m_0g}$) (kW/daN)	0,079	0,056	0,134	0,064	0,01
	Geometric characteristics					
14	Wing area S, м^2	541,1	361,6	361,6	350	845
15	Wing span ℓ, м	64,4/7,66	60,3/10,06	60,3/10,06	60,1/10,32	79.8/7.54
16	Wing aspect ratio λ / wing taper ratio η	9,54/3,66	7,2/5	7,2/5	8,6/5	11.9/4.37
17	Wing sweep angleχ^0	37,5	30	30	30	33.5
18	Relative thickness $\overline{C_0}$	0,09; 0,09	0,25; 0,125	0,25; 0,125	0,18; 0,1	
19	Fuselage diameter $D_ф$, м / fuselage aspect ratio $\lambda_ф$	6,57/10,56	5,64/11,28	5,64/11,28	6,08	7.14
20	Fuselage nose part aspect ratio / fuselage aft portion aspect ratio $\lambda_{нч}$ / $\lambda_{хч}$	2/3,4	1,7/3	1,7/3	2/3,2	2,1/3,6
21	Relative distance from fuselage nose to wing central chord	0,258		0,35	0.296	0.332
22	Horizontal tail (HT) area $S_{го}$,м^2/ $\overline{S_{го}}$	127,9	80,64	80.64	93.65	231
23	HT aspect ratio / HT taper ratio $\lambda_{го}$ / $\eta_{го}$	3,75/3,28	4,57/2,25	4,57/2,25	4.5/4	4.3/2.5
24	HT sweep angle $\chi_{во}$	35	30	30	30	35
25	HT arm $L_{го}$, m /$\overline{L}_{го}$	38,15/3,99	29.79/4,13	29.79/4,13	29.594/4.33	44.03/3.69
26	Coefficient of HT static moment $A_{gf}=\frac{S_{gf}L_{gf}}{Sb_A}$	0,543	0,595	0,595	0,920	0.725
27	Vertical tail (VT) area $S_{во}$, m^2 /$\overline{S}_{во}$	115	50,4	50,4	51	125.03
28	VT aspect ratio / VT taper ratio $\lambda_{во}$ / $\eta_{во}$	1,19/3,37	1,4/3,2	1,4/3,2	1.46/2.7	1.68/3.89
29	VT swept angle $\chi_{во}$	45	45	45	45	45
30	VTarm$L_{го}$m / $\overline{L}_{во}=\frac{L_{во}}{\ell}$	36,05/0,56	30,51/0,505	30,51/0,505	27.773/0.46	36.260/0.45
31	Coefficient of VT static moment $A_{во}=\overline{S}_{во}\overline{L}_{во}$	0,261	0,163	0,163	0.59	0.45
32	Landing gear tread $\overline{B}=\frac{B}{\ell}$	0.362	0,403	0,382	0.408	0.416
33	Main landing gear offset	0.171	0,177	0,177	0.173	0.29
	Performance characteristics					
34	Maximum velocity over altitude V_{max}/H, km/(h*m)	1150/10670	1100/12500	1050/11800	900/12000	950/15200

35	Cruise velocity over altitude $V_{кр}/H_{кр}$, km/(h*m)	940/10700	900/10650	890/10050	870/12000	900/13100
36	Landing velocity $V_{пос}(V_{зп})$, kmph	261 (285)				
37	Flight range with full payload L_p, km	13750	12500	11800	13100	13115
38	Flight range with reduced payload L_{max}, km	7170	12400	8980	7600	15000
39	Take-off run (or runway length $L_{ВПП}$), m	13430	13500	11900	10400	15200
40	Climb rate V_{y0}, m/s	3020	3000	2250	2500	2050
41	Maximum altitude H_n, m					
	Others					
42	Number of passengersn_{nac}	416/524/660	295/335/440	295/335	436	858/525
43	Cargo compartment dimensions *BxHxL*, m x m x m					
44	Airfield type	concrete	concrete	concrete	concrete	concrete
45	Fuel efficiency k_{mon}, g/pass km (g/t km)					
46	Armament					
47	Calculated g-load n_{max} (n_A)					
48	Airplane cost				267 mil $	327,4 mil $

1.1 Scientific and technological forecasting

Statistics on the aircraft-prototypes, released earlier, provides statistical graphs of their parameters on various factors of interest.

We construct a statistical chart and trend line depending on the time t extension:

As the trend function it seems logical to take a linear dependence of parameter on time:

$$x(t_i) = a + bt.$$

The unknown parameters of the trend:

$$a = (BC - AD)/(nC - A^2);$$

$$b = (nD - AB)/(nC - A^2);$$

$$x_0 = a.$$

Where

$$A = \sum_{i=0}^{n} ti;\ C = \sum_{i=0}^{n} (ti)2;$$

$$B = \sum_{i=0}^{n} xi D = \sum_{i=0}^{n} xiti,$$

B=6,8+7,73+8+7,5+7,66+10,06+10,06+9,22+10,32+7,54=84,89

A=1981+1983+1986+1988+1989+1991+1992+1997+2001+2005=19913

C=1981*2+1983*2+1986*2+1988*2+1989*2+1991*2+1992*2+1997*2+2001*2+2005*2==29909

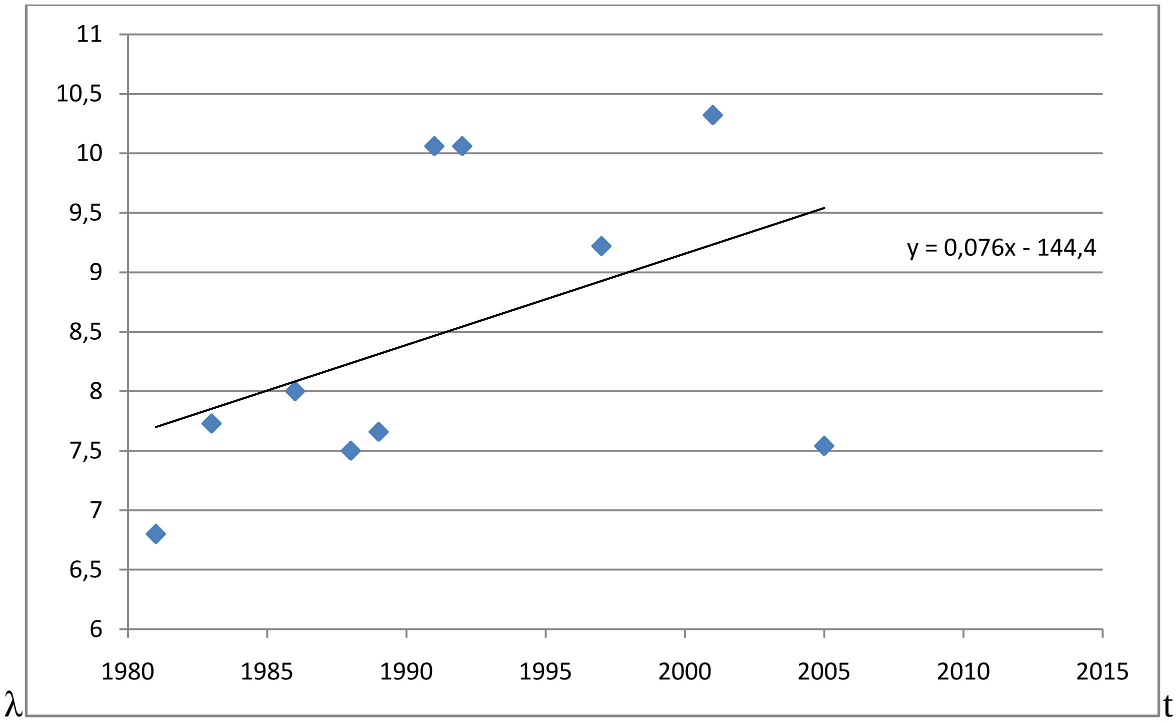
D=1981*6,8+1983*7,73+1986*8+1988*7,5+1989*7,66+1991*10,06+1992*10,06+1997*9,22+2001*10,32+2005*7,54=189732,79

