On the peculiarities of shaping the appearance of aircraft equipped with a collective rescue system for passengers and crew

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Abstract: *The relevance of the problem under study is due to the need to study the issue of the features of the formation of the appearance of aircraft equipped with a collective rescue system for passengers and crew. The purpose of the article is to study the collective rescue system for passengers and crew. The leading method for studying this problem is the method of analyzing the conceptual features of aircraft design as part of a collective rescue system (CRS). It is shown that the exclusion of the contact zone of the emergency plane with the ground will allow to qualitatively and quantitatively increase the safety of passengers and crew. The structural decomposition made it possible to identify the place of collective rescue systems in the structure of the aircraft. A procedural decomposition is given, which allows structural assembly of aircraft units and systems. A phased program for studying the problem of implementing collective rescue is given by the example of a light aircraft of vertical takeoff and landing. An example of the implementation of a collective rescue system is shown.*

Key Words: *design, security system, emergency, flight, aviation*

1. INTRODUCTION

The use of aircraft as passenger transport in the XX century has become the norm [1]. People are used to the fact that an airplane is a fast and convenient mode of transport. For these qualities, millions of people in the implementation of transport operations prefer aircraft heavier than air.

The efforts of dozens of domestic and foreign design bureaus and research institutes created aircraft of different ranges, passenger capacity and comfort, which are operated in all regions. However, the aircraft, as an object of design and operation, i.e. at all stages of the life cycle, it is a large and complex technical system, which, in turn, is an element of a large and complex technical system (aviation complex) and consists of large and complex technical systems (airframe, power plant and so on) [1]. Failure in any of the segments of this system leads to an emergency, and often to disaster [2]. The debut idea of aviation of the 21st century will be flight safety.

The contradiction between constantly improving new types of aircraft and ensuring flight safety arose from the first days of aviation, and is fundamental.

The transition to transonic and supersonic flight speeds, an increase in cargo flows and, as a consequence, an increase in the dimension of aircraft, complicate the system for ensuring passenger safety.

However, due to a number of circumstances, airplanes, despite their higher reliability than other transport systems, often end up in emergency situations, even despite triple redundancy of all vital systems that often end in catastrophes.

The practice of aircraft design has shaped design approaches that provide for the salvation of passengers and crew only on the ground.

The contact zone of the emergency plane with the ground is the most dangerous flight section, which, with a qualitative increase in flight safety, requires exclusion from practice.

2. ANALYSIS OF THE COLLECTIVE RESCUE SYSTEM FOR PASSENGERS AND CREW

One of the possible design solutions for ensuring passenger safety is a collective rescue system for passengers and crew [3]. The statistics of air crashes show [4] that in 60-70% of cases the crew had time to make a decision on emergency rescue. This system allows you to ensure safety in all flight modes.

Considering this design and layout solution as a backup system for ensuring safety, its place in the aircraft is determined by the time of the emergency that does not allow for a safe emergency landing of the aircraft, i.e. overgrowing it into a catastrophic one.

A patent search shows that a significant number of patents have been devoted to the problem of collective salvation, starting with the birth of aviation. In time, their number increases as the number of air crashes increases.

Unfortunately, many inventors went the way in which only circuit solutions at the level of ideas are considered and not taking into account the totality of heterogeneous factors does not allow CRS to be implemented in the proposed device objects at the modern level of development of science and technology, which determines their non-demand. The collective rescue system has its own prototypes in military aviation.

The rescue of UAVs and ultralight aircraft using parachute systems has been worked out to a large extent [1]. Significant progress in this area has been achieved in the aerospace complex.

The masses of the saved accelerators reach 60-70 tons, which is comparable in size, weight, and dynamics with the fuselage of main aircraft.

The closest and most developed CRS prototype can be considered the decision made when creating the General Dynamo F-111 fighter [3] (Figure 1), the FB-111 and B-1B strategic bombers.

