DESIGN, EXPERIMENTS AND DEVELOPMENT OF A POLISH UNMANNED HELICOPTER ILX-27

Session subject: Aircraft Design

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Abstract

The purpose of this paper is to present the problems of construction of unmanned helicopter ILX-27 based on the experience gained during the implementation project of the "Unmanned helicopter - robot for special missions." The article presents the current trends in the construction of unmanned flying objects (rotorcraft) and the assumptions that have been adopted in the design of an unmanned helicopter ILX-27

The presentation contains a description of the basic parameters of the helicopter and an overview of the design solutions, way of making the structure of a composite fuselage, helicopter lattice technology. It will present the results of tests carried out with particular emphasis on ground-based tests in the special cage (rotunda) and the first flight test. Basing on the conclusions of the presentation we will discuss ways to use an unmanned helicopter ILX-27

1. INTRODUCTION

The project was realized with consortium of Polish scientific research, development and industrial companies. The Institute of Aviation was responsible for the design, Air Force Institute of Technology was responsible for performance of the control system and flight testing, and Military Aviation Works No.1 in Lodz was responsible for the implementation and prototypes.

The purpose of UAV helicopter is to support the army, navy and board guards in special missions carried out in the difficult terrain such as mountains and urban areas or at risk of enemy fire. UAV helicopter represents the safe alternative to the manned air support (i.e. aircraft, helicopters) and unmanned aerial vehicles. Usage of UAV rotorcraft depends on the type of installed devices and special equipment such as any kinds of sensors.

1.1 UAV helicopter in military applications:

- Exploration from air
- Precise weapon carrier
- Supply transportation

1.2 UAV helicopter in civil applications:

- Operations in area of natural and environmental disasters
- Monitoring of land engineering facilities, bridges, railway junctions and communications, agriculture and woodlands

2. UNMANNED ROTORCRAFT IN THE WORLD

We currently observe rapid worldwide development of unmanned helicopters. They are used for both military and civilian purposes. Unmanned platforms work well wherever there is a high risk to human health or life. Therefore, more and more countries, conduct their own research and development programs and use unmanned helicopters. The majority are small unmanned helicopters used mainly as carriers of audio visual - a smaller group is used as a platform for unmanned military and transport. Cross section by all groups of unmanned platforms is shown in the following picture (unmanned platforms divided by the maximum takeoff weight).

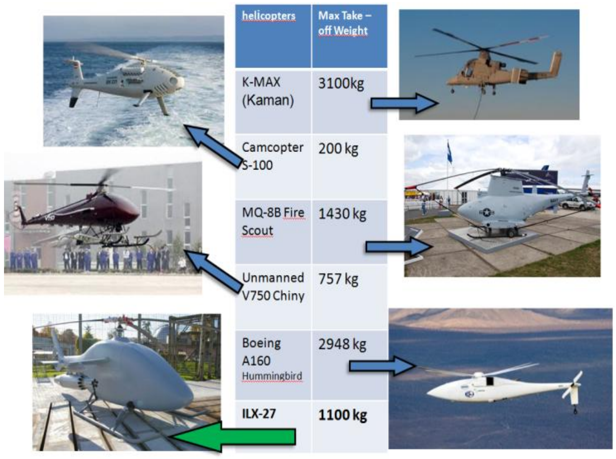

Fig.1. Unmanned rotorcraft in the world

The priority assumptions that have been made in the project unmanned helicopter are as follows:

- Polish construction idea and production
- Security and low operating costs
- Use for a wide range of missions
- Easy to use, requiring no qualified staff
- Opportunities for development
 (various versions)

3. DESIGN

A preliminary analysis of the project allowed to prepare the assumptions for the newly created structure. The aim of the project was to build a technology demonstrator, perform several tests and demonstrate its capabilities. Developed assumptions enabled us to launch the designing work. The design involves modern tools, CAD / CAM, and was prepared to use new materials that were used to build the structure of a demonstrator. Objectives that define the design phase include:

