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ANALYSIS AND IMPROVEMENT OF THE ERGONOMICS OF THE PILOT'S COCKPIT IN ACCORDANCE WITH HUMAN PROPORTIONS

Abstract: *The performance of the pilot is closely related to their comfort during flight. An important factor that needs to be addressed is the temperature in the pilot's cockpit and how it is distributed and managed. This paper aims to address the issue of air dispersion because the current location of the ventilation ports do not take into account current human proportions and adaptability demonstrated by humans with regard to global warming. Once this problem is solved, the next step is to optimize the distribution of temperature in the cockpit. As solutions, this work proposes the creation of new ventilation grids that will optimize the way air is managed in the cockpit.*

Key words: *dispersion of temperature, management of air, adapting the ventilation system, current human proportions.*

1. INTRODUCTION

The environment inside the cockpit, such as the air quality and temperature, is a crucial factor in the comfort of pilots and, in turn, their performance during flight. If the level of comfort inside the cockpit is low, the efficiency of the pilots and the safety of the flight will be affected. According to studies by Lindgren T., Norbäck and Pang L., Xu J., Fang L., Gong M., Zhang H., Zhang, Y. [1], [2], the current environment inside the cockpit is not satisfactory for pilots. In the case of civilian aircraft, the problem of thermal discomfort inside the cockpit is even more severe, considering only a general perspective without taking into account new human proportions, which further exacerbates the problem.

As a first point, as is well known, the space inside the cockpit is very small and full of electronic equipment and instruments, so the dimensions of the air vents are greatly limited in terms of design.

Secondly, pilots need fresh and high-quality air, this aspect is affected by the multitude of electronic devices around them that generate heat and thereby affecting the quality and temperature inside the cockpit. Therefore, there is a need for very good ventilation inside the cockpit.

These two aspects lead to two problems, these being the uneven distribution of temperature inside the cockpit and the way air is dispersed through the air vents at a very high level.

In recent years, many studies have been carried out to improve thermal comfort during flight, for example, the work "Thermal environment around passengers in an aircraft cabin" [3] presents a study on the level of passenger satisfaction during flight in terms of ambient temperature on a newly designed aircraft with a summer flight, proposed a new design that aimed to heat and cool the aircraft through the floor of the aircraft instead of the current model through the top ceiling. On the other hand, in the work "Determination of the optimal control parameter range of air supply in an aircraft cabin, Building Simulation" [4], attempted to find the optimal level and mode of air dispersion and in what parameters it should be included to provide optimal comfort. However, all these studies have focused on passengers, not pilots, but they provide a perspective on the needs of people inside an aircraft regardless of their role.

To solve the problem, is a crucial factor in the comfort of pilots and, in turn, their performance during flight of discomfort due to temperature and the way air is distributed in the cockpit, this paper proposes to analyze the way air is distributed in accordance with new human proportions of pilots and the constant temperature necessary in the cockpit. This will be done through simulation and experimentation to find the best solution for ventilation and air distribution in the cockpit.

2. DESIGN

2.1 Design objectives

The purpose of this paper is to improve thermal comfort inside the cockpit with minimal cost. Thermal comfort assessment indices include local air velocity, ambient temperature, and spatial temperature variations. According to ASHRAE standards [6], acceptable thermal comfort assessment indices are presented in Table 1, some descriptions are adjusted to apply to the current state of the cockpit.

Table 1

Thermal comfort evaluation indices

PARAMETERS	OPTIMAL CONDITIONS
Local Air Velocity	<70 ft/min // <0.36 m/s
Ambient Temperature	Between 18.3 and 23.9℃
Temperature Variations	In sitting position - 2.8

2.2 Concept design

Options for improving thermal comfort in the cockpit usually include: increasing the size and number of air supply inlets, optimizing the location of air supply, changing the direction of air dispersion, etc. In engineering practice, the cockpit inlet is subject to too many restrictions, making it often difficult to implement most of the above schemes. For example, changing the location of the air vents will inevitably lead to changing the interior structure of the cockpit, will indirectly affect the location of other equipment.

