МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
д-р техн. наук, проф.
_____________ С. Р. Ігнатович
«_____» ___________ 2020 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ

"БАКАЛАВР"

Тема: «Аванпроект середньомагістрального літака пасажиромісткістю до 44 осіб»

Виконав: __________ **П.О. Корж**

Керівник: канд. техн. наук, доцент ___________ **В.І Закієв**

Нормоконтролер: канд. техн. наук, доцент ___________ **С.В. Хижняк**

Київ 2020

MINISRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

Department of Aircraft Design

AGREED
Head of the Department
Professor, Dr. of Sc.
_________S.R. Ignatovych
«___» _______ 2020 y.

DIPLOMA WORK

(EXPLANATORY NOTE)

OF ACADEMIC DEGREE

«BACHELOR»

Theme: «Preliminary design of middle range aircraft with a capacity of up to 44 passengers»

Performed by: __________ **P.O. Korzh**

Supervisor: PhD, associate professor __________ **V.I. Zakiev**

Standard controller: PhD, associate professor __________ **S.V. Khizhnyak**

Kyiv 2020

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Department of Aircraft Design

Academic Degree «Bachelor»

Speciality: 134 "Aviation and Rocket-Space Engineering"

APPROVED
Head of the Department
Professor, Dr. of Sc.
_________S.R. Ignatovych
«___» _______ 2020 year

TASK

for bachelor diploma work

KORZH PAVLO

1. Theme: «Preliminary design of middle range aircraft with a capacity of up to 44 passengers»

confirmed by Rector's order from 05.06.2020 year № 801/ст

2. Period of work execution: from 25.05.2020 year to 21.06.2020 year.

3. Work initial data: cruise speed V_{cr}=435 km/h, flight range L=1100 km, operating altitude H_{op}=6.5 km, max payload is 4356 kg.

4. Explanation note argument (list of topics to be developed): choice and substantiations of the airplane scheme, choice of initial data; engine selection, center of gravity calculation, layout of passenger cabin, explanation of Active Noise Control system.

5. List of the graphical materials: general view of the airplane (A1×1); layout of the airplane (A1×1); principal scheme of active noise control system(A1×1).

Graphical materials are performed in AutoCad and are illustrated as drawings.

6. Calendar Plan

Task	Execution period	Signature
Task receiving, processing of statistical data	25.05.2020-28.05.2020	
Aircraft take-off mass determination	29.05.2020-30.05.2020	
Aircraft layout	29.05.2020-31.05.2020	
Aircraft centering determination	31.05.2020-04.06.2020	
Graphical design of the parts	02.06.2020-10.06.2020	
Completion of the explanation note	10.06.2020-10.06.2020	
Preliminary defence	11.06.2020-15.06.2020	

7. Task issuance date: 25.05.2020 year.

Supervisor of diploma work ___________ V.I. Zakiev

Task for execution is given for ___________ P.O. Korzh

ABSTRACT

Explanatory note to the diploma work «Preliminary design of middle range aircraft with a capacity of up to 44 passengers» contains:

sheets, figures, tables, references and drawings

Object of the design is development of cargo aircraft with the possibility to accommodate up 44 passengers.

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 passenger capacity up to 44 passengers, 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.

AIRCRAFT, PRELIMININARY DESIGN, LAYOUT, CENTER OF GRAVITY POSITION

Format	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 20 07K TW	Task of work	1	
	2	NAU 20 07K 00 00 00 38 GV	Mid-range passenger aircraft	2	
A1		Sheet 1	General view		
A1		Sheet 2	Fuselage layout		
	2	NAU 20 07K 00 00 00 38 EN	Medium-range passenger aircraft	2	
			Explanatory note		
A4	3	NAU 20 07K 00 00 00 38 EN	Medium-range passenger aircraft		
			Explanatory note		
			<u>Documentation for assembly units</u>		
A1	4	NAU 20 07K 00 00 00 38 SP	Principal scheme of ANC system	1	

Ch.	Sheet	Doc.№	Sign.	Date	NAU 20 07K 00 00 00 38 EN		
Performed by	Korzh P.O.				List of diploma work	list	sheet	sheets
Supervisor	Zakiev V.I.							
Adviser						402 AF 134		
Stand. contr.	Khizhnyak S.							
Head. of dep.	Ignatovich S.							

CONTENT

Aircraft Structure Department				NAU 20 07K 00 00 00 38 EN			
Performed by	Kprzh P.O.			CONTENT	Letter	Sheet	Sheets
Supervisor	Zakiev V.I.						
Adviser					402 AF 134		
Stand.contr.	Khizhnyak S.						
Head of dep	Ignatovych S.						

INTRODUCTION

Currently, we can significantly observe a decrease in passenger traffic due to quarantine. But in the future, a significant increase in traffic is expected. According to this, airlines will increase the number of routes to small towns. In this regard, there will be a need for airplanes that fly over short distances, can land on runways with different quality of coverage. To ensure the profitable operation of the fleet with high reliability and regularity of flights in a highly competitive global market, new civilian aircraft are required that meet the requirements of the international air transport organization. Aviation is one of the most profitable means of transport for people, shortening the distance between all the people of the world

The success of the air transportation of passengers depends on the proper selection of the aircraft in accordance with the characteristics of the passenger flow (direction, climate, infrastructure). In many countries, air transport is considered to be the only means of access in areas where land transport is difficult to enter.

The purpose of this diploma project is to create an aircraft intended for the carriage of 44 passengers and baggage on middle distance routes.

ABREVIATION

TP - Taper Ratio

AR - aspect ration

GV - general view

AL - aircraft layout

SP - special part

IATA- International air transport association

FAA- Federal aviation administration

PO - principle of operation

ANC - Active Noise Control

BPF - Blade Passage Frequency

ODS - Operating Deflection Shape

1. Preliminary design of a middle range aircraft with a capacity of up to 44 passengers

1.1Analysis of prototypes, short description of designing aircraft and choice of the projected data.

Under the layout is understood the process of spatial alignment of parts of the aircraft (wings, engines, plumbing, chassis), design and power schemes in one unit, the placement of passenger, household equipment fuselage, cargo and equipment. The purpose of each of them is to achieve high cost-effectiveness of the aircraft.

The main tasks of the layout, which must be solved in the implementation of the CP: placement of aggregates, target load on the aircraft, provided the necessary operating range of centers; development and interconnection of the design and power schemes of parts of the aircraft (fuselage, wings, feathers, chassis, etc.).

Prototypes of the aircraft, taking for the designing aircraft were in class 40-50 passengers. Such aircraft like ATR-42, De Havilland Canada Dash 8-300 and Saab 2000 will compete with projected aircraft in this market segment. Statistic data of prototypes are presented in table 1.1.

The scheme is determined by the relative position of the aircraft units, their numbers and shape. Aerodynamic and operational characteristics of the aircraft depends on the aircraft layout and aerodynamic scheme of the aircraft. Fortunately chosen scheme allows to increase the safety and regularity of flights, and economic efficiency of the aircraft.

Table 1.1 – Operational-technical data of prototypes

PARAMETER	PLANES		
	A	D	Saab 2000
The purpose of airplane	Passenger	Passenger	Passenger
.		3	
Maximum take-off weight, m_{tow}, kg		16466	22999
, $m_{к.max}$, kg		3407	5900
	48	44	50
$V_{w.\ ек.}$, m			6900
$m_{к.max}$, km	2040	2650	2500
		1150	1223
N	2xPW127E	2xPW123C/D	2xAE 2100A
The form of the cross-section fuselage			
Extension of the fuselage	9,4		
Extending the nose and tail unit part	3,64	3.65	
Sweepback on 1/4 chord, ^{0}		5.3	

1.2. Brief description of the aircraft

The plane is a cantilever high-wing monoplane with bypass turboprop engines placed in wings and tricycle landing gear with a front single-strut landing gear and two main gears.

The fuselage is all-metal, beam-stringer, semi-monocoque type. The power set consists of 51 bulkheads. The fuselage is technologically divided into four parts: fore - compartment F1 (11 bulkheads), middle - compartment F2 (from 12 to 33 bulkheads), hatch (from 34 to 40 bulkheads) and tail - compartment F3 (from 41 bulkheads). Most elements of the fuselage structure are made of sheet and profiled duralumin.

The nasal compartment is airtight. It has a crew cabin, between 1 and 7 frames. Behind it is a partition with a door to the passenger cabin. The spout of the fuselage, up to 1 frame, is not airtight, it has a radar antenna. Under the cockpit is the compartment of the front chassis rack. Between the 5th and 7th frames on the starboard side is a radio operator's window, and on the left - the navigator's blister. On the starboard side there is an entrance door measuring 600 × 1400 mm. There are two emergency hatches in the cockpit: the upper one, to leave the cockpit during forced landings without the landing gear or on the water, and the lower one, to leave the aircraft in the air.

The wing of the aircraft is a highly located, free-carrying, rectangular in the area between ribs No. 7 and the trapezoidal shape in areas from ribs No. 7 to the tips. The wing has connectors on ribs No. 7 and No. 12 and is divided into a center section, two middle and two detachable parts. The detachable parts of the wing are installed with anhedral wing to obtain a good ratio of lateral and directional stability of the aircraft, as well as reduce the intensity of the roll of the aircraft towards the failed engine. The center wing carries two deviating single-slot flaps, the middle parts of the wing - one double-slot retractable flap, detachable parts of the wing - two sections of ailerons. Docking of the wing parts among themselves is carried out using the connector profiles (on the panels), fittings (on the shelves of the side members) and connecting squares (on the walls of the side members). Most elements of the wing structure are made of aluminum alloys. Docking of the wing with the fuselage and the individual parts of the wing with each other is carried out by bolts and nuts made of steel of various grades.

The center section consists of a caisson, a bow and a back parts. The caisson consists of two spars, a set of ribs and trim panels, made in conjunction with stringers. The lower panels of the center section, the upper ones adjacent to the side members, are not removable, but the upper middle ones are removable. Flaps are hung on ribs. On the ribs, the attachment points of the engines and the main landing gear are located. In the area of ribs there are nests for supports of ground hydraulic lifts. Between ribs, ten fuel tanks are installed. On the upper panel of the casing there are two filling necks of the fuel tanks and four hatches for fuel gauge sensors, and on the bottom panel there are two drain valves. To the ribs are attached two middle parts of the wing.

The middle part of the wing consists of a caisson, front and back parts. The caisson consists of two spars, a set of ribs and trim panels. The upper middle panel is removable; all other panels are non-removable. On the top panel there are hatches for installing the sensors of the fuel gauge, filler neck, float valve for pumping fuel, an opening for the drainage pipeline and a hatch for the fuel gauge line. On the bottom panel there are two drain cranes, three fuel pumps, as well as

PRF-4 landing and taxiing lights. The ribs No. 8 and No. 11 are reinforced, since they perceive the load from the attachment points of the monorail of the flaps. The wall of rib No. 8a is sealed, and in its upper part there are openings for fuel flow and drainage.

Single-slot deflecting flaps are installed in the tail section of the center section between ribs No. 2 and No. 5. Each flap consists of a side member, a set of ribs and a lining. The flap is secured to the center wing by two brackets mounted on ribs No. 3 and No. 4. A screw elevator is installed between the brackets. A flap 7 is mounted pivotally to the lower tail section of the center section, kinematically connected to the flap using rocking wheels with rollers, rods and brackets. When the flap deviates by 15 °, the flap completely deviates upward and opens the gap between the center wing and the flap. When flaps are retracted, the flap closes in the reverse order.

