Chapter

The Impact of the Pandemic Effect on the Aviation in the Environmental Quality of the Air Transport and Travelers

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Abstract

The spread of the COVID-19 pandemic, caused by the SARS-CoV-2 virus occurs by the dissemination of viral infections, forcing the need for actions to control the virus. COVID-19 caused a pandemic that impacts the health system in biomedical and epidemiological order on a global. One of the measures taken by governors to contain the dissemination of the virus was the closure of airports, ports, and land borders, keeping only essential repatriation flights. The concern about agglomeration of people in public spaces causes the need for ventilation control in order to reduce the contagion and maintain hygiene in airports and planes. The sum of these factors brought, as a consequence, a resumption of decisions about how to adopt postures to control the contagion. Based on this analysis it turns out that ventilation is the fundamental factor to control the spread of the COVID-19 pandemic. In the civil aviation sector for passengers transport on planes and airports, the following related aspects are presented: (1) determining the air conditioning system coefficients in commercial airplanes for passenger transport using CFD (Computational Fluid Dynamics) simulations to check airflow; (2) present new hygiene technologies for planes and airports.

Keywords: COVID-19, airplane cabin and environmental quality

1. Introduction

In the civil aviation scenario, the pandemic affected the economic circumstances (…) showing the need to reevaluate the demand projections of passengers, aircraft, and load [1]. The efforts of the civil aviation sector are to seek safety guidelines, to intensify the sanitation of surfaces, the use of masks and alcohol gel, frequent hand cleaning with soap/water, the practice respiratory etiquette, and proper ventilation, to keep the environment decontaminated and the ventilation controlled in order to reduce the contagion in airports and planes. Since environmental quality in civil aviation is facing COVID-19 it is necessary to seek comfortable resources in the ventilation itself in an attempt to solve or soften the discomfort during the cruise. The incipient individualization of passengers' thermal comfort is one of the biggest problems faced by companies in the aviation sector. Exposed, multiple times, to considerable variation of thermal sources and different temperatures of asymmetric airspeed fields, passengers suffer the consequences of neglect with solutions that seek the individual space optimization without compromising the comfort provided in aircraft's cabins. To evaluate the thermal comfort, one must know the environmental comfort criteria to the relevant thermal environment parameters, along with the methods to its prediction (project phase) or measurement (commissioning and operation phase). From this basic premise, we need to: (a) define which are the main internal climatic parameters of temperature and asymmetric airspeed due to the cabin geometry projected with pitch,[1] and what is the restricted average width between the armchairs reducing the space between the passengers; (b) quantify its influence on the passengers, and (c) discern the plane and HVAC system in these parameters.

A large number of researches about thermal comfort was written and published. This extensive research literature was written in international standards [2–8], with the intent to guide the aeronautical project professionals to project and maintain the internal thermal environment comfortable, being internationally known as indoor climate or indoor air.

In this chapter, we research the thermal comfort and the adaptive comfort standard (ACS) based on variable climatic expectations that shift the locus of thermal regulatory responsibility to the environment of commercial and passengers transport aircraft, and back again to the airplane cabin occupants. The occupants are obligated to become way more active or interactive with the airplane internal cabin to implement the adaptation opportunities offered by the plane to create an acceptable indoor climate for passengers. After elaborating the methodological differences between these two perspectives about the person-environment relationship, the chapter examines the implications of standards and practices of thermal comfort using the computational simulation tool CFD, which allows describing the project guidelines to decision-making during the air distribution planning, considering the aircraft cabin's geometry. Confident that the obstacles to thermal comfort in the concerned aircraft can be solved with what is observed in simulations made in computational fluid dynamics – capable not only of making predictions about the thermal field and its speed but also of indicating the particle concentration of ventilated environments. The chapter finishes with a discussion about the increase of passengers' thermal comfort, adapting to variations and adjustments in the thermal environment. Such variations allow the creation and distribution of personalized ventilation that is formed around the passengers, and the best way to control this environment is through insufflation, temperature, and flow rate. Personalized ventilation, through air diffusers, highlights the Indoor Air Quality (IAQ), and the thermal comfort research gives a better understanding of the relationship between the human body and surrounding environments. In this regard, passengers play a central role in the aircraft cabins' internal environments. It is noted that, although experimental researches using mannequins provided valuable information about airflow, speed, temperature, and pollutants concentration, some other detailed information such as the airflow field around a person and the relation between the amount of heat transfer by radiation and the transfer of convective heat between the human body and its surroundings cannot be obtained in experiments. The innovation happened in the past years with the introduction of CFD

[1] Pitch is the distance between the plane's armchairs.

technology, which developed and made it possible to analyze the microclimate around a human being. It can simulate the passengers' transient inhalation and exhalation in the processes, having the geometrical representation of the Computational Thermal Manikin (CTMs) which represents the human body, being a significant factor for the ventilation personal study, representing the turbulence, grid generation, and boundary conditions model selection. The researchers conducted in Denmark (Aalborg University and the Technical University of Denmark), Japan (The University of Tokyo), and Germany (Hamburg University of Technology) use computational thermal manikins (CTMs) with the intention of determining indexes that are either unable or at least very hard to be acquired through experiments.

Because the topic is clearly within the jurisdiction, to present some of the results obtained in our investigation, we first bring a brief literature review about the subject. At this point we highlight the work in which we based the present chapter and, which yet not recognized by scientists due to lack of information about the subject, we also present observations taken sometimes from the visits we made to the airlines and theirs web portals from 2014 to 2020, sometimes from the interviews granted by old employees, whose reports mainly focused on the aircraft's internal environment development in Brazil. In short, being useful to thermal comfort practitioners.

This will allow the identification of the airport, plane, and passengers with contagion control purposes by airborne contamination, we hope that the professionals who work directly in airplanes and airports' organization and maintenance consider more actively the elements that involve environmental quality and human thermal comfort.

2. Pandemic effects on aviation

2.1 Pandemic, airport, and planes

The first identification of SARS-CoV-2 in human beings happened in Wuhan, China (2019). In that period there was paralyzation of air traffic in China. Right after the COVID-19 virus had spread to South Korea, caused the cancellation of flights, then to Iran and Italy. In that period, there were already cases of COVID-19 around the world. In March 2020, the United Nations (UN) declared a pandemic caused by the new SARS-CoV-2 virus, impacting the health system in biomedical and epidemiological order on a global scale. This fact imposed social isolation, among other measures, to protect health. At that time airports, ports, and land borders were closed except essential flights (**Figure 1**).

In earlier times the aviation sector had already suffered before, in 1976 there was the Ebola virus contamination, affecting human beings and other mammals. There was a union of forces between the civil aviation secretary and the World Health Organization (WHO) to avoid the transmission of the Ebola virus, especially improving the internal environment quality of passenger airplanes.

In 2009, emerged the Flu A H1N1 pandemic and later on with a new sub-type of influenza A (H1N1). In response to the outbreak, on April 25 the World Health Organization declared a Public Health Emergency of International Concern. Then, on April 27, the WHO announced phase 4 (human-to-human transmission) and phase 5 (sustained transmission) pandemic [9], and phase 6 (global spread) on June 11th, 2009. On this date, there were already 30 thousand cases reported in 74 countries.

Figure 1.
The impact of the COVID-19 pandemic in international airports.

The World Health Organization (WHO) declared the pandemic in March 2020, which was a decisive moment to air traffic that came with a change of attitude for the aerospace industry. However, aviation impacts also occurred in 2001, 2008, and 2010.

On September 11th, 2001 many flights were canceled, both in the United States and in other countries, due to terrorist attacks. In this period the discussions about airport security had begun, nowadays every airport security forms are the result of the standards established at that time.

In 2008 because of the US economic recession tourist and business travel decreased. Generally speaking, the business class customers are loyal company customers. In this same period, there was an increase in oil prices, which was reflected in aviation till 2011.

In 2010, the volcanic eruption in Iceland Eyjafjllajökull disrupted European air transport, especially passengers flights between the US and Europe.

According to Faury, Guillaume (CEO of Airbus), 2020 "We are now in the midst of the gravest crisis the aerospace industry has ever known". The planes used to conduct many cruises were forced to stand still, which requires maintenance before returning to operation. The airplane's maintenance, in general, follows the "Parking Mode" (1) easy to get back to service; (2) maintenance (more frequent: engine and main systems); and the "short term" (a) preserve engines; (b) remove fluids; (c) cover all entries (sensors, cracks, engines, mechanical ventilation, etc.); (d) disconnect batteries, and (e) lower the shutters of the windows. The airplanes with outdated technology (with old models and large airplanes) or for sale are stored in deserts such as Victorville, California, and Pinal County, Arizona in the United States (**Figure 2**).