a = (BC –AD) ⁄ (nC –$A^{2)}$=84.89*39826-19913*189732,79/10*39826-19913^2=8,53

b = (nD –AB) ⁄ (nC –A^2) =10*189732,79-19913*84.89/10*39826-19913^2=0,0005

The predicted value

$$x_п = a + bt_п;$$
$$x_п=8,55+0,0005*2015=9,6.$$



We construct a statistical chart and trend line which shows the dependence of the sweep angle on the cruiser speed.

It is logical to take a linear dependence of parameter on time as the function trend:

$$x(t_i) = a + bt.$$

The unknown parameters of the trend:

$$a = BC – AD ⁄ nC – A^2;$$
$$b = nD – AB ⁄ nC – A^2;$$
$$x_0 = a.$$

Where

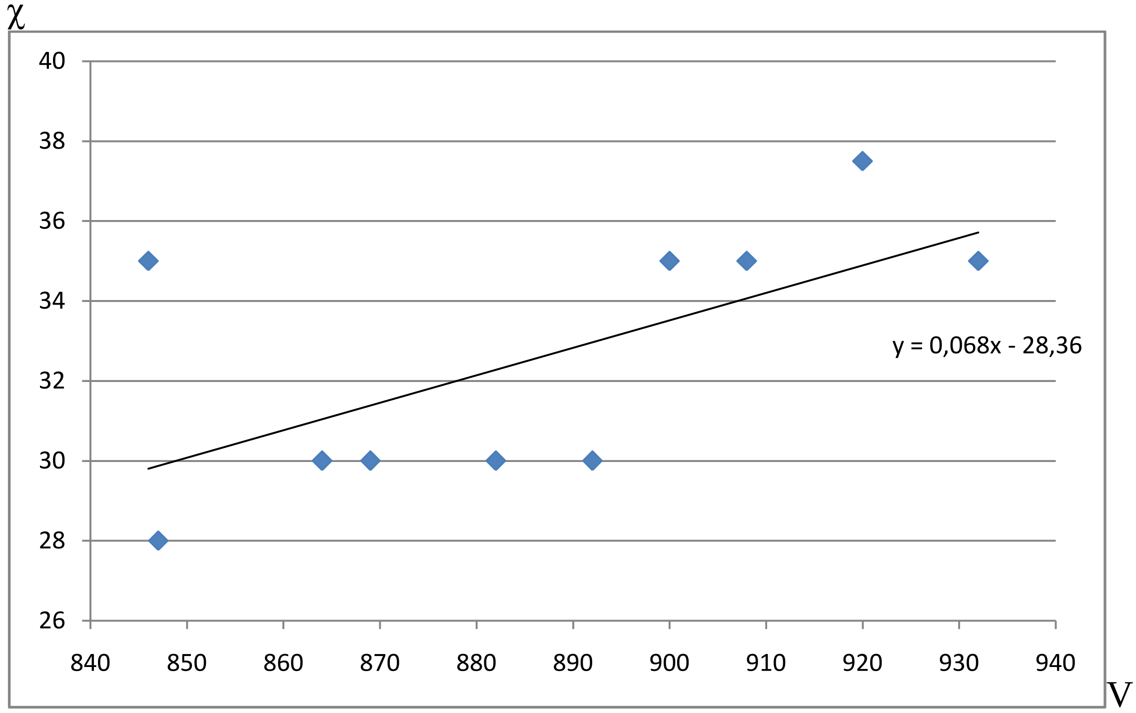
$$A = \sum_{i=0}^{n} ti; \qquad C = \sum_{i=0}^{n}(ti)2;$$

$$B = \sum_{i=0}^{n} xi D = \sum_{i=0}^{n} xiti,$$

A=908+847+846+932+920+892+882+864+869+900=8860
B=35+28+35+35+37,5+30+30+30+30+35=325,5
C=908*2+847*2+846*2+932*2+920*2+892*2+882*2+864*2+869*2+900*2=17720
D=908*35+847*28+846*35+932*35+920*37,5+892*30+882*30+864*30+
+869*30+900*35=288936
$a = BC – AD / nC – A^2 = 325,5*17720-8860*288936/10*17720-8860^2=29$
$b = nD – AB / nC – A^2 = 10*288936-8860*325,5/10*17720-8860^2 = 4,25$

The predicted value

$$x_п = a + bt_п.$$



1.2 Analysis of the project situation

Let's note the specific features of the development and the level of excellence achieved by aircraft of this type.

1. The characteristics of the propulsion system:
Maximum thrust: A-380 engines with P = 31 100 daN;
Specific fuel consumption: C = 0,38;
The thrust-to-weight ratio: m = 0,176.

2. Weights characteristics:
Full load ratio: R = 0,498;
Load ratio of payload: K = 0,15.

3. Geometrical characteristics:
Aspect ratio $\lambda \in [7,54;10,32]$
Taper ratio $\eta \in [3,66;5]$
Sweep angle $\chi \in [30^\circ;37,5^\circ]$
Fuselage aspect ratio $\lambda_{ф} \in [6,92;9,95]$
Relative base of the chassis $b_{отн} \in [0,36;0,416]$
Relative track of the undercarriage $b_{кол} \in [0,171;0,29]$

4. Flying characteristics:
Cruising Speed: $v_{кр} = 900$ km / hour.

Let’s us consider the basic ways and means to ensure the technical excellence of aircraft:

- The application of supercritical airfoils, allowing to increase the relative thickness of the wing, as well as its span, with no significant increase in weight;
- The use of vertical wingtips, weakening the cross-flow on the wing, and thus able to reduce vortex drag and fuel consumption. The numerical value of the effect of their use in combination with supercritical airfoils, may be 5%;
- Extensive use of composite materials in the construction of load-bearing elements (carbon composites), fairings and flaps (GRP). The effect of their use can be expressed in the reduction of the mass construction of aircraft by 10%.
- The use of electric remote control, display and new equipment, which can lead to a decrease in its weight by 8%.
- Installation of efficient modern turbofan engines.

2 DEVELOPMENT OF INITIAL SPECIFICATION

Initial specification of the projected plane define the basic goals and objectives of its establishment, terms of use, asking a suitable values of key parameters and characteristics of the aircraft, scheduled to the conditions of its production and operation.

2.1 Functional Requirements

Appointment of an airplane: the passenger long-range wide-body aircraft

The main tasks performed by the base plane: transport of passengers over distances up to 8,200 km.

The use cases and possible modifications: the plane can be used as a passenger (the number of passengers up to 420 people at 3 class version), as well as military transport (transport of equipment or landing).

