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PIV measurement of a jet from a gasper in an aircraft cabin mockup

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Abstract

The air conditioning system of most commercial aircrafts consists of a main system, which operates on the principle of mix ventilation, and a personalized system called gasper. Field studies show that passengers prefer to keep gasper parcially open or redirect it away from the head due to the discomfort. Therefore, there is a demand to characterize the flow of this device for future improvements. In this way, the present work aims to experimentally study the gasper jet inside a real cabin mockup using PIV. The results indicate that passengers are subjected to a high speed jet and the air in their breathing zone is mostly supplied by the mixed ventilation system due to the large entrainment ratio.

1 Introduction

A way to improve air quality inside aircrafts cabins is through personalized ventilation and the typical system included in commercial aircrafts is the gasper, a small adjustable vent positioned above passengers' head that provides an air jet directly to passengers' breath region (Li et al. (2018)). In previous studies focused on the gasper airflow, particle image velocimetry (PIV) was used in mockups that did not faithfully represents the complex geometry of a real cabin. Therefore, the present work is focused on the PIV measurement of the gasper airflow under the influence of a mixing ventilation system to evaluate jet features as velocity decay and entrainment ratio. Also, through measurement of multiple planes, a 3D airflow distribution of the gasper jet was obtained. These results allow a proper understanding of the gasper jet behavior and an assessment of its efficiency as a tool to increases passengers' comfort and safety.

2 Materials and methods

A PIV system was used to measure the gasper jet velocity field. This system consists of a 200 mJ laser sheet with a thickness of 2 mm. and a wavelength of 532 nm. provided by a double-cavity Nd:YAG laser with a frequency of 7.4 Hz. The images were recorded using a Dantec FlowSense 4M MK II camera with 2048 x 2048 pixels. Three traverse were used to move the PIV system. The laser, the camera and all traverse devices were mounted inside a fully functional mockup of an Embraer E-170 airplane, placed inside a low-pressure chamber. In each run the cabin environmental conditions were kept constant: the temperature was 21°C, the air flow in the main ventilation system was 1,050 m^3/h and the mean flow rate in the gasper was 1.7 m^3/h (ASHRAE (2018)).The diethylhexyl sebacate (DEHS) particles with a mean diameter of 2 µm. were seeded in the environment through the cabin main ventilation inlets.
For each measurement plane, a thousand of double-frame images from an area of 243.2 x 243.3 mm. was recorded. Due to the cabin material and geometry, laser reflections caused a background noise in images; therefore, the first image preprocessing step was the subtraction of a mean image from each image. Besides that, a 3 x 3 Gaussian filter and in sequence a 3 x 3 Laplacian filter was applied to reduce noise and increase the correlation peak (Raffel et al. (2018)). All PIV analysis presented in this work was made by a cross-correlation algorithm with deforming interrogation window and grid refining that yielded a spatial resolution of 1.9 mm. after vector validation through primary peak ratio (PPR) and universal outlier detection algorithm (UOD) (Westerweel and Scarano (2005); Hain and Kähler (2007)).

3 Results

From the jet middle plane (Fig. 1(a)) was possible observe that the gasper produces an annular jet where velocity increase until the reattachment point is reached and after that the velocity begins to decay in the fully developed zone. In this way, in Fig. 1(b) is presented the fitting formula for centerline non-dimensional velocity in the fully developed zone. The curve behaves in a similar way as presented in Dai et al. (2015) despite gasper's different physical characteristics.
Through PIV measurement of 20 planes separated by 2.5 mm. it was built a 3D representation of the gasper jet (Fig. 1(c) and Fig. 1(d)). Considering that the cross-section has a circular shape, the local air flow rate was calculated from the integral of the velocity profile for each axial position. It was notorious the fast increase in flow rate inside the jet (Fig. 1(e)), meaning that the air in the passenger breath region is essentially air from the cabin environment that merges into the jet.

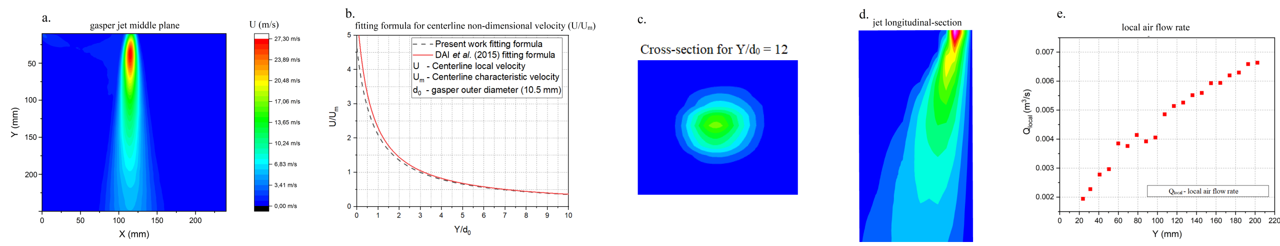

Figure 1: Results summary

4 Conclusions

Although the gasper jet measured in the present work differs from previous studies in terms of its geometry and the cabin environmental conditions, the non-dimensional centerline velocity decay obtained in the present study was very similar to the previous results. Also, it was demonstrated that due to its small outer diameter (d_0 = 10.5 mm in the present work), the gasper can provide a jet with a high-velocity that can increase passengers' draft sensation. For this reason, usually the passengers prefer to adjust the jet direction to their trunk or lower limbs instead of their heads. From PIV data evaluation was also indicated that the gasper is not an ideal barrier for virus and bacteria due to its high entrainment ratio.

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