- Implementation of an unmanned technology demonstrator
- The use of autonomous control
- The modular design
- The use of new technologies

3.1 ILX-27 – design of unmanned helicopter

Taking into account the use and markets, an unmanned helicopter should be ready for use in a wide range of missions – this rule has been adopted in the construction of ILX-27. The Design process was set in CATIA V5 and ANSYS and NASTRAN were used to perform FEM calculations and analysis of 3D Graphic systems allow full definition of a model, and facilitate further interchangeability and adaptation to customer orders. Unmanned helicopter for ease of use as well as rapid exchange of components is divided into modules. Each module is a separate structure with its own fasteners and accessories tailored to the mission. On both sides of the helicopter there are wings with weapons hardpoints. What is more, there is an ability to install practically any available weapon or other system according to customer specifications.

To enhance ability to upgrade the helicopter, shorten time and reduce input costs of (replaced) equipment - an unmanned helicopter ILX-27 is divided into modules:

- Semi-monocoque cabin of the front,
- Lattice face down in the middle fairing,
- Semi-monocoque tail boom with vertical stabilizer,
- Horizontal stabilizer,
- Suspension components

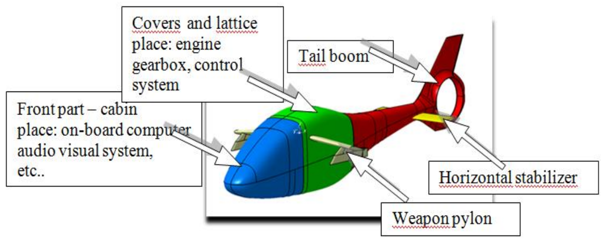

Fig.2 3D Model of fuselage


Fig.3 Unmanned helicopter fuselage

In the design of the helicopter the following were used:

- Autonomous central module - containing all of the key elements of the helicopter (engine, gearboxes, the transmission, control system, landing gear)

- Carbon composite blades head – based on research tunnel - new custom profiles and the technology of the blade have been developed. Currently the blades are manufactured by WZL1 in cooperation with ILOT

- The autonomous control - system developed and owned by the Air Force Institute of Technology

- 3 blades rotor bearing - with low speed of the tip of the blade

- The landing gear meets increased energy absorption requirements

- Lycoming 540; 6 cylinder (air-cooled, which uses fuel injection) was used as the drive unit for an unmanned helicopter

- Hydraulic system was used to control the helicopter equipped with a pump installed on the engine and actuator arrangement.

3.2 Tail boom - details of construction

The tail boom will present the most important stages of the design to the finished item. Most important assumptions of the construction of the tail boom - Mounting with four fittings, glass and carbon composite structure and the use of tunneled tail rotor. The first stage of the design work was to prepare a study of solutions used presently which inspired the design and concept of the new fuselage structure.

Designed geometry was subjected to a numerical analysis of the flow around a particular emphasis on working conditions of tunneled tail rotor.

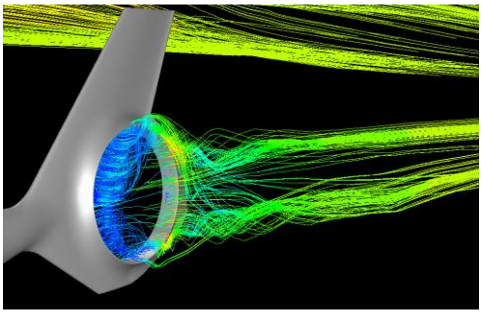

Fig.4 Aerodynamic research (tunneled tail rotor)[1]

Calculations of aerodynamic derivatives of fuselage unmanned helicopter in flight conditions were performed. Simulations were performed for the rotorcraft flight with cruise speed of proceedings at a fixed angle of attack and sideslip angle zero.