The task forces: passengers

Crew of two people.

Terms of basing class airport, the type of runway, the possibility of short takeoff and landing: plane based on the ground not less than Class I with a length of 3,000 m runway.

2.2 General technical requirements

These requirements define the basic performance of the future aircraft, its reliability and safety. These include such requirements as:

1. Ease of boarding and landing
2. High cruising speed
3. High fuel efficiency
4. Good takeoff and landing performance
5. Ease of maintenance and repair
6. Cabin volume of passengers

We make the ranking of claims.

Table 2 – Ranking of claims

	1	2	3	4	5	6	Рейтинг	Место
1	X	2	0	0	1	0	3	4
2	0	X	0	0	1	0	1	6
3	2	2	X	1	2	2	9	1
4	2	2	1	X	1	2	8	2
5	1	0	0	0	X	1	2	5
6	1	2	0	0	1	X	4	3

The results of paired comparisons allow us to write the basic requirements for this aircraft in descending order of importance:

1. High fuel efficiency
2. Good takeoff and landing performance
3. Cabin volume of passengers
4. Ease of boarding and landing
5. Ease of maintenance and repair
6. High cruising speed

2.3 Aircraft performance requirements

• cruising speed $V_{крейс}$ of 900 km / h ($M_{крейс}$= 0.83);

• cruising altitude $H_{крейс}$ of at least 10 000 m;

• the length of the takeoff $l_{разб}$ at maximum takeoff weight is not more than 3000 m;

• landing approach speed $V_{з.п}$ is not exceeding 270 km / hour.

2.4 Production and technological requirements

1. Batch production.
2. Broad use of one-piece panels
3. The main construction materials are aluminum and titanium alloys, steel and composite materials.

2.5 Performance Requirements

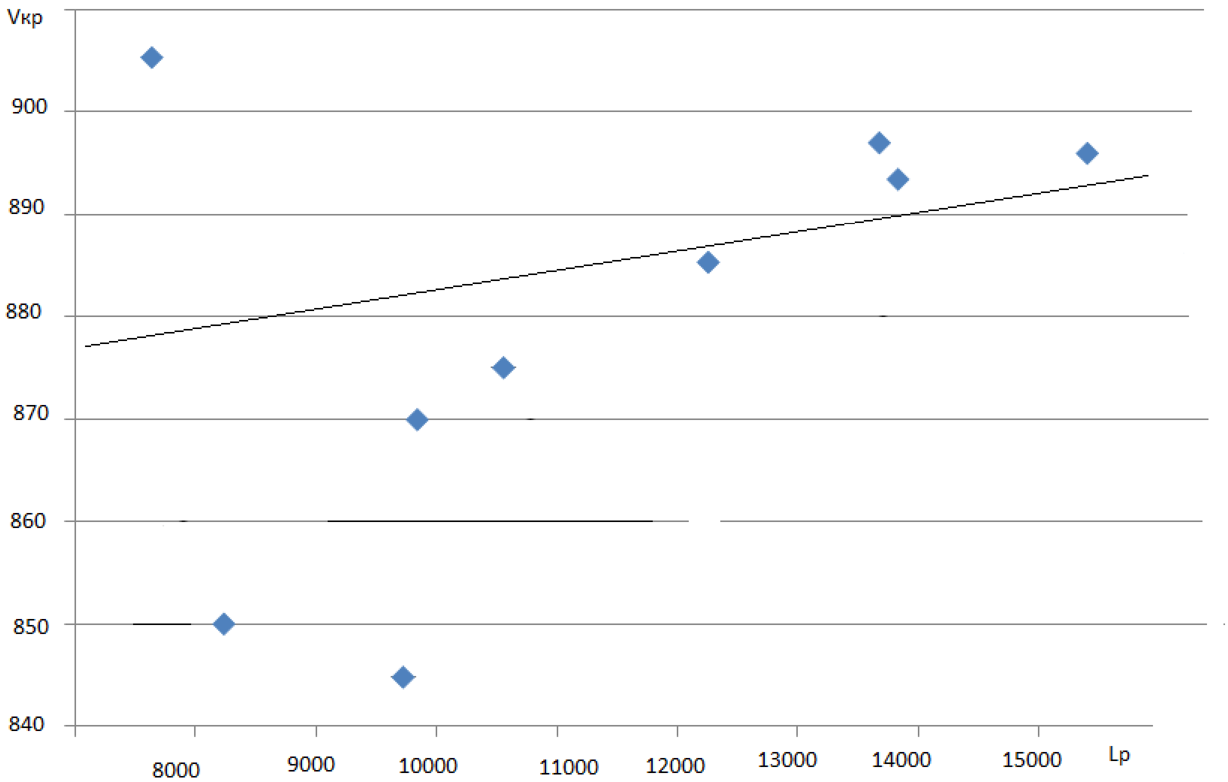
1. Ensurance of the availability of facilities for servicing, repair.
2. Allow automated control of the major aircraft systems.
3. Easily removable assemblies and components.
4. Ensurance interchangeability of units of aircraft.
5. Ensurance unification and standardization of products serviced aircraft.

2.6 The technical and economic requirements

1. Usage of load-bearing and secondary structures made from advanced materials to reduce weight and, consequently, the cost of transportation.

2. The coefficient of fuel efficiency with the progress in engine and aerodynamic characteristics of high radically new airframe K_{mon} to 100g/tkm.

We define a trend line Vкр(Lp)



A=13430+13500+1190010400+15200+7820+13000+9700+8170+9700=112820

B=940+900+890+870+900+908+932+846+847+864=8897

C=A2=112820=225640

D=13430*940+13500*900+11900*890+10400*870+15200*900+7820*908+

+13000*932+9700*846+8170*847+9700*864=100816750

a=(8897*225640-112820*100816750)/10*225640-112820^2=889

b=(10*100816750-112820*8897)/10*225640-112820^2=0,0003

3 BASELINE CONFIGURATION DEVELOPMENT

3.1 Selection of the wing parameters

Based on the analysis of aircraft we perform a selection of the optimal geometrical parameters for the designed wing aircraft.

With the increase of the wing aspect ratio λ increases aerodynamic efficiency (K), hence, decreases G_T and, therefore, reduced transportation costs. It is also improved λ by increasing of the aircraft landing, which reduces the required length. On the other hand, it increases λ with the increasing weight of the wing, and, consequently, the weight of the payload.

Aspect ratio are assigned, based on these reasons: $\lambda = 8{,}5$

High value of taper ratio η lead to the strong tendency of flow separation and increase in induced drag at the wing tips. We choose from these considerations, and analyzing the statistics $\eta = 4$.

The designed aircraft wing is swept. Based on the foregoing analysis and statistics ($\chi = 30...37{,}5°$) take $\chi = 32°$.

The relative thickness of the wing affects the weight of the wing and at cruising speed. With the increase of c the weight of the wing is reduced, but you have to reduce the cruising speed of the aircraft. In this regard, the relative thickness of the wing is assigned: $\overline{C_0} = 0{,}12$.

In the low-wing, when placing the propulsion system on the wing have to do V-wing positive, in order to prevent the possibility of contact between power plant and ground during landing. Accepted V - wing is 6^0.

3.2 Selection of the fuselage parameters

The round shape is preferred for pressurized fuselage, loaded by internal pressure, as it excludes the appearance of large local stresses in the shell and, therefore, provides the least weight design.

