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Research paper

Computational modeling of the cabin interior of the conceptual model of amphibian aircraft “Lapwing”

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ABSTRACT

The article is concerned with computer modeling of the cabin interior of the conceptual model of the amphibian aircraft “Lapwing”. Various concepts of the passenger compartment layout discussed. Designing of interior objects is carried out taking into account ergonomic norms. The stages of modeling a comfortable passenger seat from a sketch to a finished model are described in detail. The method of extruding polygons is used for modeling the interior objects. When shading a scene, the materials are assigned at the sub-object level. The final scenes of a realistic rendering of the cabin interior of amphibian aircraft are shown.

1. Introduction

At present, the development of tourism in the shelf zones of the World Ocean requires small civil hydro-aviation. At the same time there are models of business class aircraft, which were specially designed for private or administrative purposes. The modern aircraft market of this class is represented by a number of airlines that are leaders in their class. Among them, we can mention Dassault Aviation which has model Dassault Falcon 900 [9]. The Dassault Falcon 900 provides its passengers not only with an enhanced level of comfort, but also with a luxurious interior. Of the Russian aircraft, the Yak-40 model can be noted; along with numerous modifications it has an administrative configuration for the first persons of the state. Small-sized vessels with a capacity of up to 7 people include the Be-103 amphibian aircraft manufactured by the BERIEV Aircraft Company [24]. This light multi-purpose amphibian is designed for use in coastal shelf areas.

When designing the interior of the cabin, essential are the requirements of ergonomics and comfort in conditions of confined space. Given the special importance of these parameters in the development of the interior of the passenger cabin of airplanes, let us consider some references devoted to this topic. The problem of reducing noise, creating a microclimate in the passenger cabin is the problem of current importance, and a lot of research has been devoted to this subject. The work [25] is devoted to the creation of comfortable climatic conditions for the interior design of the passenger cabin of the airplane. The temperature effect, ventilation effect on comfort conditions for passengers was taken into account. In the paper [11], the problem of minimizing noises in the passenger cabin is considered. The design of the passenger compartment and the convenience of passengers during the flight are discussed in [7,23].

The work [13] is devoted to formulate the peculiarities of the practical development of the cabin interior design, choose methods, and create recommendations for the implementation of project design concepts based on hypotheses. The article [14] considers the concepts of the design of the cabins of future passenger aircraft. Various aspects of the optimum configuration of the cabin of the aircraft based on the existing technical design requirements are described. The chapter of the book [12] discusses the development of various configurations of the fuselage pointing out their advantages and disadvantages. Practical recommendations on cabin and cockpit cabin design taking into account the design of the fuselage and ergonomic standards are made. Modern trends in the design of cabins and interiors are presented in detail on the site [8]. The requirements to the design of the layout of the cabin taking into account the comfort and safety of the passengers are presented in work [21].

When designing the interior, the comfort of passengers is often linked to the design of the seat. The article [16] deals with the development of passenger seat construction in accordance with

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safety and durability standards. The results of the strength testing of a passenger seat under dynamic loads in the airplane cabin are discussed. According to the findings presented in paper [6], the sensation of comfort is mainly associated with passenger experience in the passenger seat. The article [5] describes the features of the design of the passenger seat in the interior design of the aircraft cabin.

The review [15] is devoted to revealing the factors influencing the sensation of comfort and discomfort of passenger seats. According to the conclusions of this review, the relationships between the anthropometric parameters of a human body and positions occupied in the passenger seat are the determining factors. In a recent paper [17], the issues of taking comfort into account on the basis of a passenger survey for the design of a comfortable airplane interior have been considered. The parameters of the passenger's personal space when sitting in the passenger seat have been taken into account as the dominant factors. According to the results of the review of the literature, it can be noted that when designing the interior of a passenger cabin, not only aesthetic qualities are needed, but special attention should be paid to the requirements of ergonomics and comfort.

2. The concept of the amphibian aircraft "Lapwing"

The conceptual model of the new amphibian aircraft "Lapwing" was presented by Abbasov and Orekhov in [4]. Based on the bionic forms, visually-graphic solutions for the layout of the amphibian aircraft were created. The concept of the amphibian aircraft was named after the lapwing bird, which lives in ponds and makes a virtuosic air game during the mating season. Its black-and-white color of feathering was also used in the shading of the three-dimensional model of the amphibian aircraft.

