Technology of Informing Passengers of Civil Aviation in an Emergency of High-Altitude Flight

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Abstract. An innovative technology of informing passengers of civil aviation aircraft about the potential danger of an emergency in high-altitude flight is presented, based on the calculation in real time of estimates of the reserve time of preservation of consciousness by a person when the aircraft cabin is depressurized. The methodology for calculating the assessment of the reserve time for maintaining consciousness in an emergency of high-altitude flight provides for the calculation of adequate estimates of the reserve time for any values of speeds and profiles of changes in barometric pressure in the aircraft cabin and the time of exposure to a hypoxic environment. The implementation of personalized information about the danger of an emergency in high-altitude flight is made in two versions: a system with the integration of an aviation oxygen mask and a system with the integration of an aviation passenger seat. For the first time, the results of the study make it possible to implement an innovative personified approach to personified risk metrics and personified information about the potential danger of an emergency in high-altitude flight in real time. The developed approach and the systems implementing it will find application on aircraft, during the operation of which there is a risk of depressurization of the cabin and / or cabin; when conducting tests in pressure chambers with the participation of volunteers, when staying in high altitude conditions and when solving other practical problems related to ensuring the safety of human activity in conditions associated with exposure to hypoxia. The stated information-technological concept of integrating the computing resources of an aircraft into the physical processes of personalized information about the potential hazard of an emergency in high-altitude flight has wide practical applications in the field of ensuring the safe operation of complex systems in extreme conditions.

1. Introduction

Solving the problem of ensuring the safety of passengers in an emergency of high-altitude flight requires the development and implementation of alarm systems and information about the danger of an emergency in real time [1-3]. Such systems include sensors, equipment and information components,
which are connected into a single chain of collection and processing of information, ensuring their interaction with each other for forecasting, self-tuning and adaptation to changes in the situation [4-6].

To ensure the safety of aircraft passengers in high-altitude flight emergencies, real-time emergency warning and information systems must include protective equipment - primarily oxygen masks [7].

There are numerous design options for aviation oxygen masks, oxygen equipment kits for aircraft crews. In the aspect of the problem being solved, their main disadvantage is the complete lack of informing users about the serviceability of the equipment and about the situation in an emergency situation of high-altitude flight [8-10]. At the same time, the availability of such information will improve safety in emergency situations of high-altitude flight by providing notification of aircraft passengers about the potential danger of an emergency in the dynamics of its development [11-14].

The studies have shown that the most informative indicator of the danger of an emergency in high-altitude flight is the amount of reserve time for maintaining consciousness by a person under conditions of hypoxic hypoxia [15-17]. The modern level of scientific and technological progress makes it possible to ensure the calculation and presentation by the passenger of aircraft of an estimate of the reserve time of preservation of consciousness by a person in emergency situations of high-altitude flight using inexpensive miniature sensors and microprocessors.

2. Methodology for calculating the assessment of the reserve time of preservation of consciousness in an emergency of high-altitude flight

Situations associated with the rapid impact on a person of an environment with a low oxygen content in the ambient air lead to the development of hypoxic conditions in a person, causing a high risk of loss of consciousness by a person up to his death [1, 18-20].

The solution to this problem requires assessments of the risk of loss of human consciousness, taking into account the effect of the hypoxic environment on the human body. The known mathematical models make it possible to calculate such an estimate under static conditions, that is, while maintaining the constant intensity of hypoxic exposure during the analyzed time interval, which significantly limits the scope of their application. This disadvantage can be overcome by applying theoretical approaches to normalizing the impact of a hypoxic gas environment on the human body and modeling hypoxic conditions based on the dose principle [1, 21-24].

At the same time, it is necessary to ensure the integration of the computing resources of the aircraft into the physical processes of personalized information about the potential danger of an emergency in high-altitude flight, implemented using built-in barometric pressure sensors, information boards, microprocessors, light indicators connected in chains of information collection and processing and interacting to predict, self-adjustment and adaptation in the dynamics of the emergency situation.

Analytically "dose of hypoxia" is determined by the expression

\[ D(t) = \int_{0}^{t} (p_{6500}^m - p_{t}^m) \, dt, \]

where \( D(t) \) is the exposure dose of hypoxic exposure, \( p_{6500}^m = 37.8 \text{ kPa} \) is the partial pressure of oxygen in the trachea at a barometric pressure of 44 kPa (corresponds to an altitude of 6.5 km above sea level), \( p_{t}^m(t) \) is the current value of the partial pressure oxygen in the trachea, \( T \) is the integration interval.

The partial pressure of oxygen in the trachea is related to barometric pressure by

\[ p_t^m = F(p - p_{H2O}), \]

where \( F \) is the relative concentration of oxygen in the atmosphere (\( F = 0.21 \)), \( p \) is the barometric pressure, \( p_{H2O} \) is the partial pressure of saturated water vapor at a temperature of 310K, equal to 6.27 kPa.