Given the statistics ($\lambda_Ф = 6{,}08...11{,}28$) accept $\lambda_Ф = 10$. We select $\lambda_{НЧФ} = 1{,}2$ and $\lambda_{ХЧФ} = 2{,}8$.

We will take the fuselage diameter, based on statistical data. Since this class of airplanes in the passenger cabin perform mainly three rows of armchairs with three chairs in a row, then using statistical data, the diameter of the fuselage is adopt $d_Ф \approx 6{,}2m$.

3.3 The choice of the tail parameters

Symmetrical airfoils with a relative thickness slightly less than it is for the airfoils of the wing, a slight aspect ratio and greater sweep angle are chosen for the tail.

According to statistics accept:

- For the horizontal tail aspect ratio $\lambda_{ГО} = 4$, taper ratio $\eta_{ГО} = 3$, relative thickness $\overline{c_{ГО}} = 0{,}09$ and the angle of sweep $\chi_{ГО} = 35^{\circ}$.
- For the vertical tail aspect ratio $\lambda_{ВО} = 1{,}5$, taper ratio $\eta_{ВО} = 3.4$, relative thickness $\overline{c_{ВО}} = 0{,}09$ and the angle of sweep $\chi_{ВО} = 45^{0}$.

The relative area of the horizontal and vertical tail is $\overline{S_{ГО}} = 0{,}25; \overline{S_{ВО}} = 0{,}2$ Volume coefficients $A_{ГО} = 0{,}7$; $A_{ВО} = 0{,}085$.

3.4 Selection of the control surfaces parameters

According to the table [1, Table 3.4] the high-lift devices selects to increase the lift of the wing slat and choose the double-slit sliding flap with a relative chord $\overline{b_{З}} = 0{,}3$, angle $\delta_{З} = 40^{0}$. It gives a maximum lift coefficient $c_{y\max} = 2{,}8$ at the landing angle of attack $\alpha_{пос} = 13^{0}$.

Basic controls: controlled stabilizer, rudder, ailerons. The relative areas of the rudders:

$\bar{S}_{РВ} = 0{,}35$ $\overline{b_{В}} = 0{,}25 - 0{,}3$ $\overline{b_{пр}} = 0{,}1$;

$\bar{S}_{РН} = 0{,}35 - 0{,}45$ $\overline{b_{Н}} = 0{,}25 - 0{,}3$ $\overline{b_{эл}} = 0{,}2 - 0{,}25$.

Angles of deflection:

$$\delta_{РВ} = \begin{cases} -25 \div 30^{\circ} \\ +15 \div 20^{\circ} \end{cases} \qquad \delta_{РН} = \begin{cases} -20 \div 25^{\circ} \\ +20 \div 25^{\circ} \end{cases} \qquad \delta_{ЭЛ} = \begin{cases} -15 \div 18^{\circ} \\ +15 \div 18^{\circ} \end{cases}$$

3.5. Selection of the undercarriage parameters

The main geometrical characteristics of the undercarriage with nose wheel are chosen from statistical data and guided by the recommendations of [1]:

- Aircraft ground angle $\psi = 0^{0}$
- The angle of the wing root section $\alpha_{ЗАКЛ} = 2^{0}$
- Landing angle of attack $\alpha_{ПОС} = 7^{\circ}$
- Overturning angle of the aircraft $\varphi = \alpha_{ПОС} - \alpha_{ЗАКЛ} - \psi = 7^{0} - 2^{0} - 0^{0} = 5^{0}$
- Landing gear offset angle $\gamma = \varphi + 2^{0} = 7^{0}$
- Wheel base $b = (0{,}35...0{,}4) \cdot l_{Ф}$

3.6 The relative position of the aircraft units

The wing-fuselage: We choose the type of wing attachment scheme – low-wing. The angle of the wing $\alpha_{ЗАКЛ} = 2^0$ is chosen from the cruise flight conditions with minimal drag.

The wing-feathers: Our plane is of the normal scheme. According to statistics, we choose the relative position of horizontal and vertical tail o $\overline{L_{ВО}} = 0{,}45$, $\overline{L_{ГО}} = 0{,}3$. The volume coefficient is $A_{ГО} = 0{,}7$; $A_{ВО} = 0{,}085$.

3.7 Selection of the propulsion system

We select turbo-jet turbofan engine as the engines - prototype. On passenger aircraft according to airworthiness requirements should be at least two engines, which is dictated by the terms of take-off with a failed engine. According to the statistical data we accepted: at takeoff (N = 0, V = 0) $c_{уд} = 0{,}595 кг / кгс \cdot ч$.

• Fuel consumption - no more than 0,6 kg / h daN •

• The thrust-to-weight of the engine - no more than 0,18.

3.8 Selecting the number of engines and their placement on the aircraft

When we are landing with a roll (up to 4º), engines should not touch the ground, so we are placing the engines on pylons to create a large dihedral angle equal to 6º.

Thus, we are taking at least two engines, and place them under an airplane wing.

4 DETERMINATION OF INITIAL AIRCRAFT PARAMETERS

The initial data for further development will be the range 8200 km and passenger capacity – 420 seats.

4.1 Determination of the specific load on the wing

The selected value of the specific load on the wing is tested on the following conditions:

- Providing a given speed approach:

$$p_0 \le \frac{C_{y\max\, пос} \cdot V_{з.п}{}^2}{30{,}2(1-m_m)}$$

Then

$$p_0 \le \frac{2{,}8 \cdot 71{,}5^2}{30{,}2(1-0{,}3)} = 677{,}1\, daN/m^2$$

- Provision of a given cruising speed on the estimated altitude:

$$p_0'' \le \frac{\Delta_H \cdot V_{кр}{}^2}{13(1-0{,}6m_m)}\sqrt{C_{xa0}\lambda_э} = \frac{0{,}297 \cdot 250^2}{13(1-0{,}6 \cdot 0{,}3)}\sqrt{0{,}029 \cdot 7{,}02} = 785{,}7\, daN/m^2$$

Accepted minimum value p_0=677,1 daN/м^2.

4.2 Aerodynamic parameters

The coefficient of the lift slope in the subsonic zone:

$$D_0 = \frac{k}{\pi \cdot \lambda_{эф}}$$

Then

$$D_0 = \frac{1{,}02}{\pi \cdot 7.02} = 0{,}046$$

$K_{кр} = 0{,}85 \cdot K_{\max}$ - aerodynamic efficiency in cruise mode;

$K_{\max} = \dfrac{1}{2 \cdot \sqrt{C_{X_0} \cdot D_0}}$ - the maximum aerodynamic efficiency;

$$K_{\max} = \frac{1}{2 \cdot \sqrt{0{,}0286 \cdot 0{,}046}} = 13{,}9\ ;$$

$$K_{кр} = 0{,}85 \cdot 14{,}677 = 11{,}8\,.$$

5 IDENTIFICATION OF AIRCRAFT THRUST NEEDS

Aircraft $\overline{P}_0 = 10P_0 / m_0 g$,

where

P_0 - the total takeoff thrust of all engines daN.

