DESIGN AND CALCULATION OF THE AIR CONDITIONING SYSTEM FOR A SMALL TRANSPORT AIRCRAFT WITH A TAKE-OFF WEIGHT OF UP TO 2 000 KG

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This article describes the air conditioning system as one of the most important systems of the aircraft. It has a significant impact on the comfort of the passengers, which is nowadays very important. The article describes the main types of air conditioning systems used today and a brief analysis of their components. It also describes how to select and design an appropriate air-conditioning system and air distribution system for an aircraft with a take-off weight of up to 2,000 kg.

Keywords: Air conditioning system, pipe, control panel, refrigerant, air distribution, aircraft cabin

1 INTRODUCTION

In a plane, the air conditioning system‘s role is air treatment by adjusting the temperature, humidity and pressure.

We know that the basic principles of air conditioning were used in ancient Egypt where reeds hung in the windows with water running down them. The evaporation of the water cooled the air that blew through the window, while at the same time moistening the air.

Air conditioning systems in our time have undergone many changes and modifications. In today's modern world, air-conditioning systems are installed almost everywhere. In homes, cars, and of course we cannot forget in the most modern means of transport, in aircraft. Aircraft, as a means of transport, move at high altitudes and require quick and precise ways of adjusting the air. Since passenger comfort is very important, there are many conditions and requirements, which determine the standards for air conditioning.

1.1 Tasks of air conditioning systems

Air conditioning systems are technical devices that are designed to improve the air in the form of cooling, heating, and changes in humidity to generate the desired air composition. An interconnected arrangement of these devices makes the air conditioning system of an aircraft. A block diagram of functions that the air conditioning system performs is shown in Figure 1.

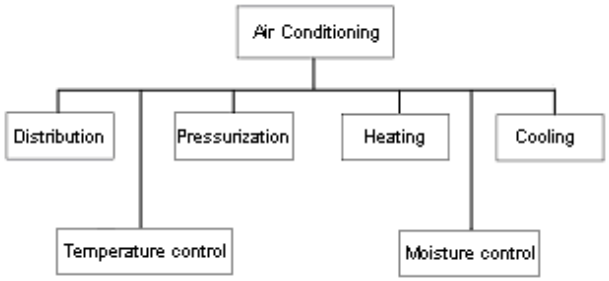

Figure 1 Scheme of air contitioning system

1.2 Types of air-conditioning systems

One of the basic requirements designed for breathing air is the correct chemical composition, because breathing passengers and crew cause a gradual degradation of the available air (decrease in oxygen, the increase of carbon dioxide). Therefore in addition to the required temperature and humidity, it is also necessary to ensure the desired composition. We protect the composition by recovery (regeneration) of the used air on board the aircraft or its replacement. Air conditioning systems are therefore divided into two types depending on how they solve this problem, namely that:

- reprocessing (closed),
- atmospheric (venting).

Another division of air conditioning systems is according to whether the aircraft has a pressurized or unpressurized cabin.

Air conditioning systems in unpressurized aircraft cabins fix the temperature using a simple solution. The system sends intake air heated in heat exchangers and mixes it in cold portions of the mixing chamber.

The amount of air supplied to the cabin is controlled by turning valves and opening dampers. An example of a four-seat aircraft’s air conditioning system is shown in the diagram in Figure 2. Individual inputs and outputs are:

A- intake air inlet to the heat exchanger, B- warm air outside the aircraft, C- mixed supply air into the cabin of the aircraft, D- mixed supply air to the cabin, E- entry for intake air into the aircraft.

