Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX
Preferred Topics: SYSINT / FLOCON / SUSTAV
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Type: Oral
Status of corresponding author: Regular

Title

Cabin Air Quality in Commercial Aircrafts with an Adaptive Environmental Control System Strategy

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Abstract

Air quality in commercial aircrafts is of prime interest, especially considering the COVID-19 pandemic. The cabin air can be contaminated by sources located both inside and outside. Examples of internal sources are represented by food, cabin materials, and cleaning solvents. Different types of external sources exist, such as ozone and particulate matter (PM). Moreover, external contamination under abnormal conditions includes releases of engine oils, hydraulic fluids, and de-icing fluids. Setting concentration criteria for this many contaminants is challenging since the health effects of pollutant exposures are uncertain. Regulations mostly focus on carbon monoxide, carbon dioxide, and ozone concentrations. The FAA [1] and EASA [2] mandate to deliver at least 0.55 lb/min or 0.28 m^3/min respectively of outside air per passenger in order to prevent cabin pollutants from accumulating. Aircraft air sensing and filtration technologies could improve Cabin Air Quality (CAQ) and diminish dilution requirements; although, they are not demanded by regulations. Collins Aerospace Ireland is developing an Adaptive ECS (aECS) strategy under the Clean Sky 2 research program. This adaptive system adjusts the fresh air demand to the CAQ, which is monitored and controlled by sensors and filters. The resulting air composition differs from the one in conventionally equipped aircrafts.

This article models and simulates CAQ in single-aisle aircraft under various flight conditions. CO2, Volatile Organic Compounds (VOCs), and PMs are considered. These pollutants have been targeted mainly based on three indicators: presence impacting health, measurable, and treatable. The simulated cruise scenarios include critical ones – e.g., hot days with high cabin occupancy – with two operative Pressurization & Air Conditioning Kits (PACKs). Each scenario is analyzed with two control options: a conventional system employing a prescribed amount of fresh air, and an adaptive strategy, based on CAQ monitoring and air filtration. A Modelica environment is used for the integrated modelling and simulation of three main sub-systems. The cabin model evaluates thermo-hygrometric conditions and air quality based on the number of passengers and crew, outdoor conditions, and fresh air quality. The recirculation loop model comprises the fan, filters, and mixing chamber. The PACK is modeled with heat-exchangers and turbomachinery for the conditioning of hot bleed air.

Today, inadequate understanding of interior pollutant concentrations makes it hard to link air quality with passengers' and cabin crew's comfort. To make things more challenging, there is no standard method for assessing CAQ. Filtration and air sensing are not required by FAA or EASA regulations. Thus, cabin air pollutants are rarely monitored or filtered during flight, and the only option to avoid their accumulation is dilution with exterior air. Conventional ECS is the most energy-intensive non-propulsive system in an aircraft since it demands a predefined amount of fresh air. This study reveals that alternative ECS architectures, with reduced and adaptable fresh air flow and with sensing and filtration capabilities, can improve CAQ and possibly save fuel. A new ECS architecture that alters fresh air flowrate based on CAQ will change the regulations' requirements, and it will position civil aviation for a more sustainable future.

References

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