1. Flying at a cruising speed $V_{кр}$ at altitude $H_{кр}$: $\overline{P_0}$
2. Provision of a given length runway ℓразб:

$$\overline{P_0} = 1{,}05\left[\frac{1{,}2\ p_0}{C_{ya\ max\ взл}\ \ell_{разб}} + \frac{1}{2}\left(f + \frac{1}{K_{разб}}\right)\right]$$

$$\overline{P}_0 = 1{,}05\left[\frac{1{,}2 \cdot 677{,}1}{2 \cdot 2200} + \frac{1}{2}\left(0{,}02 + \frac{1}{10}\right)\right] = 0{,}256$$

3. Taking off with an engine failure on takeoff:

$$\overline{P_0} = \frac{1{,}5\ n_{дв}}{n_{дв} - 1}\left(\frac{1}{K_{наб}} + \tan\theta_{min}\right);$$

$$\overline{P}_0 = \frac{1.5 \cdot 4}{4 - 1}\left(\frac{1}{10.8} + 0.03\right) = 0{,}245$$

Select the maximum thrust-to-weight ratio $\overline{P}_0 = 0{,}256$.

6 DETERMINATION OF AIRCRAFT TAKEOFF WEIGHT

6.1 Definition of the initial take-off weight

$$m_{0исх} = \frac{m_{ц} + m_{эк}}{1 - \overline{m}_{к} - \overline{m}_{су} - \overline{m}_{тс} - \overline{m}_{об}} = \frac{57330 + 225}{1 - 0{,}27 - 0{,}1 - 0{,}4 - 0{,}09} = 411107 kg$$

This is take-off weight in the zeroth approximation, determined by statistical data [1, c.130]:

$$\overline{m}_{к} = 0{,}27; \overline{m}_{су} = 0{,}1; \overline{m}_{су} = 0{,}1; \overline{m}_{тс} = 0{,}4; \overline{m}_{об} = 0{,}09.$$

6.2 Definition of the payload mass

The commercial load refers to the target load for passenger aircraft, which includes passengers, baggage, cargo and mail.

$m_{ком}$ = 1,3($m_{пас}$+$q_{баг}$) $n_{пас}$=1,3(75+30)420=57330 kg.

6.3 Definition of the equipment mass and service load

Approximately the absolute mass of this group can be defined as the sum of the masses of the crew and equipment:

$m_{сл}$=$m_{эк}$ + $m_{сн}$,

Where

$m_{эк}$ = $m_{1эк}$ • $n_{эк}$=75*3=225 kg.

$m_{1эк}$ = 75 kg – average weight of one crew member for civil aircraft;

$n_{эк}$ – number of crew members [1, c. 215] take 3 people.

The mass of equipment can be taken in a relative form and include the mass of equipment:

$$m_{сл} = m_{1эк} \cdot n_{эк} + \overline{m}_{сн} \cdot m_{0исх} = 75 \cdot 2 + 0{,}02 \cdot 411107 = 8372{,}14 kg$$

6.4 Determination of the relative weight of construction

We can take advantage of the statistical formula to determine this mass:

$$\overline{m}_{к} = \left(\alpha \cdot \varphi \cdot n_{A} \sqrt{\frac{m_{0исх} \lambda}{1000 p_0}} + \frac{5.5}{p_0} \right) \left(1 + \beta_1 \cdot \lambda_{ф} \cdot m + \beta_2 \right) + 0.065,$$

So,

$$\overline{m}_{к} = \left(0{,}03 \cdot 0{,}664 \cdot 2 \cdot \sqrt{\frac{250239{,}1 \cdot 8{,}5}{1000 \cdot 677{,}1}} + \frac{5{,}5}{677{,}1} \right) \left(1 + 0{,}065 \cdot 10 \cdot 1{,}2 + 0{,}15 \right) + 0{,}08 = 0{,}212$$

[1 c.130]; $\overline{m}_{к} = 0{,}25$.

6.5 Determination of relative weight of the fuel system

The relative weight of the fuel system is given by: $\overline{m}_{mc} = k_{mc} \cdot \overline{m}_m$,
where

$k_{mc} = 1{,}02...1{,}08$ - coefficient determining the fraction of the mass of pipes and other equipment included in the fuel system to its total mass. We assume in the calculations $k_{òñ} = 1{,}02$. The relative mass of the fuel consists of the following components.

Fuel weight for aircraft with a long cruising flight phase can be written as

$$\overline{m}_т = \overline{m}_{т\,кр} + \overline{m}_{т\,нрп} + \overline{m}_{т\,нз} + \overline{m}_{т\,пр}.$$

Fuel weight for cruise flight without fuel burning

$$\overline{m}_т^0 = \left(\frac{L_р - L_{н\,сн}}{V_{кр} - W}\right)\frac{C_{р\,кр}}{K_{кр}},$$

$$\overline{m}_m^0 = \left(\frac{8200 - 440}{900 - 70}\right) \cdot \frac{0{,}494}{11{,}8} = 0{,}391$$

Given the impact of burnout on the range

$$\overline{m}_{т\,кр} = \frac{\overline{m}_т^0}{1 + 0{,}625\overline{m}_т^0}$$

$$\overline{m}_{mкр} = \frac{0{,}391}{1 + 0{,}625 \cdot 0{,}391} = 0{,}314$$

For takeoff and landing

$$\overline{m}_{т\,нрп} = (1 - 0{,}03m)\frac{0{,}0055Нкр}{1 - 0{,}004Нкр}.$$

$$\overline{m_{mнрп}} = (1 - 0{,}03 \cdot 6)\frac{0{,}0055 \cdot 11}{1 - 0{,}004 \cdot 11} = 0{,}05$$

Aeronautical margin

$$\overline{m}_{т\,нз} = \frac{0{,}9\,C_{р\,кр}}{Kmax}.$$

$$\overline{m_{mнз}} = \frac{0{,}9 \cdot 0{,}494}{13{,}9} = 0{,}03$$

Other fuel

$$\overline{m}_{т\,пр} \approx 0{,}006.$$

Complete relative weight of fuel will be equal to:

$$\overline{m}_м = 0{,}314 + 0{,}05 + 0{,}03 + 0{,}006 = 0{,}4.$$

As a result, we can determine the relative mass of the entire fuel system:

$$\overline{m}_{mc} = 1{,}02 \cdot 0{,}4 = 0{,}408.$$

6.6 Determination of the relative masses of powerplant

Knowing the needed thrust-to-weight ratio $\bar{P}_0$ (power available $\bar{N}_0$), it is possible to determine the relative weight of the powerplant

$$\bar{m}_{су} = k_{су}\gamma\,\bar{P}_0 \text{ - for turbofan engine;}$$

$$\bar{m}_{су} = 1{,}78 \cdot 0{,}13 \cdot 0{,}256 = 0{,}08$$

6.7 Determination of relative weight of the equipment and controls

You can use the following statistical relationships to determine this weight.

