ABSTRACT

Explanatory note to the diploma work «Preliminary design of middle range cargo aircraft with payload 45 tons» contains:

sheets, figures, tables, references and drawings

Object of the design is development of cargo aircraft with the possibility to accommodate up 45 tons of cargo.

The aim of the diploma work is the preliminary design of the aircraft and its design characteristic estimation.

The method of design is analysis of the prototypes and selections of the most advanced technical decisions, analysis of centre of gravity position.

The diploma work contains drawings of the middle-range aircraft with payload 45 tons of cargo, calculations and drawings of the aircraft layout. The results of the diploma work can be implemented to the academic education and also it can be used for the design bureaus.

Introduction

According to the task on diploma work the preliminary design of cargo plane has been performed. The plane has following technical parameters: takeoff mass – max 135000kg; cruising altitude – 11000m ; cruising speed – 700-750km/h; range of flight – 1200-8000km; engines – 4.

The plain equipped with highly efficient system of high lift devices, this provides very short takeoff and landing distances: 600-1200 m for takeoff; 400 m for roll after the touch dawn.

For engines of turboprop type supply plane with 10300kWt of takeoff power.

Special part of the diploma work deals with loading and unloading cargo equipment

Designed equipment provides increasing of loading and unloading efficiency and characteristics

The plane design has been carried out on the base of the well-known planes analysis, these are: A400, AN-70, C-130-J30

Calculations of aircraft parameters were conducted according to the guides of the Aircraft Design Department.

For the drawing the software AutoCad was used.

The work has done in compliance with national and international standards and requirements, Certification Specification Part-25 and Federal Aviation Requirements Part-25 were taken into account at the process of the aircraft preliminary design and at the conceptual design

1.AIRCRAFT PRELIMINARY DESIGN

Main part of the project contains initial data of prototype of mid range aircrafts on the design of an aircraft, descriptions of the selected airframe scheme advantages, principles of optimal wing, fuselage, tail unit and engine parameters selection. It includes calculations of main masses and geometrical parameters of an aircraft, layout and alignment, main aircraft performance characteristics. The design was made by the means of training appliances made by the Aircraft Design Department handbooks, on aircraft design and strength, technical data from internet sites of aircraft design companies and according to Airworthiness Requirements FAR-25 and CS-25.

1.1. Basic project parameters.

Analysis and calculation is applied to the following characteristics and airplane parameters: crew members number, equipment; choice and motivation of the aircraft layout, mass of payload, fuel mass for the flight with full payload, main wing parameters (aerodynamic profile, and C_l of the profile, mean thickness ratio, wing sweep angle, aspect ratio of the wing on the full area, taper ratio on the full area, relative area of the wing root extensions, type of wing high-lift devices); main fuselage parameters (equivalent diameter, fuselage fineness ratio at the fuselage equivalent diameter, fineness ratios at the nose and rear parts of the fuselage); main parameters of the tail unit (sweptback angle of the horizontal tail, sweptback angle of the vertical tail); number, type and basic parameters of the engines (bypass ratio, engine pressure ratio, thrust/weight ratio or power/weight ratio) and other parameters, which are necessary for comparison the project aircraft with existing ones, which

author used in the diploma project.

1.1.1. Choice and substantiation of aircraft data

The choice of the project data of the airplane is based on the operational requirements. I have chosen An-70, Airbus A400M, C-130J-30 as the prototype aircrafts.

Table 1.1- Prototypes comparison

	Antonov 70	Airbus A400M	C-130J-30	Shaanxi Y-9
Wing Span m	44,06	42,40	39,7	38,015
Length m	40,73	45,10	34,69	33,109
Wing area m2	204,0	221,50	162,1	121,7
Cruise Speed km/h	700-750	780	640	550-600
Engine power, h.p	4 x 13880	4 x 11000	4 x 4700	4 x 4250
Empty Weight,tonns	73,0	76,5	34,3	39,0
Maximum payload,tonns	47,0	37,0	21,8	25,0
Maximum take-off weight,tonns	135,0	141,0	74,4	77,0
Cost (on 2012 year)	67,0 million $	145,0 million €	65 million $	------

They are the aircrafts that have the similar type of the engine, payload, and speed and flight range. I have collected and analyzed the data of operational characteristics correspondingly to the obtained prototypes. I make the statistics accordingly to the given data in technical literature and by the most modern aircrafts.

The structure of the plane is determined by a mutual arrangement of units, their quantity and form. Its aerodynamic and technical-operational properties depend on the structure and aerodynamic configuration of the plane. The successfully chosen structure allows increasing safety both regularity of flights, and economic efficiency of the plane. A choice of the structure of the projected plane precedes study and analysis of the planes structures accepted as the prototypes.

Aircraft scheme is determined by mutual placing of aggregates, their shape and quantity. Aerodynamic and operational qualities basically depend from the scheme and aerodynamic composition of the plane. Good chosen scheme gives the possibility to raise the safety, flight regularity and economies efficiency of the airplane. Also I have analyzed the schemes of the prototype aircrafts before choosing the scheme for the designed aircraft.

I. An arrangement of a wing and control surface relative to the fuselage, and also choice of their shape;

II. An arrangement of engines, their quantity and type, if it is not specified in the design assignment;

III. Type and arrangement of LG support.

1.1.2. Choice of the wing general geometrical parameters.

Within the main geometrical parameters of the wing we consider type of profile, relative thickness $\overline{C}_A$ or $\overline{C}_{cp}$, sweptback χ by 0.25 of the chord, aspect ratio λ, η, dihedral angle V, specific wing loading, wing shape in the plane.

Geometrical characteristics of the wing are determined from the take of weight m_0 and specific wing load P_0. These are:

- Full wing area with extensions is: 180(m^2);
- Wing area is: 63.8(m);
- Wing span is: 40(m);
- Root chord is: 6.42(m);
- Tip chord is: 2.568(m);

At a choice of power scheme of the wing we determine quantity of spars and their positions, and the places of wing portioning.

On the modern aircraft we use double or triple spars wing. The designed has three spars.

I use the geometrical method of mean aerodynamic chord determination.

Mean aerodynamic chord is equal: 4.3(m)

After determination of the geometrical characteristics of the wing we come to the estimation of the ailerons geometrics and high-lift devices.

Ailerons geometrical parameters are determined in next consequence:

- Ailerons span: 8(m);
- Aileron area: 5.85(m).
- Relative spars position is equal

$$\bar{x}_i = \frac{x_i}{b_i}$$

x_i –distance i-th spar from wing tip; b_i – wing chord i-th cross-section.

- Front spar:

$$x_1 = \bar{x}_1 \cdot b_o = 0{,}2 \cdot 8{,}551 = 1{,}71 \text{(m)}$$

$$x_1 = \bar{x}_1 \cdot b_к = 0{,}2 \cdot 2{,}634 = 0{,}527 \text{(m)}$$

- Forward spar:

$$x_2 = \bar{x}_2 \cdot b_o = 0{,}6 \cdot 8{,}551 = 5{,}130 \text{(m)}$$

$$x_2 = \bar{x}_2 \cdot b_к = 0{,}6 \cdot 2{,}634 = 1{,}580 \text{(m)}$$

- Mean relative profile thickness:

$$\overline{c_{cp}} = 0{,}125$$

- MAC tip coordinates:

$$b_A = \frac{4}{3} \cdot \frac{\eta_{кр}^2 + \eta_{кр} + 1}{(\eta_{кр}+1)^2} \cdot \frac{S_{кр}}{l_{кр}} = \frac{4}{3} \cdot \frac{3^2 + 3 + 1}{(3+1)^2} \cdot \frac{325}{52{,}56} = 6{,}7 \text{ (m)}$$

$$X_A = \frac{X_к}{3} \cdot \frac{\eta_{кр} + 2}{\eta_{кр} + 1} = \frac{8{,}16}{3} \cdot \frac{3+2}{3+1} = 4{,}011 \text{(m)}$$

$$Y_A = \frac{Y_к}{3} \cdot \frac{\eta_{кр} + 2}{\eta_{кр} + 1} = \frac{2,049}{3} \cdot \frac{3+2}{3+1} = 1,007 \text{(m)}$$

$$\chi_{пк} = 17^\circ \qquad \lambda_{пк} = 4^\circ$$

$$Z_A = \frac{l}{b_{сах}} \cdot \frac{\eta_{кр} + 2}{\eta_{кр} + 1} = \frac{52,56}{6,7} \cdot \frac{3+2}{3+1} = 13,054 \text{(m)}$$

Ailerons geometrical parameters

– Aileron span:

$$l_{ail} = 0,22 \cdot \frac{l}{2} = 5,8 \text{ (m)}$$

– Aileron area:

$$S_{ail} = 0,031 \cdot \frac{S_{кр}}{2} = 5,04 \text{ (m}^2\text{)}$$

Layout and determination of geometric parameters of high lift devices.