It is noted that the coronavirus side effect is the use of better technologies, especially when it comes to air quality. The cargo companies besides cargo-specific planes also have passenger planes that transport a portion of cargo. The Belly Cargo (Long haul Flights) is a cargo plane with passengers that carries out 23% of all the world's cargo. An important aspect of freight transport is hospital equipment products, this happens because, due to the pandemic, it was necessary to protect the whole hospital teams with suitable materials to assists patients with COVID (such as masks, aprons, hospital equipment products, etc.) which no country had in stock. Most of these products are manufactured in Asia, especially in China. In this regard, air transport is being requested to save lives (**Figure 3**).

Figure 2.
American aircraft boneyard. Commercial aircrafts in Southern California Logistics Airport (former United States Air Force base), Victorville, California, USA. Source: https://www.jocelynkelley.com/fatos-interessantes/10-cemiterios-de-aeronaves-incomuns/.

Figure 3.
Dissemination of COVID-19.

2.2 Operations in the civil aviation sector during the pandemic period

The Brazilian National Civil Aviation Agency (ANAC) acted to soften the pandemic impacts, reducing the contamination risks to the users and employees through the gradual resumption of operations of the internal and external market, with ANAC Ordinance No. 1126 of 23/4/2020 to combat an infectious agent in the standards for fighting COVID-19 published according to the International Health Regulations, in the Collegiate Board Resolutions, (Resolution—RDC No 02, 2003, Resolution—RDC No 21, 2008 and Resolution—RDC No 56, 2008 and in the guidelines of the Ministry of Health. It follows the international protocol to fight COVID and establishes (1) the central systems in operation as long as the air renewal is open at its maximum capacity, and (2) compliance with the Maintenance, Operation, and Control Plan—PMOC of the installed air conditioning systems, especially the filter, in the airport. In airplanes cleaning occurs in the supervision of the cleaning teams with cleaning and disinfection procedure in each scale, before the boarding of new passengers. With the closing of the doors, whenever possible, the airplanes air conditioning system turned on and the mode without air recirculation selected.

2.3 Aircraft's cabin air conditioning and pressurization system

The air conditioning and pressurization systems are responsible for ensuring good health and comfort conditions for aircraft's occupants since they are the components of environment control.

While in buildings we have homogeneous environments, aircraft are considered non-homogeneous once they present different temperature and velocity gradients [10]. The difference between aircraft and building air conditioning system design is due to the aircraft's weight and the pressure difference between the outside and inside of the aircraft in high altitudes. When it comes to aircraft air conditioning special equipment capable of handling temperature asymmetries or radiant temperature is necessary.

In a good air conditioning system, the airflow must occur at a high speed at the top part of the airplane. In the bottom part, the recirculation is characterized by the mixed air present in the cabin (MV, mixing ventilation). Afterward, the engine must direct the outside air to the inner parts of the cabin, where, under very high temperature and pressure, it will be breathed in. Therefore, besides promoting air conditioning, the pressurization system avoids any discomfort or damage, because of the altitude changes that the cabin undergoes, for the occupants (the fast air change in the cabin eliminates odor and removes any traces of stale air).

Usually, the command cabin controls the pressurization systems that are incorporated in a sealed unit with the luggage compartment. The pressurization system is capable of containing air under higher pressure than the outside atmospheric pressure. Although in high altitudes the aircraft's external environment does not present viable conditions to the survival of human beings. The air is dry with extremely low temperatures and pressure: according to Lombardo [11, 12], the atmosphere consists of 21% oxygen, 78% nitrogen, and 1% other gases in its volume; however, the increase in altitude implies air rarefaction and a decrease of pressure lowering the amount of oxygen necessary for human functions. That is why aircrafts that do not have air conditioning and pressurization system are usually limited to low altitudes.

The pressurization is directly related to the quality of the partial pressure of oxygen available in the breathing air inside the fuselage compartments of the airplane, occupied by the flight crew. Its purpose is to maintain the indoor pressure equal to or greater than the value of the atmospheric pressure at 8000 feet altitude. Because when the airplane flies at higher altitudes, there will be a reduction in fuel consumption.[2]

The ventilation, one of the functions for which the air conditioning system is designed, consists of a dynamic intake of pressurized air. This function is done with the aid of an airflow fan, a heating operation on the ground, or a compressor when the aircraft has pressurized air ducts installed in the front, the top, or the bottom. The air goes into the main air entrance of the heater and is heated when passing over the radiator surfaces from where it is then distributed.

The refrigeration system, which is located next to the ventilation methods, are installed to ensure comfortable atmospheric conditions to the aircraft regardless of the altitude where the plane is situated. It also works to maintain the appropriate volume of air circulating at the correct temperature and humidity inside the aircraft. The capacity of the refrigeration system depends on the fuselage cavity proportions so that the circulation of air and vapors occurs. In both cases, the treated air is pumped only in the overhead bins region at a high speed and the outlet is made by side air vents in the bottom. Meanwhile, the cabin air conditioning is made by the central air conditioning and heating system, which provides outflows of up to 700 m^3/h (412 cfm) and controls the indoor air temperature from 14 to 35°C.

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[2] For example, the indoor air of Boeing aircraft is made up of 50% outside air and the other 50% air filtered or recycled by the engine, while the air outside the plane in high altitudes is clean, pure, and cold (under −37°C) and has a low partial pressure of oxygen.

Before being recycled, the recirculated air is filtered by high-performance filters such as HEPA (High-Efficiency Particulate air filter), which is capable of retaining 99.97% of the cabin's airborne particles.

The cabin air circulation and ventilation inside an airplane are carefully designed to disperse and redirect contaminants, changing the entire cabin air volume from 20 to 30 times per hour in airplanes with the E-Jet model [13]. Higher is the frequency of air change, lower is the risk of viral dissemination, however, this air change occurs only when the plane is free-flying. The Airbus Chief Engineer Jean-Brice Dumont highlights the importance of air quality design being extremely clean with air renewal every two or three minutes, about 20 to 30 times per hour.

2.4 Air transport, travelers, and viruses

The distance between countries as well as the time to travel these distances, have decreased with the development of the aeronautic engineering industry applied to air transport. Due to factors such as international scientific conferences, work, sport or artistic events, celebrations, etc. culture and habits dissemination happens more frequently.

In that sense, air quality becomes a priority to avoid infectious pathologies and maintain public health by preserving health safety in airplanes and airports.

According to WHO director-general, Tedros Adhanom Ghebreyesus, in a press conference on Wednesday (11/03) "If the countries work to detect and track the disease, isolate the cases and mobilize human resources to respond to COVID-19, it is possible to prevent those places with few cases from becoming centers of virus dissemination and consequently from sustained community transmission." The director-general also pointed out the WHO guidelines to the countries which follow them: activate and expand the emergency response mechanisms, communicate with the population about the risks and how to protect themselves, find, isolate, test, and treat every case of COVID-19 apart from tracking all the infected.

In this context, keeping strict control on air transport before, during, and after the trip, it is possible to prevent the virus dissemination and its corresponding strains. The precautions before the flight, such as proper face mask usage, packing the luggage with plastic at the airport and/or using alcohol gel before the luggage is placed in the baggage compartment of the plane. As the International Air Transport Association states simple measures, such as the usage of masks by passengers and crewmates, as well as the guidance to use elbows to intercept coughs and sneezes, minimize the risks almost completely.

As the COVID virus could transmit among passengers on touching the infected surfaces and carelessness in using disinfecting substances, the main air companies of the world adopted new cleaning procedures to ensure that the aircraft is scrubbed after each flight, as well as ensuring passengers follow the required health and safety measures.

The air circulation in the cabin of the aircraft is done by a tube that captures external air and heats it during the flight by the engines, or by the auxiliary power unit when the airplane is on the ground. By a process of environmental control, the air is pressurized and cooled down to appropriate temperature for passengers and then it joins the recirculated air.

The air in the airplane's cabin comes from the ceiling, flows to the ground, and drains below the luggage compartment. As the air flows from top to bottom, the risk of dissemination of infectious agents diminishes regarding the front-to-back direction, the longitudinal orientation of the cabin.

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One of the functions for which the air conditioning system is designed, the ventilation, is performed by a blower to help air circulation and by a heater operation on the ground. From a dynamic compressed air valve or a compressor in aircraft which has ducts of pressurized air installed in its front, bottom, or top surfaces. The air goes into the main entrance of the heater and is heated when passing over the radiator surfaces of the heater from which it is then distributed.

The refrigeration system, which is located next to the ventilation methods, is installed to ensure comfortable atmospheric conditions for the aircraft regardless of the altitude the plane is located. They also work to maintain the appropriate volume of air circulating in the correct temperature and humidity inside the aircraft. The capacity of the refrigeration system depends on the fuselage cavity proportions in which the air cycle[3] and the vapor cycle[4] occur. In both cases, the treated air is pumped only in the overhead bins at a high speed and the outlet is made by inferior exit ducts. In the meanwhile, the cabin air conditioning is given through the air conditioning and heating central system, which provides outflows of up to 700 m^3/h (412 cfm) and controls the indoor air temperature from 14°C to 35°C.

