iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: X Month of publication: October 2025

DOI: https://doi.org/10.22214/ijraset.2025.74624

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue X Oct 2025- Available at www.ijraset.com

Experimental and Numerical Study of Airflow Distribution in an Aircraft Cabin Mock-Up with a Gasper On

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Keywords: Experimental, numerical study, Airflow, distribution, Aircraft, cabin, mock-up, Gasper

I. INTRODUCTION

The paper by You et al. (2016) titled "Experimental and Numerical Study of Airflow Distribution in an Aircraft Cabin Mock-Up with a Gaspar" offers elaborate studies of the airflow characteristics in an aircraft cabin, including the effects of Gaspar, personalized airflow outlets. The relevance of this study is because the study has incorporated experimental and numerical methodologies in determining the impact of gaspers on airflow patterns and thermal comfort.

People traveling inside an aircraft cabin are highly affected by air quality and temperature, hence the need to have a proper flow of fresh air to minimize the room temperature. Specific characteristics like limited space, high passenger density, and constant air movement make the aircraft cabin environment rather unfavorable for the occupants from the viewpoint of the air quality and thermal conditions. Gaspers in particular offer a chance for the passenger to regulate the amount of fresh air supplied and are aimed at satisfying his/her needs. The overall objective of this research, therefore, will be to assess the extent to which these gaspers affect the general flow of fresh air and the perceived warmth and comfort of the cabin.

II. RESEARCH PURPOSE AND OBJECTIVES

The main aim of You et al.'s work is to decipher the decrease in airflow distribution and thermal comfort due to gaspers in an aircraft cabin mock-up. The research objectives outlined in the article include:

1) Investigating Airflow Patterns: The scope of this project is to determine how gaspers influence the flow characteristics of the cabin, investigating both in CFD and experimentation. This includes the determination of the velocity fields and turbulence levels for various seating poses.
2) Assessing Thermal Comfort: To assess the comfort level experienced by the passengers seated at different parts of the cabin. They include analysis of temperature distribution over the area and definition of zones which might be too cold or too much affected by draught or ineffective cooling.
3) Comparing Experimental and Numerical Data: To confirm the numerical simulations of individual components of the cabin with the actual cabin mock-up experimental data. This paper intends to finalize the selection of CFD models to be applied in the study through a comparison of the data to improve their reliability and validity.
4) Providing Design Recommendations: Therefore, the study intends to provide recommendations that would be easily implementable regarding the design and positioning of gaspers within the aircraft cabin. The following recommendations concern the passenger thermal comfort and air quality standards.

Using experimental measurements together with numerical simulations entails a holistic manner of analyzing the various factors that come with the airflow regions in an aircraft cabin. The consequences of the performed investigation have major relevance for the further research and development of aircraft ventilation systems, especially with the focus on improving their characteristics and efficiency standards to promote greater passenger satisfaction and overall air quality.

III. RESEARCH CONTEXT AND RELEVANCE

It is therefore important to locate this study within the current available literature and research being conducted in the field on the enhancement of IAQ and thermal comfort in enclosed spaces. Earlier and/or related research works have demonstrated the difficulties of achieving proper ventilation of the aircraft cabins and the problems arising in this respect steering on the total air quality as well as the partial quality regarding the passengers. They also stated that some positive developments that may offer rectification to these difficulties include; the use of individual control systems for example the gaspers. . Although the article specifically focuses on an aircraft cabin mock-up, it provides valuable insights into airflow dynamics, which apply to the broader context of an aircraft fuselage. The methodologies and findings related to airflow patterns, thermal comfort, and the use of gaspers (personalized air outlets) can inform and enhance the understanding of airflow distribution in various sections of an aircraft fuselage. Therefore, the applicability of You et al.'s study transcends the context of aircraft cabins. The findings of this study can also be transferred to other enclosed areas for inhabitants, workplaces, public transport, and healthcare centers where the effectiveness of the provision of personalized ventilation will significantly contribute to occupants' improved quality of comfort.

In summary, the paper by You et al. introduces significant papers to the field of indoor air quality and thermal comfort, explaining the airflow characteristics inside an aircraft cabin and sharing useful suggestions and tendencies regarding cabin ventilation systems. In terms of research, the study's extensive scope and its relevance to the process of design and optimization bring it into the spotlight of a given field.

IV. METHODOLOGY

In the study, by You et al., the airflow distribution in an aircraft cabin mock-up was analyzed with an experimental as well as computational study. The experimental rig used in the full-scaled cabin mock-up has gaspers and techniques such as Particle Image Velocimetry (PIV) and thermal anemometry were used to make measurements. Numerical simulations were done using CFD with FLUENT code, using the Reynolds-Averaged Navier-Stokes (RANS) equations and the k-ε turbulence model.

The features of the experimental configuration and instruments, PIV, and thermal anemometers are suitable for describing airflow features. Thus, PIV provides high-resolution velocity field data, which is very useful for the validation of the numerical model. The usage of CFD calculations supplements the experimental results, as the CFD approach helps in visualizing the airflow distribution, which is rather hard to measure experimentally. Nevertheless, a more turbulence model could have been employed in the study, for instance, LES, although it is computationally intensive compared to the current model used in this study.