Passenger magisterial aircraft with $m_{0исх}$> 10000 kg:

$$\bar{m}_{об\ упр} = \frac{250+30n_{пас}}{m_{0\ исх}} + 0{,}06 + \bar{m}_{сн},$$

where

$$\bar{m}_{оисх} = 250239{,}1\,\text{kg};$$

$$n_{пас}=420.$$

Then

$$\bar{m}_{обупр} = \frac{250+30\cdot 420}{250239{,}1} + 0{,}06 + 0{,}02 = 0{,}109$$

$$\bar{m}_{об\ упр}=0{,}11$$

6.8 Definition of take-off weight of the first approximation

Determine take-off mass of the aircraft of the first approximation:

$$m_0^I = \frac{m_ц + m_{эк} + m_{сн}}{1-\bar{m}_к - \bar{m}_{су} - \bar{m}_{TC} - \bar{m}_{об.упр}} = \frac{57330+225+8372{,}14}{1-0.25-0{,}08-0{,}4-0{,}11} = 412044{,}6kg$$

7 DETERMINATION OF THE ABSOLUTE DIMENSIONS OF THE AIRCRAFT

7.1 Selection of engines

According to the required thrust-to-weight ratio $\overline{P_0}$ of engines we can find the total thrust for take-off mass $m^1{}_0$:

$$\sum P_0 = \frac{g \cdot m_0^1}{10}\overline{P_0} = \frac{9{,}81 \cdot 412044{,}6}{10}0{,}256 = 103479{,}23 daN$$

and we find the thrust of one engine

$$P_0 = \frac{\sum P_0}{n_{дв}} = 25869{,}8 daN$$

where $n_{дв}$ - number of engines on aircraft.

Engine PW4062.P=28600 daN

7.2 Determination of the fuel mass and volume

Required mass of fuel is the following

$$m_T = \frac{\overline{m}_{TC} \cdot m_0^1}{K_{TC}} = \frac{0{,}41 \cdot 412044{,}6}{1{,}02} = 161586{,}12 kg$$

The volume of the fuel

$$U_T = \frac{m_T}{\gamma_T} = \frac{161586{,}12}{800} = 201{,}98 m^3$$

Volume of the fuel tanks

$$U_{тб} = U_т + \Delta U_т = 201{,}98 + 35{,}8 = 237{,}8\ m^3$$

where

$$\Delta U_т = \frac{\Delta m_к}{800} = \frac{28665}{800} = 35{,}8$$

7.3 Specifying the wing parameters

We determine the wing loading p_0=677,1 daN/m^2, corresponding winf area for takeoff weight of the aircraft $m^1{}_0$ = 412044,6 kg is:

$$S = \frac{m_0^1 \cdot g}{p_0} = \frac{412044{,}6 \cdot 9{,}81}{677{,}1} = 596{,}9 m^2$$

Wingspan $l = \sqrt{\lambda \cdot S} = \sqrt{8{,}5 \cdot 596{,}9} = 71{,}23 m$

Tip chord $b_k = \frac{2}{1+\eta} \cdot \frac{S}{l} = \frac{2}{1+4} \cdot \frac{596{,}9}{71{,}23} = 3{,}35 m$

Central chord $b_0 = \frac{2 \cdot \eta}{1+\eta} \cdot \frac{S}{l} = \frac{2 \cdot 4}{1+4} \cdot \frac{596{,}9}{71{,}23} = 13{,}4 m$

Mean aerodynamic chord $b_A = \frac{2}{3} \cdot b_0 = \frac{2}{3} \cdot 13{,}4 = 8{,}93m$

Sweep angle χ =32°, dihedral angle must be given the choice of scheme the plane.V = 6.

We find the relative sizes and the chord along the span ailerons, spoilers, absorbers of the uplifting force, the flaps, and slats [1, 394]. We select the shape, size and location of the terminal lenses of vortices according to the given statistics.

7.4 Definition of the plumage parameters

We define the relative position of horizontal and vertical tail,using the volume coefficients $A_{го}$ and $A_{во}$:

$$L_{ГО} = \frac{b_a \cdot S}{S_{ГО}} \cdot A_{ГО} = \frac{8{,}93 \cdot 596{,}9}{149{,}22} \cdot 0{,}7 = 25\,\text{m};$$

$$L_{ВО} = \frac{l \cdot S}{S_{ВО}} \cdot A_{ВО} = \frac{71{,}23 \cdot 596{,}9}{119{,}38} \cdot 0{,}078 = 27{,}7\,\text{m}.$$

The scale and the chords tail are defined the same way as similar to the size of the wing relative to the selected parameters $\lambda_{го}$,$\eta_{го}$, $\lambda_{во}$, $\eta_{во}$:

$$l_{ГО} = \sqrt{\lambda_{ГО} \cdot S_{ГО}} = \sqrt{4 \cdot 149{,}22} = 24{,}43\,\text{m};$$

$$l_{ВО} = \sqrt{\lambda_{ВО} \cdot S_{ВО}} = \sqrt{1{,}5 \cdot 119{,}38} = 13{,}38\,\text{m};$$

$$b_{кГО} = \frac{2}{1+\eta} \cdot \frac{S_{ГО}}{l_{ГО}} = \frac{2}{1+3} \cdot \frac{149{,}22}{24{,}43} = 3{,}05\,\text{m},$$

$$b_{kВО} = \frac{2}{1+\eta} \cdot \frac{S_{ВО}}{l_{ВО}} = \frac{2}{1+3{,}4} \cdot \frac{119{,}38}{13{,}38} = 4{,}05\,\text{m},$$

$$b_{0ГО} = \frac{2 \cdot \eta}{1+\eta} \cdot \frac{S_{ТО}}{l_{ТО}} = \frac{2 \cdot 3}{1+3} \cdot \frac{149{,}22}{24{,}43} = 9{,}16\,\text{m},$$

$$b_{0ВО} = \frac{2 \cdot \eta}{1+\eta} \cdot \frac{S_{ВО}}{l_{ВО}} = \frac{2 \cdot 3{,}4}{1+3{,}4} \cdot \frac{119{,}38}{13{,}38} = 13{,}79\,\text{m},$$

$$b_{АГО} = \frac{2}{3} \cdot b_{0ГО} = \frac{2}{3} \cdot 9{,}16 = 6{,}1\,\text{m},$$

$$b_{АВО} = \frac{2}{3} \cdot b_{0ВО} = \frac{2}{3} \cdot 13{,}79 = 9{,}19\,\text{m}.$$

7.5 Determination of the fuselage dimensions

We apply a two-class layout: II and III classes, the fuselage's diameter is equal to 6 m. We find the length of the fuselage, the length of fore and aft of its parts

$$L_{ф} = \lambda_{ф} \cdot D_{ф} = 11 \cdot 6{,}22 = 68{,}42; D_{ф} = 1520 \cdot 3 + 2 \cdot 650 + 2 \cdot 50 + 2 \cdot 130 = 6{,}220\,\text{m},$$

$$L_{Н.ч.ф} = \lambda_{Н.ч.ф} \cdot D_{ф} = 1{,}1 \cdot 6{,}22 = 6{,}842\,\text{m},$$

$$L_{хв.ч.ф} = \lambda_{хв.ч.ф} \cdot D_{ф} = 2{,}2 \cdot 6{,}22 = 13{,}68\,\text{m}.$$

7.6 Determination of the undercarriage parameters

Basic parameters for the adopted the scheme of chassis are determined by the following: $\varphi = \alpha_{пос} - \Delta\alpha_{ЗАК} - \psi = 7^0 - 2^0 - 0^0 = 5^0$,

where

$\alpha_{пос}$ - Landing angle of attack;

$\Delta\alpha_{зак}$ – twist angle of the root section;

ψ - aircraft ground angle;

- Landing gear offset angle $\gamma = \varphi + 2^0 = 7^0$;
- Wheel base $b = 0{,}38 \cdot l_{\phi} = 25m$;
- longitudinal position of nose and main wheels $e = b - a = 25 - 23{,}5 = 1{,}5$m;

$a = 0{,}94 \cdot b = 24{,}53$m;

- Wheel track B=11m.