This paper discusses the conceptual solutions for the layout of the interior of the amphibian aircraft "Lapwing", the step-by-step creation of the passenger compartment from the drawing to the three-dimensional model. The novelty of the article lays in the development of original layouts, taking into account the operational purpose, the creation of an ergonomic model of a new comfortable passenger seat and a cozy interior of the amphibian aircraft cabin. For the passenger modification of the amphibian aircraft Be-200 the interior design issues were considered by Abbasov and Orekhovin [3].

The intended purpose of the amphibian aircraft "Lapwing" is both administrative exploitation and the transportation of officials of state institutions and commercial organizations. Aircraft of this class have a passenger cabin, which can accommodate from 6 to 10 people. Work of administrative aircrafts has a constant character, which helps them to perform operatively. Such aircraft are used by private persons for personal flights, transportation of employees and partners. Today, the term "business jet" is used to refer to aircraft of this class, the word "jet" means only jet engines, but machines with turboprop or piston engines can be used as an administrative aircraft too.

The concept of the layout of the amphibian aircraft "Lapwing" is based on the water-swinging wing with the possibility of gliding at three points (redan, right and left rear edges of the center section). This arrangement has the advantage of the stability of motion on the water at the takeoff and landing modes and in the increase of seaworthiness. The low wing position increases the lifting force due to the screen effect on takeoff and landing, which makes it possible to simplify and facilitate the design of the aircraft.

Fig. 1 shows a sketch of the model of the amphibian aircraft with reference to the operating environment, the wingspan is 18.5 m, the length of the aircraft is 16.9 m, and the height is 4.87 m. The dimensions of the prototype fuselage are designed taking into account the requirements of the future interior and with space for the placement of freight containers. Fig. 2 shows the proto-type drawings of the amphibian aircraft tied to anthropometric parameters, taking into account the requirements of ergonomics [22,2]. It is proposed that the developing model would occupy the middle segment in the hydro-aviation market, the crew will consist of 2 people, and up to 9 passengers can be accommodated in the passenger cabin.

3. Layout concepts

The development of any internal space of the aircraft must begin with a new scheme. The design of the cabin of the aircraft, unlike the interior of residential or public premises, is limited primarily by the dimensions of the fuselage and the overall layout of the aircraft. In this case, the designer needs to organize a space that corresponds to all the necessary ergonomic and anthropometric requirements [10,19,20]. Along with aesthetics and utility, one should also take into account the hygienic properties of materials for interior design. Trauma safety in flight also depends on the competent ergonomics of the interior of the cabin.

At the stage of searching for the cabin interior concept, you should analyze the layout and arrangement of the equipment, work out several options for layout, depending on the purpose of the aircraft, taking into account ergonomics. Let's consider a number of layout solutions for the interior space of the aircraft, designed to carry 8–10 passengers. The layout of the passenger compartment with passenger seats located in the direction of movement is shown in Fig. 3, there is a mini-bar with soft drinks in cabin, and a restroom is located in the bow section. Such arrangement of the cabin allows placing comfortable seats with an individual media unit, if necessary; the seats take an ergonomic position for comfortable sleep during the flight.

Lack of time is forcing businessmen to conduct business meetings or briefings, both during parking and in flight. For this purpose, the seats might be placed in face-to-face position with a table between them, for convenience (Fig. 4). In addition, we can suggest a layout that will divide the cabin of the aircraft into two compartments for individual meetings and negotiations. This arrangement will allow, if necessary, transform the seats into sleeping places (Fig. 5).

The layout solution affects not only placement in horizontal directions, but also vertically. Fuselage contours provide for maximum use of internal space with external compactness [21] (Fig. 6). In the design process, it is necessary to work out the dimensions of the elements of the passenger compartment and passenger seat, taking into account the anthropometric parameters [5].

4. Development of a passenger seat

Development of the seat begins with a detailed drawing that takes into account ergonomic requirements and human parameters (Fig. 7), the length of the seat is assumed to be 1.258 m, height – 1.211 m, width – 0.732 m. The body of the seat is made in the form of a bucket; the angle of the seat backrest makes it convenient to spend many hours in flight. This drawing will be the basis for three-dimensional modeling of the passenger seat in the future.