With numerical integration, the expression for the hypoxia dose can be written as

\[ D_s = \sum_{t_i} (p^m_0 - p^m(t_i)) \Delta t, \]

where \( \Delta t \) is the duration of hypoxic exposure, and the difference \( p^m_{6500}-p^m(t) \) is defined as the intensity of hypoxic exposure (\( U \)).
The dose approach makes it possible to overcome these difficulties due to the fact that, having determined in accordance with the dose of hypoxia with a change in \( P_m \) and dividing its value by the measurement time, the value

\[
\Delta P^m = D_i / \sum_{i=1}^{n} \Delta t,
\]

equivalent to the received dose of hypoxia, subject to the condition of constant partial pressure of oxygen in the trachea (flight at a constant altitude), and, consequently, barometric pressure and altitude above sea level uniquely associated with it. Then the dose-equivalent value of the partial pressure of oxygen in the trachea is

\[
P^m_e = \Delta P^m_e + P^m_0.
\]

This value is used for dynamic calculations of estimates of the reserve time of consciousness retention under hypoxic conditions. Having determined the values of these parameters and knowing the dynamics of the emergency situation (change in barometric pressure in the aircraft cabin over time), estimates of the probability of loss of consciousness are calculated [21-26].

The method for calculating the estimation of the reserve time for preserving consciousness in an emergency of high-altitude flight is as follows.

Measure the barometric pressure in the aircraft cabin every three seconds. If the obtained value is greater than the barometric pressure at an altitude of 6500 m (44,06 kPa), then the reserve time for maintaining consciousness is considered unlimited.

As soon as the current barometric pressure is less than the barometric pressure at an altitude of 6500 m:

- a timer is turned on and the time spent by passengers in such conditions is determined;
- the estimate of the reserve time of preservation of consciousness \( T \) is calculated by the formula

\[
T = (710,37 - 0,2093(44060 - P)) / (0,2093(44060 - P))
\]

As soon as the measured barometric pressure is greater than the barometric pressure at an altitude of 6500 m, the reserve time for maintaining consciousness is considered unlimited.

The methodology of the dose approach and the mathematical support that implements it allow calculating the time of preservation of human consciousness in conditions of hypoxic hypoxia and its recovery after loss of consciousness caused by exposure to hypoxia. The time of the beginning of the recovery of human consciousness is the moment when the sign of the hypoxia dose changes, and the time of complete recovery of consciousness is the moment at which the absolute value of positive and negative doses of hypoxia becomes equal.

This approach provides the calculation of adequate estimates of the probabilities of the considered adverse effects at any values of the rates and profiles of changes in the partial pressure of oxygen in the trachea, the rate, and the time of exposure to the hypoxic environment.

The developed technique provides the possibility of communication between the computational and physical elements of an integrated system for ensuring safety in emergency situations in high-altitude flights, providing the possibility of informing about the danger of an emergency in high-altitude flight [22-25].

3. Technical solutions for the implementation of information about the danger of an emergency in high-altitude flight

The implementation of personalized information about the danger of an emergency in high-altitude flight is made in two versions: a system with the integration of an aviation oxygen mask and a system with the integration of an aviation passenger seat. The basis for the construction of these systems is the information technology concept of integrating the computing resources of an aircraft into the physical processes of personalized information about the potential danger of an emergency in high-altitude flight.

The functioning of the developed systems, which combine barometric pressure sensors, a microprocessor, an information board, a comparator, a wireless interface unit, a multi-mode LED and an oxygen mask connected to oxygen equipment, is as follows. In an emergency (emergency) situation
of high-altitude flight, the oxygen mask falls out of a special compartment on board the aircraft and "hangs" in front of the passenger. At the same time, a continuous supply of oxygen to the mask is switched on and an overpressure is created in it. The passenger "pulls up" the mask and presses it to the face.

Due to the presence of excess pressure in the mask, its obturator, acting on the principle of a petal, is pressed against the face and ensures the necessary tightness of the mask. During exhalation, the excess pressure in the mask increases by an amount greater than the force of the membrane pressure on the mask seat, so the exhalation petal valve and exhalation valve membrane move away from the seat, and the exhaled mixture is released into the environment. Since the horizontal stripes of the human nose contour shaper in the mask are compressed to the shape of the user's nose, and due to the shape of the lower part of the frame, deeply enclosing the under-beard, the thickness of the frame web ensures an ergonomically comfortable use of the mask.