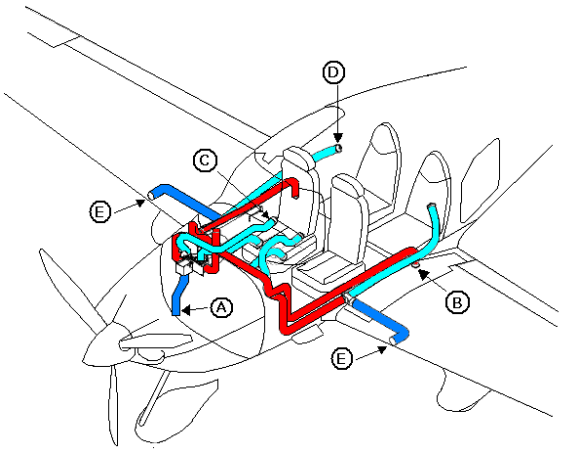

Figure 2 Air condition system in unpressurized aircraft

Air conditioning systems for pressurized aircraft are significantly more complex than unpressurized systems, because along with the temperature and humidity controls

of the air conditioning, it must ensure the necessary pressure in the cabin. Therefore, the air source cannot be direct intake air like in an unpressurized cabin, but instead compressed air from the engines, using compressors or Auxiliary Power Units APU.

2 ADVANTAGES AND DISADVANTAGES OF THE AIR CONDITIONG SYSTEMS

Individual air-conditioning systems have their advantages and disadvantages. Since we are discussing the air conditioning systems for aircraft with take-off weights up to 2000 kg, this chapter lists the pros and cons of different types of air conditioning systems, as well as a selection of the appropriate type.

2.1 Intake air conditioning for unpressurized cabins

This is the air conditioning system, which is used for small aircraft flying at lower altitudes.

Advantages lie mainly in the simplicity of the system and its low weight, which is critical for the final selection. It consists of a relatively small number of elements. It is a system of pipes (supply and distribution), an air exchanger around the exhaust of the engine, mixing chamber, and control valves. The system is easy to maintain as well as reliable.

The disadvantages of intake air conditioning are mainly due to its inaccuracy. It lacks the finer temperature control and complex air treatment. The inability to control pressure means that it is necessary to restrict flights to lower altitudes, which leads to the aircraft consuming more fuel and thus higher costs to fly.

2.2 Air conditioning for pressurized cabins

This system is far more complex than for unpressurized cabins. It is used in all commercial and transport aircraft with pressurized cabins.

The benefits are primarily in precise regulation of parameters for the air entering the cabin, which ensures increased passenger comfort. Because of the regulated pressure in the cabin, the aircraft can fly at higher altitudes and thereby ensure an economical flight.

The disadvantages are mainly the complexity of the air conditioning system. It also requires more maintenance and has higher failure rates. In addition to adjusting the temperature and humidity, it is necessary to regulate the pressure in the system so pressure adjustment elements need to be added, which negatively affects the overall weight and complexity of the system.

2.3 Selecting an appropriate air-conditioning system

Because the proposed aircraft needs to serve as transportation with a take-off weight of up to 2000 kg with an unpressurized cabin, I believe the appropriate air conditioning system is the intake air conditioning with various modifications. This type of air conditioning is commonly used in aircraft with such specifications. A small aircraft cannot afford the excess weight caused by a complex air conditioning system, which contains many elements. My proposed system is simple and easy to maintain. The goal when designing a new aircraft type is to ensure the smallest possible mass of the aircraft, so that the total operation is not too expensive. A simple intake air conditioning system ensures sufficient air treatment while maintaining low weight and reasonable costs.

3 SPECIFIC DESIGN FOR THE AIR CONDITIONING

The specific design solution includes air distribution, heating, cooling, an air conditioning control panel and a proposal for air conditioning diffusers.

3.1 Air distribution

Distribution means the air carriage from intake openings on the wing to the final element. Fresh air is pushed into the thrust of an aircraft through the four air intake vents. Two of them are used for the cooling of hot air in the heat exchanger and two are for supply cool air to the mixing chamber. In the mixing chamber is distribution fan which drives air through our distribution pipe to the cabin of the aircraft.

Pipe flow into the cabin through air outlets. Air-conditioning outlets are located on the front panel there are 2 pieces on the ceiling above the heads of the pilots also 2 pcs and rear of the aircraft assigned to the crew is 8 outlets. Each passenger has a two diffusers, which may partially regulate.