– Total slats span:

$$l_{slats} = l_1 + l_2 = 5,290 + 7,742 = 13,032 \text{ (m)}$$

– Total slats area:

$$S_{slats} = S_1 + S_2 = 3,317 + 3,862 = 7,179 \text{ (m}^2\text{)}$$

Increasing of l_{ail} and b_{ail} more than recommended values is not necessary and convenient. With the increase of l_{ail} more than given value the increase of the ailerons coefficient falls, and the high-lift devices span decreases. With b_{ail} increase, the width of the xenon decreases.

In the airplanes of the third generation there is a tendency to decrease relative wing span and ailerons area. So, l_{ail} = 0.122. In this case for the transversal control of the airplane we use spoilers together with the ailerons. Due to this the span and the area of high-lift devices may be increased, which improves take off and landing characteristics of the aircraft.

The aim of determination of wing high-lift devices geometrical parameters is the providing of take off and landing coefficients of wing lifting force, assumed in the previous calculations with the chosen rate of high-lift devices and the type of the airfoil profile.

Before doing following calculations it is necessary to choose the type of airfoil due to the airfoil catalog, specify the value of lift coefficient $C_{y\max bw}$ and determine necessary increase for this coefficient $C_{y\max}$ for the high-lift devices outlet by the formula: $\Delta C_{y\max} = (\frac{C_{y\max l}}{C_{y\max bw}})$.

Where $C_{y\max l}$ is necessary coefficient of the lifting force in the landing configuration of the wing by the aircraft landing insuring (it is determined during the choice is the aircraft parameters).

In the modern design the rate of the relative chords of wing high-lift devices is:

b_{sf} = 0.25..0.3 – for the split edge flaps;

b_f = 0.28..0.3 – one slotted and two slotted flaps;

b_f = 0.3..0.4 – for three slotted flaps and Faylers flaps;

b_s = 0.1..0.15 – slats.

1.1.3. Choice and substantiation of the fuselage scheme

The fuselage is a thin-walled cylindrical shell framed in the middle and tapered with a double curvature nose and tail sections.

The fuselage conventionally divided into three parts - the nose part, middle part and tail unit. To prevent the formation of stagnant zones (moisture accumulation) and to prevent corrosion in the fuselage there is a drain system.

Placed in the fuselage and cabin crew cabin transport, bay mounting tail and APU compartment. Fuselage cabin is pressurized.

Airframe cover, made of aluminium alloy, stressed skin includes a longitudinal force set in the form of stringers and beams, the transverse force in the form of a set of frames and walls, and floors in the cabins. The cross-section of the fuselage is round.

To the main frame are the transverse and longitudinal force sets, strengthening openings of doors and hatches.

Fuselage skin attached to the longitudinal and transverse framing shall ensure that the aerodynamic shape and the load acting on the fuselage during the operation.

Fuselage skin consists of sheet steel casing, seating and overhead sheets.

Airframe has the row of slots according to which it is divided on separate technological parts. To get the minimal mass of the airframe construction structural components has variable cross-sections that are obtained by the means of program and chemical milling cut. Also structures made by the means of stamping and pressing and cell constructions with the composite materials are widely used in the airframe design.

The basic advantages of the normal scheme are:

– an opportunity of an effective utilization of mechanization of a wing;
– easy balancing of the plane with extended flaps;
– accommodation of the control surfaces behind a wing allowing to produce the nose part of the fuselage shorter, that not only improves the review to the pilot, but also reduces the area of vertical tail, as shortened nose part of the fuselage causes occurrence of smaller destabilizing moment;
– An opportunity of reduction of the vertical and horizontal tail areas, as the shoulders of vertical and horizontal tails are much more, than at other schemes.

It is natural, that in the considered scheme there are disadvantages also:

Horizontal tail creates negative lift force on all modes of flight, that results in reduction of lift force of all plane;

Horizontal tail functions in the indignant air flow behind a wing that negatively has an effect for its job.

Crew cabin. Configuration of workplaces of pilots provides to any of them safety control of airplane. Characteristics of stability and controllability of the plane, the structure, characteristics and automatization of flight navigation equipment and onboard systems, structure and configuration of equipment of display provide performance by pilots of their functional duties without excess of the existing norms of loading.

Application of conic windshields of a radome of a crew cabin provides o good overview for pilots and satisfy the requirements of flight operation in the expected conditions. There is a possibility of manual and automatic control from any place of pilots.

Placement of devices and light signaling devices on a control panel of pilots is executed according to requirements of standards of the flight airworthiness. On a peak of a control panel in a zone of the best reach and the review quickly used control panels of command radio stations and systems of automatic control are placed.

On the top control panel of onboard systems are placed fuel, hydraulic, power supply, anti-icing, air conditionings, start of engines and APU, fire extinguishing switches and a board of the warning alarm system.

On the central pilot panel not only traditionally established control levers engines are placed, but also there are panels of the navigation and landing equipment.

1.1.4. Choice and substantiation of the wing location

Wing - swept, high attached, high aspect ratio, free-carrier. The wing consists of center section and two console parts.

The projected plane is executed according to the high-wing scheme that is widely used on the airplanes because it gives possibility to set engines under the wings. The advantages of the high-wing scheme are the following:

– In comparison with others small aerodynamic resistance from interference, especially for round fuselage. Lift-to-drag ratio of the high-wing aircraft with round fuselage is on 4-5% greater than in low-wing aircraft (with other the same conditions). The higher values of C_{ymax} are got thanks to the conserving under the fuselage aerodynamically completely or partially clean wing, better work of wing mechanization due to decreasing of tip effect on the flaps.
– There is the possibility of maneuvering of special vehicles appears;

The distance from the fuselage to the ground decreases that provides convenient loading and unloading of the passengers without using of high ladders, and loading and unloading of the cargoes and baggage are made without usage of complex mechanisms. All these decrease cost of operation, especially of cargo aircraft;

– Longer resource life of the engines as they are located far from the ground and getting different parts, such as sand and stones from the aerodrome surface during take-off and landing to the inlet ducts, is lower. Resource life of the engines on the high-wing aircraft is on 10-15% greater than on the low-wing aircraft. That's why cost price of the transportations on the high-wing aircraft decreases;
– It is increased the weight of force elements (formers) of the fuselage, which perceive loadings from landing gear, if main landing gear is attached to the fuselage;
– It is difficult to provide necessary track of the landing gear for stability and controllability of the aircraft on the ground;
– In total weight of the structure of the high-wing aircraft increases on 2.5-3% from take-off weight if landing gears are attached to the fuselage and on 0.6-1.0% if landing gears are attached to the wing;
– Complicated operation of the high located engines and other aggregates installed on the wing;

1.1.5. Choice and substantiation of engine location on the aircraft

The power plant consists of:

- four sustainer propulsion system consisting of a Turboprop Engine D-27

- electronic automatic control system propulsion systems - fuel system, located in the wing tanks, three tanks (one in the wings and one in the center section)

- Engines unload wing structure in the flight, decreasing bending and torque moment from external loadings that allows to decrease wing weight on 10-15%;
- Centre of masses of the aircraft with loading and without it is placed approximately on the same distance on mean aerodynamic chord of the wing (MAC), because engines on the wing and payload in such scheme are located near from centre of masses;
- Engines damp wing vibrations during flight in turbulent atmosphere, and because of offset of their centre of masses forwardly there are improved flatter characteristics of the wing;
- Convenience of engine removal and change for another one in aircraft modification;
- Aircraft centre of masses due to the fuselage is moved forwardly in comparison with engine location in aft part of the fuselage, nose part of the fuselage is shorter, the shoulders of horizontal and vertical tail units are increased, and weight of the tail units is less.

Disadvantages of the location of engines on the wing:

- In the case of engine failure it is created great moment, which rotates, in horizontal plane, that is especially dangerous during take-off when efficiency of vertical tail is not enough.