For computer modeling of the interior of the amphibian aircraft cabin, the graphic system 3ds Max is used [1]. Modeling of interior objects can be done in several ways, one of which is the method of sequential extrusion of polygons (Polygon Extrude). This method allows you to more accurately track the coordinates of the polygon vertices in the modeling process based on a two-dimensional drawing. As a result of multiple repetition of the Polygon Extrude operation, half of the seat model is created for further processing. The seat has a vertical axis, the axis of symmetry, which allows making a mirror half.

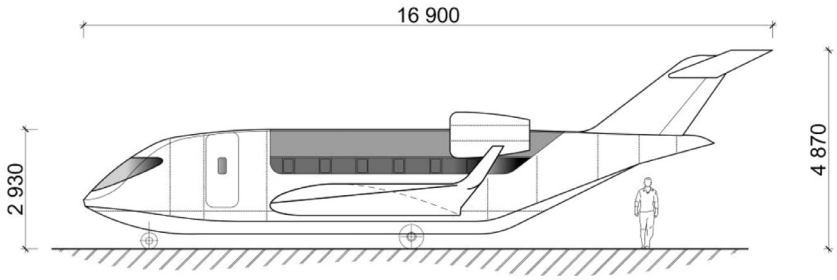

Fig. 1. View of the prototype from the left side.

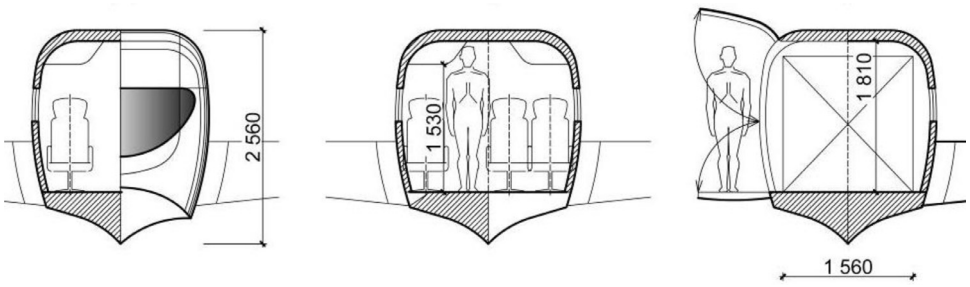

Fig. 2. Linking the fuselage to anthropometric and ergonomic requirements.

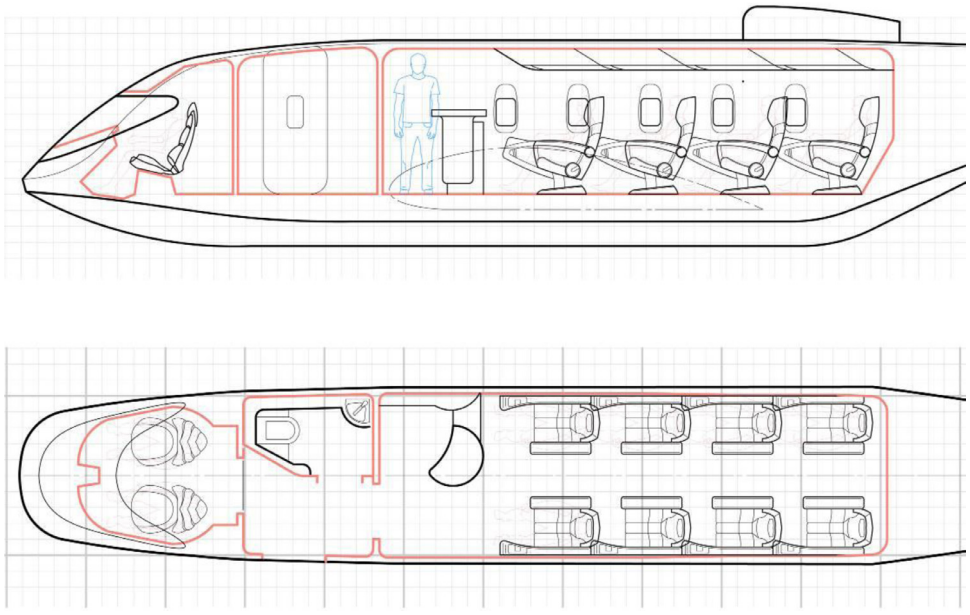

Fig. 3. Arrangement of the cabin in two types with the placement of seats in the direction of movement.