Double-slot retractable flaps are installed in the rear part of the ribs No. 7 and No. 12. By design, double-slot flaps the are similar to the center wing flaps, but a profiled deflector is attached to using webs. Two carriages are attached to the flap spar and two brackets for screw lifts. Two curved monorails are attached to the rear spar 1 in the area of ribs No. 8 and No. 11, and two screw lifts are mounted between ribs No. 7 and No. 8, No. 10 and No. 11. Release and retracting of the flaps is carried out by screw lifts, while the carriages move along the lower shelves of the monorails.

Empennage free-bearing, single-keel. It consists of two stabilizer brackets with a rudder, a keel with a rudder and a dorsal fin. Stabilizer and fin of two-spar design. Trimmers are installed on both rudders, and a spring trimmer -servo compressor is installed on the rudder directly. The rudders have axial aerodynamic compensation and are balanced. The total area of the stabilizer is 19.83 m², the fin is 13.28 m², and the dorsal fin is 2.57 m². The area of the rudder height is 5.16 m², the angles of deviation are 25 ° (up) and 20 ° (down). The area of the steering wheel is 5 m², the angles of deviation are ± 25 °.

Crew cabin

Structurally, the dashboard consists of three flat panels that are not interconnected: left, middle and right. Each panel is attached to structural elements through standard shock absorbers. A visor is installed above the dashboard, which serves to protect the instrument scales mounted on the board from sun glare.

For ease of viewing and use, the switches of devices, assemblies, systems and other equipment on the left and right panels are mounted on separate shields that are bent towards the pilots. Under the middle panel of the dashboard there is a panel with switches, which is mounted obliquely to the panel.

On the visor are installed: automatic attack angles and overload indicator - above the middle panel of the dashboard, left and signal panel blocks - above the left and right panels of the dashboard. An indicator of the radar station, indicators of the onboard vibration-converting equipment, indicators of the position of the output shaft of the temperature limit system, and a magnetic compass are installed above the visor on the cockpit light.

Instruments on the dashboard panels are placed as follows: on the left panel and the upper left part of the middle panel, the main flight and navigation instruments of the left pilot are located. In the upper right part of the middle panel are navigation instruments of the right pilot. The rest of the middle panel is occupied by instruments controlling the operation of engines, fuel system, landing gear retracting and releasing systems, flaps, air intake from engines for pressurization and sealing of cabs, as well as signal lamps and displays of various systems.

The passenger furnishing of the plane provides necessary conveniences on board. It includes adjustable chairs of pilots, flight attendance seats and passengers' seats; light filters and light-protective blinds and toilet.

Between a cabin of crew and a passenger cabin the toilet room and galley are placed (toilet on the left board, galley on the right board). The area of the toilet room is 1 square meter.

In a toilet are located a tank with water and technical liquid. In a toilet the toilet bowl of water vacuum type is established. Onboard there are three first-aid kits (one in a crew cabin, one is included in structure of crash equipment and one - in tail part).

Emergency equipment includes ropes, oxygen masks, smoke-proof masks, oxygen devices, the manual fire extinguisher, first-aid kits, an axe, emergency radio stations and a radio beacon, light marking of ways of evacuation, emergency lighting, a board "EXIT" near each emergency exit, life jackets on places of work of crew and the observer, life rafts on crew members and passengers.

Control system.

Control of the aircraft in flight is provided by control systems of rudders, ailerons, their trimmers and flaps. Control of rudders and ailerons direct (booster-free), double, that is can be carried out from places of both pilots. To ensure synchronicity of control, the rudders and pedals of the left and right pilots are kinematically connected to each other. Steering wheels and pedals are mounted on the general control panel located behind a dashboard.

Trimmers are installed on each half of the height rudder and on the left aileron, and a trimmer-servo compensator is installed on the rudder. In addition, servo compensators are installed on each aileron.

The steering wheels and ailerons in the parking lot are locked. To prevent takeoff with locked rudders and ailerons, there is a lock that restricts the movement of the rudder.

The rudders for steering the trimmers of the rudder, the control switches for the trimmers of the rudder and aileron, as well as the handle for locking the rudders and ailerons are located on the central console. Emergency control of rudder and aileron trimmers is provided. The steering, ailerons and trimmers of the rudder include an autopilot with four steering machines.

The steering system is connected to the braking system and the turning of the wheels.

The control system of flaps is electrohydromechanical. Release and retracting of flaps is carried out by the hydraulic drive by means of a transmission shaft and screw elevators. Control of release and retracting of flaps is made from the central panel.

Landing gear

The aircraft has a retractable landing gear, made according to the three-support scheme, consisting of:

- two main and one front support;
- chassis retracting and releasing systems;
- wheel braking systems of the main landing gear;
- steering systems for turning the wheels of the front landing gear.

The struts of the main landing gear are installed in the engine nacelles and in flight are retracted forward into special compartments under the engines. Two wheels with low-pressure pneumatics and disc brakes are installed on each amortization rack on a common fixed axis.

The front shock strut is installed in the nose of the fuselage and in flight retracts forward into the compartment under the cockpit. Two non-brake wheels with low-pressure pneumatics are mounted on a common suspension rotating axis. In the released and retracted position, the struts are fixed with mechanical locks that open with the help of hydraulic cylinders.

Chassis compartments are closed by flaps both with fully retracted and extended positions of the srtuts. With the released position of the struts, only the shutters located directly at the suspension struts do not close. The chassis flaps open and close with the help of mechanisms kinematically connected with the amortization pillars.

The flaps of the main landing gear when the amortization pillars are retracted are fixed with mechanical locks kinematically connected with the locks of the retracted position.

The main control for retraction and releasing the chassis is electro-hydraulic, emergency - mechanical, due to the manual opening of the locks of the retracted position. The braking control of the wheels of the main landing gear and the rotation of the bow support is hydromechanical.

The wheel braking system of the main chassis supports provides basic, emergency and parking braking. In the main braking mode, anti-skid automation works.

The system of turning the wheels of the front landing gear provides taxiing and take-off and landing operation modes, as well as a self-orientation mode when towing and in the event of a failure of the take-off and landing control mode.

To prevent accidental folding of the chassis on the ground, it is possible to block the operation of the retraction system with compressed shock absorbers (limit switch on the double link of the right support). In addition, the limit switch mounted on the front shock absorber locks the front wheels turning system after taking them off the ground and turns on the MS-61 and MSRP-12, and the limit switch mounted on the two-link left shock rack blocks the heating circuit of the RIO-3 signaling device when crimped shock absorber.

Engines

The aircraft is equipped with two AI-24WT turboprop engines with a takeoff power of 2820 hp. The engines are located in nacelles on the centerplane. AI-24W is equipped with a ten-stage compressor and a three-stage turbine. The combustion chamber is ring with 8 nozzles. The engine also includes: starter-generator, alternator, aerodynamic sensors, icing detector, torque transmission system, oil filter and propeller speed regulator. T-1 and TS-1 fuel is used to power the engines. The engine is mounted on the center of the wing with a quick-release frame with shock absorbers and a power truss with a front power frame.

Auxiliary power unit

In the tail of the right nacelle is an additional power plant (APU): turbojet engine RU19A-300 with a thrust of 800 kgf.

It provides:

- additional thrust during takeoff and climb;
- required thrust in case of engine failure AI-24W;
- on-board start of AI-24WT engines;
- power supply of the aircraft onboard network in the parking lot, when the AI-24WT engines are not working and when the STG-18TMO-1000 generators fail.

The RU19A-300 engine is equipped with a seven-stage compressor, an annular combustion chamber, a single-stage turbine and an unregulated jet nozzle.

1.2.1 Description of aircraft systems

Fuel system

The fuel system includes 10 soft tanks and two tank compartments. The tanks of each half-wing are divided into 3 groups. To power the engines, fuel is first taken from the first group of tanks, then from the second, and then from the third. Tank 3a is also used as an expansion tank for even fuel distribution between the left and right sides of the aircraft. Filling of tanks can be carried out from above through refueling mouths or centrally through the refueling union in a compartment of the chassis of the left nacelle. In flight, the neutral gas system fills the space above the fuel with carbon dioxide, and this system is also used as an additional means of extinguishing fires.

Oil system

Each engine has an autonomous oil system (OS), which provides oil supply for engine lubrication and cooling, propeller control and torque change system operation. OS is divided into internal and external. The internal OS consists of: injection and pumping section of the OS, air separator, oil filters, engine channels, oil collector and pipelines located directly on the engine. External OS consists of: oil tank, drainage tank, oil cooler with thermostat, pump, piping and control devices. The volume of the OS is 64 liters, and before the departure of the aircraft in the oil tank pour another 35-37 liters of oil. The engine oil system uses a mixture of lubricants: 75% transformer oil MK-8 and 25% oil MS-20 or MK-22.

Fire protection system

The aircraft has a stationary fire protection system and hand-held portable fire extinguishers. The stationary system is divided into an aircraft fire protection system and an engine fire protection system.

The firefighting system of the aircraft is designed to eliminate fires in the compartments of the left and right parts of the wing and in the left and right nacelles. The system consists of four fire extinguishers OS-8MF or UBC8-1, two blocks of fire valves, fire alarm system SSP-2A, spray collectors and pipelines. The system is controlled manually from the fire protection panel and automatically from the alarm sensors. Also at emergency landings without the released chassis from the limit switches located on the bottom of a fuselage, all fire extinguishers work, and all valves open.

The fire-fighting system of engines is intended for elimination of a fire in engines. The system consists of four fire extinguishers OS-2 or UBSH2-1, filters, fire alarm system SSP-7, tees and pipelines.

Hydraulic system

Hydraulic system (HS) is designed for retracting / releasing the chassis, turning the wheels of the front support of the chassis, braking the wheels of the main supports of the chassis, release / retracting the flaps, for wipers, emergency activation of spools controls of a ramp of a cargo hatch. AMG-10 mineral oil is used as a working fluid. The total volume of HS 65 liters. HS consists of a main, emergency and manual pump system.

The main HS is used under normal conditions and serves all nodes that operate from the HS. The source of pressure for the main HS are two pumps located on the engines. Also in the system there are hydraulic accumulators which provide work of knots at aircraft parking.

The emergency HS can be used to release the flaps, brake the wheels, open the emergency hatch cover and control the cargo hatch ramp, in case of failure of the main HS. The source of pressure of the emergency HS is an electric pump. If necessary, this pump can be connected to the main HS.The hand pump system can be used to control the ramp.

All HS has a common tank with a capacity of 37 liters. However, the fluid intake fitting for the main system is above the bottom, and the emergency and manual pump system is at the bottom. This provides a supply of fluid for these systems in the event of fluid loss from the main HS.

Electrical system

Prvides power supply with a direct current voltage of 27 V, alternating current (with a frequency of 400 Hz) single-phase current with a voltage of 115 V and three-phase current with a voltage of 36 V. Two STG-18TM starter generators are used as the main source of direct current generators. The source of alternating current, voltage 36V, is the converter PT-1000TSS. For emergency power supply of DC consumers there are three rechargeable batteries 12AM-2V, AC voltage 115V - converter PO-750A, and AC voltage 36V - transformer TS-310S04A, the primary winding of which is connected to the right AC generator GO16PN8. The AGD-1 air horizon and the GIK-1 compass have a separate backup power supply from the PT-200 voltage converter.