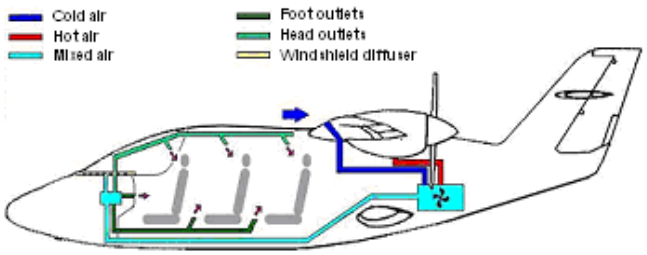

Figure 3 Air distribution system in aircraft

Passengers and crew of the aircraft can arbitrarily close and open each air outlet as they wish and need. For each of the seats there are two air outlets (the head and chest, the legs). Example of the proposed air outlets seen in Figure 4.

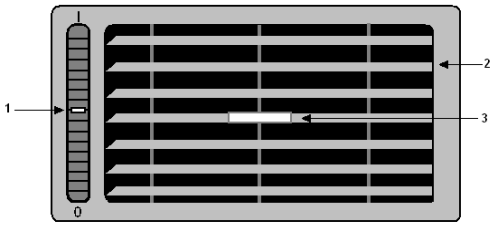

Figure 4 Air condition outlet

Passengers with Knob (# 1) upwards (the character "I") opened Air Vent (No. 2) and scrolling down (the

character "0") concluded Air Vent. Motion control (No.3) sideways changing direction blowing air into the cabin.

3.2 Heating Air

Hot air in an aircraft provides us with an air-heat exchanger (Fig. 5), which operates on the principle of heating a cold ram air with engine aircraft. Ram air that is pumped into the heat exchanger placed around the motor output system is heated due to heat transfer from the output of the engine.

Warm air is then fed to the mixing chamber, where it mixes with cold air to the desired temperature required for air conditioning control panel. Since the optimal temperature in the cabin is 21 ° C engine can deliver sufficient ram air heater for heating the cabin of the aircraft. Heating is possible only when engine aircraft is on. Possibility of auxiliary heating to solve this problem, but it would greatly the total price of the aircraft. In terms of price limits do not consider this possibility.

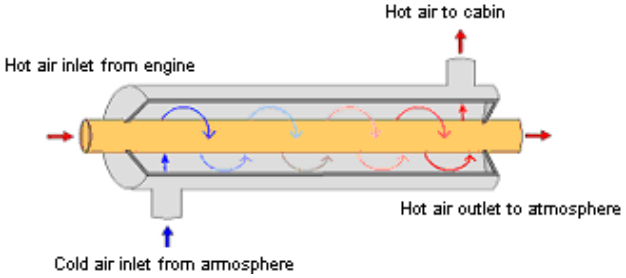

Figure 5 Heat exchanger

3.3 Cooling air

Cold air is fed into the cabin of the aircraft from the outside atmosphere. This is a ram air that the aircraft receives from two inlets located on the wings of the aircraft.

When choosing a lower temperature on the control panel a gradual closing of the solenoid valve in the pipe warm air. Valve in the pipe cold air is more and more open. As the valve is opened only in "cold" pipe temperature air flowing into the cabin of the aircraft is the same as the air temperature outside the atmosphere.

Because aircraft flying in every season and for different atmospheric conditions and temperatures, there is sometimes a situation where the outside air temperature is higher than the desired temperature in the cabin. In such cases, the aircraft is equipped with air conditioning system (Fig.6), that cools air and adjusted to the desired temperature.