According to Conceição [14], the cabin must also have a humidifying system, responsible for maintaining the relative air humidity between 20 and 70% inside the cabin. It also must control the temperature of the walls once again from 14°C to 35°C, by an additional climatization and temperature control system, as shown in **Figure 4**.

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[3] The air cycle refrigeration type consists of an expansion turbine (refrigeration turbine), an air-to-air heat exchanger and valves that control the airflow through the system.

[4] The refrigeration system for vapor cycle is used in multiple large sized transport aircrafts.

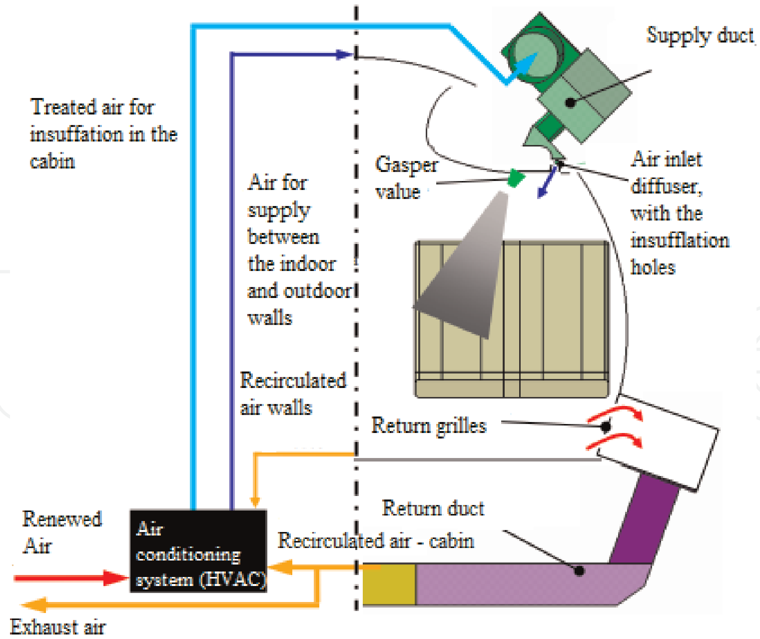

Figure 4.
Cross-section of thermal mock-up. Source: Conceição [14].

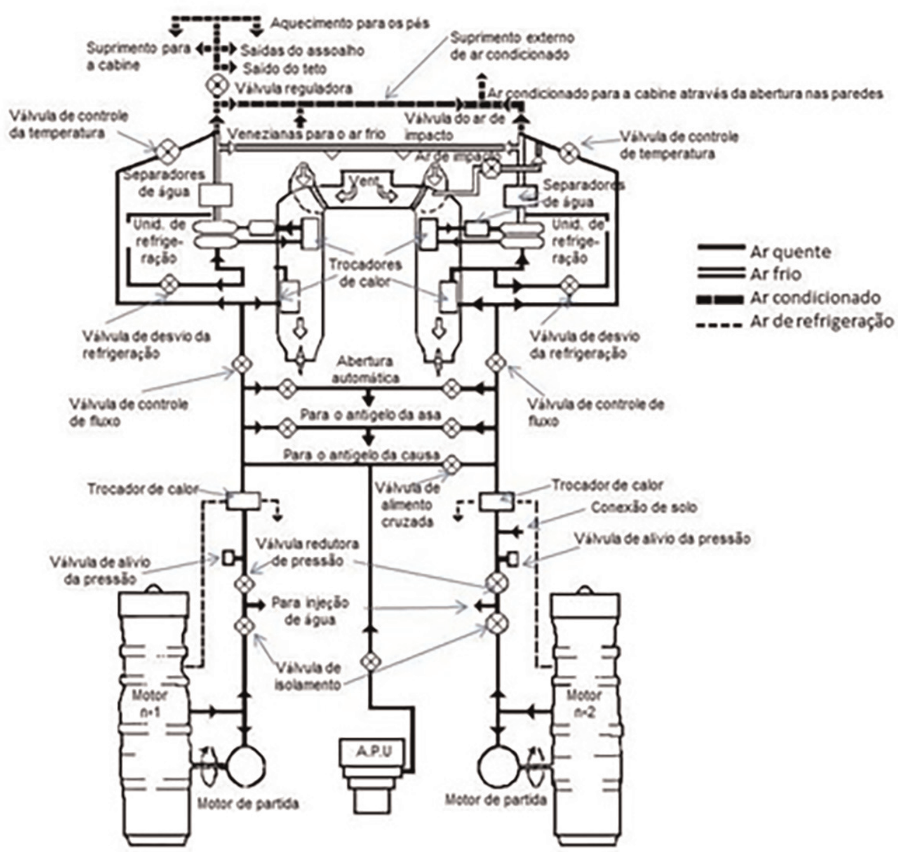

Figure 5.
Typical air conditioning and pressurization system. Source: ANAC [1].

Control valves, sensors, and electrical cables regulate the indoor air temperature when activated by air conditioning system valves, located in the cockpit panel (**Figure 5**). If there is an automatic control malfunction, there must be manual controls available.

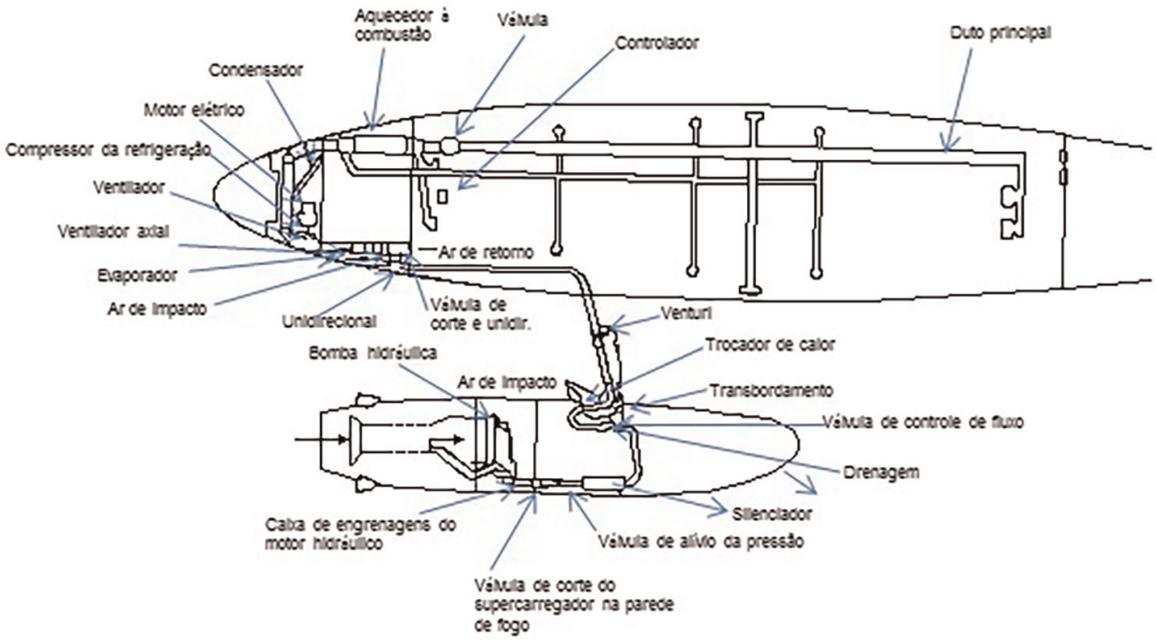

Figure 6.
Typical air distribution system. Source: ANAC [1].

It can be seen that the cabin's air distributor includes air ducts (with rectangular or circular sections when used in air distribution systems (**Figure 6**), or with other shapes when allocated in the passengers' individuals air exits and the window defroster), filters and heater exchangers, silencers, unidirectional valves, humidifiers, sensors of mass flux control and meters. The cabin's pressure sources cover positive displacement compressors (superchargers), centrifugal compressors, and supercharger controls. Supercharger tools working as airflow meters, pressurization valves, pressurization controls, cabin pressure regulator, and also air pressure safety valve.

According to Lombardo [11], the refrigeration machines which operate with air cycle are the predominant systems in aeronautical applications, especially when it comes to passenger transport aircrafts. The option is justified because of the availability of the working fluid (compressed air from the plane's propulsion system) and also by the fact that the air cycle (air cycle machine or ACM) do not demand the transport of new working fluid, which would require weight and occupied space restrictions. So, the air is partially treated in high-quality filters, similar to those used in hospitals surgery rooms, and thereafter is mixed with the same proportion of external air. The renovation of conditioned air is necessary for long distance flights and with a large number of crew members in the airplane cabin in a closed environment. The airflow must therefore meet thermal comfort requirements through an air conditioning operating system and be compliant with external environmental atmospheric conditions.