Table 1. 2 - Selected engine parameters

Main engine parameters	Units of measurements	Value
Type and subtype of engine (design)	Д-27	4
Specific fuel consumption	lb/lbf*hr	0.170

By pass ratio		5.6
Engine mass	Kg	1650
Diameter	Mm	1370
Length	Mm	4198

1.1.4. Choice of wing main parameters

To number of the basic parameters of a wing concern a structure and relative thickness C, sweep angle by ¼ of the chord (MAC), aspect ratio, angle of incidence, dihedral angle of a wing and specific loading on a wing. Aerodynamic characteristics of a wing are greatly defined by the form of a wing in the plan. The parameters of a profile (and relative thickness of a wing (C), as the practice of aircraft construction shows, depend on the cruise flight Mach number (see tab. 1.1)

Table 1.3. Dependence of wing parameters on Mach number

M_{cr}	$\chi°$	λ	H	C, %	X_c, %	f, %
0.85-0.9	35-40	6.5-8.5	3.5 – 4.5	9 -12	35 - 45	0 – 2.5
0.6-0.8	0-25	7-12	2.5 – 3.5	12 - 18	30 - 40	1.0 – 3.5

To the modern subsonic airplane wings are applied close to symmetric and asymmetric structures by sharper forward edge and with a rather back position of the maximal thickness X_c = 35... 45 %. Smoother distribution of pressure along the chord of a wing is characteristic for them that lowers meanings of local air speed above the top surface of a wing and promotes increase of critical number of flight

M_{cr}. In the last years for subsonic aircraft there are used so called supercritical profiles (profiles of double curvature), which in comparison with common profiles, of the same relative thickness, have more great (on 0.08-0.1) values of M_{cr}.

Sweepback of the wing is mean to increase critical Mach number of the flight. Increase of the wing sweepback not only displace on greater speeds of the flight beginning of wave crisis and also smoothes its proceeding, decreases increment of resistances, improves stability and controllability characteristics of the aircraft on transonic speeds. Besides, wing sweepback increases critical speed of flatter and divergence. However with increase of sweep angle are reduced $C_{y\ max}$ and K_{max} of a wing, the efficiency of take-off-landing mechanization decreases.

Because of lateral flowing of a boundary layer by the ends of the swept wing it has a tendency to trailer failure of a flow at the large corners of attack, which consequence can be loss of cross controllability and longitudinal instability of the plane at landing. Sweep angle construction complicates manufacture and increases of weight of a wing.

The specified circumstances cause “economical” application of sweep angle, i.e. the sweep angle of a wing of the subsonic plane gets out usually on the minimum determined by size of given speed (of number M) of cruise flight.

The aspect ratio of a wing is parameter essentially influencing size of inductive resistance and the maximal quality of a wing and the plane. Besides that it influences on weight and rigidity characteristic of a design of a wing.

Large (with maximum payload greater then 100 tons) subsonic transport airplanes with $M < 0.8$ have the wings with medium sweep angle. The aspect ratio of wings with sweepback angle lays in a rather wide range 7...12, and the large

meanings of aspect ratio concern, as a rule, to large planes with the large settlement range of flight. Due to all said above and statistical data of prototypes the aspect ratio is chosen as $\lambda = 9.5$ and sweepback angle $\chi = 22^{o}$.

The taper ratio of a wing renders inconsistent influence on aerodynamic, weight and rigidity characteristics of a wing.

Increase of taper ratio η favorably has an effect for distribution of external loadings, rigidity and weight characteristics of a wing. It results also in increase of building height and volumes of the central part of a wing, that facilitates accommodation of fuel and various units, and the increase of the area of a wing served mechanization, appreciably raises its efficiency.

However increase of taper ratio has also negative sides. Main of them is tendency of a wing with the large taper ratio to trailer failure of a flow at simultaneous decrease of ailerons efficiency. In connection about specified by circumstances the taper ratio of direct wings of subsonic planes which $M_{cr} < 0.8$ is filled usually small and makes size $\eta = 2.5...3.5$ that provides inductive resistance, close to a minimum, of a wing and high meanings of C_{Ymax}.

The dihedral angle of a wing V, as it is known, serves as mean of maintenance of a degree of cross stability of the plane. Its size and mark depend on the plane structure, and for planes with swept wings – also from the sweep angle. For direct wings subsonic planes the meaning of dihedral angle V lay in a range from -1...-5 – for high-wing. Sweep angle increases cross of a wing and consequently to swept wings should be given negative angle V. However layout and other requirements (for example, landing with a roll) can cause positive V of the swept wing. It will entail installation in a control system automatic damper yawing and will require some increase of the area of vertical tail.

We choose the following basic parameters of a wing $\eta = 2.5$; $C = 0.125$.

The mean aerodynamic chord has been determined by the graphic method (fig.1.1).

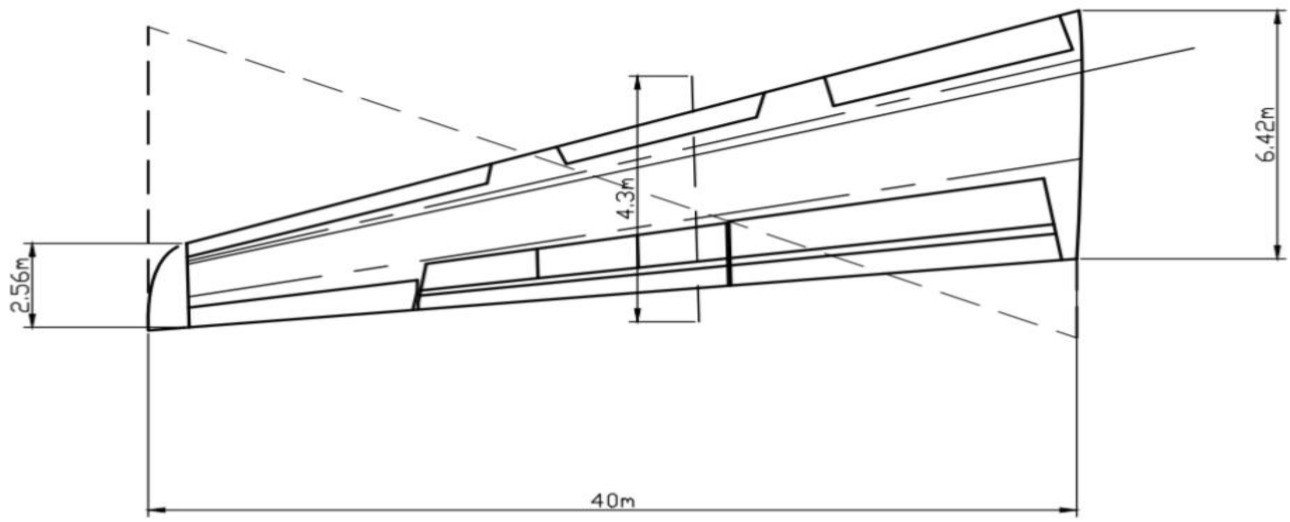

Fig. 1.1. Wing MAC positioning calculation scheme

1.2. Brief description of the airplane structure

Fuselage. The fuselage is all-metal, beam-stringer construction (like semi-monocoque). This type of construction is characterized by the presence of a relatively thick skin, backed by stringers and frames.

The fuselage, rationally combining the advantages of shape and elongation of parts, has a min possible resistance and a high critical value of the number M.

In the cockpit there are seats for the first and second pilots. There is also a space for a flight engineer crew member.

The first pilot is on the left on the flight, the second pilot on the right, the flight engineer in behind of the second pilot. In front of the pilots, instrument panels are installed, and between them an average pilot console. Over the glazing of the cockpit canopy there is an upper electric switchboard. The port side of the fuselage has a side console for the first pilot, and for the right side there is a side console of the co-pilot.

Ahead of the first and second pilot's seats there are steering wheels for driving the elevator and ailerons and pedals for steering the rudder. On the dashboard mounted flight-navigational instruments for monitoring the operation of the power plant and other instruments, and signaling devices.

On the left and right sides of the salons are windows, there are emergency exits on the left and right side. The main force elements of the fuselage are frames, stringers, longitudinal beams of the chassis front support awning, sheathing.

Wing. The wing of the caisson structure, arrow-shaped in plan. It consists of a centroplane and two detachable parts of the wing, attached along the ribs.

The nose part of the wing is equipped with an air-thermal and an electrothermal anti-icing device. The warm air in the sock of the center wing is fed from the aircraft engine compressors.

The structure part of the wing is the caisson 3, 5, which receives the main loads acting on the wing. The sock and tail of the wing perceive only local air loads and transfer them to the caisson.

The wing has a relatively small distance from the ground, resulting in an increase in the lift factor C_Y due to the influence of the ground, thereby improving the takeoff and landing characteristics.

The wing is made swept, as a result of which it has a larger M_{cr} and a weaker wave crisis, but there are a number of drawbacks:

- Large tearing speeds and landing and, as a consequence, a long run and run length.

- It has smaller aerodynamic qualities than direct, greater drag of the aircraft and a shorter range, and the duration of the flight.

- Have a tendency to end the flow from the wing.

- Lowest coefficient of maximum lift.

- External lateral stability, leading to aircraft swinging.