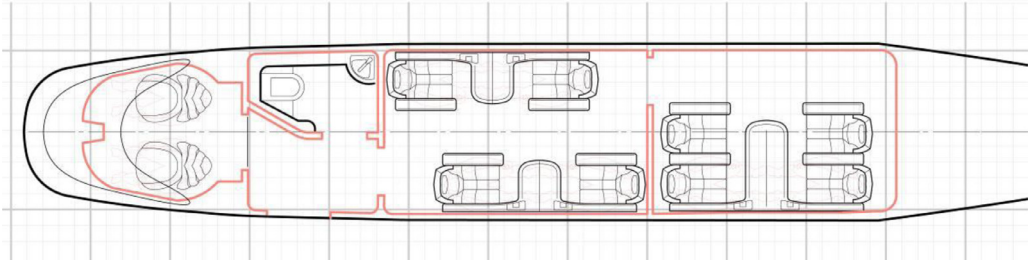

Fig. 4. The layout of the cabin divided into two compartments for work.

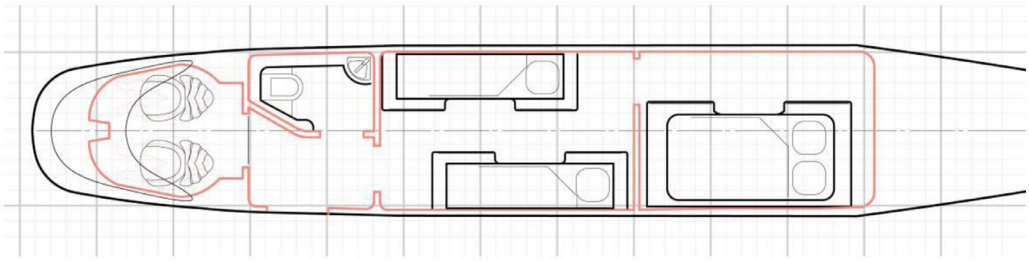

Fig. 5. Transformation of passenger seats into sleeping places for a cabin with two compartments.

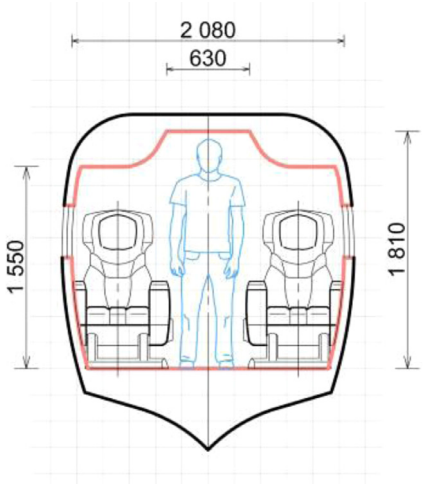

Fig. 6. A cross-section of the cabin with the main dimensions.

At the next stage, the geometry of the model is being refined, initially it has a faceted surface (Fig. 8, left). The capabilities of the 3ds Max graphics system make it possible to smooth the model in various ways. One of these methods is to convert the Editable Poly model to objects of the NURMS subdivision type [18]. The result of applying this command significantly improves the appearance of the model (Fig. 8, right). Before proceeding to the assembly stage, the armrests of the passenger-fat seat are being modified.

5. Modeling of the cabin interior

Next, all other interior objects of the aircraft cabin are created. When making a realistic model of the fuselage, the developed plans, cuts and sections of the future fuselage are used. The main fuselage contours were performed on the basis of the Spline Extrude method.

In the next stage, the seats are distributed along the longitudinal axis in the cabin. For this, the 3 ds Max graphics system has a convenient tool called Array. The tool window allows you to set the offset value of subsequent copies relative to each other, and in all three planes simultaneously. At the final stage, all the interior objects of the future model are assembled (Fig. 9). To maintain the accuracy of the alignment, you should use object snapping, and then you need to go to the materials setup and to the scene lighting setup.