Researches related to air conditioner maintenance of airlines such as TAM and Embraer (2014) show that the air distribution is operated by a container that works at 35% of its capacity, meanwhile, the other 65% of the air volume stands still on the floor, without returning to circulate through the cabin. In other words, the clean air is not used in the internal environment of the aircraft and likewise, the same air used before circulates yet again causing many airborne viral pathologies to be transmitted. Besides, in these situations, health problems caused by engine oil particles that were found in the air filters have become common.

Given the possible damages to passengers' health, there were established flow standards for air conditioning systems. Maintaining the internal air quality demands that the renewal tax of the external air be high. In the same way, it is fundamental that the supply of external and recirculated air occurs in the appropriate temperature and relative humidity conditions. The temperature control of the cabin's interior avoids areas with stagnated air, as well as enables the dissipation of contaminants and odors.

Efforts to maintain the good air quality inside the cabins turn out to be especially important as Quinyan Chen and her partners' researches in the Purdue University College of Engineering (USA) pointed out that ventilation causes the dispersion of contaminants from expiratory activities (for example sneezing, coughing, talking or breathing). Presenting their studies about the main characteristics of particles dissemination in airplane cabins, researchers demonstrated how they can be involved in contamination events. Nevertheless, they suggested the relevance of paying attention to the subject, since there is little research about personalized ventilation systems that can be used along with a mixed ventilation system. It is known that before being supplied to the cabin, the recirculated air is filtered through equipment with high-efficiency particles. Those air filters also known as HEPA filters must be capable of reducing the risks of a cross and longitudinal infection of the airflow supply [15]. Next, Computational Fluid Dynamics (CFD) analysis of the airflow will be used to determine air conditioning coefficients in commercial passenger airplanes.

2.6 Methodological procedure

The aircraft cabin e-170 uses the normal ventilation system with a longitudinal direction. In this chapter, it will be applied and validated, in a testing phase, in mock-ups, with digital thermal manikins controlled by the Autodesk software with a Computational Fluids Dynamic (CFD) tool in order to determinate the temperature and speed coefficients and their corresponding thermal loads.

The tests include three steps: construction of the aircraft prototype; model construction of the empty cabin, with passengers standing and with the digital manikins seated; analyzing the actual air conditioning system to define the cabins' thermal environment characteristics inside a commercial aircraft for passengers transport.

3. Research development

3.1 The construction of the aircraft prototype with the manikins seated and standing

Prototype construction of the aircraft e-170 with the internal layout of armchair, luggage rack. A digital mock-up will be used for the tests to reproduce the cabin section of a commercial airplane with the dimensions of $3 \times 3 \times 2.5$ m in height **Figure 7**.

The construction of the passengers digital model is made from the use of the digital thermal manikin, built using the software "Solid Works", it helps in the anthropometric analysis of the armchair to evaluate the equivalent temperatures. The thermal manikin has 1.70 m in height, which allows a more representative temperature modeling of the surface of the body, to verify the passengers' comfort and discomfort.

Figure 7.
Prototype construction of the aircraft e-170.

The thermal manikin, for now described to the passenger as a digital-physical model controlled by three control modes: constant temperature (air temperature and speed), constant power, and Fanger's comfort equation.

Fanger's method will be used to verify the thermal exchanges and the thermal balance of the human body, in other words, the "CLO-FANGER-MET" method with the influence of atmospheric pressure. The air temperature and speed are measured in the cabins' thermal environment **Figure 8**.

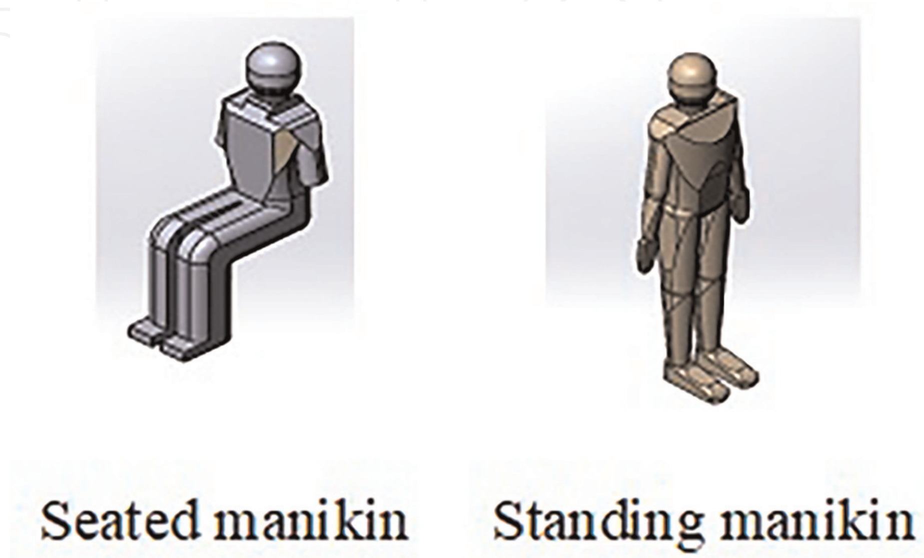

Figure 8.
Digital model construction of the passenger.

4. Results and discussion

4.1 Simulation steps in CFD

The air quality and its impact on humans during the cruise are determined by the aeronautical comfort design and have strong influences on the thermal conditions of the passenger. The air recirculation used before the airborne pathologies by various types of viruses. For example, according to researches presented during the Roomvent Congress, 2014, ventilation is related to the circulation of contaminants in airplanes cabins which from expiratory activities, cause cross-contamination events. Belonging to the list of studies about environmental comfort this research therefore, evaluates the actual thermal behavior of the airplane commercial user. In the face of the need to investigate air diffusers, responsible for the crew discomfort and for the transmission of diseases such as the so-called SARS (Severe Acute Respiratory Syndrome), and the challenges that are imposed on the intentions to design a healthy and comfortable environment in the cabins, we analyze the air distribution in the interior project of such cabins. The research focuses around the armchair and duct shapes with the use of the Computational Fluid Dynamic (CFD) tool.

The results of this chapter present a model based on computation that can predict the temperature and airflow as well as the parameters of environmental air distribution in commercial airplanes cabins, in empty cabins, and with passengers seated or standing. The model is known as CFD (Computational Fluid-Dynamic Model). The purpose of this item is to present to the reader some of the main fundamentals that are necessary for the applications of CFD related to internal environmental technology in commercial aircrafts.

This item presents the information used in the data entry for the CFD commercial airplane e-170 cabin simulation: **Figure 9**.

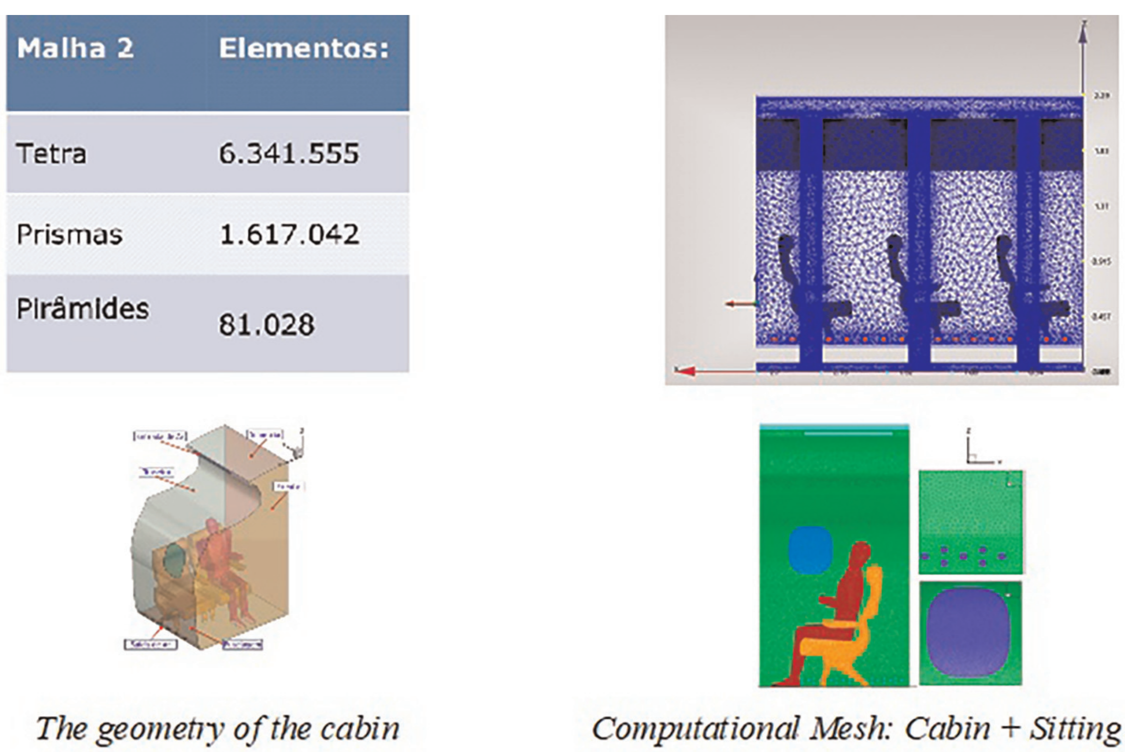

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Figure 9.
Mesh refinement.