In comparison, it is a practical and efficient method to optimize the direction of air supply by changing the air supply inlets in the cockpit, so as to improve the placement of the flow field and temperature field in the cockpit in accordance with the necessary areas to be reached in relation to current human proportions and needs.

The original style of the air supply grille of a certain civilian aircraft cabin is shown in Figure 1a. In the early design, the angle of the grille was optimized for the proportions and needs of that time. Due to the minimum requirement of fresh air (because there were not as many electronic devices on board the aircraft) and the limitations of the cabin space, the air supply grille cannot be designed in the form of a adjustable shape. Therefore, the focus of this article is not to optimize the angle of the grille, but to propose two new grill shapes. The two new grills are designed to solve two obvious discomfort problems, namely the non-uniform distribution of the flow field and temperature field and the high local air velocity in areas of sensitivity for the current proportions and needs of pilots. The two new grills are presented in Figure 1b and 1c. It should be noted that grill 1b has two air supply directions, which avoids concentrating air supply too much in one direction and is conducive to a uniform distribution of the flow field and temperature field. Grill c) not only has two air supply directions, but also has side air supply, which increases the effective area of air supply and further reduces the local air velocity.

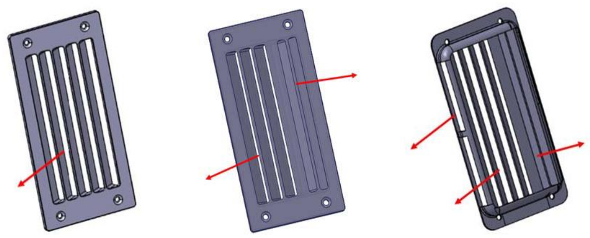


Figure 1 Proposed vents:
a) original vent; b) bidirectional vent c) multidirectional vent.

3. PROPOSED SIMULATION

3.1 Models for simulation

The goal of this work is to improve the thermal comfort inside the cockpit of an airplane with minimal cost. The thermal comfort evaluation indexes include local air velocity, ambient temperature, and spatial temperature variations. According to ASHRAE standards, the acceptable thermal comfort evaluation indexes are presented in Table 1, with some descriptions adjusted to apply to the current state of the cockpit.

In most civilian aircraft, almost all of the air to regulate the temperature and airspeed inside the cabin comes from the main air supply intake. There are two main air supply intakes, located on the main ceiling of the cabin, as shown in Figure 2.

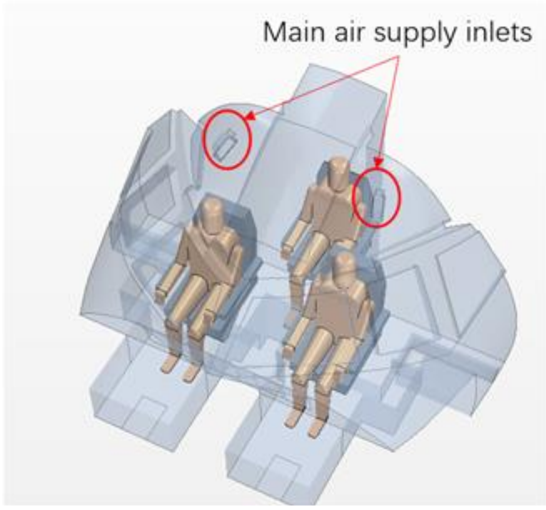


Figure 2 The simplified model of cockpit.

In most civilian aircraft, almost all of the air to regulate the temperature and airspeed inside the cabin comes from the main air supply intake. There are two main air supply intakes, located on the main ceiling of the cabin, as shown in Figure 2.

3.2 Setting simulation parameters

In order to perform the simulation of fluid dynamics within the cockpit, certain settings of parameters such as the density of air, viscosity, specific heat, and thermal conductivity are necessary. These need to be adjusted in accordance with the actual conditions within the cockpit and are used to generate a precise model of the airflow and temperature distribution within the cockpit. Also, it is necessary to define the area of air intake and the area of air outlet, as well as the air intake velocity in order to perform a realistic simulation.

In this study, numerical simulations are carried out using the CFD Star-CCM+ software, as a guide for the use of this software we used "Simcenter STAR CCM+ for HVAC effectiveness" [5]. The air in the cabin is assumed to be a compressible and viscous Newton gas, and the fluid has a constant density. The main settings of the physical model are presented in Table 2.