Anti-icing system

It consists of air-thermal and electro-thermal systems. The air-thermal anti-icing system is equipped with wings, aircraft tail cone and engine air intakes. Hot air enters the anti-icing system from the 10th stage of the compressor of each engine through a pipe laid on the starboard side of the nacelle. The air-heat system uses a micro injector method of air distribution with recirculation of exhaust air. This method provides efficient, uniform heating of the surface along its entire length, as well as economical consumption of hot air.

Electro-thermal anti-icing system is equipped with propellers, cockpit windshield and air pressure receivers.

Air conditioning system

The air conditioning system is designed to maintain in a sealed cabin temperature and air pressure within acceptable limits at high altitudes. Air for heating / cooling, ventilation and inflating the cab is extracted from the compressors of the main engines. To cool to the desired temperature, the air passes through the refrigeration unit, and then enters the cabin. The air is extracted at a speed of 1440 kg / h, which provides 20-26 times the air exchange in the cabin. The cabin pressure is regulated by the exhaust valve.

Conclusion to the analytical part

After analyzing the data of the prototypes, their technical characteristics, we came to the conclusion that for the design of the aircraft, the most optimal will be the aerodynamic scheme of a high-wing monoplane with a standart tail unit.

The high-wing monoplane scheme has many advantages such as: improving the view in the lower semi sphere, which makes it easier to observe land when approaching. The high position of the engines reduces the probability of their damage during take-off and landing on unequipped runways. The round cross-sectional shape is the most beneficial, because provides the minimum perimeter for a constant cross-sectional area, respectively, the minimum surface area at a constant volume, and therefore, such a fuselage will have a low friction. It provides the best aerodynamic and strength characteristics.

There was chosen tricycle landing gear, because it is simpler piloting technique on take-off, landing and run. It has close horizontal position of the floor of passenger and cargo cabs. As well, stability of motion on the run and run, which is ensured by the application of friction forces of the wheels of the main supports behind the center of mass of the aircraft, and also there is more intense braking on the run and the possibility of speed landing, which ensures the elimination of the danger of aircraft nosing.

1.3 Airplane design and calculations

Layout of the airplane consists from compiling the relative location of its parts and structures, and all kinds of the loads (crew, systems, furnishing, and so on).

The choice of the composition and parameters of the aircraft is aimed at better compliance with operational requirements.

1.3.1. Wing geometry calculation

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

Full wing area with extensions is:

$$S_{wfull} = \frac{m_0 \cdot g}{P_0} = \frac{18529 \cdot 9,8}{2383} = 76,19\ [\,m^2] \quad (1.1)$$

Relative wing extensions area is 0.1

Wing area is:

$$S_w = 215.43 \cdot 0.9 = 193.88 \quad [m^2] \quad (1.2)$$

Wing span is:

$$l = \sqrt{S_w \cdot \lambda_w} = \sqrt{11.37 \cdot 76.19} = 29.432\ \ [m] \quad (1.3)$$

Root chord is:

$$b_0 = \frac{2S_w \cdot \eta}{(1+\eta)l} = \frac{2 \cdot 76.19 \cdot 2.92}{3.92 \cdot 29.432} = 3.85 \quad [m] \quad (1.4)$$

Tip chord is:

$$b_t = \frac{b_0}{\eta} = \frac{3.85}{2.92} = 1.318\ \ [m] \quad (1.5)$$

At a choice of power scheme of the wing we determine number of longerons and its location, and the places of wing portioning.

On the modern aircraft we use xenon double – or triple – longeron wing; longeron wing is common to the light sport, sanitary and personal aircrafts. Our aircraft has three longerons.

I use the geometrical method of mean aerodynamic chord determination (figure 1.1). Mean aerodynamic chord is equal : b_{mac}=2.7907

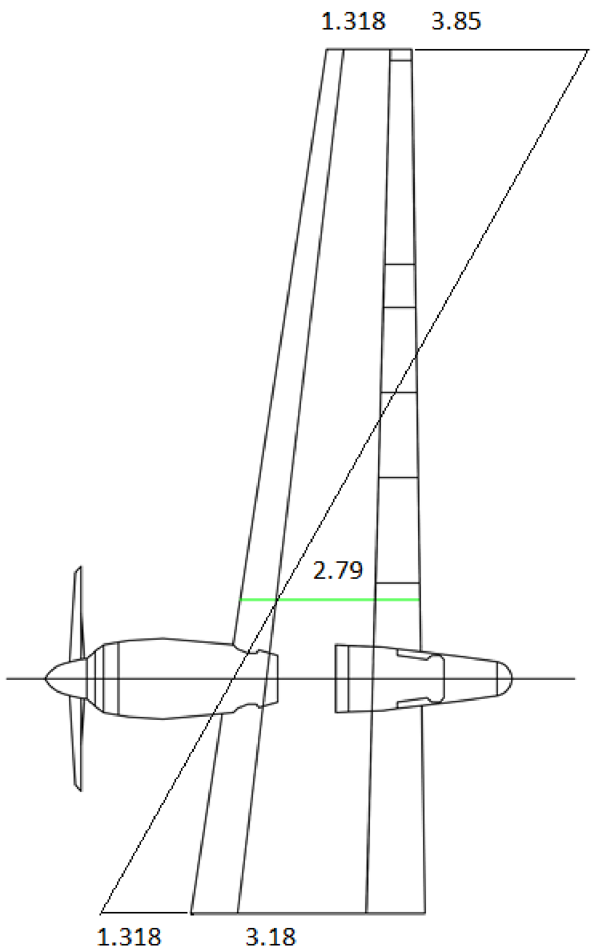


Figure 1.1 – Determination of mean aerodynamic chord

After finding 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 order:

Ailerons span:

$$l_{ai} = 0.375 \cdot \frac{l_w}{2} = 0.375 \cdot \frac{29.432}{2} = 5.518 \ [m] \tag{1.6}$$

Aileron area:

$$S_{ail} = 0.065 \cdot \frac{S_W}{2} = 0.065 \cdot \frac{76.19}{2} = 2.476 \quad [m^2] \tag{1.7}$$

Aerodynamic compensation of the aileron.

Axial $S_{axinail} \leq (0.25\ldots0.28)$

$$S_{ail} = 0{,}26 \cdot 5{,}518 = 1{,}43 \quad [\,m^2] \tag{1.8}$$

Inner axial compensation $S_{inaxinail} = (0.3..0.31)\ S_{ail}$;

Range of aileron deflection

Upward $\delta'_{ail} \geq 20°$;

Downward $\delta''_{ail} \geq 10°$.

The purpose of finding of wing high-lift devices geometrical parameters is the ensuring of take of and landing coefficients of wing lift , received in the previous calculations with the selected rate of high-lift devices and the type of the airfoil shape.

Before performing following calculations it is necessary to select the type of aerodynamic profile due to the airfoil catalog, indicate 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 lift force in the landing configuration of the wing by the airplane landing insuring (it is determined during the choice is the airplane 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.

Efficiency of high-lift devices (C^*_{ymaxl}) increases proportionally to the wing span increase, serviced by high-lift devices, so we need to obtain the biggest span of high lift devices ($l_{hld} = l_w - D_f - 2l_{ail} - l_n$) due to use of flight spoiler and maximum reduction of the engine and chasis nacelles.

During the choice of structurally-power schemes, hinge-fitting schemes and kinematics of the high-lift devices we need to proceed from the statistics and experience of domestic and foreign airplane construction. It should be noted that in the most of existing structure elements of high-lift devices are made by longeron structurally-power schemes.

Fuselage layout

During the choice of the shape and the size of fuselage cross section we must proceed from the aerodynamic requirements (streamlining and cross section).

Applicable to the subsonic passenger and cargo aircrafts (V < 800 km/h) wave impedance does not affect it. Therefore we need to select from the conditions of the list values friction resistance C_{xf} and profile resistance C_{xp}.

During the transonic and subsonic flights, shape of fuselage nose part affects the value of wave impedance C_{xw}. Using of circular shape of fuselage nose part significantly reduces its wave impedance.

For transonic airplanes fuselage nose part has to be:

$$l_{nfp} = 2.1 \cdot D_f = 2.1 * 8 = 16.8 \quad [m]$$

In addition to taking into account the aerodynamic requirements when choosing a cross-sectional shape, we need to take into account the strength and layout requirements.

To ensure of the minimum weight, the most convenient fuselage cross section shape is circular cross section. In this case we have the minimal fuselage skin width.

To geometric parameters we relate: fuselage diameter D_f; fuselage length l_f; fuselage aspect ratio λ_f; fuselage nose part aspect ratio λ_{np}; tail unit aspect ratio λ_{TU}. Fuselage length is determined taking into account the aircraft scheme, layout and airplane center-of-gravity position peculiarities, and the conditions of landing angle of attack α_{land} ensuring.

Fuselage length is equal:

$$l_f = \lambda_f \cdot D_f = 2.65 * 8 = 21.2 \quad [m] \tag{1.9}$$

Fuselage nose part aspect ratio is equal:

$$\lambda_{fnp} = \frac{l_{fnp}}{D_f} = \frac{16.8}{8} = 2.1 \tag{1.10}$$

Length of the fuselage rear part is equal:

$$l_{frp} = \lambda_{frp} \cdot D_f = 2.1 * 8 = 16.8 \quad [m] \tag{1.11}$$

During the determination of fuselage length we strive for approaching minimum mid-section S_{ms} from one hand and layout demands from the other hand.

For passenger and cargo aircraft fuselage middle-section first of all taking from the size of passenger compartment or cargo cabin. One of the main parameter, determining the middle part of passenger airplane is the height of the passenger compartment.

For short range airplanes we may take the height as: h_1=1.75m; passage width b_p=0.45...0.5m; the distance from the window to the flour h_2=1m; luggage space h_3=0.6...0.9m.

For long range airplanes correspondingly: the height as: h_1=1.9m; passage width b_p=0.6m; the distance from the window to the flour h_2=1m; luggage compartment h_3=0.9...1.3m.

From the design point of view it is convenient to have round cross section, because in this case it'll be the strongest and the lightest. But for passenger and cargo accommodation this shape is not always the most convenient one. In the most cases, one of the most suitable ways is to use the combination of two circles intersection, or oval shape of the fuselage. We need to remember that the oval shape is not suitable in the production, because the upper and lower panels will bend due to additional pressure and will demand additional bilge beams, and other construction reinforcements.

The normal bulkhead pitch in the fuselage construction is in the range of 360...500mm, depends on the fuselage type and class of passenger compartment.

Form the design consideration with the diameter less than 2800mm we don't use such shape and we follow to the intersecting circles cross section. In this case the flour of the passenger compartment is done in the plane of are closing.

The windows are arranged in one light row. The shape of the window is round, with the diameter of 300...400mm, or rectangular with the rounded corners. The window step corresponds to bulkhead step and is 500...510mm.

For economic salon with the scheme of allocation of seats in the one row (2 + 2) determine the appropriate width of the cabin

$$B_{cab} = n_{2chblock} \cdot b_{2chblock} + b_{aisle} + 2\delta = 2.50 \quad [m] \tag{1.12}$$

The length of passanger cabin is equal:

$$L_{cab} = L_1 + (n_{raws} - 1) \cdot L_{saetpeach} + L_2 = 19.8 \ [m] \quad (1.13)$$

Lavatories

Number of toilet facilities is determined by the number of passengers and flight duration: with t> 4:00 one toilet for 40 passengers, at t = 2 ... 4 hours and 50 passengers t <2 hours to 60 passengers.

The number of lavatories I choose according to the original airplane and it is equal:

$n_{lav}=1$

Area of lavatory:

$S_{lav}=0.5m^2$

Width of lavatory:1m. Toilets design similar to the prototype.