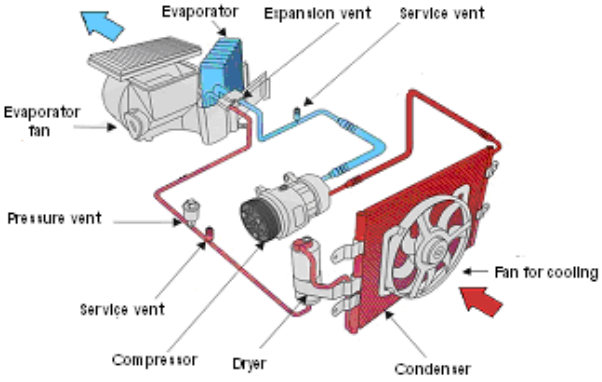

Figure 6 Air conditioning system

The principle of air conditioning system is that, the compressor sucks refrigerant in a gaseous state from the evaporator. The compressor compresses it, thereby increasing its pressure and its temperature simultaneously. Thus pushing the heated refrigerant to the condenser, where it cools and liquefies. This is done so that the condenser is fed ram air or it it blows fans. The refrigerant passes around its temperature and thus cools. If the cooling rate is low, electronics fans turn on and cooling the condenser. The actual rate of cooling evaluates the information of pressure sensors in the system. Liquefied refrigerant is discharged from the capacitor to filter a dehydrator (dryer). Filter doubles as a reservoir of liquid refrigerant. Here, the refrigerant eliminate any moisture that might be in the system, and there is also a coolant filtration. The refrigerant is directed to the expansion valve (chipping) and then into the evaporator, where it is at -28 degrees evaporates and extracts heat to their surroundings. Fan, which is located in the mixing chamber drives air over the evaporator (where it cools) and with air pipes led to the outlet on the dashboard and to the aircraft. The evaporated refrigerant is sucked back into the compressor and the whole process starts again.

3.4 Design of air conditioning control panel

Control panel (Fig.7) is not only used to control the air conditioning, it is also a control unit which, on the basis of data from temperature sensors (in the mixing chamber, in the aircraft cabin) controls the solenoid valves located in the flow of air to move the required amount of air. On the basis of the temperature sensor in the mixing chamber, the control unit evaluates and eliminates differences in temperature of the mixing chamber from the desired temperature, which we selected on the control panel. Temperature sensors in the aircraft cabin again serve to indicate the current temperature of the air in the cabin.

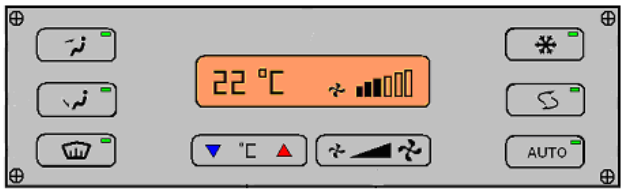

Figure 7 Control panel

Control panel is a modern look with transparent deployment of elements of control for easy handling it. Each button has a graphic indication of the functions carried out by the press. Button is active when it comes to green. Disposable activated by pressing the button and press it again to deactivate it. On the left panel are buttons by which we choose the direction of the blowing air ventilation. In the middle of the panel there is located the display. The display shows the selected temperature in degrees Celsius (º C) and the intensity of blowing air. The right side panel has three buttons with different functions that are not directly related to the modification of the air, but serve to turn on the air conditioning system for opening the valve for air recirculation and to enable automatic management mode of the air conditioning system.

4 CONCLUSION

As the development of aviation is still in motion and today air transport is becoming the most popular means of transport must be developed and various aircraft systems in which the integral is the air conditioning system. Since comfort is guaranteed "availability"of the aircraft, such as air conditioning systems, which have a great impact on the comfort of the passengers have to walk side by side with the latest technologies.

BIBLIOHRAPHY

[1] SLAVÍK, Svatomír: Drak a systémy, nouzové vybavení letounu. Brno: Akademické nakladatelství CERM, s.r.o., 2005. ISBN 80-7204-437-0
[2] SLAVÍK, Svatomír a kol.: Aerodynamika, konstrukce a sytémy letounu – Učební texty dle předpisu JAR – 66 (studijní nodul 11). Brno: Akademické nakladatelství CERM, s.r.o., 2004. ISBN 80-7204-367-6
[3] MOIR, Ian – SEABRIDGE, Allan: Aircraft Systems. 2008. ISBN 978-0-470-05996-8
[4] CHYSKÝ, Jaroslav – HEMZAL, Karel: Větrání a klimatizace. BOLIT-B Press, 2002. ISBN 80-901574-0-8
[5] FIŠER, Jan: Optimalizace klimatu v kabinách malých dopravních letadel: Doktorská práce. Brno: VÚT, 2011. 162 s.
[6] ZIGO, Anton: Lietadlové systémy - Prvé vydanie. Košice: Vydalo VVLŠ SNP Košice, 1990

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