- The lateral controllability is reduced at large angles of attack due to a stall from the wing ends, has a reverse roll response.

The lateral stability decreases with M> Mmax

Tail unit. The empennage is swept, consists of vertical and horizontal stabilizers and control surfaces.

Vertical tail includes fin and rudder, horizontal tail - stabilizer and elevator.

In front of the fin dorsal fin is mounted on the fuselage.

The sweep of the vertical and horizontal tail is greater than the sweep of the wing, so that the aerodynamic characteristics of the tail unit with an increase in the number M do not deteriorate faster than the characteristics of the wing. The large sweep of the vertical plumage is also suitable, because at the same time the horizontal plumage efficiency is increased due to the increase of its moment arm.

The vertical and horizontal tails profile is symmetrical. Symmetric profile allows to maintain the same character of aerodynamic loads during deflection of rudders in different directions and, in addition, has a smaller resistance.

Vertical tail in comparison with horizontal tail has an increased relative thickness of the profile in order to reduce the mass of fin loaded with forces, both from vertical and horizontal plumages.

Control system. The aircraft control system includes: elevator control system, stabilizers, rudder, ailerons and aileron-spoilers, air brakes, flaps and slats.

The aircraft control system includes the automatic on-board control system, designed to improve the stability and controllability of the aircraft during help piloting in all flight modes from take-off to landing, to automate aircraft control during climb-up stages, route flight and descent by signals of navigation systems airborne complex, as well as to provide automatic and director control of the aircraft during approach.

The aircraft control system works accordingly in the following modes:

- Steering control mode - the mode in which aircraft control is made by the first or second pilot by the usual movement of command levers(columns, steering wheels, pedals) when the automatic system is operating;

- semi-automatic control mode - the mode in which the pilot drives by plane (using the same command levers) by the position of the commander pilot-command instrument or other navigation-flying instruments;

- automatic control mode - the mode in which the aircraft is controlled by the automatic system in conjunction with the flight-navigation complex.

The control of the main controls is double: each pilot has command levers of these systems installed on the consoles of the first and second pilots in front of the seat of each of them, and control can be performed simultaneously by two pilots and separately - the first or second.

System of cargo floor height regulation. System of cargo floor height regulation serves for decrease of cargo floor height during performance of cargo operations, and for improvement of conditions of ground operation.

System is electrical-remote, hydraulic.

System provides:

– cargo floor lowering and lifting due to simultaneous shortening (elongation) of all main landing gears;
– shortening (elongation) of any strut of main landing gear separately.

Aircraft control. System of aircraft control includes roll control system and control system of high-lift devices.

Roll control system. Roll control system serves for control on pitch, roll and yaw in manual and automatic modes with provision of necessary stability and controllability characteristics.

For aircraft control there are used mini control wheel and pedals without offset of neutral positions during trimming.

Operating controls of roll control system are elevator, ailerons, multifunctional spoilers (three sections on each semi-wing) and rudder. Flatter of external sections of rudder and elevator, which don’t have weight balances, is prevented by holding them from vibrations with the help of steering gears of system of column control.

Roll control system provides the following functions:

– control of rudder and elevator sections, ailerons and spoilers;
– loading and trimming of efforts on control levers;

– tactile indication of exceeding of allowable angle of attack, bank angle and side overloading.

In the channels of pitch and roll there are realized integral laws of control.

The base of roll control system is multi-channel digital-analog electrical-remote system (ERCS).

Digital part of ERCS consists of three parallel working digital computers, each of which gives control signals for all three control channels.

Analog part of ERCS of rudder, elevator and ailerons is performed as two working in parallel independent subsystems, each of which has three sub-channels – two active and one model.

Level of ERCS redundancy and interacting systems provides practical availability of ERCS and invariance of stability and controllability characteristics in change of any single failure, except mechanical one. For the case of disconnection or seizure of any part of mechanical wiring in ERCS there are foreseen means, which allow finishing of the flight with such failure.

After failure of ERCS digital part control is made from analog subsystems in small decrease of level of stability and controllability characteristics. During this trimming of efforts on the control levers and changing of gear ration in the channels of pitch and yaw are realized by double-channel electrical mechanisms.

As the mean of diverse backup of ERCS it is used hydraulic-remote control system (HRCS). Transfer on control from HRCS is performed by turning off of servo drives of ERCS from mechanical control wiring.

Normal and emergency exits, emergency means. Dimensions of side door cutouts on the left and right sides of the cargo cabin: Width 0,8 m; height 1,8 m.

Dimensions of emergency hatch cutouts on the left and right sides of the cargo cabin: Width – 0,61 m; Height – 1,22 m.

– The dimensions of the cutout of the upper emergency hatch in the cockpit: 0,5×0,6 mDimensions of the cutout of the lower emergency hatch in the cockpit:

0,7×0,95 m

Wing high-lift devices control system. Wing high-lift devices control system includes:

– flaps control system;
– slats control system;
– control system of stabilizer deflected nose;
– spoilers control system.

Flaps control system consists of two same double-channel electrical-remote control systems.

Besides, each control system has double-channel system of electrical-mechanical brakes control.

System of electrical-mechanical brakes control provides automatic braking of transmission of correspondent flaps by turning on two electrical-mechanical brakes and gives signals on turning off of flaps swinging mechanism in manual and backup modes.

When alternating current is absent in the electrical circuit, both flaps control systems are transferred on emergency supply of direct current in the mode of limited power, which provides flaps extension in the backup mode on the angle not more than 25º with the velocity much less than nominal one.

Slats control system provides control of slats in two modes – main and backup.

In main mode system provides:

– slats extension;
– slats retraction.

Besides, slats control system provides:

– during asymmetry of left and right sections of the slats more than allowable value, deflection and locking of hydraulic drive in main and backup modes, and also turning on of down-lock mechanism.

Deflector's extension and retraction is made in two modes – main and backup.

Spoilers control system with the help of ERCS provides spoilers operation into three modes:

– spoiler-aileron mode;
– glide-path mode;
– brake mode.

In the spoiler-aileron mode it is provided automatic deflection of the spoilers on all flight modes.

In glide-path mode it is provided synchronic deflection of all spoilers.

In brake mode on the landing run or during aborted take-off it is provided synchronic deflection of all spoilers on full angle.

Besides, in brake and glide-path modes spoilers control system provides:

– retraction of earlier extended spoilers;
– cut-off and retraction of any pair of the spoilers during asymmetry between spoilers of this pair more than allowable;
– it is foreseen forced cut-off of any pair of spoilers by correspondent switches.

1.3. Cargo cabin and transport equipment

In the cargo cabin of the aircraft there is performed transportation of the cargoes. Aircraft can provide transportation of every wide range of the cargoes:

– nominal combat material;
– bulky cargoes;
– self-propelled and non-propelled machines;
– cargoes in aviation containers;
– cargoes on the pallets;
– heavy agricultural machines etc.

Pressurized cargo cabin provides transportation of cargoes which general weight is near 35 tons, cargo paradropping on the platforms, and also prepared cargoes and technique without usage of the platforms. Volume of the cargo cabin is covered railway wagons. Made of titanium alloy floor of the cargo cabin allows loading of all kinds of self-propelled and non-propelled vehicles and tracklaying vehicles

For crew and attendants protection from cargo displacement during emergency landing there is provided installation of barrier devices.

Dead roller equipment provides cargo movement in the containers and on the pallets in aircraft cargo cabin and their fixation.

Loading, unloading and fixation of cargoes is performed by transport equipment of cargo cabin.

Transport equipment consists of:

– upper loading equipment;
– lower loading equipment;
– mooring equipment;
– dead roller equipment.

Upper loading equipment consists of four monorail motor hoists, each of which has load-carrying capacity 5000 kg.

Lower loading equipment consists of:

- two winches;
- tackle system;
- protective floorings on the floor and ramp.

Upper and lower loading equipment don't functioning in the flight and is considered as cargo, fixed in the cabin. Strength of the fixation in the cabin is expected on all flight and landing cases of loading, including emergency landing.

Mooring equipment provides cargoes fixation in the cargo cabin.

Mooring equipment consists of:

- tie-down fittings;
- mooring chain devices;
- tie-down belts;
- straps and clamps.

Dead roller equipment includes:

- roll tracks;
- latch beams;
- side directrices;
- end locks.

1.4. Power plant

The power plant consists of the following components:

- four bypass engines;
- auxiliary power unit;
- engines control system;
- fuel system;
- fire-extinguishing system.

The power plant provides proper thrust that is needed to provide airplane take-off, flight and landing.

Engine is attached to the wing with the help of braces in forward and backward planes of the mounts. Side loads and thrust effort are transmitted by separate engine unit on the bracket pin, installed on the beam.