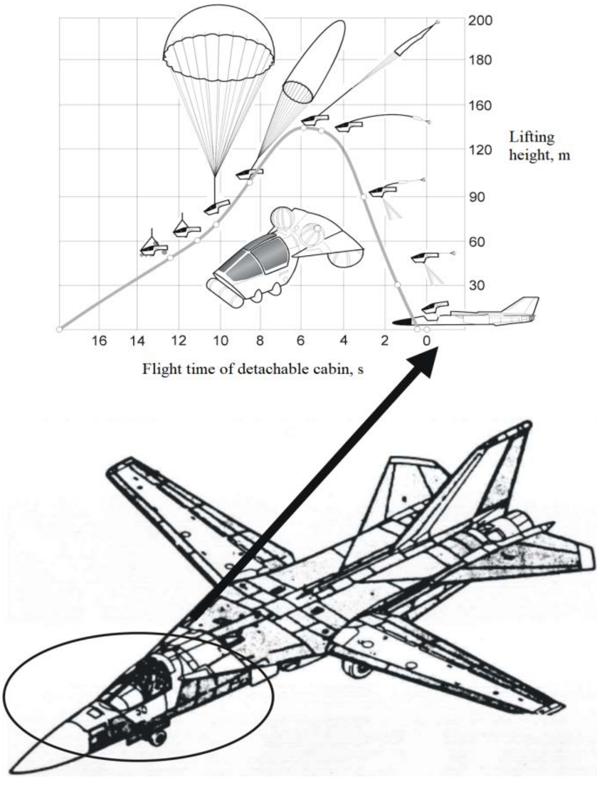

Fig. 1 – Rescue of the crew of the General Dynamics F-111 fighter

Aircraft F-111A (Figure 1) [3], [5], [6] has a cabin with lantern flaps opening upwards. Crew members do not have individual parachutes. In an emergency, the cockpit, together with part of the wing structure, is separated from the aircraft using directional pyro-charge, cutting the supporting frame along the communication loop with the glider, and using the rocket engine with a thrust of 176.4 kN, the rescue capsule is separated from the aircraft. The contour of the separation of the cockpit from the fuselage passes behind the dashboard under the cockpit floor and behind the crew seats. The pilots seats are located nearby, their position can be adjusted in three axes. The air conditioning system in the cabin maintains pressure at all altitudes, corresponding to an altitude of 2400 m, and provides the ability to fly without high-altitude suits. Pilots are equipped with oxygen masks, but can take them off in flight [3]. With the help of a brake parachute, an auxiliary engine and two sets of shields, the detachable cabin is stabilized in accordance with the flight conditions determined by the high-speed pressure sensor. The parachute system opens automatically using a barostat. At the same time as the charge is activated and the rocket engine is turned on, an emergency transceiver and a flashing beacon are activated by the control system signal to facilitate crew rescue operations.

To mitigate the impact when landing, the cabin has a shock-absorbing system. The cabin has everything necessary to ensure the life of the crew and protection from the influence of the external environment, including an emergency oxygen system. Cab bailout can be carried out at zero speed and at zero height. When actuating any of the two bailout handles located on the central console of the cabin, the following operations are automatically performed [3], [5]: both crew members are attracted to the seat backs with safety belts and held in position with the help of an inertial lock of safety belts; emergency oxygen system and cabin pressurization system are switched on; the rocket engine is turned on; simultaneously with the ignition of the rocket engine, a cumulative charge is detached, which separates the capsule from the aircraft; after about 0.6 s, a stabilizing parachute is released and the rocket engine turns off; when the capsule is reduced to a height of 4500 m, the main rescue parachute is released. If the ejection speed exceeds 555 km/h, the release of the parachute is delayed until the negative longitudinal overload is less than 2.2 g; 3 seconds after the opening of the main parachute, the pneumatic shock absorber is filled with air. The pneumatic shock absorber absorbs impact energy when the capsule lands. For landing on water, the capsule has inflatable floats. The cabin of the F-111B aircraft had a device that is operated under water and automatically separates the capsule from the aircraft when it reaches a depth of 4.5 m (Fig. 1) [3]. The floats were supposed to push the capsule to the surface of the water and set it in the correct position.

The capsule development process required an extensive test program, which included: tests on the rocket-dynamic section of the track to demonstrate the trajectory of the capsule at different speeds; dropping from a great height to determine the characteristics of free fall; shock absorption tests to develop an acceptable cushioning system; tests during a long stay in a capsule of people in order to demonstrate the compatibility of the capsule, life support system and people in emergency conditions; vibration and strength tests and reliability tests.

The effectiveness of the detachable cockpit of the F-111A aircraft crew was tested on October 19, 1967 [3], when the crew of the 15th experimental F-111A aircraft was forced to leave the aircraft at an indicator speed of 520 km/h at an altitude of 8.200 m. According to the crew, the noise and overload at bailout were acceptable. The flight path of the cockpit was parabolic. The impact during landing on a relatively flat surface was weak, the exit from the cockpit was not difficult, although the cockpit rolled over to the starboard side and the pilots left through the left exit hatch. Inspection of the cabin showed that, with the exception of soot in places where cumulative charges were placed, the cabin was clean, the skin was smooth, without dents, and the glazing remained intact. A sample of the cabin of this model is in the training laboratory of the department No 101 “Design of aircraft” MAI [5], [7].