1.3.3 Layout and calculation of basic parameters of tail unit

One of the most important tasks of the aerodynamic layout is the choice of tail unit location. For ensuring longitudinal stability during overload, its center of gravity should be located in front of the airplane focus and the distance between these points, associated with the average value of the aerodynamic belt of the wing, determines the index of longitudinal stability.

$$m_x^{Cy} = \overline{x}_T - \overline{x}_F < 0$$

Where m^{Cy}_x –is the moment coefficient; $x_{T.}$ x_F- center of gravity and focus coordinates. If m^{Cy}_x=0, than the plane has the neutral longitudinal static stability, if m^{Cy}_x>0, than the plane is statically instable. In the normal airplane scheme (tail unit is behind the wing), focus of the combination wing – fuselage during the installation of the tail unit of moved back.

Static range of static moment coefficient: horizontal A_{htu}, vertical A_{vtu} given in the table with typical arm Htu and Vtu correlations. Using table we may find the first approach of geometrical parameters determination.

Determination of the tail unit geometrical parameters

Area of vertical tail unit is equal:

$$S_{VTU} = \frac{l_W S_W}{L_{VTU}} \cdot A_{VTU} = \frac{29.432 \cdot 76.19}{21} \cdot 0.599 = 14.96 m^2 \quad (1.14)$$

Values L_{htu} and L_{vtu} depend on some factors. First of all their value are influenced by: the length of the nose part and tail part of the fuselage, sweptback and wing location, and also from the conditions of stability and control of the airplane.

Determination of the elevator area and direction:

Altitude elevator area:

$$S_{el} = 0.2765 \cdot S_{HTU} = 2.25 \quad [m^2] \tag{1.16}$$

Rudder area:

$$S_{rud} = 0.02337 \cdot S_{VTU} = 5.9 \quad [m^2] \tag{1.17}$$

Choose the area of aerodynamic balance.

$0.3 \leq M \leq 0.6$, $S_{eb}=(0.22..0.25)S_{ea}$, $S_{rb}=(0.2..0.22)S_{rd}$

Elevator balance area is equal

$$S_{el} = 0.2765 \cdot S_{HTU} = 4.13644 \quad [m^2] \tag{1.18}$$

Rudder balance area is equal:

$$S_{rb} = 0.2337 \cdot S_{VTU} = 3.496152 \quad [m^2] \tag{1.19}$$

The area of altitude elevator trim tab:

$$S_{te} = 0.08 \cdot S_{el} = 0.33 \quad [m^2] \tag{1.20}$$

Area of rudder trim tab is equal:

$$S_{tr} = 0.06 \cdot S_{rud} = 0.354 \quad [m^2] \tag{1.21}$$

Root chord of horizontal stabilizer is:

$$b_{0HTU} = \frac{2S_{HTU} \cdot \eta_{HTU}}{(1+\eta_{HTU}) \cdot l_{HTU}} = \frac{2 \cdot 8.17 \cdot 2.4679}{(1+2.4679) \cdot 7.56} = 1.5381 \quad [m^2] \tag{1.22}$$

Tip chord of horizontal stabilizer is:

$$b_{0HTU} = \frac{b_{0HTU}}{\eta_{HTU}} = \frac{1.5381}{1.4679} = 1.0478 \quad [m] \tag{1.23}$$

Root chord of vertical stabilizer is:

$$b_{0VTU} = \frac{2 \cdot S_{VTU} \eta_{VTU}}{(1+\eta_{VTU}) \cdot l_{VTU}} = \frac{2 \cdot 14.96 \cdot 1.9572}{(1+1.9572) \cdot 3.75} = 5.28 \quad [m] \tag{1.24}$$

Tip chord of vertical stabilizer is:

$$b_{0VTU} = \frac{b_{0VTU}}{\eta_{VTU}} = \frac{5.28}{1.9572} = 2.7 \quad [m] \tag{1.25}$$

1.3.4 Landing gear design

At the initial design stage, when the airplane center-of-gravity position is determined and there is no drawing of airplane general view, only the part of chassis parameters may be determined.

Main wheel axel offset is:

$$e = 0.2673 \cdot b_{mac} = 0.7459 \quad [m] \tag{1.26}$$

With the large wheel axial displacement the lift of the front gear during take-off is complicated, and with small, the drop of the airplane on the tail is possible, when the loading of the back of the airplane comes first. Chassis wheel base comes from the expression:

$$B = 0.4526 \cdot L_f = 21.2 \cdot 0.4526 = 9.59512 \quad [m] \tag{1.27}$$

The last equation means that the nose support carries 6...10% of aircraft weight. Front wheel axial offset will be equal

$$d_{ng} = B - e = 8.84922 \ [m] \tag{1.28}$$

Wheel track is:

$$T = 0.6072 \cdot B = 5.82616 \quad [m] \tag{1.29}$$

On a condition of the prevention of the side nose-over the value K should be > 2H, where H – is the distance from runway to the center of gravity.

Wheels for the chassis is chosen by the size and run loading on it from the take-off weight; for the front support we consider dynamic loading also.

Type of the pneumatics (balloon, half balloon, arched) and the pressure in it is determined by the runway surface, which should be used.

We install breaks on the main wheel, and sometimes for the front wheel also. The load on the wheel is determined:

K_g = 1.5...2.0 – dynamics coefficient.

Nose wheel load is equal:

$$P_{NLG} = \frac{(9.81 \cdot e \cdot k_g \cdot m_0)}{(B \cdot z)} = 12364.1615 \quad [N] \tag{1.30}$$

Main wheel load is equal: 0

$$P_{MLG} = \frac{(9.81 \cdot (B-e)m)}{(B \cdot n \cdot z)} = 20954.8996 \quad [N] \tag{1.31}$$

Table 1.2 – Aviation tires for designing aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
1050x 400	18	700x250 mm	12

1.4 Center of gravity calculation

1.4.1 Trim-sheet of the equipped wing

Mass of the equipped wing consists of the mass of its structure, mass of the equipment located in the wing and mass of the fuel. Regardless of the installation location (to the wing or to the fuselage), the main chassis and the front gear are included in the mass register of the equipped wing. The mass register includes names of the objects, mass themselves and their center of gravity coordinates. The origin of the given coordinates of the mass centers is selected by the projection of the nose point of the mean aerodynamic chord (MAC) for the surface XOY. The positive meanings of the coordinates of the mass centers are accepted for the end part of the aircraft.

The example list of the mass objects for the aircraft, where the engines are located under the wing, included the names given in the table 3.1.The example list of the mass objects for the aircraft, where the engines are located in the wing, included the names given in the table 3.1. The mass of AC is 91295 kg. Coordinates of the center of power for the equipped wing are defined by the formulas:

$$X_w^{/} = \frac{\Sigma m_i^{/} x_i^{/}}{\Sigma m_i^{/}}$$

n	object name	Mass units	Total mass	Coordinate	Mass moment
1	wing (structure)	0,15617	2893,67393	1,3356	3864,790901
2	fuel system	0,00124	22,97596	1,3356	30,68669218
3	airplane control, 30%	0,00351	65,03679	1,908	124,0901953
4	electrical equipment, 30%	0,009	166,761	0,318	53,029998
5	anti-ice system , 70%	0,01379	255,51491	0,318	81,25374138
6	hydraulic systems , 70%	0,0196	363,1684	1,908	692,9253072
7	power plant	0,10032	1858,82928	-1,2	-2230,59514
8	equipped wing without landing gear and fuel	0,30363	5625,96027	0,4650196	2616,181699
9	Nose landing gear	0,0039552	73,2859008	-6,81	-499,076984
10	Main landing gear	0,0454848	842,7878592	1,749	1474,035966
11	fuel	0,102	1889,958	1,3674	2584,328569
	total	0,45507	8431,99203	0,7323856	6175,469249

1.4.2 Trim-sheet of the equipped fuselage

Origin of the coordinates is selected in the projection of the nose of the fuselage on the horizontal axis. For the axis X the construction part of the fuselage is given. The example list of the objects for the AC, which engines are mounted under the wing, is given in

The CG coordinates of the FEF are determined by formulas:

$$X_f = \frac{\Sigma m_i^{/} X_i^{/}}{\Sigma m_i^{/}};$$

After we determined the C.G. of fully equipped wing and fuselage, we construct the moment equilibrium equation relatively to the fuselage nose:

$$m_f x_f + m_w (x_{MAC} + x_w^{/}) = m_0 (x_{MAC} + C)$$

From here we determined the wing MAC leading edge position relative to fuselage, means $\boldsymbol{X_{MAC}}$ value by formula:

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w^{/} - m_0 C}{m_0 - m_w}$$

where $\boldsymbol{m_0}$ – aircraft takeoff mass, kg; $\boldsymbol{m_f}$ – mass of fully equipped fuselage, kg; $\boldsymbol{m_w}$ – mass of fully equipped wing, kg; $\boldsymbol{C}$ – distance from MAC leading edge to the C.G. point, determined by the designer.

$\boldsymbol{C}$ = (0,22...0,25) $\mathbf{B_{MAC}}$ –low wing ;

$\boldsymbol{C}$ = (0,25...0,27) $\mathbf{B_{MAC}}$ – center wing;

N	objects names	Mass		C.G coordinates Xi, м	mass moment
		units	total mass		
1	fuselage	0,15973	2959,63717	11,89	35190,08595
2	horizontal tail	0,01627	301,46683	1,10925	334,4020812
3	vertical tail	0,01618	299,79922	1,4875	445,9513398
4	radar	0,0034	62,9986	1	62,9986
5	radio equipment	0,0045	83,3805	1	83,3805
6	instrument panel	0,0079	146,3791	2,5	365,94775
7	aero navigation equipment	0,0068	125,9972	2	251,9944
8	aircraft control system 70%	0,0078	144,5262	11,89	1718,416518
9	hydro-pneumatic sys 30%	0,00822	192,99738	16,646	3212,634387
10	electrical equipment 70%	0,021	493,059	11,59	5862,47151
11	not typical equipment	0,0021	49,3059	11,59	586,247151
12	furnishing and thermal equipment	0,0107	251,2253	11,35	2987,068817
13	anti ice and airconditioning system	0,0197	462,5363	15,457	7149,423589
14	Galley and lavatory	0,00223	52,35817	11,5	602,118955
15	baggage	0,02497	586,27063	3,5	2051,947205
16	additional equipment	0,00213	50,01027	12,34	594,6221103
17	equipped fuselage without payload	0,31363	6261,94777	9,8211791	61499,71087
18	passengers	0,2223	4118,9967	11,5	47368,46205
19	crew	0,009	160	2,5	400
	TOTAL	0,54493	10540,94447	10,36607	109268,1729
	TOTAL fraction	1			

1.4.3 Calculation of center of gravity positioning variants

The list of mass objects for centre of gravity variant calculation given in Table 3.3 and Center of gravity calculation options given in table 3.4, completes on the base of both previous tables.