Engine nacelle provides minimal aerodynamic resistance of the power plant in the flight, organized engine cooling and its aggregates, and creates limited compartment, localizing fire spreading in the case of its appearance.

Air inlet-heat exchanger forms input channel into the engine and serves as primary air-to-air heat exchanger for preparation of the air in the air conditioning system in the aircraft cabin.

Caps of the cowling are made of fire-resistant material and are attached to the beam with the help of hinge units. The caps are connected between each other by tabled scarves. When opening the cap it is provided access to the engine aggregates during ground operation.

Cargo compartment. For transport aircraft one of the most important parameters are sizes of the cargo cabin, especially height of the cabin. Very important is possibility to transport non-standard cargoes.

It is necessary to take into account, that the presence of required sizes of the cabin yet does not allow finding the optimum sizes of the fuselage cross section. From the constructive point of view it is rational to have round fuselage cross section, as in this case its will be strongest and easy. However for accommodation of the passengers and cargoes such form not always can appear optimum. Often it appes more rationally to generate fuselage cross section as oval or crossing of two circles. It is necessary to remember, that oval form is inconvenient in manufacture, and top and bottom panel at superfluous pressure will work on a bend and the introductions of beams and other strengthened bulkheads in a design will require.

The step of normal frames in fuselage designs is within the limits of 360... 600 mm, depend on the fuselage sizes and configuration of cabins.

Determination of the diameter fuselage is made on prototypes, so D_f = 4.5 m.

As we have cargo aircraft all place will be occupied by the cargoes. For cargo aircraft the opportunity to take more cargoes is one of the most important advantages before competitors, so we will make the cabin the long as possible.

There are different types of cargoes and many of them require special conditions. In order to deliver cargoes in proper appearance and save their characteristics it is necessary to create proper conditions inside the aircraft. That's why cargo cabins are also pressurized.

By norms of airworthiness is stipulated, that at flights with H = 3500 m the cabin should be pressurized, superfluous pressure in a cabin not less than 567 mm of a hg (2400 m), speed of change of pressure in a cabin no more than 0.18 mm hg/s, temperature in a cabin 18... 22ºC and humidity 30... 60%. As in the cabin there will be placed two load masters, and then all these requirements should be satisfied.

Crew cabin. The cabin of the crew should occupy probably smaller volume, but at the same time to provide normal working conditions and rest conditions for crew. The strictest requirements are given to workplaces of the pilots. Except of convenience they should provide good review. The size of a service cabin depends on structure of crew. On intercontinental and long-range aircraft the crew consists of 3... 5 men, on midrange and short-range aircraft it has 3...4, on local lines – 2...3 men.

In modern aircraft is tendency to decrease the aircraft staff, but of cause in the limits of flight safety.

Crew of the aircraft consists of the three members:

– pilot-in-command;
– co-pilot;
– flight engineer.

Crew seats provide convenient position during the flight and the rest, and also safety in the case of emergency landing.

Seats are moved along directional rails. On the seats there are set mechanisms of the forced rolling away. During rolling away of the seats to the end position, they are displaced to the board. Seats are fixed in end and intermediate positions.

Crew seats are equipped by electrical mechanisms of the height regulation.

Interior of the crew cabin, architecture and colour decision correspond to the modern requirements of the technical esthetic.

On the cargo aircraft besides the flight crew there are also two load masters.

Their seats will be placed in the cargo cabin. Depending on a route of the flight the staff of crew and number of members can be changed. The pilots are placed in armchairs directly opposite to window, flight engineer more often is located behind armchair of the co-pilot, to provide between him and commander of the plane the visual communication. In modern plane there is foreseen the place for the inspector. To workplaces of other members of the crew the requirements are not given.

The cabin of crew is separated from other compartments by a rigid frame with a locked door.

Galley. As designed aircraft spends in the flight near 10 hour, it is necessary to make a galley for the provision of the crew and load masters by food.
For designed airplane it is enough to make only one galley. The galleys and buffets should be placed necessarily near the door; it is desirable between a cabin of the crew and cargo cabin, or to have a separate cargo door. In designed plane the galley is placed between crew cabin and cargo cabin in order to provide the shortest way for both members of the crew and load masters to it.

For such long flight it is foreseen three meals a day on one crew member: breakfast, dinner and supper - for 800 grammas; tea and water – for 400 grammas.

Galley is project similarly to the aircraft of the same class.

Wardrobes. The wardrobe for the top clothes of the crew and load masters is placed near the main doors for an entrance and exit of the members of the crew. As we have only five members on the board and only in some special cases the number of the crew can be larger, wardrobe is as small as possible in order to occupy the smallest volume. In the wardrobe clothes are placed on the coat hangers. Hats are kept on shelves located on the top of the wardrobe. Height of the shelves from a floor of a cabin 1700... 1800 mm.

Wardrobe is designed similarly to the prototype aircraft.

Lavatory. The quantity of lavatories is defined by number of passengers and duration of flight. The duration of flight is long, that’s why it is necessary to set lavatory on the board. But as we have only five members on the board of the aircraft it is enough to have only one lavatory. Even in the case of additional crew members for some flights, it will satisfy free access to it.

The area of the lavatory is 1.5…1.6 (m^2).

Lavatory is designed similarly to the prototype.

It is foreseen by the norms to have store of the water and chemical liquid. The quantity of water and chemical liquid is calculates as $m_l = q \cdot n_{pax}$.

Normal and emergency exits and emergency means. In the forward part of the fuselage there are placed two doors on the port side and starboard. The normal door for an entrance and exit of the crew and load masters carries out on the left board of the plane with board ladder, which is

retracted manually and is set on the board inside the fuselage. The door is open outside in the direction of the flight as manually so remotely. Height of a door depends on a diameter of the fuselage and is equal to 1400... 1830 mm. Width of a door should be not less than 860 mm. The threshold at a door is not supposed, the door aperture from below is limited by a floor.

The door on the starboard of the aircraft is used as the emergency exit in the case of emergency situations for leaving the airplane by the load masters.

For the emergency leaving of the aircraft by the crew it is also foreseen exit door in the upper panel of the crew cabin. The crew also can leave the plane through the first main door together with the load masters.

Sometimes exit doors are made in the ceiling of the aircraft. But in our case there are no any doors on the upper plane of the aircraft because it is the high-wing airplane.

In the tail part of the aircraft there is cargo door, which is closed by the ramp and pressurized doors. Ramp performs the function of ladder for loading of different cargoes.

Near the exit doors there are placed inflatable escape chute and liferaft in the region of forward left wing fillet.

The windows (illuminators) are of round form with the diameter 400 mm. they provide good lighting by daylight and view from the cargo cabin.

On the aircraft there are installed electronic indication system, which monitors the position of side doors and cargo door, and signalization, which warn pilots about non-closed position of each door of the aircraft.

In the structure of all doors there are foreseen means for prevention of autocratic opening in the flight and fixation of the doors in the case of emergency landing or landing on the water.

1.5. Calculation of the main parameters of the landing gear

During the work we have choosen the scheme of the LG, the number of the wheels, determined main LG parameters: track, base, etc., typical angles and pneumatics.

On the modern planes the tricycle scheme is applied with the nose landing gear. The number of the struts can be different 2, 3, 4 and greater.

The base of the landing gear is defined by the next formula:

$B = (0.3…0.4)\cdot L_f = 14.6$ (m).

Main LG wheels axel offset:

$e = (0.15…0.2)\cdot b_{MAC} = 1.005$ (m),

Nose LG wheels axel offset:

$d = B – e = 13.595$ (m).

The track of the landing gear is determined as:

$K = (0.7…1.2)\cdot B = 9.8$ (m).

The wheels of the landing gear are chosen due to parking load from take-off weight on them; during choosing of the wheels to the nose landing gear we should take into account dynamic loadings. The type of the pneumatics (balloon, semi-balloon, arch) and pressure in them are determined due to the type of the runways, on which the plane will be operated. On the main landing gear the brakes should be installed. The loading on the wheels is equal to:

$P_{MLG} = \frac{(B-e)\cdot m_o \cdot g}{B \cdot n \cdot z} = 101{,}761$ (kN) – main landing gear wheels,

$P_{NLG} = \frac{e \cdot m_o \cdot g \cdot k_Д}{B \cdot z} = 67{,}703$ (kN) – nose landing gear wheels.

k_d – is the dynamic coefficient.