The aircraft is designed for operation from airfields in class A (runway length> 2550 m, Rekv<450 kN).

We select wheels on the parking load:

on the main strut - CT 86;

on bow strut - 88 CT.

$P_{экв}$ = 240 kN.

$$P_{ствзл} = \frac{m_{взл} \cdot g}{n} \cdot \frac{a}{a+e} = \frac{412044{,}6 \cdot 9{,}81}{16} \cdot \frac{23{,}5}{23{,}5 + 1{,}5} = 237476075N$$

$$P_{ствзл} = \frac{m_{взл} \cdot g}{n} \cdot \frac{a}{a+e} = \frac{294317{,}6 \cdot 9{,}81}{16} \cdot 0{,}94 = 169626{,}26N$$

$$m_{пос} = \frac{m_{взл}}{1{,}4} = \frac{412044{,}6}{1{,}4} = 294317{,}6N$$

Pick up the wheel 1500*500B: $P_{взл} = 260000N \quad P_{пос} = 180000N$

8 AIRCRAFT WEIGHT ESTIMATION

Masses of the main aircraft assemblies and parts are determined during the weight estimations, a list of equipment is estimated in groups with their weight , and weight of the target and service loads specified. Further refinement of the take-off weight of the aircraft is the result of the calculation. Weight summary of the aircraft, which is based on the weight calculation, determines the aircraft take-off mass of the second approximation.

8.1 Wight summary

The coefficient of the mass aircraft return at full load

$$m_{пуст} = m_к + m_{су} + m_{обупр} = 125729{,}214 + 32963056 + 37084{,}014 = 195776{,}79$$

$$к_{пн} = \frac{m_{пн}}{m_о}100\% = \frac{m_0 - m_{пуст}}{m_0} = \frac{407460{,}7 - 195776{,}99}{407460{,}7} = 51{,}95\%$$

The coefficient of mass impact on payload

$$k_н = \frac{m_н}{m_0} \cdot 100\% = \frac{57330}{407460{,}7}100 = 14{,}07\%$$

Table 3 – Wight summary of aircraft

NAME	m_i, kg	m_i
1. Construction	125729,21	0,308
Wing	52741,7	0,129
Fuselage	37084,014	0,091
Plumage	23871,8	0,058
Landing gear	12031,7	0,029
2. Propulsion system	32963,56	0,08
Engines	32317,22	0,079
Eggregates	646,3	0,0015
3. Equipment and control	37084,014	0,091
4. Empty aircraft	195776,79	0,480
5. Equipment and service load	8597,14	
Crew	225	
Office equipment	8372,14	
6. Zero fuel	341533,56	
7. Payload	57330	0,14
Passengers	31500	
Luggage, mail	12600+2100	
8. Fuel	162984,28	0,4
9. Full load		
10. Take-off weight	407460,7	

9. AICRAFT LAYOUT

9.1 Aircraft volume-weight assembly

Placing a full load of equipment and the aircraft must meet the following requirements:

- Ensuring the best conditions for the crew;
- Creating a comfortable environment for passengers;
- ensuring maximum efficiency of equipment and systems;
- Rational use of the internal volume of the fuselage and wings;
- Achieve the desired alignment for all possible options for loading the aircraft, which is achieved by placing a variable and consumed load (payload, fuel) as close as possible to the center of mass of the aircraft or symmetrically with respect to it.

The layout of toilet facilities: If duration is more than 4 hours, and there are more than 200 passengers we take a toilet for 50 passengers. We get 420/50 = 8 toilets. The area of the toilet 1.05 * 1.05 m

The wardrobe layout: two wardrobe place in the nose and the tail of the fuselage.

$$S_{гард}=0.035*420=14.7m^2$$

$$V_{гард}=0.05*420=21m^3$$

We will place the 14 stewards on a guide wire for 30 passengers inside.

Installation of engines: Setting of engines in the modern aircraft must meet the following requirements:

- Ensure a minimum increment of weight and drag of aircraft;
- Ensure easy mounting and dismounting of engines, as well as easy access to all units during the inspection;
- Allow for rapid containment and extinguishing a fire in the engine.

The design of engine mount must provide a compensation for thermal deformations and damping engine.

9.2 The structural layout of the aircraft

We are choosing construction materials:

D16AT material is used for making spar caps, machined panels.

OT4-1 material is used for the manufacture of skin and highly loaded parts.

The material VT22 is used for the manufacture of parts of the undercarriage, connecting rods, bellcranks.

The material 30KhGSA for the manufacture of highly loaded welded assemblies, hot-parts, power frames, brackets.

Material of the steel VNS-5 is used fo under engines frames. It has high impact strength.

Material Steel CH-4 is used for production of the elements of honeycomb panels made of thin sheets. Well sealed, stamped and soldered.

Composite materials are used for the manufacturing of slats, spoilers.

Thick covering, supported by a set of stringers, semi-monocoque fuselage perceives design (stringer), the power factors. Power frames for uniform load distribution are set to the places of focused approach forces. Ordinary frames have no virtually load and they are intended primarily to maintain the shape of fuselage.

Wing three rails has a bends construction, so strut is required, as in the caisson to make cuts impossible, to secure the main landing gear.

This constructive - power circuit design provides the least weight with good strength characteristics.

During the designing of power circuit we are guided by general principles of obtaining power structures of minimum weight:

- Transfer of effort on the shortest path;
- Maximum use of the height of the building, working on a bend;
- The use of thin-walled closed-loop transfer torque;
- The combination and integration of force elements to transfer loads acting at different times and under different loading cases;
- Minimum disturbance smoother flow of power of various concentrators (notches, holes, sharp corners, sharp changes in cross section), leading to weight reduction and design resource.

10 AIRCRAFT BALANCE

10.1 Choice of balance range

The valid range of center of gravity position depends on the type of aircraft and, first of all, the shape of the wing i scheme, as well as the parameters of longitudinal control. Bounds of the allowed range are usually determined by the calculation of the longitudinal stability and controllability of the aircraft. In the early stages of design, when these calculations are still not allowed, balance range is chosen approximately, based on statistical information.

The initial or baseline center of gravity of fully loaded aircraft (m_0) must lie roughly in the middle of the acceptable range $\chi^0 = 35^\circ, \overline{x_m} = 0{,}26 - 0{,}3$

0,26 – 0,30 - for aircraft with swept wings.