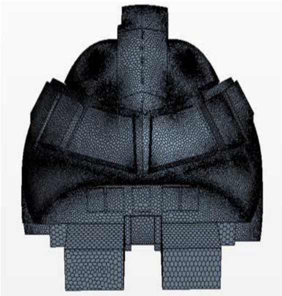
Table 2

Parameter settings

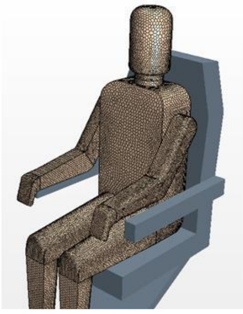
PARAMETERS	MODEL ATRIBUTIONS
Enabled Models	Three Dimensional
Time	Steady
Flow	Segregated Flow Gradient
Equation of State	Constant Density
Viscous Regime	Turbulent Reynolds-Averaged Navier-Stokes
Reynold-Average Turbulent	K-Epsilon Turbulence Realizable K-Epsilon Two-Layer Exact Wall Distance Two-Layer All y+ Wall Treatment
Optional Models	Segregated Fluid Temperature Gravity Boussinesq Model Gray Thermal Radiation

3.3 Properties of 3D models

In this simulation, all materials used are generated by the software CFD Star-CCM+. The elements used in this simulation include Surface Remesher, Automatic Surface Repair, Polyhedral Mesher, Prism Layer Mesher, and others. The basic material density is 0.01m, however, in certain areas the density may differ, such as in areas close to the air supply or pilots. The method of generating and assigning materials can be seen in Figure 3.



a) Pilots cockpit



b) Pilot model

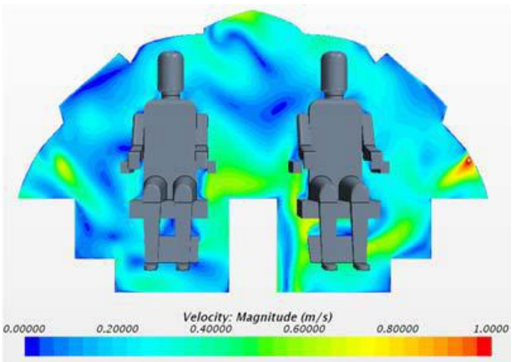
Figure 3 Properties of 3D models.

4. SIMULATION RESULTS

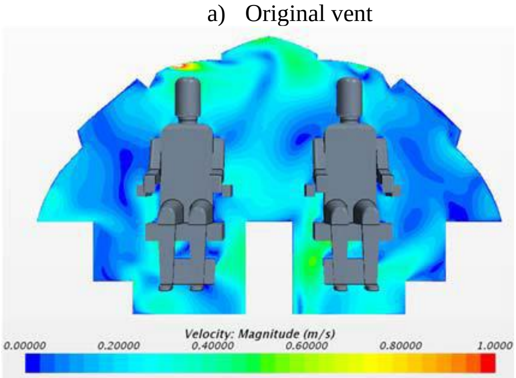
In order to compare the performance of the three air supply grilles as effectively as possible, three cross-sections were selected. The three cross-sections include two vertical sections and one horizontal section, representing the vertical and horizontal distribution of the airflow or temperature of the air in the cabin.

4.1 Air distribution

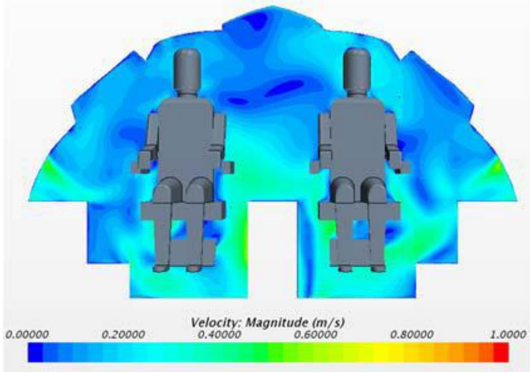
Figure 5 shows the distribution of air around the captain and co-pilot for each model of ventilation grille.



a) Original vent



b) Bidirectional vent



c) Multidirectional vent

Figure 4 Air distribution around the pilots.