6. Assignment of materials and rendering of the scene

The objects around us have important properties that determine their appearance. To make photorealistic images, essential is to make a right choice of material and setting of its basic properties, including lighting. These realistic parameters can be provided by the external rendering module V-Ray, so the material library

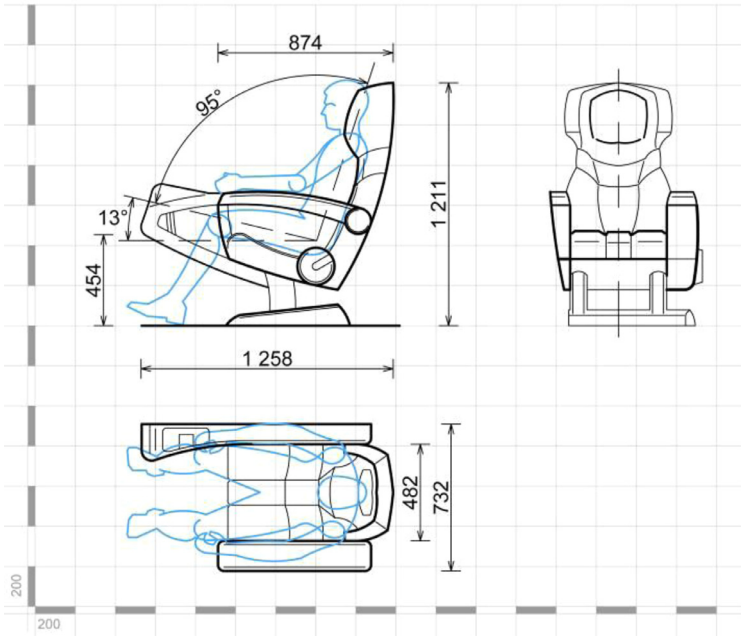

Fig. 7. Drawing a conceptual model of a passenger seat.

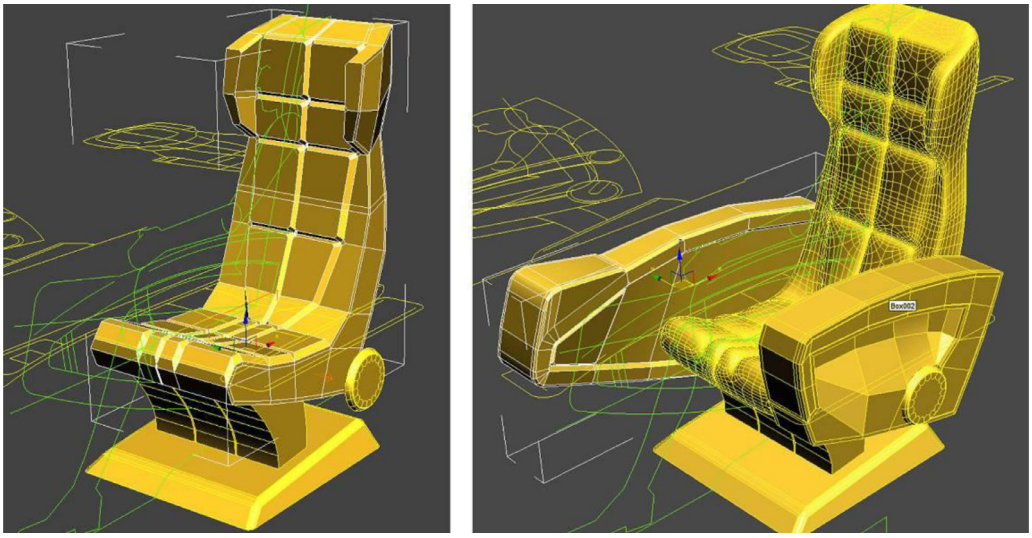

Fig. 8. Primary faceted model and final assembly of the passenger seat.