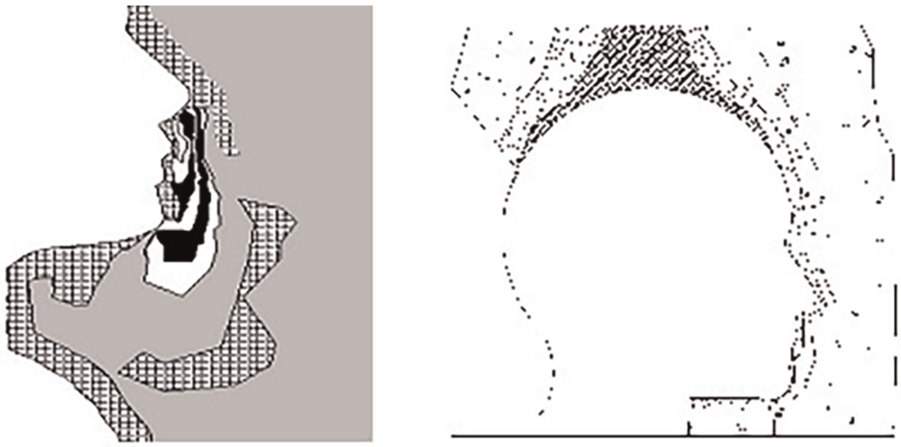

Figure 10.
Shows the air breathed by passengers.

4.2 Results

The results of this chapter present a model based on computation parameters that the air distribution and environment temperature in the commercial aircraft cabin are the passengers breathing, empty cabin, and with the passenger seated or standing. The

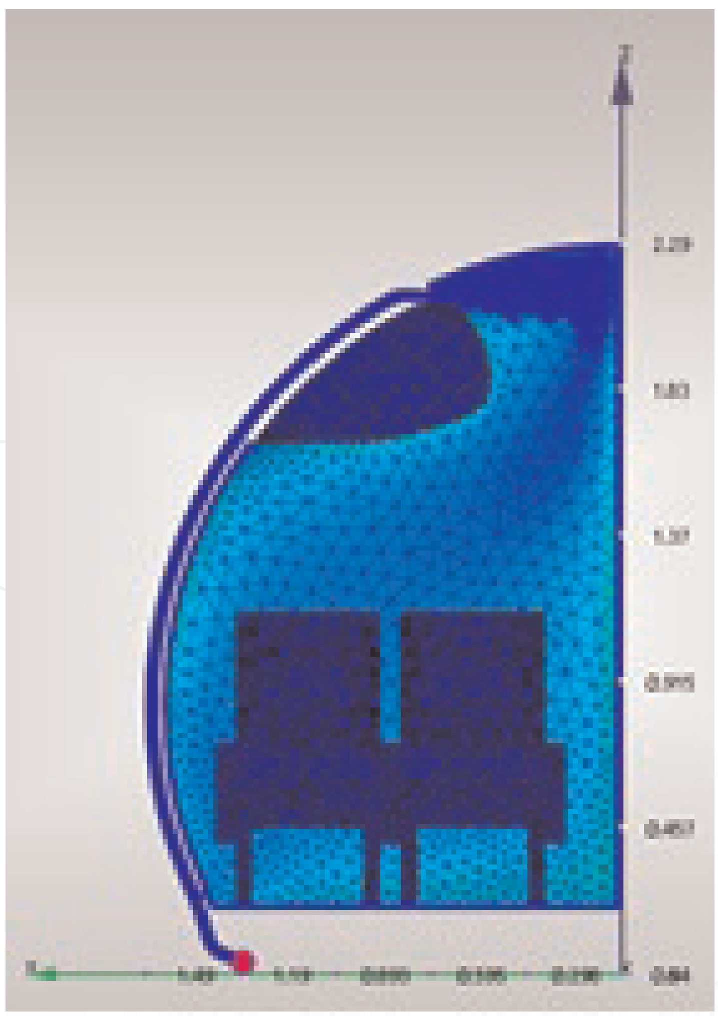

Figure 11.
Air supply diffuser representation using a computational mesh to demonstrate a Fluid Domain mesh.

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4.3 Passengers breathing

The passangers breathing inside the plane's cabin is presented in **Figure 10**.

4.4 Empty cabin

The representation of the empty cabin with the representation of the air supply diffuser going from the top part to the bottom one with the cabin height of 0–1.70 m and 0–1.50 m length is presented in **Figure 11**. **Figure 12** identifies the magnitude velocity from 0 to 0.9 m/min noticing that the maximum airspeed is concentrated close to the gasper outlet, decreasing its speed throughout the path to the air outlet at the bottom of the cabin. The air temperature in degree Celsius is presented in **Figure 13**, ranging from 22°C to 28°C, notice that this temperature is used for tropical climate inhabitants, different from the countries located in Scandinavia, where temperature above 18°C is the upper limit in summer. The air supply diffuser using a computational mesh through the cabin is shown in **Figure 14**. **Figures 15** and **16** demonstrate, as an example, the points of a constant air temperature value and speed for an empty cabin.

4.5 Front view of the cabin with the standing manikin

The airspeed with the passenger standing is represented in **Figure 17** with a variation of magnitude velocity from 0 to 0.11 m/s. **Figure 18** presents the air surface

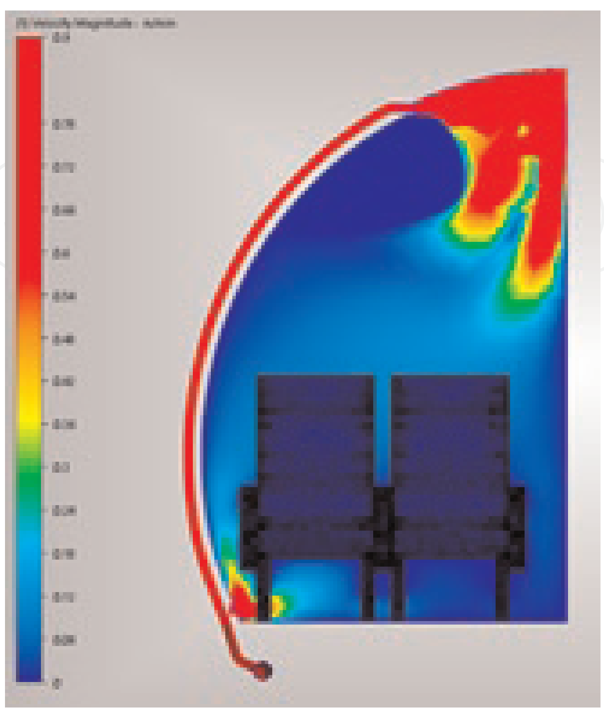

Figure 12.
Airspeed in the empty cabin.

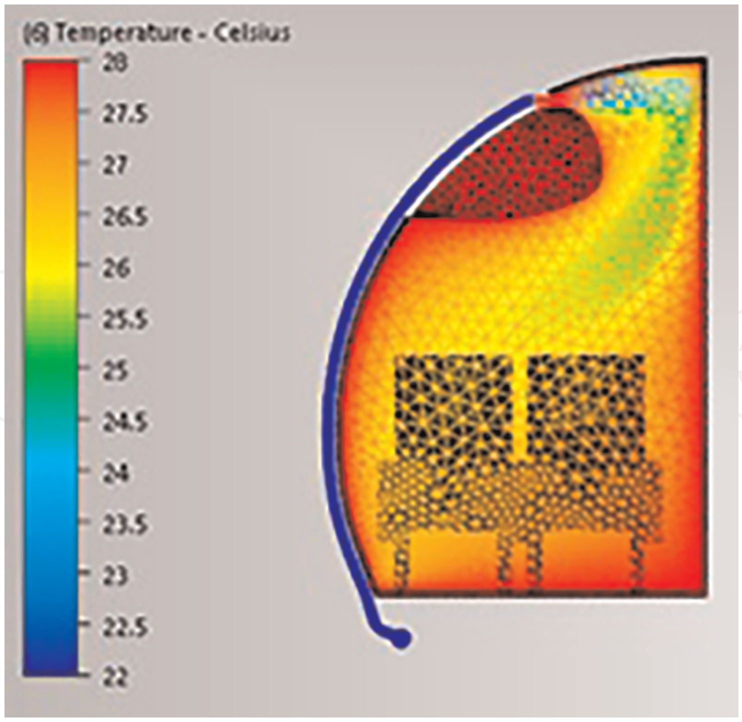

Figure 13.
Air temperature in the empty cabin.