The use of both experimental and numerical techniques for the analysis of the present problem affords a comprehensive and accurate understanding of the airflow in the aircraft cabin. More conspicuous is the choice of PIV for the measurement of flow inside the channel within the framework of the experiment. The well-known PIV is among the most popular methods to obtain velocity fields with high spatial resolution, which is required for the validation of the numerical models. The study could have been reinforced in a further sense if turbulence intensity and frequency, such measurements, had been carried out with hot-wire anemometry and the results compared with CFD.

The flow model used by You et al in their numerical simulations was the RANS equations with the k-ε turbulence model. Although the k-ε model is the most popular and gives fairly good results these days in many practical calculations, it is recognized that this model has some drawbacks concerning application for complex turbulent flows with a high degree of anisotropy and swirl. LES or Detached Eddy Simulation (DES) could give more substantial results because associated with advanced turbulence, it is possible to predict the current distribution with higher accuracy, for example, in the region near the gaspers.

V. RESULTS AND DISCUSSION

Consequently, the presence of gaspers was discovered to have a strong impact on the rate of air circulation in the area. The gaspers produce little zones of high-velocity jets, which improve the speed of mixing of air but at the same time give high turbulence levels. The thermal comfort study proved that the passengers who sit below the gaspers have received elevated air velocities and reduced temperatures compared to the passengers who sit in the spaces away from the gasper. Emphasizing the aspects of ventilation concerning the current studies, it can be concluded that the strategy of the individual supply of fresh air provides optimum control of thermal conditions in the sealed compartments of airplanes.

Comparing these outcomes with other similar studies, for instance, with the study conducted by Cao et al. (2022), in which the authors explored the distribution of airflow in a cabin with and without personalized ventilation, we are going to observe the reinforcing trends only. Cao et al. (2022) also linked the effectiveness of isolated seats, such as gaspers and preferred ventilation systems, in enhancing air quality and thermal comfort due to the availability of fresh air to the passengers. They also admitted certain challenges with the draft and the non-uniformity of the temperature and the presence of the cold areas, which were also mentioned by You et al.

VI. VALIDATION AND LIMITATIONS

Still, one of the major achievements of the work is the validation of used numerical model used with the experimental data. The general trends of the PIV measurements and CFD results show the validity of the numerical procedure. Nevertheless, the present analysis is not without certain limitations. The RANS model is good for a steady-state simulation; however, some specifics of the airflow might not be covered by it. Future studies toward the present work can be enhanced by using LES or by applying hybrid RANS-LES models.

Another limitation that can be noted is that the simulations performed in this work assume that the system is in a steady state at each time step. In practice, there are many transient factors such as passengers' movement, opening and closing of doors, and fluctuations of the outer environment. Including these factors in the simulation would come up with a better way of estimating the airflow distribution.

If observations made by You et al. are compared to other studies, overall, one can conclude that the application of gaspers and the principles of personalized ventilation, as a rule, improve the level of thermal comfort and air quality. For example, Bogdan and Chludzinska (2010) conducted a study on personalized ventilation in office environments; the results revealed that the systems significantly enhanced the participant's perception of air quality and thermal comfort over conventional systems. This aligns with You et al There is the likelihood that arm's length use of gaspers and other methods of personalized ventilation can have certain advantages in enclosed compartments such as aircraft cabins.

In the same regard, however, there are still other research papers that demonstrate the possible disadvantages of the use of personalized ventilation approaches. For example, Melikov, Cermak, and Majer (2002) observed that although the systems of Personalized Ventilation offer better IAQ and comfort, the occupants complain of getting draught, which causes discomfort. This concurs with You et al.'s observation that there were higher air velocities and lower temperatures for the seated passengers directly under the gaspers. Altogether, these works imply that even though personalized vents can bring a lot of advantages, implementation should be done with proper design and decision concerning optimization to eliminate possible unfavorable circumstances.

VII. IMPLICATIONS FOR AIRCRAFT DESIGN

From these findings, the following conclusions can be of significance to the designing of aircraft ventilation systems. Thus, the employment of gaspers can improve thermal comfort and indoor air quality due to the possibility of regulating airflow individually. However, gaspers' placement and intensity should be effectively thought out by designers as drafts and temperature irregularities may occur. Superior system-level and passenger-level ventilation therefore a possible optimal region of operation is the integration of centralized and personal ventilation systems to meet the balance between the volume of air and control.

This view is in harmony with the assertion by Mboreha et al. (2022) that pointed out that there is a call for an interdisciplinary approach to ventilation in the confined Aero space including the aircraft cabins. Their research confirmed that the interaction of displacement ventilation with personalized systems can help in regulating the supply of fresh air and controlling the thermal comfort of the indoor space as supported by You et al.

