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Adaptive Environmental Control System Strategy for Cabin Air Quality in Commercial Aircrafts

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Abstract : The cabin air quality (CAQ) in commercial aircraft is of prime interest, especially in the context of the COVID-19 pandemic. Current Environmental Control Systems (ECS) rely on a prescribed fresh airflow per passenger to dilute contaminants. An adaptive ECS strategy is proposed, leveraging air sensing and filtration technologies to ensure a better CAQ. This paper investigates the CAQ level achieved in commercial aircraft's cabin during various flight scenarios. The modeling and simulation analysis is performed in a Modelica-based environment describing the dynamic behavior of the system. The model includes the following three main systems: cabin, recirculation loop and air-conditioning pack. The cabin model evaluates the thermo-hygrometric conditions and the air quality in the cabin depending on the number of passengers and crew members, the outdoor conditions and the conditions of the air supplied to the cabin. The recirculation loop includes models of the recirculation fan, ordinary and novel filtration technology, mixing chamber and outflow valve. The air-conditioning pack includes models of heat exchangers and turbomachinery needed to condition the hot pressurized air bled from the engine, as well as selected contaminants originated from the outside or bled from the engine. Different ventilation control strategies are modeled and simulated. Currently, a limited understanding of contaminant concentrations in the cabin and the lack of standardized and systematic methods to collect and record data constitute a challenge in establishing a causal relationship between CAQ and passengers' comfort. As a result, contaminants are neither measured nor filtered during flight, and the current sub-optimal way to avoid their accumulation is their dilution with the fresh air flow. However, the use of a prescribed amount of fresh air comes with a cost, making the ECS the most energy-demanding non-propulsive system within an aircraft. In such a context, this study shows that an ECS based on a reduced and adaptive fresh air flow, and relying on air sensing and filtration technologies, provides promising results in terms of CAQ control. The comparative simulation results demonstrate that the proposed adaptive ECS brings substantial improvements to the CAQ in terms of both controlling the asymptotic values of the concentration of the contaminant and in mitigating hazardous scenarios, such as fume events. Original architectures allowing for adaptive control of the inlet air flow rate based on monitored CAQ will change the requirements for filtration systems and redefine the ECS operation.

Keywords : cabin air quality, commercial aircraft, environmental control system, ventilation
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