Figure 14.
Air supply diffuser representation using a computational mesh.

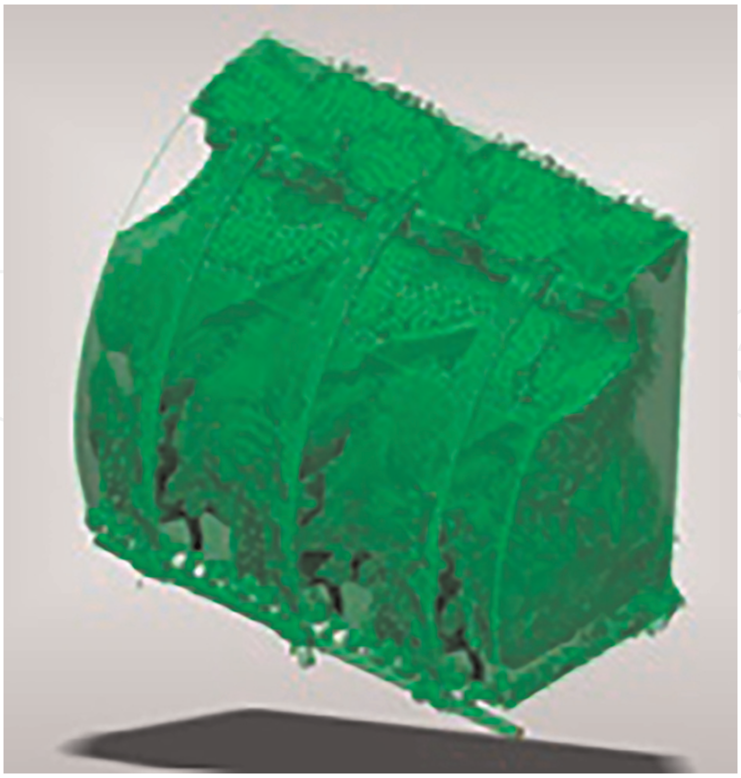

Figure 15.
Iso surface are surfaces that represent points of a constant number. For example, temperature and airspeed.

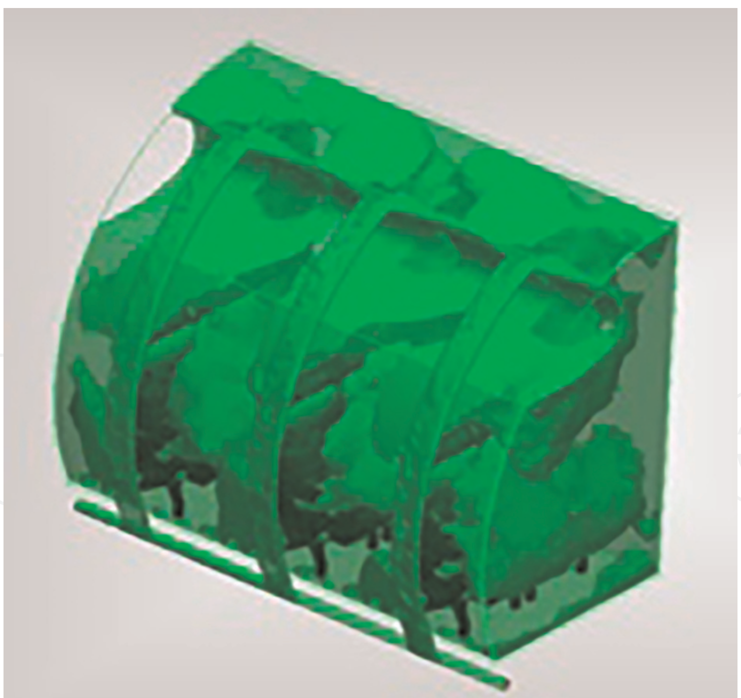

Figure 16.
Iso surface are surfaces that represent points of a constant number. For example, temperature and airspeed.

and **Figure 19** identifies the air temperature between 24.88 and 27.04°C. Demonstrated in **Figure 20** is the image from the perspective of the cabin. The cabin refining mesh is presented in **Figure 21**.

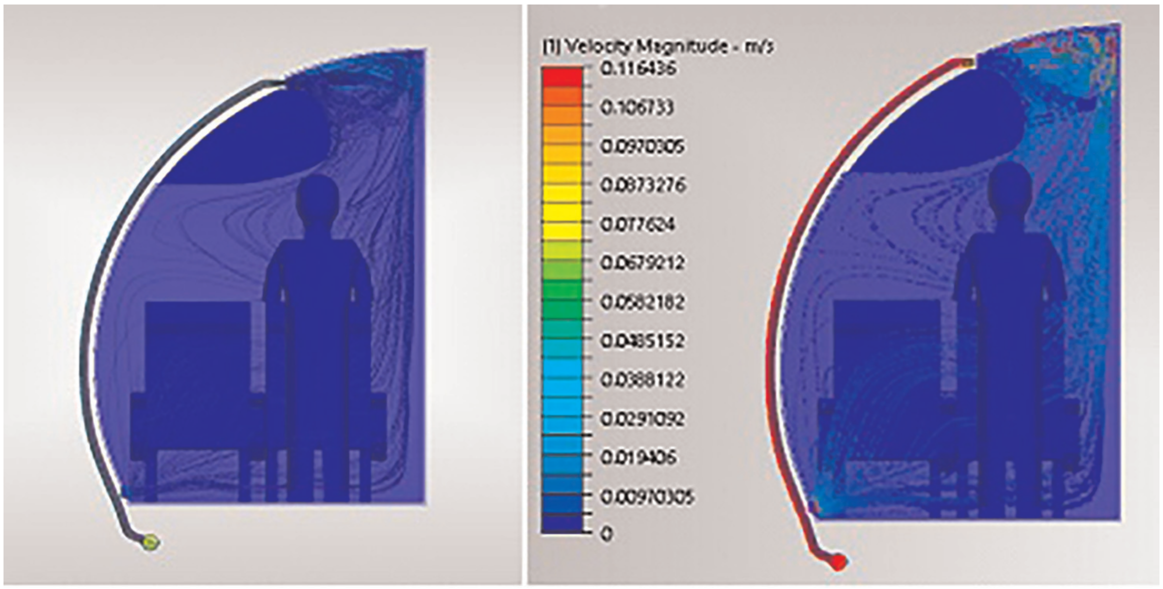

Figure 17.
Airspeed with passenger standing.

Figure 18.
Iso surface of the cabin with passenger standing.

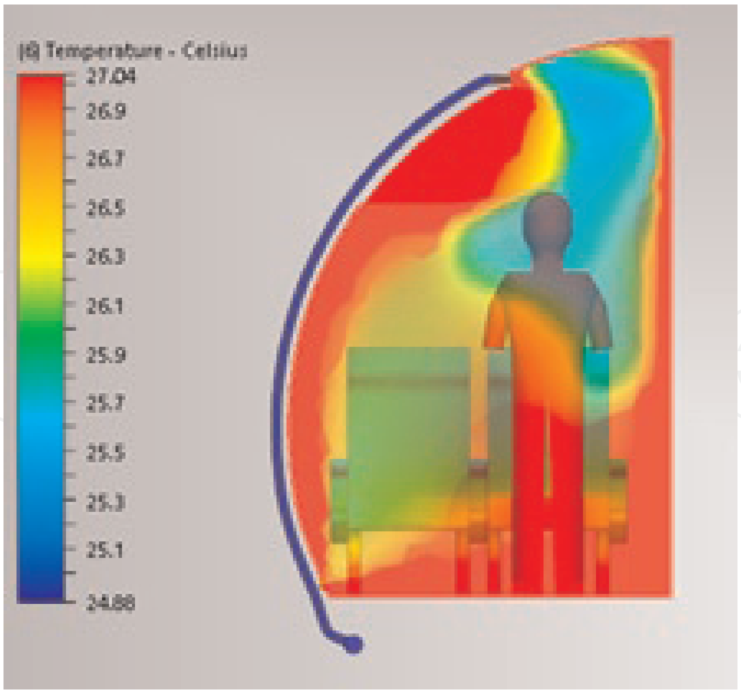

Figure 19.
Cabins temperature exhibition with passenger standing.