Consequently, the study by You et al. has relevance to thermal comfort and health in aircraft cabins. Temperature control is a key determinant of passengers’ comfort and perception of their well-being and can be improved by controlling individual portions of the occupants’ surrounding environment as offered by gaspers. But at the same time, it is also revealed that it is critical to manage air velocity and temperature in order not to have problems with draft as well as with temperature stratification.

The study by Mboreha et al. (2021) on thermal comfort in aircraft cabins also affirms these findings by showing that passengers’ thermal comfort depends on the temperature, airflow rate and relative humidity. Talking about the same question, Mboreha et al. (2021) also focused on the ability to control the ventilation to meet each person’s comfort level, also described by You et al. (2016).

In the aspect of the impact on health, the findings of You et al. demonstrate that with the aided adoption of the PV system, fresh air will be supplied directly to the passengers. This is even more crucial when it comes to small areas such as the aircraft cabins since air is more likely to stagnate.

Research by da Silva, Broday and Ruivo (2023) and Mayer et al. (2022) on indoor air quality and health impacts signal the compounding of desirable indoor environmental quality with avoidance of hazardous substances to enhance health, such as respiratory illnesses and weariness.

According to the current literature, the study of You et al. adds onset knowledge regarding possible improvements in health conditions, which can be attained using personalized ventilation systems in aircraft cabins.

VIII. FUTURE DIRECTIONS AND RECOMMENDATIONS

Based on the analysis of the presented material, it is possible to state that the study by You et al. can serve as a starting point for further research on airflow distribution and thermal comfort in aircraft cabins. For future work, it is necessary to investigate the application of a superior turbulence model like LES or DES to increase the reliability of the numerical modelling. Moreover, the modelling of such transient factors concerning passengers' movements, entering and opening the door, and variations in the weather conditions also would give a better prediction of the airflow distribution and thermal comfort evaluation.

For this paper, further research regarding the health consequences of various forms of airflow and temperature fluctuations inside the aircraft is also called for. Longitudinal studies could provide valuable insights into how different ventilation systems impact passengers' health and well-being over time. Furthermore, studies on the energy efficiency of personalized ventilation systems could help in developing sustainable solutions that balance comfort, air quality, and energy consumption.

IX. CONCLUSION

You et al.'s study (2016) helps advance the knowledge about the airflow distribution and thermal comfort of airplane cabins. Such experimental proof coupled with a numerical analysis as done in this study gives a clear understanding of the impact of the gaspers on the airflow and thermal comfort. The outcomes of this study can be relevant and correlated with the outcomes of other studies regarding specific systems of ventilation for occupants.

Such research should under-consider the need to enhance the precision of the numerical models, estimate the chronic impacts of various ventilation solutions, and seek technology that will allow the create energy efficient aircraft environment with desired thermal comfort and air quality. The findings of this work will be beneficial to designers, engineers, and academics involved in the development and design of aircraft interiors that enhance passengers' comfort and health.

In conclusion, this paper presents a significant contribution to the knowledge enhancement in aircraft cabin ventilation and the result of the study will be useful for the designers, engineers and researchers engaged in the improvement of passenger comfort and air quality in the aircraft cabin.

REFERENCES

[1] Bogdan, A., & Chludzinska, M. (2010). Assessment of thermal comfort using personalized ventilation. HVAC&R Research, 16(4), 529-542.
[2] Cao, Q., Liu, M., Li, X., Lin, C. H., Wei, D., Ji, S., ... & Chen, Q. (2022). Influencing factors in the simulation of airflow and particle transportation in aircraft cabins by CFD. Building and environment, 207, 108413.
[3] da Silva, M. G., Broday, E. E., & Ruivo, C. R. (2023). Indoor climate quality assessment in civil aircraft cabins: A field study. Thermal Science and Engineering Progress, 37, 101581.
[4] Mayer, F., Fox, R., Space, D., Bezold, A., & Wargocki, P. (2022). Indoor air quality in commercial air transportation. In Handbook of Indoor Air Quality (pp. 2057-2094). Singapore: Springer Nature Singapore.
[5] Mboreha, C. A., Jianhong, S., Yan, W., & Zhi, S. (2022). Airflow and contaminant transport in innovative personalized ventilation systems for aircraft cabins: A numerical study. Science and Technology for the Built Environment, 28(4), 557-574.
[6] Mboreha, C. A., Jianhong, S., Yan, W., Zhi, S., & Yantai, Z. (2021). Investigation of thermal comfort on innovative personalized ventilation systems for aircraft cabins: A numerical study with computational fluid dynamics. Thermal Science and Engineering Progress, 26, 101081.
[7] Melikov, A. K., Cermak, R., & Majer, M. (2002). Personalized ventilation: evaluation of different air terminal devices. Energy and buildings, 34(8), 829-836.
[8] You, R., Chen, J., Shi, Z., Liu, W., Lin, C. H., Wei, D., & Chen, Q. (2016). Experimental and numerical study of airflow distribution in an aircraft cabin mock-up with a gasper on. Journal of building performance simulation, 9(5), 555-566.