Table 1.5 – Calculation of C.G. positioning variants

Name	mass in Kg	coordinate	mass moment
object	m_i	X_i,, м	Kg.m
equipped wing (without fuel and landing gear)	5625,96027	10,51574399	59161,158
Nose landing gear (extended)	479,47614	13,55072441	6497,249
main landing gear (extended)	1917,90456	22,11072441	42406,259
fuel reserve	461,92797		
fuel	19842,29973	22	436530,59
equipped fuselage (without payload)	11977,96261	11,89	142417,98
passengers of business class	900	0	8280
passengers of economy class	8100	9,2	74520
baggage	2400	11	26400
cargo	1677,53	0	0
crew	520	2,5	1300
nose landing gear (retracted)	479,47614	12,55072441	6017,7729
main landing gear (retracted)	1917,90456	21,11072441	40488,355
reserve fuel	2570,98413	22	56561,651

Table 1.6 – Airplanes C.G. position variants

№п/п	Назва об'єкта	Маса, m_i кГ	mass moment m_iX_i	center of mass $X_{цм}$	center X_C %
1	take off mass (L.G. extended)	63591	797513,2356	12,541291	19,6019
2	take off mass (L.G. retracted)	63591	795115,8549	12,503591	30,5413
3	landing weight (LG extended)	36169,81771	417544,2924	11,543998	22,7552
4	ferry version	40363,60331	685915,8549	16,993425	12,9266
5	parking version	20001,30358	250482,6416	12,523316	14,4839

Conclusion to the main part

In this part, we calculated the basic geometric parameters of the layout of the aircraft, such as: wing, fuselage, tail unit, landing gear. Our goal was to compare the technical and tactical characteristics of the prototypes and create an airplane based on them, which we did. According to the data received, we chose the wheels that will be available to our aircraft. They will provide more intensive braking. We also chose the AI-24 turboprop engine to ensure good flight performance and low fuel consumption.

2. Active Noise Control in Propeller Aircraft

2.1 Introduction

Noise issues in our houses have received considerable attention. In industry, for instance, fans, transformers, engines and compressors emit noise. In boats, trains automobiles and aircraft, for instance, noise reduces comfortableness. Lighter materials and more powerful motors are used in high-speed vehicles, which leads to in a general increase in cabin noise levels.

The main trouble of noise in the low periodicity range is not only the dormant hazard of the hearing damage. Low frequency noise is annoying and during periods of long exposure it causes inconvenience, tiredness and loss of concentration. Decreased concentration may also be the cause of an increased risk for accidents. The masking effect which low frequency noise has on speech also reduces words intelligibility. Low words intelligibility is perceived as disturbing and annoying.

Reconstruction could decide noise issues. This is usually very expensive, however, on the another side, noise issues can be determined using traditional passive treatment or treatments based on the principle of active noise control. The choice of technology is based on the performances of the noise as well as of the application of selected technology. Nevertheless, this part of diploma project will not solve the problems of attenuating noise using passive methods of noise control. Instead it directs only on the method of active noise control. Traditional passive method composed on reflectors, absorbers and barriers. The absorbers commute the acoustic energy to thermal energy, while the barriers and reflectors forbid the noise from ingoing a space from second space by rebounding the incident wave field. From the point of view of practical size passive treatment are appropriate when decreasing noise in the frequency range over approximately 500 Hz. The depth of the acoustical absorbers, or the range between the absorber and the wall, must be larger, nearly on one quarter of a length of wave, to obtain reasonable low frequency reduction, e.g. a frequency of 100 Hz results in a wavelength of 3.4 meters. Moreover, in order to decrease the sound transmission from one space to another, a heavyweight barrier between these spaces is required. Hence, the usage of passive treatments to damp low frequency noise is often impractical since considerable extra bulk and weight are required. In all kinds of vehicles high weight is associated with high fuel consumption.

In order to overcome the troubles of inefficient passive inhibition of low frequency noise, the technology of Active Noise Control (ANC) plant oneself of greatly interest. The key tenet of active noise control is based on the superposition of sound waves. Secondary sources create an “anti-noise” of peer amplitude and contrary phase to the initial or objectionable noise. The superposition of the initial and generated noise leads to the destruction of interference and noise reduction. The accuracy of the amplitude and phase of the generated anti-noise determines the attenuation of noise. Active noise canceling systems significantly increase volumetric capacity to attenuate low-frequency noise below almost 1 kHz, which leads to potential advantages in volume and weight. The high frequency for which active control is suitable is determined by the application. However, in cases with dimensions of several meters, for example in aircraft compartments, the upper frequency is limited to a few hundred Hz. A higher frequency limit is greater for smaller cases, such as headphones. For noise above 1 kg, the Hertz passive procedures show a higher potential, since neither large volume nor weight is required to achieve a significant reduction. The active and passive approaches, therefore, complement each other, and thanks to the combination of these two methods, high noise reduction in a wide frequency range becomes possible, indeed in the entire range of audible frequencies (20–20 kHz). Active noise management is applicable to a wide range of low-frequency noise problems in transport, consumer products and industrial applications.

2.2 Active noise reduction in an airplane

One of the main sources of noise inside an airplane is the propulsion system. In particular, for aircraft with a turboprop in the cockpit, harmonic low-frequency noise generated by propellers predominates. The most disturbing noise is characteristic of the first three or four harmonics of the blade pass frequency (BPF). The noise is transmitted through the cab in several ways, see Figure 1.

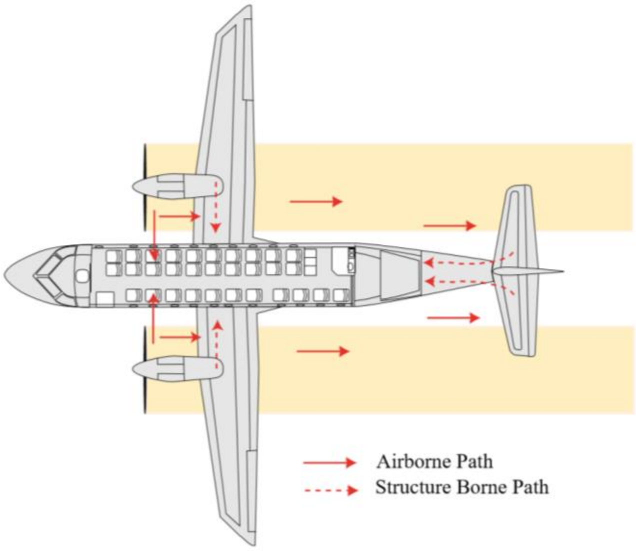


Figure 2.1-The main noise in the cab is of two different types: noise of the boundary layer and noise emanating from the power plant system.

Vibrations from the engines are transmitted through the engine mounts to the wing structure, which, in turn, excites the entire aircraft body; Turbulence from propellers raises the rear wing, which in turn causes vibrations at the rear of the aircraft. The second significant part passes through the fuselage in the plane of the propellers; propeller blades cause very large pressure fluctuations outside the fuselage, which are transmitted to the passenger compartment. The importance of different transmission paths depends on the frequency. In BPF, the sound field is usually excited throughout the cabin, while harmonics are usually excited mainly in the plane of the propellers. Due to the low frequency range, usually 80-450 Hz, the actual use of passive noise reduction methods is very limited. The aircraft fuselage is designed as a lightweight rigid wall with negligible loss in low frequency transmission. By using tuned buffers, transmission loss can be significantly increased. A tuned buffer is a mechanical resonance system consisting of a mass and a spring with a rather high coefficient of mechanical losses.

The buffer is tuned to one frequency, usually BPF at normal cruising speed or one of the harmonics of BPF. Using multiple buffers, noise can be reduced at a wider frequency level. One of the main disadvantages of tuned shock absorbers is the additional weight, which can be equal to one tariff or more. This is significant for an aircraft rated at 35-50 fares. Another disadvantage is that performance is typically directed to one flight condition, which means that the vibration absorption effect is reduced under other flight conditions. An active noise control system offers much greater potential for a noise control engineer in the future. First of all, the general attenuation is usually greater than that which can be obtained with passive tuning. Since the controller is connected to the engines, attenuation is maintained throughout the flight cycle, including descent, cruise, and climb. If the controller is connected to both motors, the runout that occurs when the motors become unsynchronized is also controlled. Even with many (over 30) speakers, including cabinets, the active noise reduction system is lighter than a regular set of tuned buffers. The first commercial turbo-prop aerodynamic panel in the world to use this treatment is SAAB 340 and its successor SAAB 2000. The first SAAB 340 was manufactured in the spring of 1994, and the first SAAB 2000 was made later. Currently, most of the aircraft produced are interested in the ANC, as comfort is a key issue. Figure 2 shows the ANC system in an airplane to actively control the noise generated by the propeller.

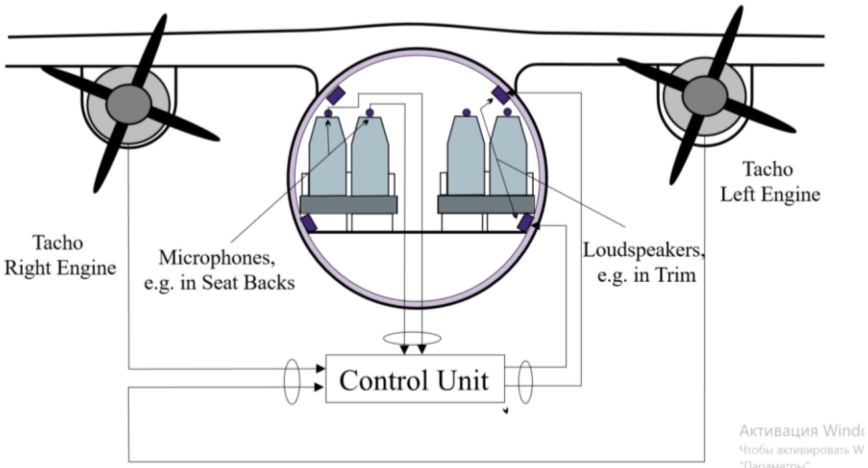


Figure 2.2-Active aircraft noise control.

The most commonly used sources for creating a secondary interacting sound field “anti-noise” are loudspeakers. However, since vibrations in the bounding walls usually excite the sound field, another approach is to use vibration exciters attached to the wall surface. Processing using control inputs applied directly to the structure to reduce vibration distribution in order to reduce sound emission is called Active Acoustic Structure Management (ASAC). Microphones are used as monitoring sensors to monitor the reduction in internal noise. In recent years, interest has also been shown in the use of ASAC treatment. This method can also be used in the practice of jet aircraft to reduce the frequency elements arising from an imbalance in the power of jet engines. The use of silent seats has also generated considerable interest along with the use of active headsets. The silent seat system provides local attenuation of noise around the passenger’s head using the built-in headrest speakers. Moreover, active headsets are much cheaper than installing an ANC system in the cabin. Vibrations at low frequencies also cause discomfort to passengers. These fluctuations arise due to the imbalance of the engine and the driveshaft and are transmitted through the wings to the fuselage

Since the vibrations are low frequency and the vibration sources and the transmission paths are known, active methods also have the potential of being able to reduce such vibrations.