Optimization and the positive results of aerodynamic simulations allowed to start the next stage which is to prepare the structure of the tail boom. The graphics used in the program was fully documented CATIA 3D in modeling and design drawings Software development also required taking into account the associated components installed on the tail boom such as a tail rotor gearbox, tail rotor drive shaft, etc.. Completion and verification phase of construction has resulted in further work in preparation for the implementation of models composite elements and then the finished tail boom

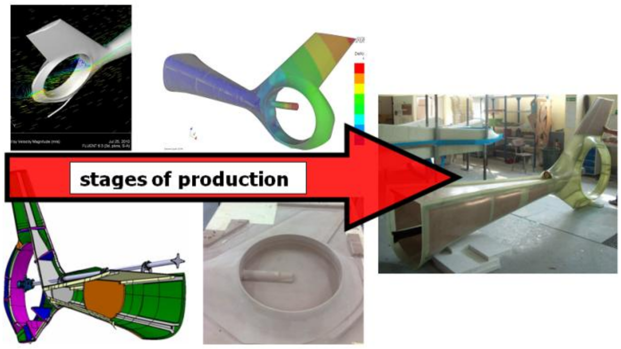

Fig.5 Stages of production tail boom

Another important element is the lattice structure of the fuselage. The diagram work was very close to the tail boom of the project, but the implementation technology was different. Welding of the lattice was carried out in a specially designed and prepared the device. Each of the pipes was fitted and TIG welded Parts of fittings, fasteners, cantilever, were made using CNC machining. It guarantees reproducibility and quality of the finished part.

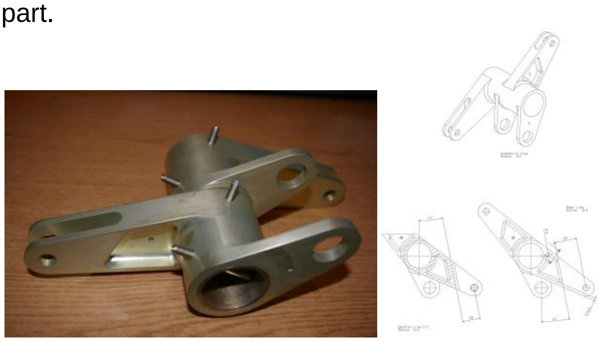

Fig.6 Element of the control system

3.3 Performance of ILX – 27

During the design, calculations of performance of unmanned helicopter ILX-27 were carried out. Verification of the performance is currently under testing in ground (“rotunda”) and flight tests. The helicopter is equipped with a set of sensors and recorders that allow safe tests conduction and results recording.

Max Take-off weight	1100	[kg]
Payload	300	[kg]
Max Speed	215	[km/h]
Maximum rate of climb	10	[m/s]
Service Ceiling	4	[km]
Range	440	[km]
Lycoming IO-540 Engine	260	[HP]

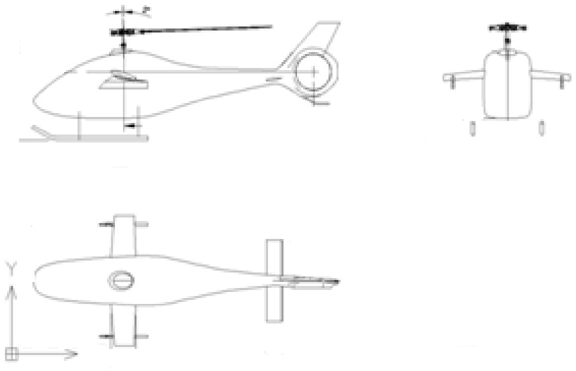

Fig.7 ILX-27 in 3 views

4. GROUND TESTS

Ground tests were among the last steps before preparing the helicopter for flight tests. Tests, in which the rotor revs up with weights instead of blades, replacement blades, normal blades and finally tail rotor operation tested. Everything took place in the “rotunda”. It is a specially prepared, secure facility for rotorcraft ground tests. It has a double steel grid which captures dangerous or detached items[4] The substrate is a concrete slab with fixed rails. They are used for secure attachment of the test. Diameter of the rotunda allows to perform a safe trial of leap of the tested objects. The rotunda was connected to a ground station - wired or wirelessly, to the test object