3. STUDY OF NEW DESIGN SOLUTIONS FOR THE DESIGN OF CIVIL AIRCRAFT EQUIPPED WITH CRS

The use of such systems in civil aviation can go in two ways. The first involves the modification and modernization of the existing fleet of aircraft. Despite the apparent simplicity in this situation, all the weight, aerodynamic, and so on costs must be clearly defined not only, but the differential weight increment of both the units and the design of the airframe and systems must be taken into account.

For these reasons, despite the fact that this system will satisfy the requirements of the aviation market, it will be necessary to take into account the deterioration in the weight return on the mass of an empty equipped aircraft, and, consequently, a decrease in the commercial load or flight range.

The second way allows you to optimize design solutions taking into account causal factors of transformation of the appearance of the aviation complex according to the results of internal design, which is based on the concept of CRS application.

However, this requires the identification of new design decisions and design features of passenger aircraft equipped with CRS, which, in terms of time and material costs, corresponds to R&D, which is complex and its implementation will require the involvement of organizations - co-contractors of almost the entire domestic aerospace complex: aircraft construction, rocket science, parachute building, aerospace technology, aerospace medicine.

At the initial stages of aircraft design, which make up only 5-10% of the total labor costs for creating the project, up to 70-80% of decisions are made that will ensure its effective operation in the future. It is at this stage that a decision is made to use the collective rescue system.

The presence of original systems that provide safety requirements makes an adjustment to the structure and composition of the tasks to be solved within the framework of the formation of the appearance of an airplane (FAA) [7], [8], [9], [10], [11], [12], [13], [14]. When solving the problem of forming the appearance of an aircraft equipped with CRS in order to remove uncertainties, it is necessary to carry out structural decomposition of the design object (aircraft) and procedural decomposition of the design process.

A graphical interpretation of the hierarchical structure of the aircraft [15], [16], [17], [18], [19] is presented in Figure 2.

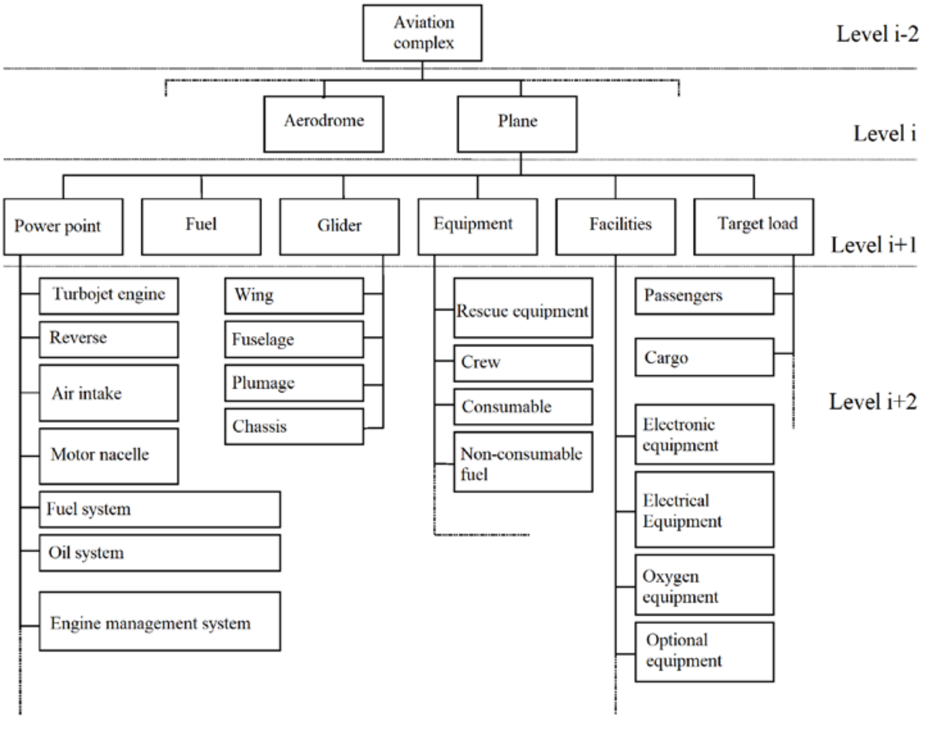

Fig. 2 – Graphical interpretation of the hierarchical structure of the aircraft (structural decomposition of the design object)

Conventionally, as part of the task, the aircraft as a design object corresponds to the itch level of the hierarchical structure.