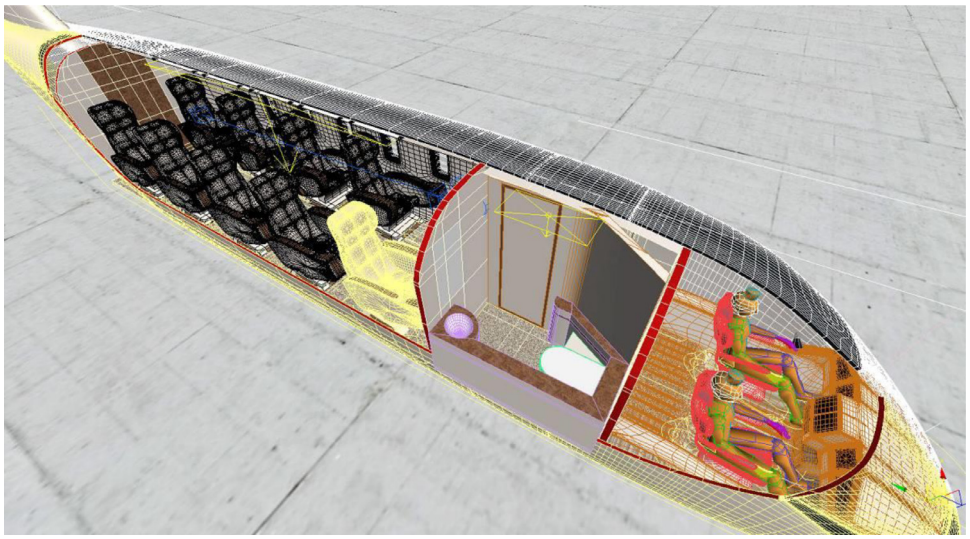

Fig. 9. Final interior assembly.

VRayMtl is used to render objects. One of the important parameters of the material is its basic color (diffuse color). To make a realistic simulation of the seat, you need to apply materials to it at the sub-object level. The process of materials application begins with the partitioning of the model at the Element level of the Editable Poly object.

Fig. 10 shows the process of creating a seat arm material using the material editor. By displaying a sample of material (Fig. 10, left), it can be determined that the armrests will simulate the surface of the lacquered redwood.

Fig. 11 shows the scene of rendering of the passenger seat with the assigned materials. Objects of the scene can be visualized with varying degrees of accuracy. The graphics system 3ds Max uses several rendering mechanisms: to examine objects in the projection window, to view the sketches of the materials and to obtain the final image. These mechanisms allow us to find a compromise between the speed of rendering and the quality of the image. Fig. 12 shows the scene of rendering of the interior of the cabin of amphibian aircraft after the arrangement of seats, and the restroom is shown in the bow part.

The external rendering module V-Ray is based on the creation of indirect lighting, this method is used by many of the modern rendering modules. Indirect illumination implies the illumination of a scene only by diffuse reflected light from other objects, without the participation of a direct ray of light from an immediate source of light. In Fig. 13 there is the final stage of rendering of the toned interior model of cabin of the amphibian aircraft “Lapwing”.

7. Usability and comfort cabin interior

In connection with the special importance of the requirements of usability and comfort, we will describe the proposed convenience criteria for the interior design of the airplane cabin. Each detail of interior finish is aimed at creating maximum comfort for passengers. Thus, the interior surface of the cabin is lined with synthetic incombustible materials of light, soft tones that do not cause passenger’s fatigue during the flight and create the impression of spaciousness [23]. Armrests are made with wooden inserts, faced with decorative fiberglass. The floor is covered with a synthetic carpet; the windows are equipped with curtains-light filters. Materials used in the finish, meet the requirements of a fire hazard for the interior design of the airplane cabin.

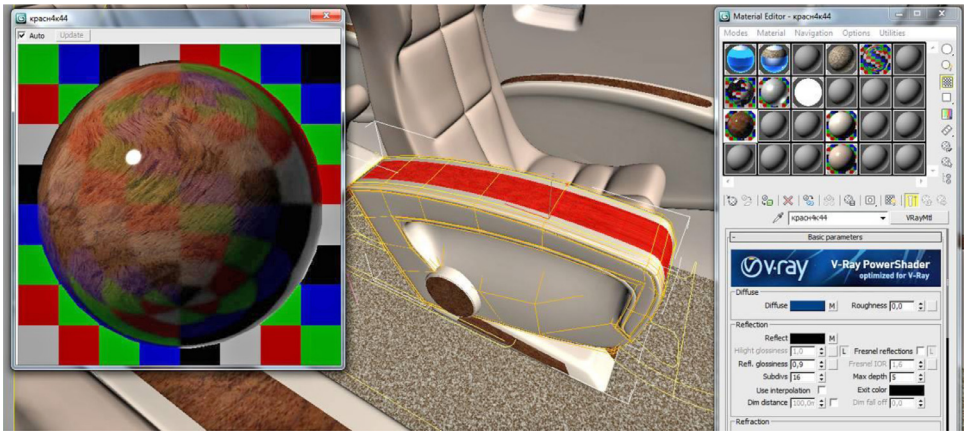

Fig. 10. The process of assigning material to individual seat model polygons.

Fig. 11. Rendering of the conceptual model of the passenger seat with the assigned materials.