Figure 4b shows the airflow generated by grille b). Compared to Figure 4a, the air dispersion speed around and under the waist of the two pilots has decreased. However, the air dispersion speed has increased around the heads of the two pilots, which can lead to a stronger current sensation. Figure 4c shows the airflow in the condition of grille c). Compared to Figure 4a, the air dispersion speed has decreased in the area around the heads of the two pilots and the directional air dispersion speed has also decreased, around and under the waist of the two pilots, almost meeting the acceptable condition.

Figure 5 shows the distribution of airflow near the observer in the different grille air supply conditions. Similar to the above analysis, it can be seen in Figure 5a that the airflow dispersion speed near the observer is approximately 0.5 m/s to 0.8 m/s, which means a strong current sensation for the observer in the original air supply grille condition. Compared to Figure 5a, the local air speed in Figure 5b and Figure 5c is approximately 0 to 0.3 m/s, both meeting the acceptable thermal comfort condition, which means that grille b) and grille c) can improve the thermal comfort of the observer in terms of current sensation.

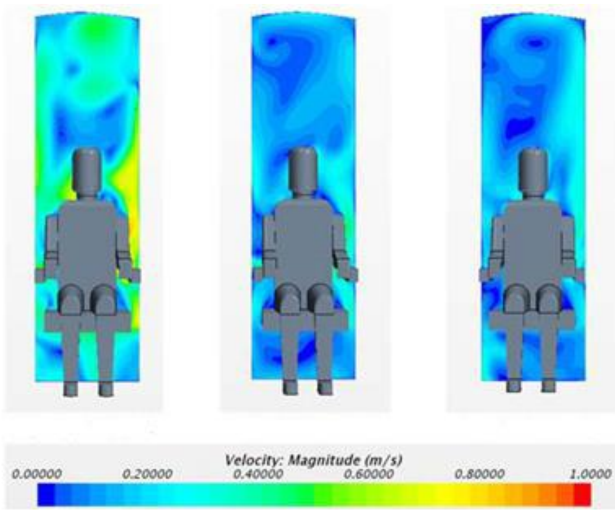


Figure 5 Distribution of air around the observer.

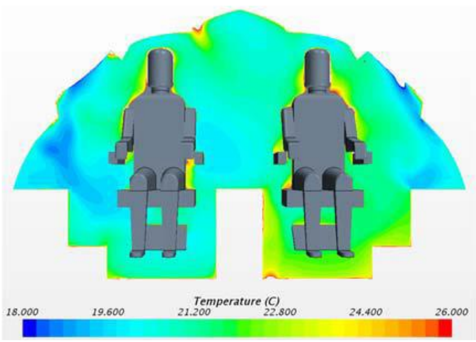
Summarizing the information presented above, in the case of the original grille air supply, the air dispersion speed around the three pilots is too high according to

ASHRAE standards [6]. In addition to this aspect, we also take into account the evolution of human proportions, the areas indicated in the simulation have an even greater impact and therefore lead to discomfort during the flight, reducing the efficiency of the pilots.

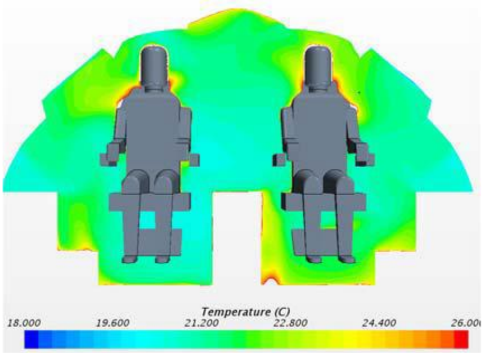
In the air supply condition of grille b), the airflow field near the flight deck and co-pilot is not improved, but the local air speed near the observer is reduced. In the air supply condition of grille c), the local air speed near the three pilots has been significantly reduced and almost meets the acceptable condition.