2.3 The Control System

Active noise control system described in this paper is based on a multiple-reference narrowband feedforward control treatment and is allotted to attenuate the tones produced from the airscrews. The controller is based on the actuator-individual normalized filtered-x Least Mean Squares (LMS). This algorithm is synchronized to both airscrews. The need for a synchronization signal from each airscrew rise from the fact that the synchrophaser mechanism are incapable to completely synchronize the two airscrews during a complete flight cycle. By using the synchronization signals, internal single-frequency reference signals are produced and instantaneously settled by adaptive weights before driving the control sources, e.g. loudspeakers. Control sensors supervise the residual noise and the output signals from these are used to regulate the adaptive weights so that the overall noise level is minimized. The cabin noise inside turboprop airplane is basically dominated by strong tonal members at the harmonics of the blade passage frequency of the propellers. Propellers or periodic noise sources running with a slight rotational speed difference stimulate an acoustic beating. The capacity for the ANC system to handle beating sound fields is dependent on the structure of the controller. A structure response on a single filter and a single reference signal composing of the sum of all reference signals does not make the best use of the information assured by the reference signals. Since the frequencies of the reference sinusoids are close together a long FIR (finite impulse response) filter is required, resulting in slow convergence of the adaptive algorithm. With the parallel filter structure each reference signal is individually processed, which in narrowband ANC involves individual harmonic control. The shorter filter can be used with better convergence. If possible, the parallel structure is used rather than a single filter structure in order to achieve efficient and robust control of beating sound fields. The parallel structure has proven advantageous in the attenuation of propeller-generated noise and noise produced by rotating machines with almost the same rotational speeds. The base of the control system is a multi-channel, narrowband feedforward controller using complex signals and complex filter-weights. The complex reference signals are individually processed by a single complex weight that adjusts the amplitude and phase for each actuator. The structure of a twin-reference, multi-channel feedforward active noise control system is shown in Fig. 3.

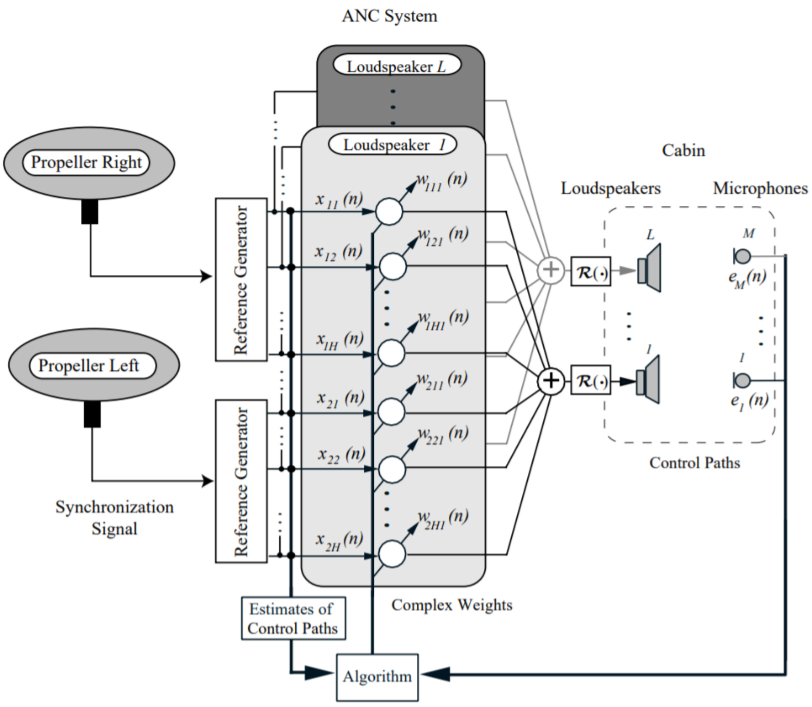


Fig. 2.3-The control system for active control of periodic noise.

One main advantage with narrowband active control of periodic noise members is that the reference signals can be synthesized internally in the controller. In this investigation, the synchronization signals obtained from the noise creation system were used to produce the complex reference signals. With reference signals generated in this manner, the adaptive control becomes extremely chosen and it is maximum to determine which harmonics are to be controlled and which are not.

2.4 Control algorithm

The control algorithm, consist of the complex algorithm called actuator-individual normalized filtered-x LMS algorithm is represented for a common monitoring setup with M control sensors, R reference signals, L loudspeakers, where each reference has H harmonics. Expect that the real valued control-sensor signal,

$e_m(n)$, at microphone m is given by

$$e_m(n) = d_m(n) + y_m(n)$$

where $d_m(n)$ and $y_m(n)$ described the uncontrolled sound and the "anti-noise" (the second noise field produced by the L loudspeakers) relatively at microphone m. The cost function, which should be minimized, is given by the sum of the squares of the output signals from the control microphones:

$$\mathrm{J(n)} = \sum_{m=1}^{M} \mathrm{e_m^2(n)}$$

The update scheme used to configure complex weights in an adaptive control system to minimize this cost function is defined by the following algorithm

$$\omega_{rhl}(n+1) = \omega_{rhl}(n) + 2\mu_{rhl}x_{rh}^*(n)\sum_{m=1}^{M} F_{rhml}^*e_m(n)$$

where * denotes complex conjugate and F_{rhml} is an estimate of the frequency response function of the control path between loudspeaker l and microphone m associated with a given reference signal $x_{rh}(n)$. Here the step-size parameter for reference r, harmonic h and loudspeaker l is given by

$$\mu_{rhl} = \frac{\mu_0}{\rho_{rh}\sum_{m=1}^{M}|F_{rhml}|^2}$$

where the step-size μo lies in the interval $0<\mu_0<1/(LRH)$. This update algorithm is motivated by the assumption that the single-frequency reference signals, $x_{rh}(n)$, are mutually uncorrelated, thereby enabling individual control of each frequency. Since only one adaptive complex coefficient is required for each reference signal and loudspeaker, it is extremely efficient in the sense that it employs a minimum of adaptive coefficients. The implementation can usually be made very compact, which leads to fast execution of the code.

2.5 Experimental results

The enclosed buttonhole characteristic of the mechanism was affirm by exposing the portside of the airplane to artificial airscrew noise using the speaker-ring system. The first occasion investigated was control at 61 Hz (910 rpm, BPF) applying sensor feedback to control the three actuators. Four sensors were located above the area of high open cycle vibration at each of the three axial positions where piezoelectric actuators were bonded. Mean of every set of four measurements were applied as the sensed quantities for both feedback and feedforward control approaches. The feedback control mechanism was constructed with peak loop gains of between 25 and 30 dB, gain margins of between 8 and 15 dB, and phase margins of between 14º and 50º, for the diagonal elements of the transfer function matrix. The feedforward approach applied filtered-x LMS adaptive control. An IIR (infinite impulse response) filter with 15 forward and 14 recursive filter factors was applied to model the second path applying a band limited casual signal among 55 and 75 Hz for off-line LMS mechanism identification of the plant. The control filter was selected to be a FIR filter with 15 indexes. The shortening in the vibration degree for the twelve sensors positions as well as for the three mean sensor meanings are given in Table 1.

Accelerometer	Vibration Attenuation (dB)	
	Feedback Control	Feedforward Control
1	7	8
2	9	13
3	16	21
4	4	4
5	0	5
6	10	16
7	9	14
8	6	7
9	2	5
10	11	18
11	16	19
12	8	11

Table 2.1-Vibration attenuation at 61 Hz, vibration sensing

It could be seen from the vibration attenuation information that the feedback and feedforward cases yielded similar effects, either in separate sensor and mean evidence. There were certain differences between the individual results, although the trends were similar. Peak vibration reduction in both cases occurred at the same accelerometer position. For a direct-coupled control case, the spectra for the control and shutdown data for sensor 3 are shown in Fig. 4.

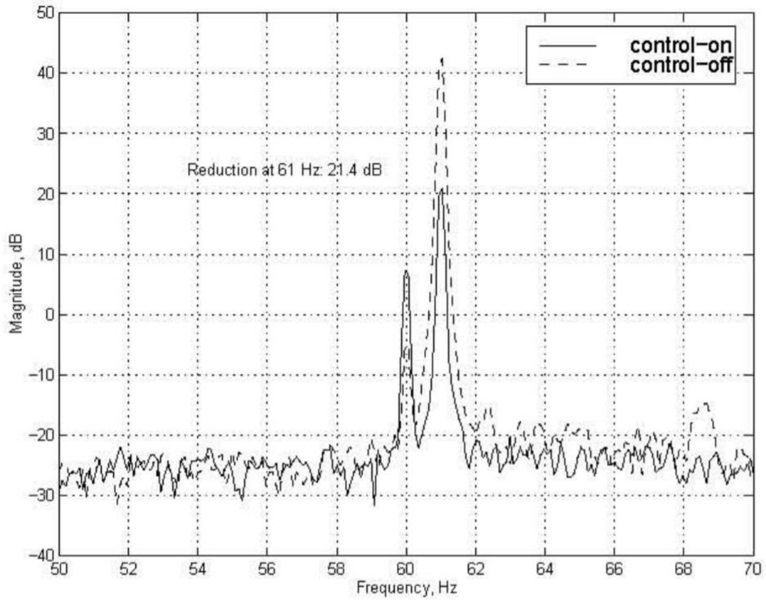


Fig.2. 4.-Acceleration spectrum for sensors, vibration sensing, feedforward control

In order to monitor the noise reduction performance, microphones were positioned at the seated head height for the two port side seats and at standing height for the aisle center for seat rows 1, 2 and 3. The noise attenuation data using the ANC system realized with both feedback and feedforward control algorithms determined above for vibration error sensing, are presented in Table 2.

Microphone Location	Noise Attenuation (dB)		
	Fdback, vibration sensing	Fdforward vibration sensing	Fdforward noise sensing
Row 1, window seat	-3	2	1
Row 1, aisle seat	9	24	9
Row 1, standing aisle	2	6	19
Row 2, window seat	11	10	11
Row 2, aisle seat	11	9	18
Row 2, standing aisle	4	7	20
Row 3, window seat	6	14	7
Row 3, aisle seat	28	10	13
Row 3, standing aisle	5	6	13
Average	8.1	9.8	12.3

Table 2.2- Interior sound attenuation at 61 Hertz, acoustic sensing

The control-on and control-off noise level spectra at the aisle seat in row 1 for the vibration error sensing feedforward case are presented in Fig. 5.

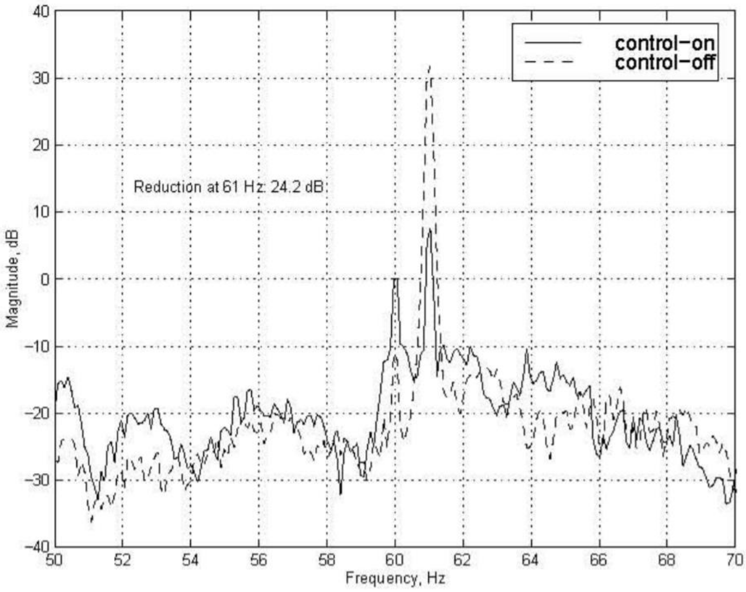


Fig. 2.5- Sound level spectra for row 1 aisle seat, feedforward control, vibration sensing, 61 Hz

The final attenuation in the inside sound levels was also the same. The highest reduction, which was 28 dB, take place at the aisle seat in third row. The shortenings in row two, which was near to the airscrew of the aircraft, were 11 dB for both the aisle and row seats. Only one place, suitable to the window seat at the first row, exposed a very little increase in sound level. This place had exposed the weakest open loop sound pressure, and therefore the slight rise was of small meaning. The exposes in both the sound and vibration degree were materially overall with great shortening in the noisiest cabin compartment regions. The sound control characteristic for the feedback and feedforward cases of active control with vibration sensing were not identical in outcomes, since the highest shortening in each occasion take place at different occurrence. These odds can be referable to amount of factors, the most essential of which was apparently the thing that although the actuator and sensor positions were the same in two cases, the control design approaches were totally diverse. For the feedback approach there were great diverse in peak gains for the 3 loop transfer functions considered. In matching, for feedforward control, the only utilizer conditioned parameters for the mechanism authentication and control operations were the convergence factors, which were selected to be equal for all channels. The outcomes also highlighted the highly sensitive dependence of sound shortening performance on vibration reduction; the differences in residual vibration in both cases were small compared to the differences in residual noise levels. This is sequential with thing that the vibrational regimes that were responsible for much of the noise transmission may not be those that dominated the vibration field. Therefore, two similar vibrational fields may practically have product essentially different noise fields inside passenger compartments. When sound shortening was selected as the performance metric or criterion, the results determining applying microphone error sensing were major superior to those for vibration sensing. The control at 61 Hz was investigated with the same actuator design, but using the 3 microphones in the second seat row as the error sensors. The noise reduction obtained applying microphone error sensing were superior to those for vibration sensing. The outcomes, which are given in the last column of Table 3, demonstrated the superiority in this noise reduction performance when compared to vibration sensing results.