Table 1.3 - Landing gear wheels parameters

Wheel size	$P_{st.toff}$, N	$P_{st.land}$, N	P_o, 10^5Pa	δ_{st}, mm	$P_{fract.}$, N	V_{land}, Km/h	V_{toff}, Km/h
For Main Landing Gear							
1100×330B	110000	86000	10	81	540000	260	330
For Nose Landing Gear							
1000×280B	66000	5750	10	65	345000	240	330

Table 1.4 - Values of aircraft masses

Object name	**Mass, kg**	**Relative mass, %**
Frame	37497,73	0,26
Wing	13977,37	0,098
Fuselage	14650,15	0,10
Horizontal tail unit	1412,56	0,009
Vertical tail unit	1416,83	0,009
Nose L.G.	604,08	0,0042
Main L.G.	5436,72	0,038
Equipment and control	18021,2	0,126
High-lift devices	2579,95	0,0181
Cabin equipment	28,50	0,0002

Decorative covering	826,72	0,0058
Loading equipment	4247,66	0,0298
Control system	712,69	0,005
Hydraulic system	2095,32	0,0147
Electrical equipment	4062,36	0,0285
Locational equipment	527,39	0,0037
Navigational equipment	798,21	0,0056
Radio communication equipment	399,10	0,0028
Instrumental equipment	926,50	0,0065
Other equipment	816,74	0,00573
Additional equipment	260,84	0,00183
Power plant	23802,58	0,16699
Fuel system	798,21	0,0056
Fire protection system	2850,78	0,02
Anti-ice system	712,69	0,005
APU	1268,59	0,0089
Engine equipment	11403,12	0,08
Engine nacelle power units and engine mounts	6769,17	0,047
Dry weight	79582,37	0,558
Equipment	1063,34	0,00746

Crew	170	0,00119
Documentation and tools	120	0,00084
Water, chem.liquid	100	0,00070
Oils and working fluid	420	0,0029
Emergency-rescue equipment	168,34	0,0011
Empty equipped aircraft	80645,71	0,565
Fuel	26892,83	0,188
Commercial load	35000,45	0,245
Payload	61893,28	0,434
Take-off mass	142539	1

1.6. Center of gravity positioning

Final lay-out and center of gravity positioning is persistent process. For providing the desirable static stability and controllability of the plane its center of gravity should lie in some range on the mean aerodynamic chord.

In the process of the plane operation, its center of gravity position may change. Aft its center of gravity position should be so, that the minimally necessary reserve of static stability would be provided. The forward center of gravity position is defined by the effectiveness of organs of longitudinal control (balancing). The larger is the effectiveness of organs of longitudinal control, the wider will be the range of operational center of gravity positioning.

Determination of wing center of gravity positioning

Results of the mass calculations required for the center of gravity positions are shown in table 1.5

Table 1.5.- Trim sheet of equipped wing masses

№	**Object name**	**Mass, kg**	**Coordinate x, m**
C.G. positioning of equipped wing			
1	**Wing (structure)**	13977,37	2,48
2	Fuel system (part)	558,75	0
3	Power plant (part)	14751,36	-1,41
4	Aircraft control (part)	213,80	3,42
5	Electrical equipment (part)	1218,70	0,57
6	Anti-ice system	199,55	0,57
7	Hydraulic system (part)	1047,66	3,42
8	Nose strut - "Extended"	604,08	-12,77
9	Nose strut - "Retracted"	604,08	-13,63
10	Main strut - "Extended"	5436,72	2,34
11	Main strut - "Retracted"	5436,72	3,84
12	**Fuel used**	23156,88	1,072
13	**Fuel of navigational reserve**	3735,94	3,49
1.6. **Equipped fuselage masses**			
1	Fuselage	14650,15	19.22
2	Horizontal tail unit	1412,56	37,64
3	Vertical tail unit	1416,83	37,015
4	Aircraft control (part)	498,88	19,22
5	Electrical equipment (part)	2843,65	19,22

6	Anti-ice system	513,14	0,43
7	Hydraulic system	1047,66	19,82
8	High-lift devices	2579,95	19,22
9	Locator	100	1,14
10	Decorative covering	826,72	4,25
11	Main crew seats	70	-11,3
12	Crew rest apartment equipment	50	9,8
13	Crew	170	11,3

1.7. Calculation of centering options

№	Loading options	Mass,kg	Mass moment, kg*m	Center of mass,m	Centering
1	Main takeoff, l.g. extended	133681	342897,1	12,74	0,281
2	Main takeoff, l.g. retracted	133681	342627,95	12,73	0,279
3	Landing l.g. extended	117566,15	428917,6	12,67	0,26
4	Transit, l.g. retracted	98681	408879,9	12,63	0,255
5	Parking empty equipped	82566	276959,4	12,49	0,217

Conclusion to Part 1

1. According to the task on diploma work the preliminary design of the cargo plane with the following characteristics has been performed: loading capacity -135 t, speed - 740 km / h, height of cruising flight – 11000 m.

2. The aerodynamic scheme is selected on the basis of the analysis of prototype aircrafts such as: AN-70, C-130J-30, Airbus A400M.

3. Aircraft parameters reflect current trends in aviation industry.

2. TELFER DESIGN FOR CARGO LOADING SYSTEM

The primary functions of a cargo equipment are as follows:

1. To increase the speed of loading.
2. Improve the quality of loading.
3. To reduce the quantity of personnel per loading.
4. To make the personnel and mechanism less loaded.
5. To prevent the damage of cargo and injuries of personnel.

The design of the telpher and some components of the calculation for the telfer are presented below.

Fig.2.1(a). – Telphers in Il-76 cargo compartment

2.1 General description of the cargo equipment

Telpher – is designed for lifting up the cargos (fig.2.1.). There are four telphers on the plane, each of them could lift 2.5 tonns payload.

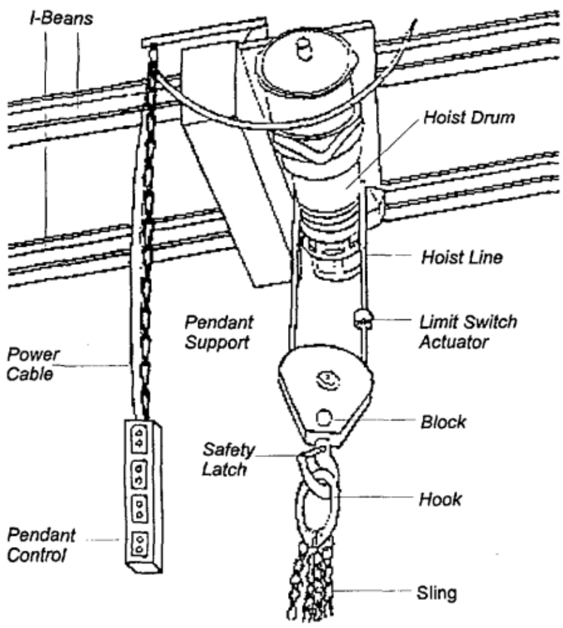

Fig. 2.1. - Telpher components

Telpher can be used as separate mechanism as well as a component of loading machines, for example overhead crane.

Telpher consists of following principle components: Electric motor; gearbox reducer (planetary or cylindrical gearbox reducer); brake; load gripper and hook; bottom block - (load block) - the assembly of hook or shackle, swivel, bearings, sheaves, pins and frame suspended from the hoisting ropes or chains; limit switch - device which restricts the raising and lowering capabilities of the hoist through altering the electrical circuit associated with that hoist; upper limit switch - contact device which restricts the upward travel of the hoist based on counting revolutions on drum or when the block contacts a device below the hoist drum; lower limit switch - contact device restricting the downward travel of the hoist based on counting revolutions on drum, in which case the LLS ensures one full wrap* of rope shall remain on the hoist drum when the hook is in its fully extended position; pendant station - controls suspended from the hoist for operating the unit from the floor; drum - a cylindrical-flanged barrel on which the wire rope is wound for operation or storage. It may be smooth or grooved.