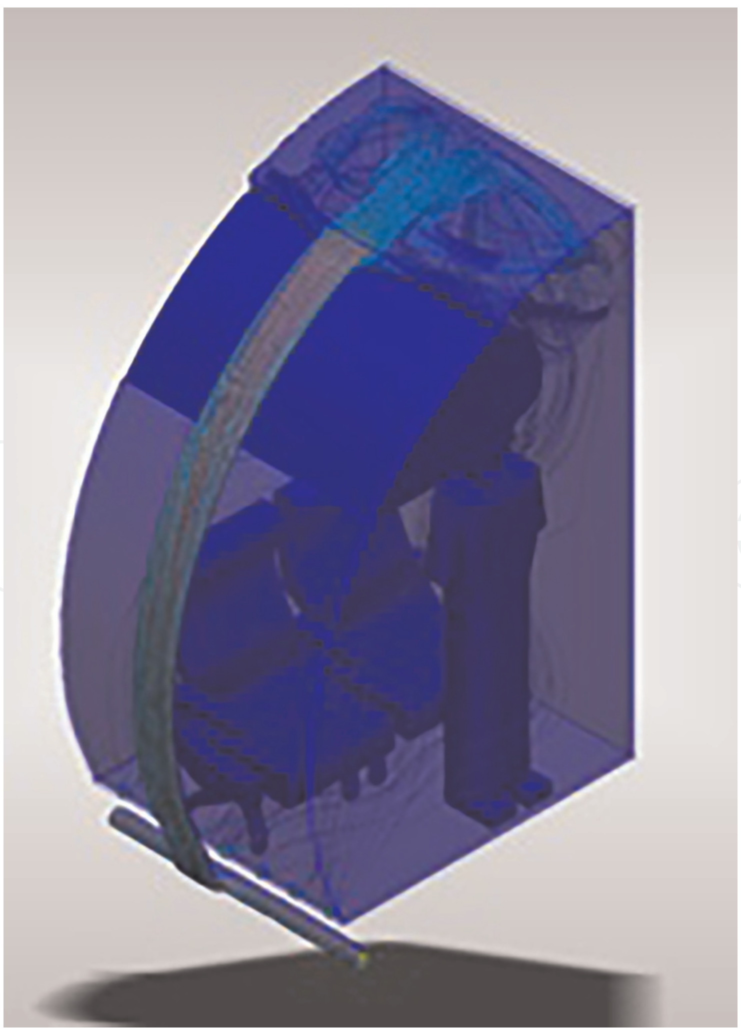

Figure 20.
Iso surface of the airflow line with passenger standing.

Figure 21.
Cabins mesh refinement with passenger standing.

4.6 Seated passenger

A seated passenger in the cabin has an isometric view with Magnitude Velocity from 0 to 0.007 m/s in **Figure 22**. In **Figure 23** the airspeed with the passenger seated (0.35–0.49 m/s) with the airflow going from the top part to the bottom part of the cabin. The air temperature with front view is shown in **Figure 24** with a variation of 23.4–27.4°C and the airspeed with a variation of 0–0.37 m/s in **Figure 25** and with airspeed ranging from 0 to 0.89 m/s in **Figure 26**. Seated passenger mesh refinement is presented in **Figure 27**.

4.7 Temperature and ventilation: computational fluid dynamics

The air quality and its impact on humans during the cruise are determined by the aeronautical comfort design and have strong influences on the thermal conditions of the passengers. The air recirculation used before the cause of airborne pathologies by various types of viruses. For example, according to researches presented during the Roomvent Congress, 2014, ventilation is related to the circulation of contaminants in airplanes cabins that from expiratory activities, cause cross-contamination events. Belonging to the list of studies about environmental

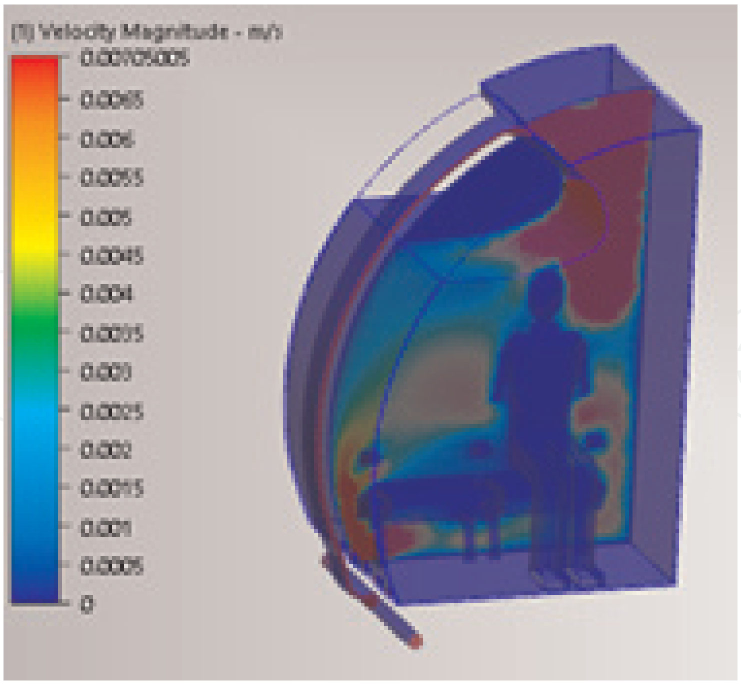

Figure 22.
Isometric view of passenger seated airspeed.

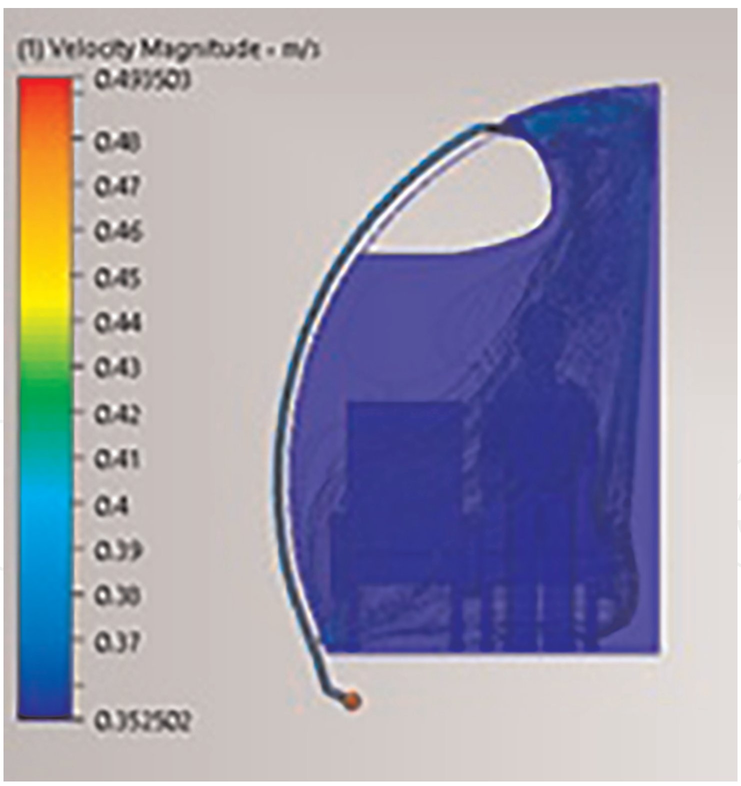

Figure 23.
Airspeed with a seated passenger (0.35–0.49 m/s).

comfort this research therefore, evaluates the actual thermal behavior of the airplane commercial user. In the face of the need to investigate air diffusers, responsible for the crew discomfort and for the transmission of diseases such as the so-called SARS (Severe Acute Respiratory Syndrome), and the challenges that are imposed on the

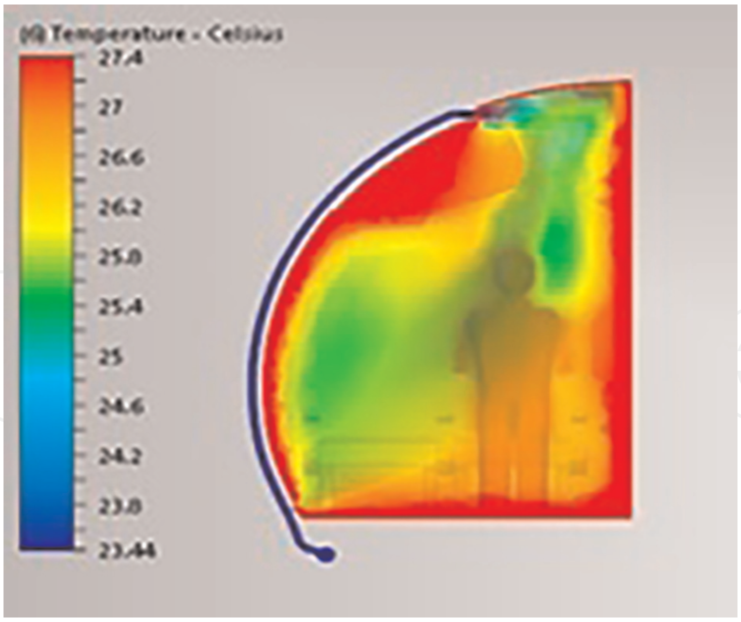

Figure 24.
Air temperature with a seated passenger (23.4–27.4°C).