4.2 Cockpit temperature

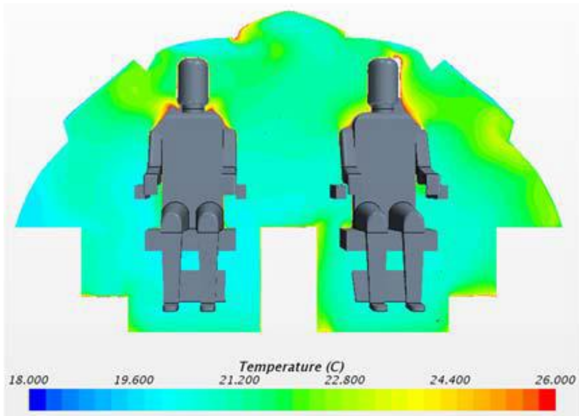
Figure 6 shows the temperature distribution near the captain and co-pilot in the different grille air supply conditions. Figure 6a shows the temperature field in the case of the original air supply grille, it can be seen that the temperature is mainly distributed in the range of 19°-23°, except for the contact area between the pilot and seat. This limited high local temperature is mainly caused by heat dissipation from the pilots, and thermal comfort should be evaluated by the temperature outside the limit layer. Therefore, the temperature range is acceptable. In addition, the temperature at height, near the head, waist, and ankle of the pilots is about 21°-23°, which means that the vertical temperature variation is within the acceptable range (vertical operational temperature variation within a seat < 2.8° according to the study presented earlier. Similarly, in Figure 6b and Figure 6c, the temperature range and vertical temperature variation is also within the acceptable range. However, the temperature in Figure 6b and Figure 6c appears to be more uniform than in Figure 6a. Therefore, in the air supply conditions of grille b) and grille c), the vertical temperature variation and temperature range are within the thermal comfort range and even better than those in the case of using the original air supply vents.



a) Original grille.



b) Bidirectional grille.



c) Multidirectional grille.

Figure 6 Thermal distribution around the pilots.

Figure 7 shows the temperature distribution near the observer in the different grille air supply conditions. Similarly to the analysis above, the vertical temperature variation and temperature range are within the thermal comfort range in the air supply conditions of any of the three grilles. However, the temperature variation in Figure 7b is higher than in Figure 7a and Figure 7c, and the temperature variation in Figure 7b is lower than in Figure 7a. Therefore, grille c) is the most likely to make the observer feel thermal comfort.

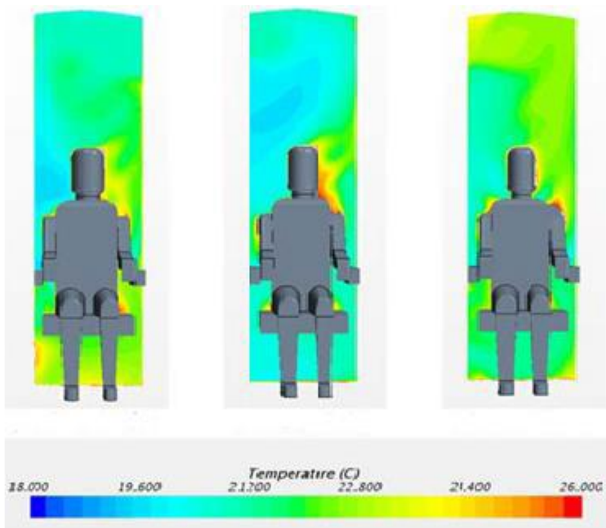


Figure 7 Distribution of temperatures around the observer.

5. CONCLUZIONS AND FUTURE REASEARCH DIRECTIONS

In this paper, two new types of grilles are proposed to improve thermal comfort in the pilot's cabin and the distribution of airflow and temperature in the different grille air supply conditions is obtained through simulations. The results confirmed the issues of high local air speed and temperature variation in the cabin in the original air supply grille condition. It should be noted that the air speed near the observer is approximately 0.5 m/s to 0.8 m/s, which can lead to a strong current sensation, especially in view of the current human proportion increase. Both new types of grilles are useful in making the airflow and temperature fields more uniform, and the local air speed near the pilots can be reduced to the acceptable range in the air supply condition of grille c), which means that thermal comfort can be significantly improved in the cabin with minimal cost.

As a future research direction, the possibility of new materials can be studied to reduce temperatures in the contact areas of the pilots with the aircraft surfaces.

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