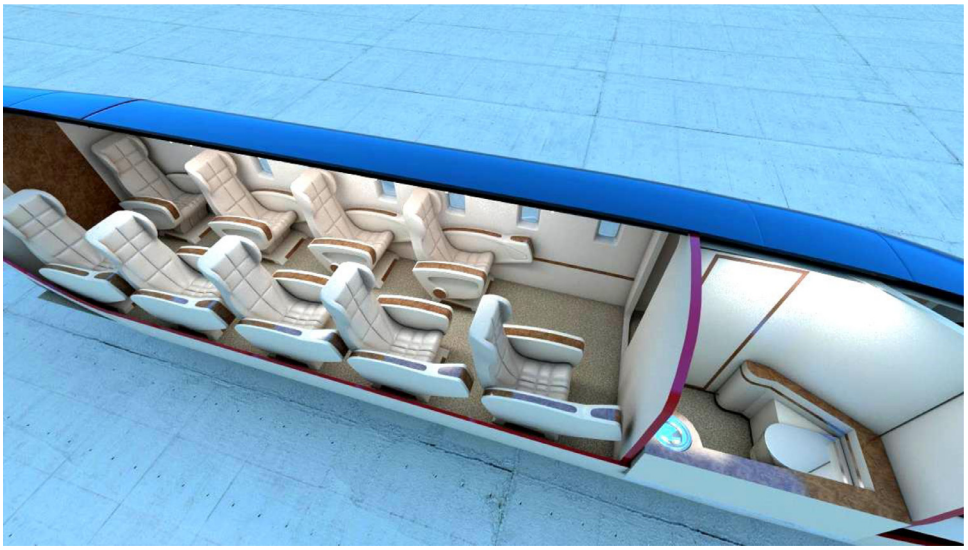

Fig. 12. Final rendering of the cabin on the top view.

Fig. 13. The final rendering of the passenger compartment of the amphibian aircraft "Lapwing".

Passenger seats are not only aesthetic, beautiful but also comfortable. The dimensions of the seats, their proportions, as well as the properly selected profile of the seat and the backrest, reduce the passenger's fatigue during a long flight [6]. Chair backs, as usual, can be deflected back, there a passenger can take a comfortable pose, and in the case of a rough landing, have the opportunity to lean forward. This feature of the seat design protects passengers seated in the back from bruises.

The chairs are made in the form of a single-seat block. The blocks of the left and right sides of the cabin are made in a reflected form and have a similar attachment to the floor rails; there are pockets for storing individual lifejackets when flying over water areas and safety-belts. The minimal step of installation of armchairs is 1 m. The backrest of the chair in its original position is inclined to back from the vertical by an angle of 15°, and by means of the adjustment mechanism, it can be deflected back from the initial position by another 25° with fixation of the intermediate positions.

Mechanisms for deflecting and fixing backs of the seats are mounted on the extreme armrests. When you press the button, you can deflect the seat back in the desired position; when the button is released, the backrest is fixed in the deflected position. When the button is pressed again, the spring acting on the lever returns the backrest to its original position. The armrests of the chair do not recline, for the convenience of service of the interior, backrests recline on seats, and seat pads rise up to a vertical position. The seat framework, which is the main element of the chair, consists of two pipes, on which legs of the chair and supports for installation of armrests, backrests, seats, and levers of folding tables are mounted.

There are solid shelves for small items along the two sides; on the lower surface of the shelves, there are individual passenger service units, on which adjustable individual ventilation nozzles, adjustable reading lamps, and flight attendant call buttons are mounted. The cabins are well lit by the ceiling lights. At night flights, when the general lighting is off and the telltale light – a light bias behind the top panel remains, a passenger can switch on one of the three adjustable lamps located above his/her head on the individual passenger service unit.

8. Conclusion

In conclusion, it can be noted that passenger comfort criteria remain one of the most important parameters when designing an interior of an airplane cabin. While this condition must be met, we should not forget about the space limitations. In this paper, we made an attempt to create a concept for the ergonomic interior of a light aircraft of the business jet class. In this article we proposed original layout schemes for a salon of different operational purposes, an ergonomic model of a comfortable passenger seat, and a cozy interior of the amphibian aircraft cabin was designed. As a result of developments, it can be noted that the resulting photorealistic rendering of the interior of the passenger compartment can visually show the interior design features of the future aircraft.

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