We have $\overline{X_m} = \dfrac{X_m - X_a}{b_a} = \dfrac{39119 - 36819}{8930} 100\% = 0{,}309$

Table 4 - Center of gravity positions table

№	Name of aggregates, cargoes belonging to the point	m, kg	x, m	mx, kg*m	y, m	my, kg*m
1	Fuselage (front compartment)	7537	5,115	38551,755	5,955	44882,835
2	Fuselage (cylindrical part)	37623,52	34,65	1303308,47	5,955	223988,51
3	Fuselage (fin compartment)	8114,4	60,246	489006,202	6,321	51291,122
4	Wing	52993	39,999	2119667,01	5,865	310803,95
5	Horizontal tail assembly	8560,52	63,03	539569,576	7,809	66849,101
6	Vertical tail assembly	5707,02	63,45	362110,419	12,935	73820,304
7	Nose landing gear	4076,44	7,58	30899,4152	1,504	6130,9658
8			5,625	22929,975	3,775	15388,561
9	Main landing gear (1)	8152,9	40,604	331040,352	1,564	12751,136
10			40,604	331040,352	3,721	30336,941
11	Main landing gear (2)	8152,9	41,781	341370,076	1,564	12751,136
12			39,002	317979,406	4,187	34136,192
13	Propulsion systems (internal)	18324,8	30,074	551100,035	2,95	54058,16
14	Propulsion systems (outdoor)	18324,8	37,588	688792,582	3,721	68186,581
15	3rd class passengers (first salon)	11212,5	16,719	187461,788	6,168	69158,7
16	3rd class passengers (second salon)	20475	35,635	729626,625	6,168	126289,8
17	3rd class passengers	9262,5	51,468	476722,35	6,168	57131,1

	(third salon)					
18	Aircrew	225	4,042	909,45	6,322	1422,45
19	Payload, mail and passengers' baggage (in front of the center section)	7020	16,743	117535,86	4,392	30831,84
20	Payload, mail and passengers' baggage (behind the center section)	11360	46,249	525388,64	4,392	49893,12
21	Fuel (in front of the center of gravity)	64634,4	36,937	2387400,83	5,865	379080,76
22	Fuel (with the center of gravity)	96951,66	43,949	4260928,51	6,186	599742,97
23	Kitchen	8350	23,546	196609,1	4,524	37775,4

The coordinates of the aircraft center of gravity for all possible options to operate the aircraft loading are defined

$$x_m = \frac{\sum mixi}{mi} \quad y_m = \frac{\sum miyi}{mi} = 5.74m$$

The relative distance of the center of mass of the aircraft is then converted to the relative position along longitudinal axis

$$\overline{X_m} = \frac{X_m - X_a}{b_a}$$

where XA - coordinate along the X axis.

10.2 Specified loading conditions

1. Takeoff weight of aircraft released landing gear:

$$X_м = \frac{\sum m_i x_i}{\sum m_i} = \frac{16018908{,}42}{407644} = 39{,}29\ \text{m}; \quad \overline{X}_м = 0{,}309.$$

2. Takeoff weight of aircraft retracted landing gear:

$$X_м = \frac{\sum m_i x_i}{\sum m_i} = \frac{16008578{,}69}{407644} = 39{,}27\,\text{m}, \quad X_м = 0{,}306.$$

3. Landing weight, released landing gear:

$$X_м = \frac{\sum m_i x_i}{\sum m_i} = \frac{11954589{,}01}{305733} = 39{,}10\,\text{m}, \quad X_м = 0{,}256.$$

4. Landing weight, retracted landing gear:

$$X_м = \frac{\sum m_i x_i}{\sum m_i} = \frac{1194425{,}9}{305733} = 39{,}07\,\text{m}, \quad \overline{X}_м = 0{,}251.$$

5. Maximum range option (without payload with additional fuel capacity, released landing gear)

$$X_м=\frac{\sum m_i x_i}{\sum m_i}=\frac{14507561{,}8}{367201{,}92}=39{,}51\,m,\quad \bar{X}_м=0{,}301.$$

6. Maximum range option (without payload with an additional supply of fuel, retracted landing gear)

$$X_м=\frac{\sum m_i x_i}{\sum m_i}=\frac{14497232{,}07}{367201{,}92}=38{,}48\,m,\quad \bar{X}_м=0{,}298.$$

7. Maximum range option (landing weight, released landing gear)

$$X_м=\frac{\sum m_i x_i}{\sum m_i}=\frac{13588954{,}96}{342964}=39{,}62\,m,\quad \bar{X}_м=0{,}313.$$

8. Maximum range option (landing weight, retracted landing gear)

$$X_м=\frac{\sum m_i x_i}{\sum m_i}=\frac{13578625{,}23}{342964}=39{,}59\,m,\quad \bar{X}_м=0{,}310.$$

9. The empty plane (in the parking lot, released landing gear)

$$X_м=\frac{\sum m_i x_i}{\sum m_i}=\frac{7071098{,}227}{181377{,}88}=38{,}98\,m,\quad \bar{X}_м=0{,}271.$$

Maximum front center of gravity position – landing configuration, retracted landing gear (0,152)

Maximum rear center of gravity position – maximum range configuration, landing weight, retracted landing gear (0,152) (0,346)

11 DEVELOPMENT OF A GENERAL DRAWING VIEW AND AIRCRAFT TECHNICAL DESCRIPTION

General information. Passenger aircraft to transport 420 passengers at a distance of 8200 kilometers was designed. The aircraft is made of a normal scheme, with a low-wing, double-deck, cargo hold and a kitchen on the lower deck.

Aircraft structure. It consists of semi-monocoque fuselage, wing spars three, caisson-type chassis' beam. Slats and two slotted flaps are used to improve the landing characteristics.

The nose strut is removed on the forward flight, the main - in the fuselage and wing. Coupled brake wheel are at the bow racks, four-wheeled trolley with brake wheels are on the major

Control of the aircraft. Wire control system with quadruple redundancy is used at this aircraft. This reduces the weight of the aircraft and simplifies the automation process of piloting.

Aircraft equipment and systems. Different equipment is used at this airplane: meteorological radar, navigation radar, laser locator station of range navigation, which provides automatic approach to a height of 5 meters; it is possible to install the runtime system of the fully automatic flight (or by the instructions of the software from the ground).Fire alarm system has four stages, triggered automatically or manually, fifth stage - only by hand.

Defrosting system: nose of the wing and aircraft keel are heated by air, drawn from the engines, glass of the cockpit and the front edge of the stabilizer are heated by electricity.

Aircraft is adapted for usage by state, so it installed sensors that measure the state of parts of the airframe and its engines. Fiber-optic cables that can significantly reduce the mass of the system and increase its reliability are used in the wiring.

Propulsion system. The aircraft is fitted with four engines PW-4062. Engines are mounted by using pylons to power the wing ribs.

Cruising speed 900km / h;
Flight distance 8200km;
Cruising altitude 10 km;
Take-off weight 407460kg;
The maximum payload 57330kg;
Wing loading 677.1 daN/m2
Wing area 596.9m2;
Engines Turbofan 4 * PW-4062;
The total static thrust 633.23daN;
The crew of 3 persons

CONCLUSION

Aircraft for 420 passengers, a range of 8200km is designed according to the assignments. Its basic parameters were calculated: mass, capacity, etc. The aircraft layout and alignment of the aircraft was produced.

BIBLIOGRAPHY

1. Житомирский, Г.И. Конструкция самолётов [Текст]: [учебник для студентов авиационных специальностей вузов]. - М.: Машиностроение, 1991. – 400с.: ил.

2. Проектирование самолёта и агрегатов [Текст] : учеб. пособие / И.П. Вислов; СГАУ. – Самара, 1996. 76с.

3. Проектирование самолётов [Текст]: [учебник для вузов] / [С.М. Егер, В.Ф. Мишин, Н.К. Лисейцев и др. Под редакцией С.М. Егера]. – 3-е издание, переработанное и дополненное. – М.: Машиностроение, 1983. – 616 с.