Telphers in the cargo hold of plane-analouge (An-70) is shown in fig.2. 2

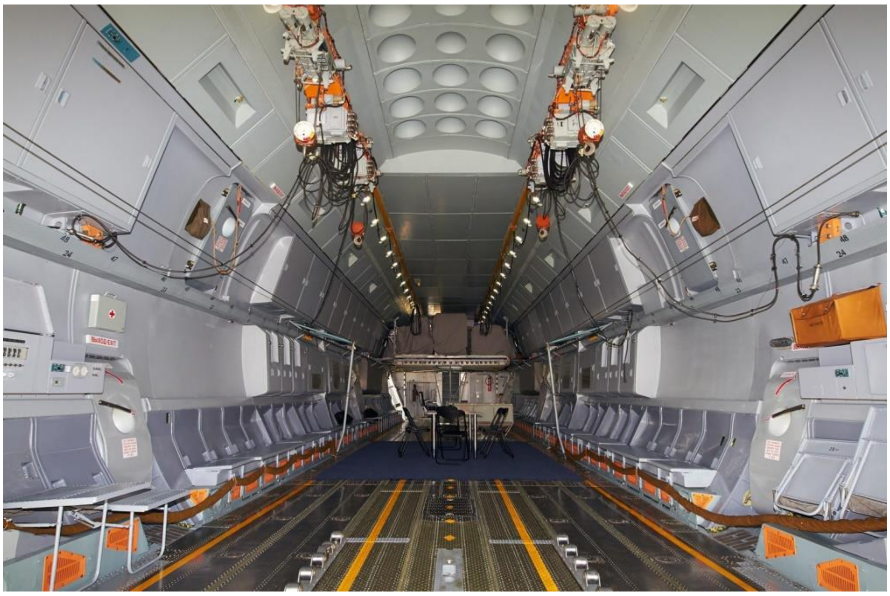

Fig.2.2. Telphers in the cargo hold of An-70.

The scheme of the telphers application in designed plane is shown in fig. 2.3

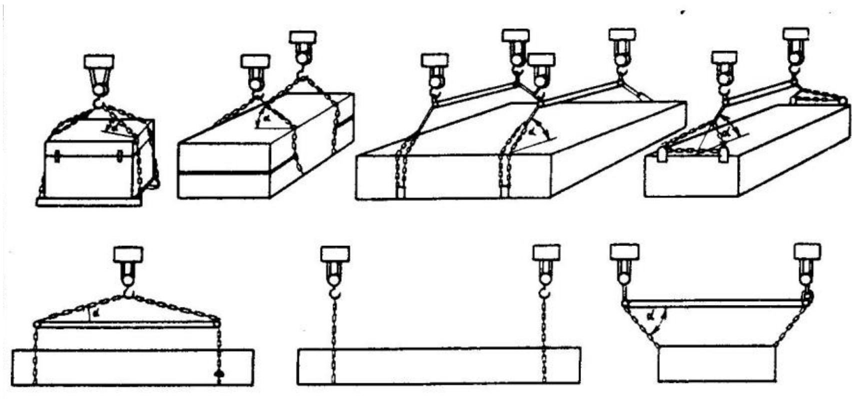

Fig.2.3.Telphers application in designed plane

2. Calculation of actuator and cable for telfer.

Given data:

Cable (Rope) load F=25000N.

Circumferential speed of drum V=0,7 (m/s).

Life span L_h=10000 (h).

Length of cable H=50 (m).

Type of lubrication – dipping.

Symbols and abbreviations

P_{ef} - useful power, KW;

P_{mot} - power of motor, KW;

d_{cab}- cable diameter, mm;

D_{drm} - drum diameter, mm;

u - gear ratio;

T - torque moment, Nm;

$[\sigma_H]$ - allowed contact stress, MPa;

$[\sigma_F]$ - allowed bending stress, MPa;

d_w - pitch diameter, mm;

m - gear module;

a_w - distance between axles, mm;

d_a - outside diameter, mm;

d_f - root diameter, mm;

b_w - face width, mm;

N_{H0}, N_{F0} — base number of repeated stress cycles;

N_H, N_F — rated number of stress cycles;

n_σ — normal stresses margin;

n_τ — shear stress margin;

n — total strength margin;

F_t — circumferential force, N;

F_r — radial force, N.

Calculation of motor power and frequency

Motor power:

$$P = \frac{F \cdot V}{1000 \cdot \eta p} = \frac{25000 \cdot 0{,}7}{1000 \cdot 0{,}87} = 20{,}114 \ (\mathbf{kWt})$$

η_p - gear box efficiency factor:

$\eta_p = \eta^2_{cpl} \times \eta^3_{bearing} \times \eta^2_{gear} \times \eta_{o.m} = 0{,}98^2 \times 0{,}99^3 \times 0{,}98^2 \times 0{,}98 = 0{,}87$, where

η_{cpl}=0,98 - coupling efficiency factor;

$\eta_{bearing}$=0,99 - bearing efficiency factor;

η_{gear}=0,98 - gear efficiency factor;

$\eta_{o.m.}$=0,98 - oil mixture efficiency factor.

Frequency of the magnetic field produced by the motor stator

$$n = \frac{60 f}{p} = \frac{60 \cdot 50}{2} = 1500 \ 1/\text{min}$$

where p - number of motor pole pairs

f - frequency of current, Hz.

Select motor:

P_{eng}=20kWt. Motor nomenclature - 20AM112M4У3.

Frequency of spinning with sliding accounting,

n_{spin}=1430 1/min.

$\frac{Tstart}{Tnom} = 2$, $\frac{Tmax}{Tnom} = 2{,}2$, $\frac{Tmin}{Tnom} = 1{,}6$, d_{in}=28mm

Calculation of fracture force and determination of drum diameter.

Cable (rope) fracture force with margin coefficient. *k=3*:

F_{fract}=kF= 3 × 25000 = 75000N

Rope diameter.

Steel rope with ultimate stress 400 kgf/mm^2.

Rated fracture force of all wires in cable.

F_{frac}= 75300N.

Cable diameter. d_{cable}= 38mm.

Diameter of central wire: 7 wires

$d_{c.w.}$= 0,8mm

Wire diameter in layers: 126 wires

d_{lay}= 0,76mm

Rated cross section of all wires.

A=75,85mm^2.

Rated mass of 1000 m of greased cable

m= 532,5 kg.

Drum diameter of the winch:

D_{dr}=(20…52)×d_{cable}=(20…25)×38=760…950(mm)

Adopt D_{dr}=780mm.

Gear ratio determination

Linear speed of the drum:

$$V = w\frac{Ddr}{2} = \frac{\pi \cdot ndr}{30} \cdot \frac{Ddr}{2}.$$

Drum rotation frequency:

$$n_{dr} = \frac{60 \cdot V}{\pi \cdot Ddr} = \frac{60 \cdot 1{,}4}{3{,}14 \cdot 0{,}78} = 34{,}2\ rpm.$$

Actual gear ratio:

$$u = \frac{neng}{ndr} = \frac{1430}{34{,}2} \approx 41{,}8.$$

Gear ratios of stages,

$u=u_{12} \cdot u_{34}$=6,63 · 6,3=41,8, where

u_{12}=6,63 - gear ratio of first stage

u_{34}=6,3 - gear ratio of second stage

Following tasks being solved by the methods of Machines Details. These are:

- Calculation of spur gear 1st stage;
- Selection of materials;
- Determination of the number of cycles of the wheel and gear alternating stresses;
- Determination of permissible stresses;
- Determination of initial(dividing) diameter of the gear;
- Determination of engagement modulus;

- Verification calculation;
- Calculation of planetary spur gears of the second stage;

2.2. Nondestructive inspection of steel ropes.

Wire ropes are consumable items with limited life. During service the physical properties of the wire rope will change. At the commencement of service, the individual wires and strands settle into position and the rope breaking strength increases. After reaching a maximum it decreases rapidly. (Fig.2.4)

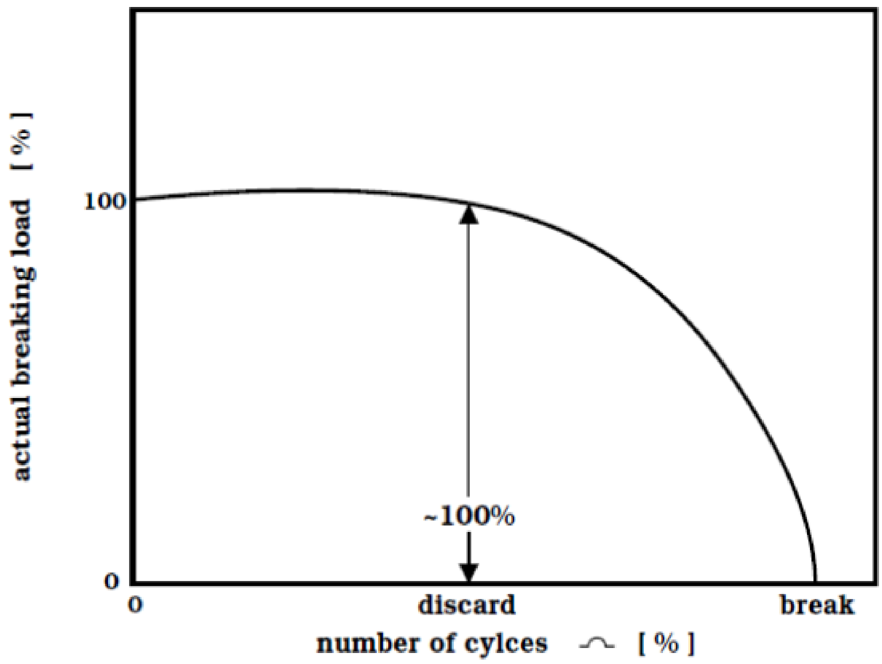

Fig. 2.4. Physical properties of the wire rope change during service

One of the objective of inspecting or examining a wire rope is to supervise the normal process of deterioration so that rope can be removed from service before becoming a hazard to safety. Another benefit of the inspection and examination procedures is to detect unexpected damage or corrosion.