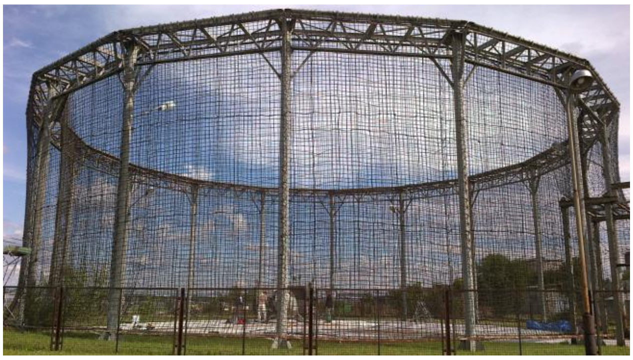

Fig.8 Special cage (rotunda)

The design process required to check the construction and design solutions. In the case of helicopters, which characterize by high vibrio-acoustical activity we should pay attention to the vibrations occurring in the structure, which can result to its destruction. It was very important during designing ILX-27 to analyze the optimal parameters of the helicopter before the first tests in flight. The Research was performed in two directions, firstly providing high fatigue life of components and secondly a minor nuisance to the environment because of the noise. In parallel to the research on the structure of the helicopter was made a lot of analysis in finite element method. The first step was the determination of the natural frequency of the structure by using the model which was built in finite element method. For this purpose the helicopter model was created in Ansys software[2,3]. This analysis was aimed at supporting research of the resonance, which was investigated parallel on the structure. Resonance analysis of the helicopter was made through the use of an electrodynamic exciter type EDSW 2000, which stimulated vibration of the structure along and across the hull through the shaft of the rotor and tail boom. In this case was applied variable harmonic force of values 200N

Fig. 9 Helicopter during resonance tests.

During the tests were performed changes the position of the helicopter relative to ground with 50%, 75%, 90%, until to the hover above the ground. The tests included research with additional mass which weight was 800kg.

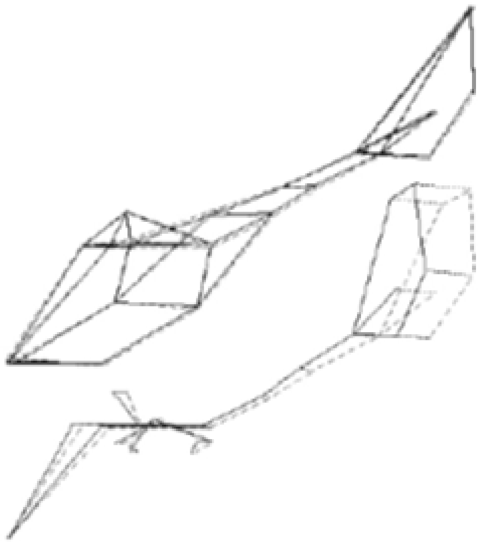

Fig. 10 Amplitude for 7 Hz frequency deviations. Rocking the x-axis and the bending of the hull

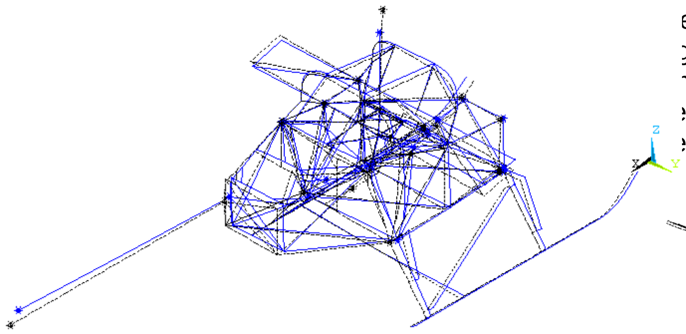

Fig. 11 The figure for the frequency 7,45Hz.