The mask has a built-in indicator of the reserve time for the preservation of consciousness, which includes a case, in the walls of which a barometric pressure sensor is built flush with the outer surface, and a display for displaying the reserve time of preservation of consciousness by a person, and the outer wall of the case, opposite the outer wall with a built-in display, is equipped with a mount, and a barometric pressure sensor is connected to an information storage device connected to a calculator, the output of which is connected to a comparator connected to the display and to the wireless interface unit. The calculation of the assessment of the reserve time for the preservation of consciousness is carried out using the described method.

At the same time, with the help of the indicator, the user of the mask is informed about the value of the reserve time for preserving consciousness without using the mask, which is shown on a display that is part of the indicator and is built into the mask flush with its outer surface so that the indicator readings are visible to the user of the mask, and the barometric pressure sensor is the surrounding gas environment ensured the objective registration of the measured values of barometric pressure (the outer surface of the sensor should not be covered by mask components, etc.) [1, 19-21].

In addition, to further inform the user of the maxi about the danger of an emergency in high-altitude flight, an LED is built into the mask, which has at least three modes of light (green, yellow, red). The LED is embedded in the mask flush with its outer surface so that it is visible to the user of the mask, and is connected to a computer that controls the LED illumination modes depending on the calculated reserve time of consciousness.

The calculation of the reserve time estimate based on the mathematical apparatus for describing the dose of hypoxia in the form of an integral of the intensity of hypoxic exposure within the action time of this flight factor made it possible to move to the dynamic area of studying the effects of exposure to a hypoxic gas environment and assess its influence on the human condition when the intensity of hypoxic exposure changes over time which is essential in a high-altitude flight emergency. Based on the values of the reserve time of consciousness and the glow of the LED, the passenger of the aircraft in an emergency situation of high-altitude flight can assess the real danger of being without an oxygen mask, for example, when taking action to assist other passengers, moving around the cabin of the aircraft, etc.

Awareness of passengers about the real danger of an emergency in extreme conditions of high-altitude flight, in addition, contributes to maintaining calm, which is essential for ensuring safety in an emergency. The functioning of the developed system, which combines barometric pressure sensors, a microprocessor, an information display, a comparator, a loudspeaker, a wireless interface unit, a multi-mode LED and an aviation passenger seat, is as follows.

An aviation passenger seat contains a seat, a backrest with a headrest and armrests. To build a cyber-physical system, a scoreboard is built into the backrest flush with its outer surface, a barometric pressure sensor and a loudspeaker are built into the headrest flush with its surface, connected to a microprocessor fixed inside the chair, the output of which is connected to the scoreboard.

During the flight, as in the previous case, readings are taken from the barometric pressure sensor in the aircraft cabin. The barometric pressure values are fed through the information and control bus to
the microprocessor, which calculates the estimate of the reserve time of preservation of consciousness by a person under conditions of hypoxia and generates audio information for playback through a loudspeaker.

If the calculated estimate of the reserve time for preserving consciousness is less than 300 s, then a signal is given to turn on the scoreboard and the loudspeaker. At the same time, in the digital digits, the indicator board displays the calculated estimate of the reserve time of preservation of consciousness by a person, which changes in real time with a discreteness equal to the frequency of measurement of barometric pressure in the surrounding gas environment. The inscriptions in Russian and English are highlighted simultaneously with the inclusion of the scoreboard and with the appearance of the calculated estimate of the reserve time for preserving consciousness. Through the loudspeaker, alternately in Russian and English, they give out audio information about the size of the reserve time for preserving consciousness. If, with the scoreboard and loudspeaker turned on, the calculated estimate of the reserve time for preserving consciousness becomes greater or equal to 300 s, then a signal is issued to turn off the scoreboard and loudspeaker. The passenger in the seat sees the information on the display, which is part of the seat installed in front of him, and hears the information through the loudspeaker - thereby informing passengers about the potential danger of the situation caused by the risk of exposure to hypoxia.

The presence of a wireless interface unit in the systems (in the two described variants of their implementation) provides the possibility of transmitting estimates of the reserve time of preservation of consciousness to the crew and ground services in the interests of developing and implementing a rational strategy of actions in terms of planning the flight trajectory of the aircraft, determining the need and level (the first, qualified, specialized) required medical care, etc.

4. Conclusion
For the first time, the results of the study make it possible to implement an innovative personified approach to personified risk metrics and personified information about the potential danger of an emergency in high-altitude flight in real time.

The developed approach and the systems implementing it will find application on aircraft, during the operation of which there is a risk of depressurization of the cabin and / or cabin; when conducting tests in pressure chambers with the participation of volunteers, when staying in high altitude conditions and when solving other practical problems related to ensuring the safety of human activity in conditions associated with exposure to hypoxia.

The stated information-technological concept of integrating the computing resources of an aircraft into the physical processes of personalized information about the potential hazard of an emergency in high-altitude flight undoubtedly has wide practical applications in the field of ensuring the safe operation of complex systems in extreme conditions.

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