Regardless of the construction, ropes deteriorate during their operation due to similar reasons, e.g. fatigue, corrosion, abrasion, mechanical damage, and overheating. Fatigue in wire rope is normally caused by repetitive bending on sheaves, drums, and causes wire brakes.

Broken wires or fractures, allocated on very short distance, are accepted to name as localized flaws (LF). They are one of indicator of rope degradation. When the number of broken wires exceeds affordable limit, the rope must be discarded.

Corrosion may occur even in very dry environment, especially on unprotected, nongalvanized wires. Abrasion is very typical for outer wires; however internal wires also may be abraded due to friction, while the rope moves over sheaves. Moreover for some rope constructions deterioration starts internally, and rope which looks good from outside may be dangerous due to high level of deterioration of internal wires. Corrosion and abrasion cause missing some amount of metal from wires. This is called as loss of metallic cross-section area (LMA), and is normally measured as relative amount in percentage to the cross section area of a new rope. According to relevant norms, the rope should be discarded when LMA value reaches limit, established for particular rope construction and application.

Broken Wire. A rope must be discarded if the permissible number of wire breaks is reached or exceeded. It must also be replaced when local concentrations of wire breaks occurs.

Reduction in diameter. Reduction in diameter can be caused by abrasion, corrosion or local failure of the rope core. According to BS 6570, "wire should be discarded when the rope diameter is anywhere reduced by 90% of the nominal diameter in the case of six and eight strand ropes".

Corrosion. Corrosion can be external or internal, general or localized. According to BS 6570, "wire rope should be discarded when the surface of the wire is completely roughened or pitted, or if the wires are slack within the strands due to wastage.

Rope deformation are: a) Waviness; b) Basket deformation; c) Loop formation; d) Loose wires; e) Nodes; f) Thinning of the ropes; g) Misplaced outer wires; h) Kinks; i) Flat areas.

Damage caused by heat. Heating rope wires to approximately 300 degree Celsius and over will lead to considerable reduction in tensile strength of the wires. Wire ropes which have been subjected to excessive heat must be discarded.

Where wire ropes must be inspected? During an inspection or a periodic examination by a competent person, full length of the ropes should be inspected. The following areas may require more detailed attention. a) Rope zones with the highest number of cycles. b) Pick up points c) End fittings d) Equalizing sleeves e) Zones of maximum wear on drums f) Sheaves g) Rope sections working in a hostile environment.

Visual testing. Visual testing (VT) enables to reveal outer defects such as corrosion, broken and missing wires if rope surface is accessible for visual examination. VT may be accompanied with haptic testing, use of mirror, magnifying glass, and is carried at low speed. For these reasons VT is tiresome, and requires sufficient time being very subjective. Most wires in the rope may not be visually inspected. Only outer wires are available for examination, but these wires disappear inside the rope on half of their length, and may be covered with heavy grease, that reduces effectiveness of such inspection. Ropes with protecting coating may not be inspected visually.

Note, that low rotation multilayer rope, widely used for lifting operations, start deterioration from inside, however inner broken wires may not be revealed visually. Nevertheless visual inspection in combination with use of magnetic instruments considerably increase reliability of information obtained from tested rope.

MFL (Magnetic Flux Leakage) **rope inspection.** Nowadays MFL principle is common for nondestructive testing of wire ropes. MFL instruments can precisely and fast measure LMA (Loss of Metallic cross-section Area) to assess level of abrasion and corrosion, and detect outer and inner LFs even under the grease or protecting coating. To obtain high LMA accuracy and LF (Localized Flaws). sensitivity MFL equipment should contain strong magnets to magnetically saturate the rope under test, and inspect the rope at applied magnetic field, i.e. while the rope is magnetically saturated. The operating principle is described at Fig. 2.5.

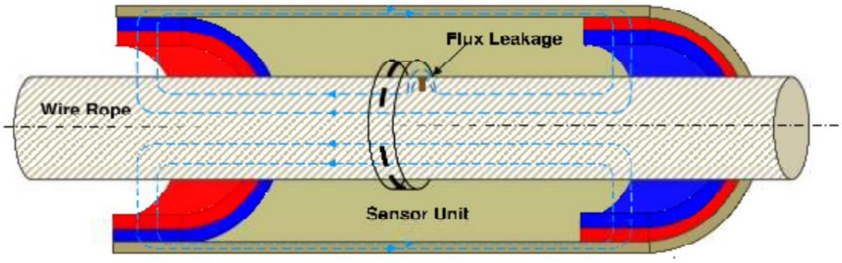

Fig.2.5 MFL instrument with strong magnetization. Principle of operation.

Magnetic head of the instrument usually comprises magnetizing system with permanent magnets, surrounding the rope under test and producing the magnetic flux along the rope. While rope is passing through the head, the section of rope inside the head is magnetically saturated. Sensors (Hall generators or coils), which are located inside the head close to the rope surface, catch magnetic flux leakage distortion, created by LF or/and LMA. Permanent magnets must be strong enough to magnetically saturate the rope, i.e. to reach working point A at hysteresis curve (Fig. 3). Most of equipment, designed for rope NDT, operate MFL principle, and for this reason inspection of rope with such instruments often called magnetic rope testing (MRT).

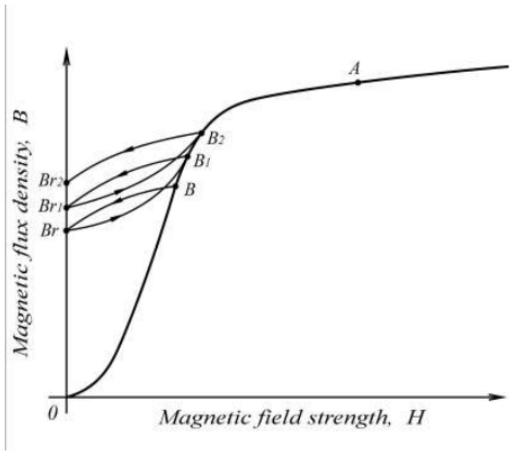

Fig.2.6. Hysteresis curve

Inspection with applied strong (A) and residual weak magnetization.

The larger is rope diameter the stronger magnets should be used, thus magnetic system becomes heavier and bigger.

Nevertheless there are two important reasons to uphold strong magnetization: - Magnetic properties of the rope may vary due to operational conditions, mechanical and thermal effect, etc. and variation in magnetic condition may cause reading errors.

Strong magnetization makes a magnetic property uniform and so provides higher inspection reliability and increases measuring accuracy; - Uniform magnetic flux in the rope provides higher sensitivity to both outer and inner broken wires.

Weak magnetization instruments for inspection of rope in residual magnetic field, recently appeared on the market may seem as worthy alternative to MFL instruments mentioned above due to relatively small weight.

However weak magnetization may not provide uniform steel magnetic properties and so performance of relevant instruments is worse: they have lower sensitivity, especially to inner defects; readings obtained from consecutive runs vary (Br , Br1, Br2 at Fig.2.6.) i.e. measuring repeatability is poor. Even use of sensors of higher sensitivity and increase of gain factor may not improve their performance. Besides, the testing results from weak magnetization instrument depend on previous magnetic condition of the rope. For instance, “magnetic spots” on the rope, created by heating, mechanical impact, etc. may be interpreted as defects. This was proved experimentally, by comparative test of weak and strong magnetization instruments available on the market.

Conclusion to part 2.

During working on part 2 was obtained some important parameters of cargo equipment which meets the requirements for prototype aircraft, this are:

Motor power: 20,114 (kWt).

Cable diameter: 38mm.

Rated mass of 1000 m of greased cable :532,5 kg.

Drum rotation frequency: 34,2 rpm

General conclusions

1. According to the task on diploma work the preliminary design of the cargo plane with the following characteristics has been performed: loading capacity -135 t, speed - 740 km / h, height of cruising flight – 11000 m.

2. The aerodynamic scheme is selected on the basis of the analysis of prototype aircrafts such as: AN-70, C-130J-30, Airbus A400M.

3. Aircraft parameters reflect current trends in aviation industry.

4. The telpher for loading system has been developed.

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