In accordance with the systematic approach to solving problems of a certain hierarchical level, for the correct consideration of the problem, it suffices to consider two adjacent hierarchical levels either (i-2) or (i+2).

The collective rescue system forms many requirements and limitations that have a dominant influence on the image of the aviation complex, and corresponds to the tasks to be solved at the stages from (i) to (i+2) the hierarchy. Figure 3 shows the structure of design procedures for the FAA.

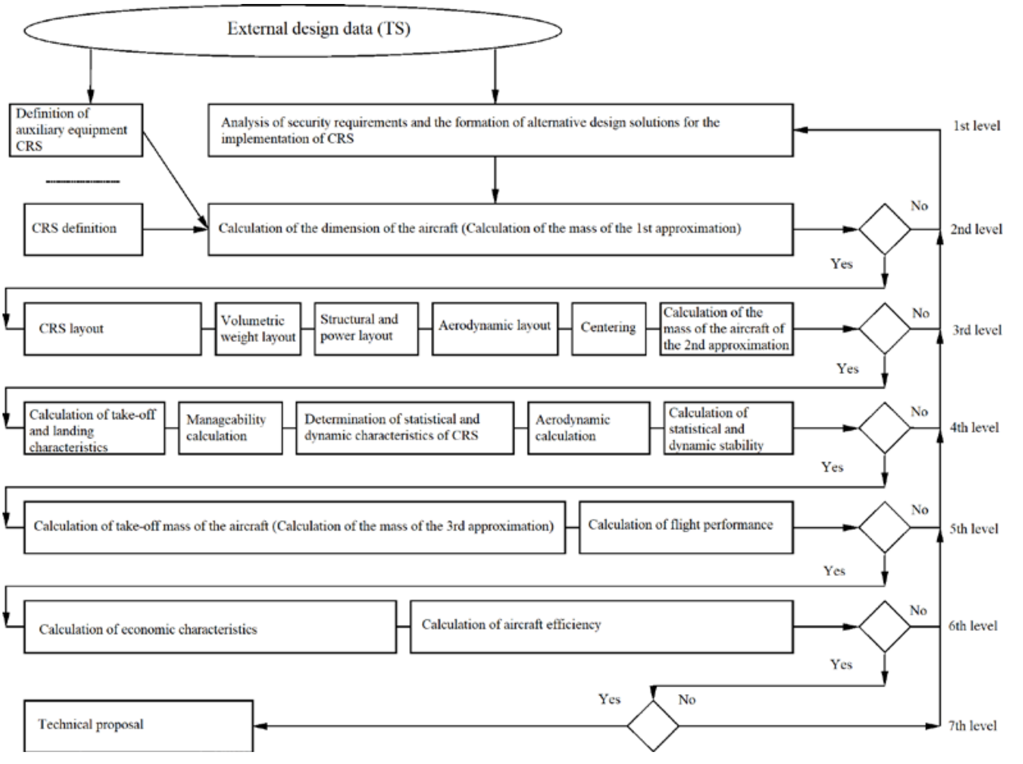

Fig. 3 – The structure of the design procedures for the formation of the appearance of the aircraft (procedural decomposition of the design process of the aircraft with CRS)

At the first level, the flight safety requirements laid down in the TS in general are translated into CRS circuitry. The aircraft layout should provide an open area to the lower or upper rear hemisphere. Aircraft decomposition is one of the problems that must be correctly taken into account in the early stages of aircraft design. It is solved by the modular principle and the use of the technological division scheme of the aircraft. The identification of new design solutions, dimensions, type, purpose and design features of civil aircraft equipped with CRS requires research and, in the future, research and development in several stages: creating a dynamically similar CRS model based on UAVs; modification of a business class aircraft; modification of the main aircraft, which does not require separation of the fuselage into modules; modification of the main aircraft, which requires the separation of the fuselage into modules; development of a promising aircraft equipped with CRS.

The analysis of aviation accidents for 1990-2000 shows that 58 cases out of 100 CRS could save passengers and crew for accidents in which the emergence of an emergency into a catastrophic situation occurred during cruising flight modes (Fig. 4).