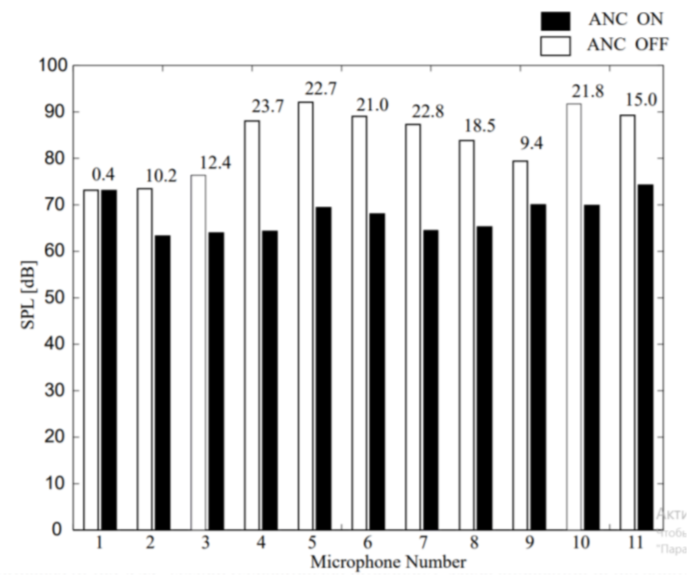


Table 2.3- Interior sound attenuation at 61 Hz, acoustic sensing

Noise reduction for other flight conditions was also achieved successfully applying the actuator design approach described earlier and using vibration sensing. The operating deflection shape (ODS) for deformation of the fuselage at twice the BPF at 910 rpm (121 Hz) which had a greater number of nodes than the previous case of the 61 Hz ODS, is shown in Table 6.

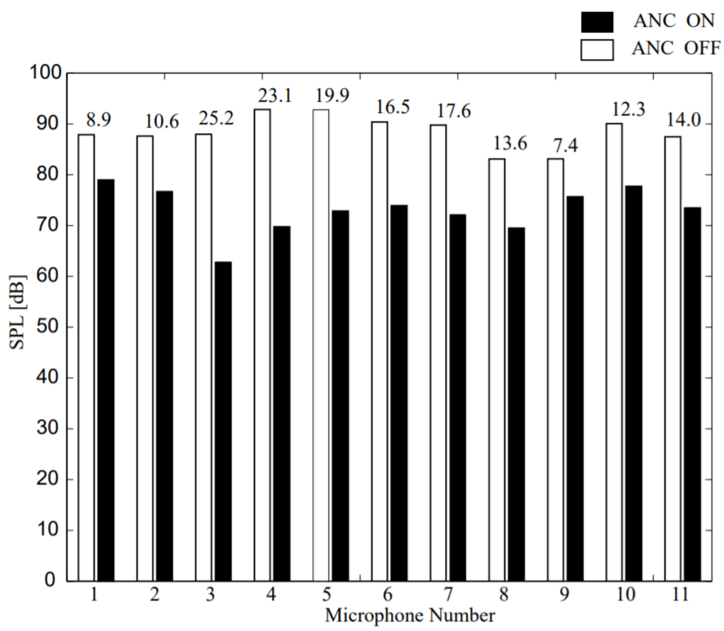


Table 2.4-Performance of the ANC system due to simulated propeller noise, 2×BPF, 910 rpm (121 Hz)

Applying the feedforward control algorithm described previously, the achieved vibration and noise reduction was again large. The vibration and, in particular, the sound decrease efficiency was little lowered compared to the efficiency for vibration sensing and there were a few microphone locations that exposed little rises in sound levels. However, there were large reductions in the key placing of high noise as well as a general global noise reduction in the cabin.

Conclusions to the Part 2

The use of Active Structural Acoustic Control (ASAC) has been successfully applied to reduce internal noise and vibration in a full-blown aircraft fuselage to improve the living environment. The results of this application show that, due to the well-thought-out drive and sensor design, ASAC systems using coupled piezoelectric drives and vibration or acoustic error sensors can simultaneously provide significant reduction in propeller noise and vibration reduction in the passenger cabin of a turboprop aircraft. The noise reduction in the passenger compartment was significant with a peak measured attenuation of more than 28 dB. The observed attenuation was essentially global throughout the cockpit. In addition, it has been shown that an optimized system provides a significant reduction in other modes that may be present. Most importantly, such an active system can be adaptively modified locally to account for changes arising from operating conditions, to provide a time-varying, optimized vibration and noise control system to improve habitability of the aircraft cabin.

REFERENCES

1. Aircraft. Design: Lecture course / M.V. Karuskevich, T.P. Maslak. – K. :NAU, 2013-176c.
2. Гаража В.В. Конструкция самолетов: Учебник. – К.: КМУГА, 1998.
3. Методические указания по выполнению бакалаврских работ для иностранных студентов по направлению 6.070103 «Обслуживание воздушных судов». – Киев: НАУ, 2012- 25с.
4. Компоновка и центровка самолета: Методические указания. -К.: КИИГА,1989- 45с.
5. Выбор пареметров и расчет масс самолета: Методические указания. – К.: КИИГА, 1989г. – 46 с.
6. Borchers, I.U., Hackstein, H.J., Bartles, P., Gruneweld, M., and Wenigwieser, C., "Summary of Dornier 328 Interior Noise Control Study," in Inter-noise, 1990, pp. 811-816 c.
7. Methodical recommendation for executing of bachalors diploma work / O.V. Popov, T. P. Maslak, G.A. Volosovych, - K. :NAU, 5.07.2002.- 56p.
8. Челюканов И.П. Компоновка и центровка самолета. – К.: КИИГА, 1989.- 78с.
9. Bhat, R.B., Sobieszczanski, J., and Mixson, J.S., "Reduction of Aircraft Cabin Noise by Fuselage Structural Optimization," in Noisexpo, 1977,40-45 p.
10. Mixson, J.S. and Powell, C.A., "Review of Recent Research on Interior Noise of Propeller Aircraft," AIAA/NASA 9th Aeroacoustics Conference, AIAA Paper 84-2349, Williamsburg, VA., October 1984. -38p.
11. Waterman, E.H., Kaptein, D., and Sarin, S.L., "Fokker's Activities in Cabin Noise Control for Propeller Aircraft," SAE Paper 830736, 1983. –135p.
12. Halvorsen, W.G. and Emborg, U., "Interior Noise Control of the Saab 340 Aircraft," SAE Paper 891080, April 1989, General Aviation Aircraft Meeting and Exposition.-156p.

Appendix A

Project Aircraft with TPFE

NAU, Aircraft design department

Project Diploma Calculation is done 23.09.19

Performed by Korzh P.O.

2INITIAL DATA FOR CALCULATION WORK

Passenger Number 44

Flight Crew Number 2

Flight Attendant or Load Master Number 1

Mass of Operational Items 412.57 kg

Payload Mass 4356.00 kg

Cruising Speed 435 km/h

Cruising Mach Number 0.3836

Design Altitude 6.5 km

Flight Range with Maximum Payload 1100 km

Runway Length for the Base Aerodrome 1.68 km

Engine Number 2

Thrust-to-weight Ratio in N/kg 0.2700

Pressure Ratio 7.50

Assumed Bypass Ratio 0.22

Optimal Bypass Ratio 5

Fuel-to-weight Ratio 0.22

Aspect Ratio 11.37

Taper Ratio 2.92

Mean Thickness Ratio 0.12

Wing Sweepback at Quarter Chord 5

High-lift Device Coefficient 0.58

Relative Area of Wing Extensions 0.00

Wing Airfoil Type supercritical Winglets installed

Spoilers installed

Fuselage Diameter 2.65 m

Fineness Ratio 8

Horizontal Tail Sweep Angle 15 deg

Vertical Tail Sweep Angle 21 deg

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point 0.50003

Induce Drag Coefficient 0.00995

ESTIMATION OF THE COEFFICIENT Dm = Mcritical - Mcruise

Cruising Mach Number 0.38364

Wave Drag Mach Number 0.67939

Calculated Parameter Dm 0.29576

Wing Loading in kPa (for Gross Wing Area): At Takeoff 2.273

At Middle of Cruising Flight 2.279

At the Beginning of Cruising Flight 2.332

Drag Coefficient of the Fuselage and Nacelles 0.00818

Drag Coefficient of the Wing and Tail Unit 0.00995

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight 0.035176

At Middle of Cruising Flight 0.03153

Mean Lift Coefficient for the Ceiling Flight 0.50003

Mean Lift-to-drag Ratio 15.85867

Landing Lift Coefficient 1.549

Landing Lift Coefficient (at Stall Speed) 2.324

Takeoff Lift Coefficient (at Stall Speed) 2.065

Lift-off Lift Coefficient 1.487

Thrust-to-weight Ratio at the Beginning of Cruising Flight 0.090

Start Thrust-to-weight Ratio for Cruising Flight 0.134

Start Thrust-to-weight Ratio for Safe Takeoff 0.140

Design Thrust-to-weight Ratio 0.145

Ratio Dr = Rcruise / Rtakeoff 0.956

SPECIFIC FUEL CONSUMPTIONS (in kg/kN*h):

Takeoff 0.3100

Cruising Flight 0.2624

Mean cruising for Given Range 0.2635

FUEL WEIGHT FRACTIONS:

Fuel Reserve 0.02493

Block Fuel 0.08868

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing 0.05617

Horizontal Tail 0.01936

Vertical Tail 0.01926

Landing Gear 0.04915

Power Plant 0.12064

Fuselage 0.10811

Equipment and Flight Control 0.1582

Additional Equipment 0.0027

Operational Items 0.0165

Fuel 0.11361

Payload 0.23508

Airplane Takeoff Weight 18529 kg

Takeoff Thrust Required of the Engine 1340 kN

Air Conditioning and Anti-icing Equipment Weight Fraction 0.0219

Passenger Equipment Weight Fraction (or Cargo Cabin Equipment) 0.0249

Interior Panels and Thermal/Acoustic Blanketing Weight Fr. 0.0199

Furnishing Equipment Weight Fraction 0.0122

Flight Control Weight Fraction 0.0025

Hydraulic System Weight Fraction 0.0117

Electrical Equipment Weight Fraction 0.028

Radar Weight Fraction 0.003

Navigation Equipment Weight Fraction 0.0046

Radio Communication Equipment Weight Fraction 0.0069

Instrument Equipment Weight Fraction 0.0035

Fuel System Weight Fraction 0.0081

Additional Equipment: Equipment for Container Loading 0.0032

No typical Equipment Weight Fraction 0.0027

(Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed 180.97 km/h

Acceleration during Takeoff Run 1.67 m/s2 Airplane Takeoff Run Distance 756 m

Airborne Takeoff Distance 578 m

Takeoff Distance 1334 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed 171.92 km/h