The next stage of research, there were attempts rotor in the special cage (rotunda) (Fig. 8, 12).

They relate to, among other things:
- attainment the nominal speed without blades and tail rotor blades,
- attainment the nominal speed of rotor with special masses which replaced the blades of main rotor,
- attainment the nominal speed of rotor with the changes pitch tail rotor blades,
- attainment the nominal speed of rotor with the changes pitch tail and main rotor blades,
- attainment the nominal speed of rotor with the blades of main rotor mounted and the tail rotor blades. The test of the radio controller and prepared to start power.

Fig. 12 Helicopter in special cage (rotunda).

The last step of the trial design in the special cage (rotunda) the tests were controlled by the radio controller. Tests to reach start power values by the main rotor at the start of the flight, due to the sliding of the structure on the ground were very dangerous due to the possibility of the ground resonance. Therefore we need to ensure the safety of the helicopter during testing sow we realized a lot of simulations aimed at mapping behavior of the structure during the detachment of the chassis from the ground skids. The last step of the project were the first attempts to start the helicopter. Due to the danger of losing control of the helicopter, and ensure the safety of the persons responsible for the tests we used the special mobile control station. Due to e lack of data on susceptibility helicopter on the ɟnals sent by the pilot carried out additional nulations unbalanced uncontrolled landing the elicopter. Simulations confirmed the validity of the esign solutions (support rotor shaft).

Drgania giętne belki ogonowej.

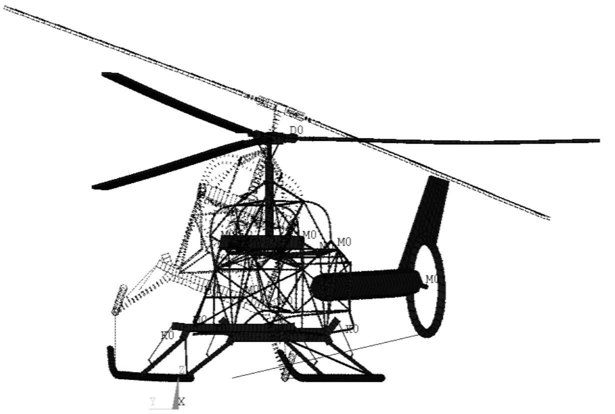

Fig. 13 View of the model helicopter at the start of the analysis (interrupted black) and end (black).

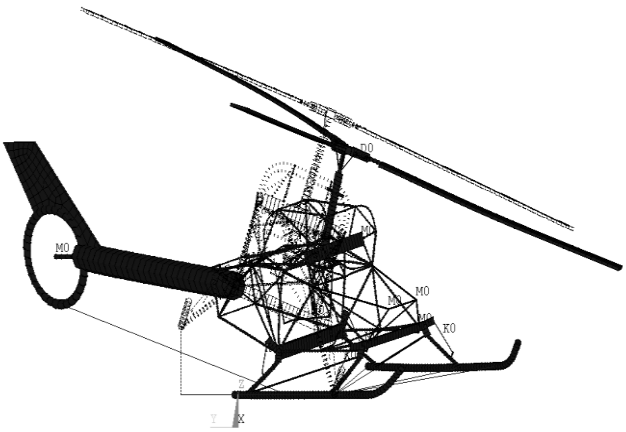

Fig. 14 View of the model helicopter at the start of the analysis (interrupted black) and end (black).

Fig.15 ILX – 27 during flight tests.

5. SUMMARY:

Work on the unmanned helicopter ILX - 27 were successful. During the first tests ILX - 27 hovered above the ground. Now we continue a research test this helicopter on the special area and we try to realize develop ILX - 27. The first test in flight shown that this construction can be a good unmanned helicopter in the future.

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