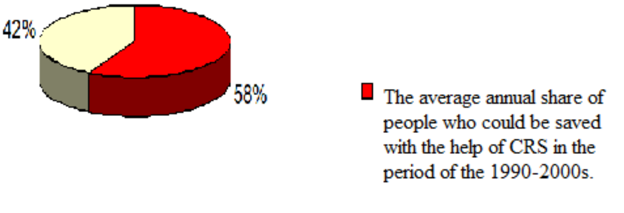

Fig. 4 – The average annual share of people who could be saved using CRS

Figure 5 shows the design of an airplane [1] vertical ultra-short take-off and landing (VTOL) business class.

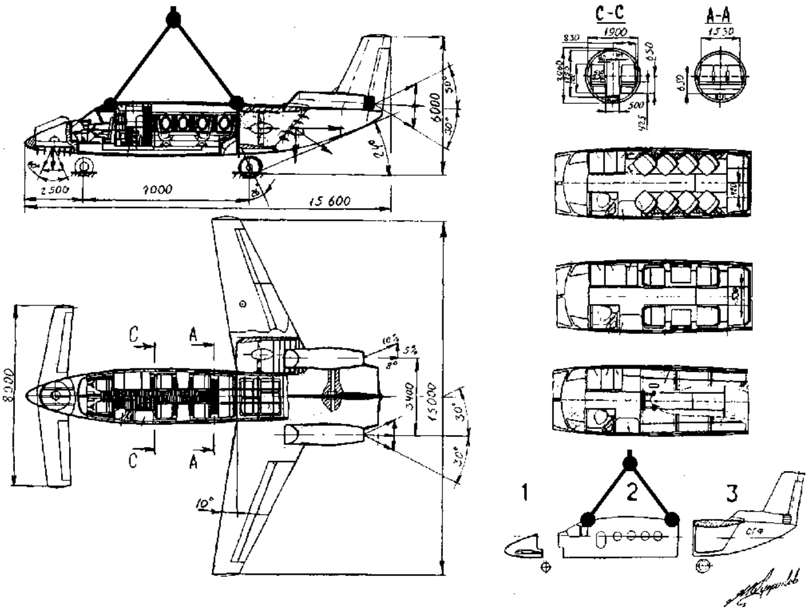

Fig. 5 – Aircraft vertical ultrashort takeoff and landing

For VTOL aircraft, the safety of passengers and crew in pre-evolutionary flight modes is the most difficult problem to solve. CRS allows satisfying this requirement. The modular principle of the aircraft is due to the combination of the Duck aerodynamic balancing scheme with the reverse sweep wing, the “three-bearing with the nose wheel” landing gear scheme and a single power unit with fan thrust amplification units, one of which is located in the bow and two others in the rear of the aircraft under wing. The separation of the central module of the fuselage is determined by the structural-power scheme, the scheme of technological division, the aerodynamic and energy layout of the units and systems of the aircraft, and provides a reduction in the mass of the rescue module to 20-22% of the take-off weight of the aircraft. The use of CRS for such aircraft organically fits into their concept and does not require additional weight costs based on the weighted summary of the equation of aircraft existence, or leads to their minimization.

4. CONCLUSIONS

The exclusion of the contact zone of the emergency aircraft with the ground, as the most dangerous part of the flight, will improve the safety of flights. At the initial stages of aircraft design, which make up only 5-10% of the total labor costs for creating the project, up to 70-80% of decisions are made that will ensure its effective operation in the future. It is at this stage that a decision is made to use the collective rescue system. The presence of original systems that provide safety requirements makes adjustments to the structure and composition of tasks to be solved within the framework of the formation of the appearance of an airplane The analysis of aviation accidents for 1990-2000 shows that 58 cases out of 100 CRS could save passengers and crew for accidents in which the emergence of an emergency into a catastrophe occurred during cruising flight modes.

The ability to equip an CRS aircraft requires at the stage of forming the appearance of an accounting aircraft, both circuit solutions and design cases based on the prevention of the development of an emergency into a catastrophic one. The separation of the central module of the fuselage is determined by the structural-power scheme, the scheme of technological division, the aerodynamic and energy layout of the units and systems of the aircraft, and provides a reduction in the mass of the saved module to 20-22% of the take-off weight of the aircraft. For VTOL aircraft, the safety of passengers and crew in pre-evolutionary flight modes is the most difficult problem to solve. CRS allows satisfying this requirement. Conducted predictive studies on the use of collective rescue systems in civil aviation make it possible to significantly promote domestic aircraft in the international aviation market and to sell them abroad on the basis of a qualitatively new approach to ensuring safety in civil aviation.

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