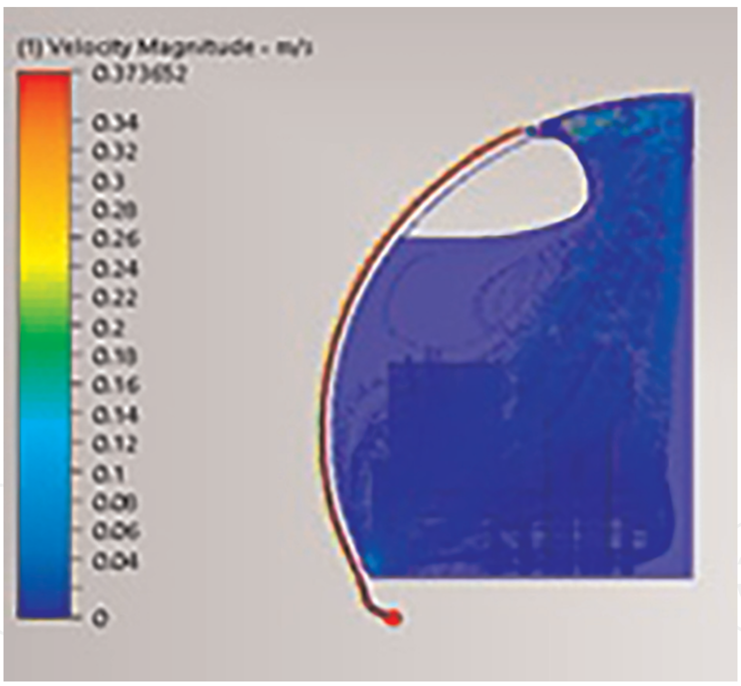

Figure 25.
seated passenger airspeed (0–0.37 m/s).

intentions to design a healthy and comfortable environment in the cabins, we analyze the air distribution in the interior project of such cabins. The research focuses on the armchair and duct shapes with the use of the Computational Fluid Dynamic (CFD) tool. The CFD simulation used the software Autodesk Geometry/Mesh/Solver/Post processing.

Through CFD simulations it was found that the air exits run from the top part to the bottom part of the plane.

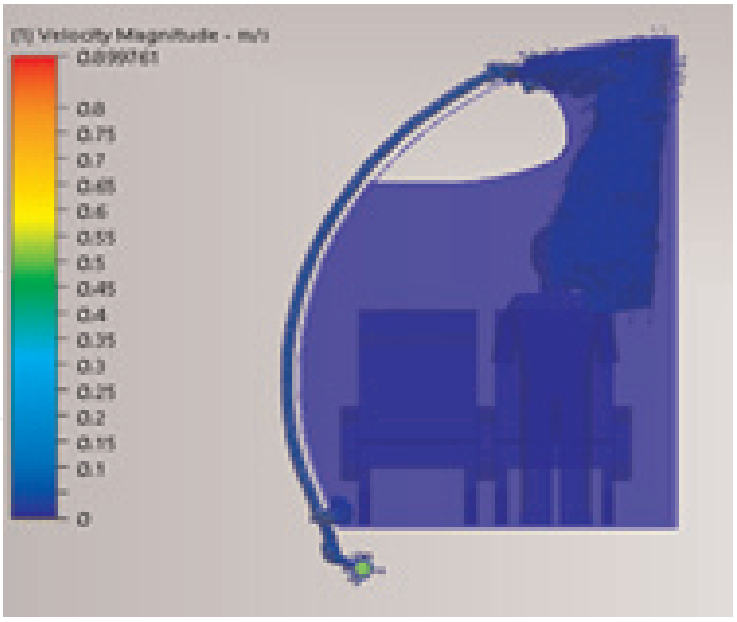

Figure 26.
Seated passenger airspeed (0–0.89 m/s).

Figure 27.
Seated passenger refinement mesh.

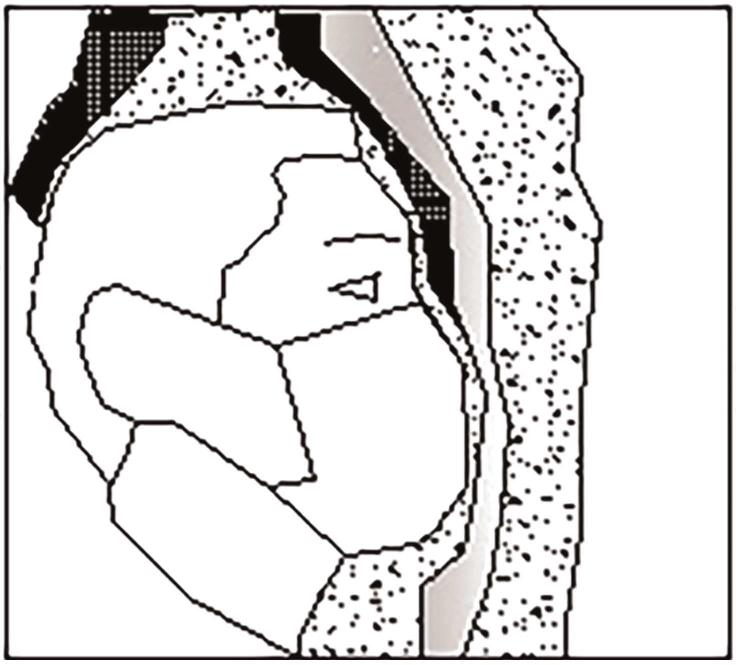

Figure 28.
Mask usage during flight.

Figure 28 shows the effect of the air current circulation and dispersion of particles throughout the aircraft cabin. This demonstrates that it is important to use personalized ventilation during the covid-19 pandemic period. According to Anvisa [16], the airflow of the gasper must be directed straight between passengers to avoid that they inhale the air from one another, avoiding disease dissemination.

5. Conclusion

The aeronautical project quality is essential for providing passengers with acceptable environmental conditions in order to achieve their thermal comfort. The research demonstrates the utmost importance of the aeronautical community (industries, research labs, and universities) in the fluids modeling field and the practical applications in the industry's daily job.

This research results present models based on Computational Fluid Dynamics (CFD) with parameters analysis of temperature and airspeed distributed in a real environment with a cabin sometimes empty, sometimes with passengers standing and/or seated.

It was verified that the temperature and airspeed are influenced by passengers' behavior, whether they are seated or standing in the plane's cabin. Breathing influences the airflow, being able to cause contamination in its environment. So, ventilation from the roof of the cabin promotes more particle dispersion throughout its area.

Another significant aspect to highlight is the importance of achieving the plane's thermal comfort in a cruise. Having an adequate air conditioning system that contributes to the well-being, health, and the aircraft's users' health, as well as the other aspects that influence the passengers' environmental comfort, when based on the cabins' geometry, the armchairs positioning and ergonomics will also contribute positively in the aircraft's mechanic system. We suggest the use of the air insufflation systems to avoid contamination through the air in the interior of the cabin.

As this research's results demonstrate, simulations in CFD showed that there are three variables, and they must be considered to better evaluate the thermal comfort and indoor air quality in an aircraft cabin, which are- the profile of different temperatures, the airspeed, and human breathing. Therefore, the airflow circulation from the upper (ceiling) to the lower air supply duct (floor) promotes a wider dispersion of particles throughout the cabin that is associated with the characteristics of the mixing of this ventilation through passengers and the airplane's seats. However, it is also important to investigate the airspeed and temperature associated with air humidity.

The use of personalized ventilation is important during the pandemic period of COVID-19, for instance, when the gasper is opened, the airflow must pass between passengers, the air circulation must be oriented directed to the floor's lower duct. Another precaution that helps to protect the passengers is the use of masks and facial protectors during the flights, which must have non-ventilation and be approved by government agencies. Another security measure adopted to protect the people is to remain at a distance from others and always use alcohol gel.

The concern with passenger air transport relates to public health and safety aspects which must be analyzed in order to have a faster response for such risks. This is fundamental so that measures, such as prevention and vaccine development, in addition to efforts to mitigate COVID-19 transmission and dissemination, can be effective. Technical and scientific researches, as well as public policies to aid and enforce these measures must be constant and applied to the aeronautics industry everywhere in the world, with decisions made according to international health regulations. An additional investigation must be carried on about contamination of material carried in the aircraft.

Acknowledgements

English version by: Samantha A.L. Takatui, Mayor Edson da Silva and Eng. Nilson Carneiro, Prefeitura Municipal de Araraquara, São Paulo, Universidade Federal de São Carlos, PPGEU, Instituto de Pesquisa Tecnológica do Estado de São Paulo, IPT e Universidade de São Paulo, São Carlos.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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