Mean Acceleration for Continued Takeoff on Wet Runway 0.17 m/s2 Takeoff Run Distance for Continued Takeoff on Wet Runway 1410.88 m Continued Takeoff Distance 1949.47 m

Runway Length Required for Rejected Takeoff 2019.95 m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight 17714 kg Time for Descent from Flight Level till

Aerodrome Traffic Circuit Flight 12.8 min

Descent Distance 15.44 km

Approach Speed 187.68 km/h

Mean Vertical Speed 1.61 m/s

Airborne Landing Distance 495 m

Landing Speed 172.38 km/h

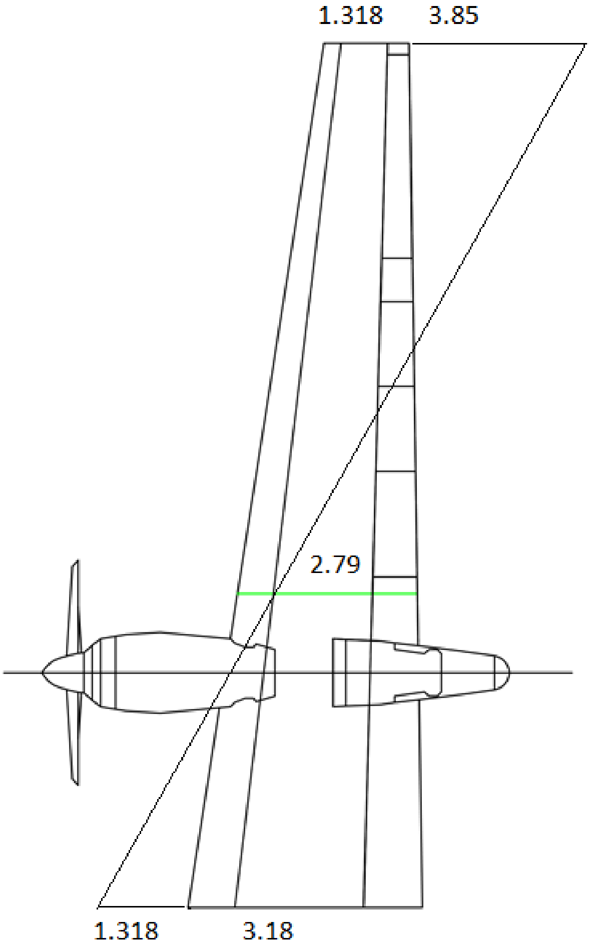
Landing run distance 456 m

Landing Distance 950 m

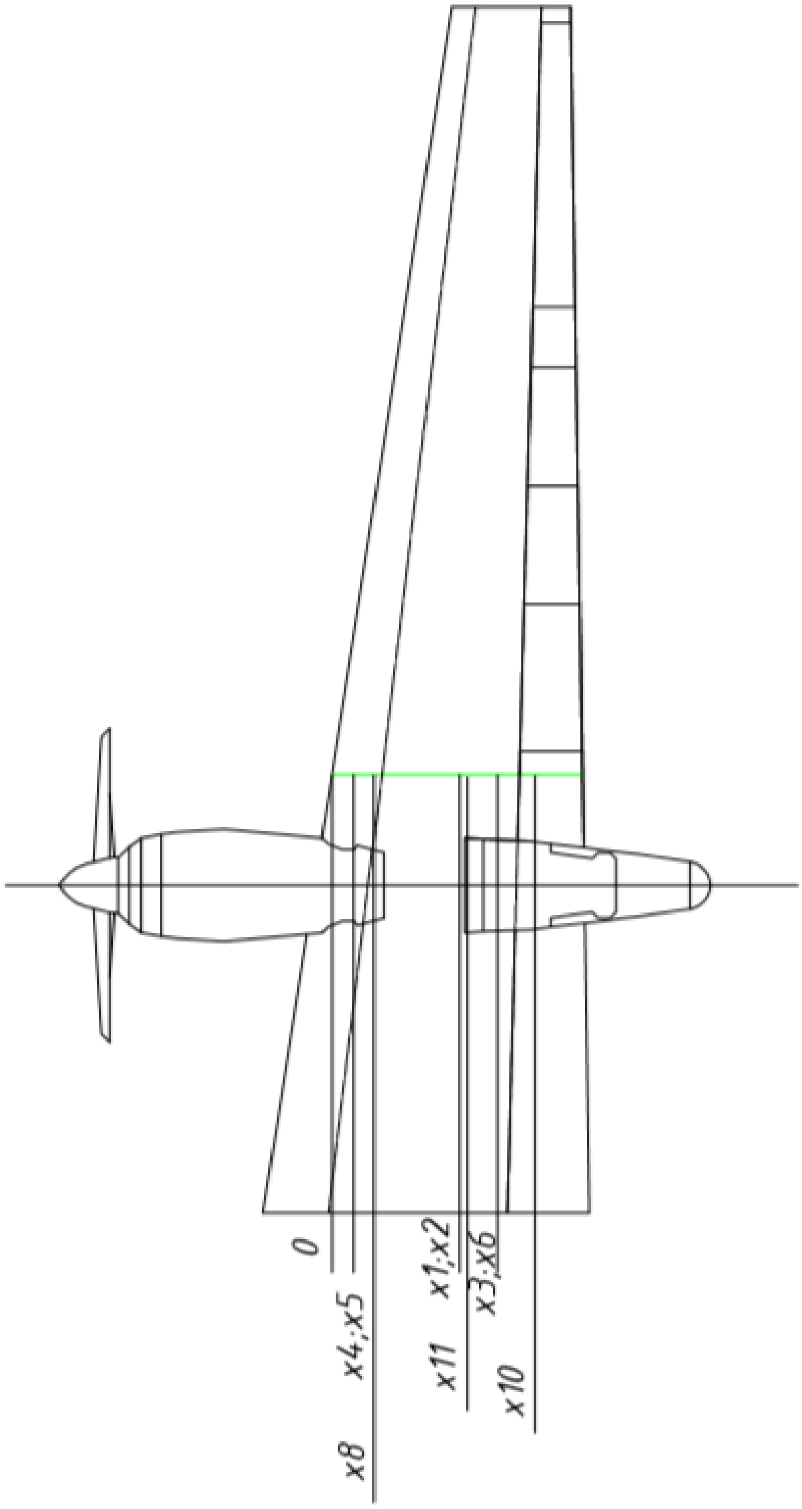
Runway Length Required for Regular Aerodrome 1587 m

Runway Length Required for Alternate Aerodrome 1350 m

Appendix B

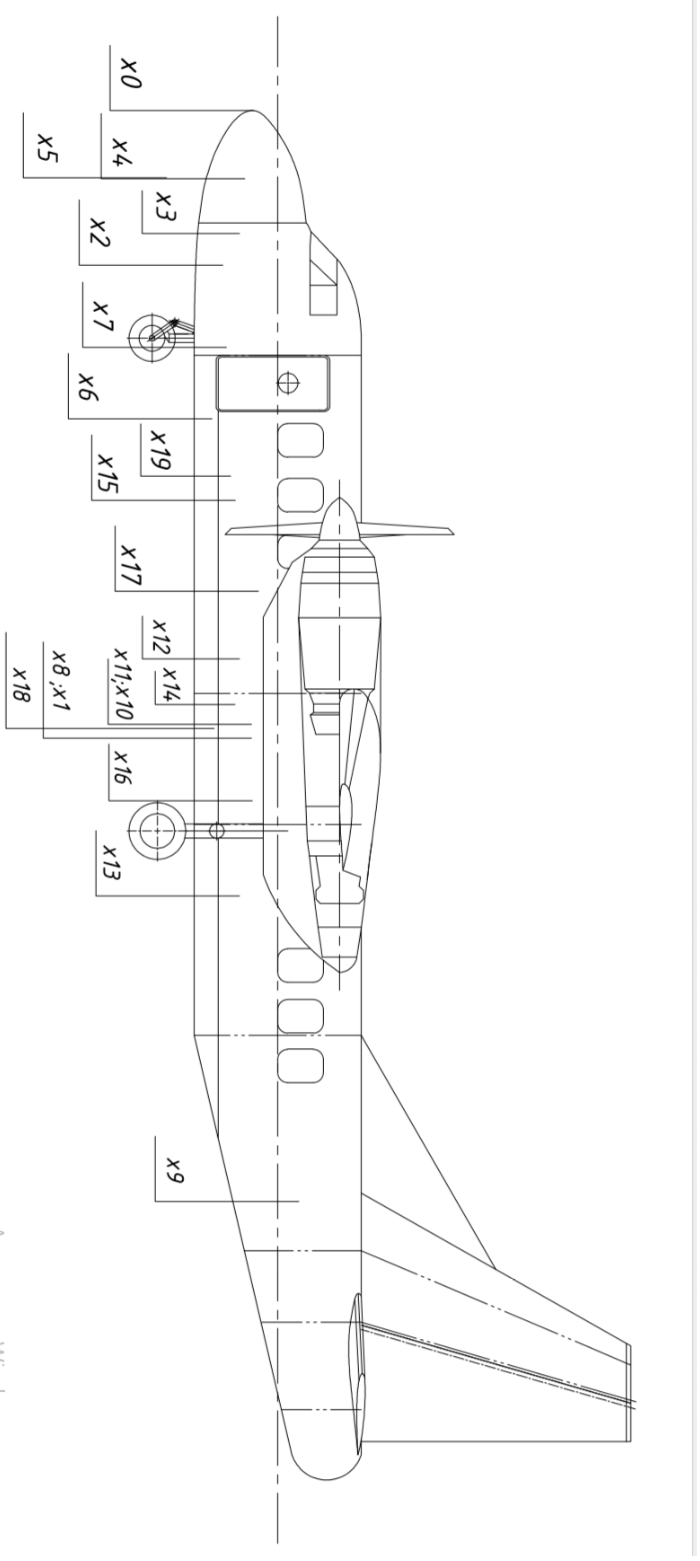


Department of Aircraft Design					NAU 20 07K 00 00 00 38 EN			
Ch.	Sheet	Doc. №	Sign.	Date				
Performed		Korzh P.O			Appendix B	Letter	Sheet	Sheets
Checked by		Zakiev V. I.						
Adviser						402 AF 134		
Stand.		Khvzniak S. V.						
Head of		Ignatovych S.R.						



					NAU 20 07K 00 00 00 38 EN	Sh.
Ch.	Sheet.	Doc. №	Sign.	Date		

Appendix C



Department of Aircraft Design					NAU 20 07K 00 00 00 38 EN		
Ch.	Sheet	Doc. №	Sign.	Date			
Performed		Korzh P.O.			Appendix C	Letter	Sheet	Sheets
Checked by		Zakiev V. I.						
Adviser						402 AF 134		
Stand.		Khvzniak S. V.						
Head of		Ignatovych						