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Effects of Environment Control System Operation on Ozone Retention Inside Airplane Cabin

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Abstract

High concentration ozone presented at airplane cruise altitudes will enter the cabin with bleed air and threaten occupants' heath. While current airworthiness standards have regulated the maximum level of ozone permitted, there still is a lack of a thorough understanding of the whole process which affects ozone retention within the whole airplane, especially the influence of airplane environment control system (ECS) operation. We have proposed different analytical models to evaluate the ozone removal efficiency and to consider different flow conditions and deposition mechanisms, including Distributed Parameters Model (DPM) for ECS and steady analytical model for cabin. By taking Boeing model 747-400 as a sample, we found that ECS contributes to overall ozone retention only to a limited extend at under clean conditions. The effects will be enhanced by the chemical reaction between ozone and bleed air contaminants deposited inside ECS and change with the variations of operation conditions, especially the bleed air pressure.

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Keywords: Airplane cabin; Environment control system; Ozone retention

1. Introduction

Ozone is a strong oxidant which presents at cruise altitudes of civil aircraft, and its final concentration in aircraft cabin is cared by many researchers[1]. Bischof et al.[2] found that the ozone concentration was greater than 0.1 ppm for 75% of the flight time, with maximal concentration of 0.4 ppm averaged over 4 h and 0.6 ppm over 1h on 14

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flights over polar areas, and indicated that the highest ozone concentration in the cabin is experienced during high altitude, long distance flight at high latitude.

Concentration of the ozone inside the cabin depends heavily on the ambient concentration and the transportation. Deposit process starts from bleed airport of engine, goes through ozone converters in most cases and ECS and finally reach the supply port of cabin, where the cabin and ECS both contribute largely to ozone retention by surface deposition or chemical reaction. Tamas et al. [3]systematically evaluated the factors which affects ozone removal rates in a simulated airplane cabin, considering the variation of the presence or absence of people, soiled T-shirts, airplane seats and a used filter, and found that the optimal way to reduce people's exposure to both ozone and ozone oxidation products is an effective way to remove ozone from the air supply system of an airplane. Numerical simulations conducted by Rai et al. [4] revealed the similar ozone removal rates and deposition velocities in airplane cabin environment.

Researches about ozone consuming in building air condition system [5][6] helps to understand the ozone removal inside ECS onboard aircraft. The ECS-generally captures a variety of contaminants, such as oil vapor and gaseous pollutants, solid dust particulate and other contaminants adhering on them, while such contaminants will also react with ozone and contribute much to the total ozone removal, as revealed by experiments conducted by UK CAA and Austrian DSTO[7]. Ke et al.[8]numerically investigated the ozone retention in heat exchanger and revealed that it could consume more ozone under certain special conditions. However, the relationship between the retention ratio and ambient ozone level is still unambiguous. Perkins et al. [9] measured the ozone retention ratios for some kinds of Boeing 747 and obtained the average values of 0.47 and 0.83 respectively. FAA [10] have come up with a simplified equation to estimate the ozone concentrations in cabin, where the constant retention ratio about 0.7 were elected not to introduce the complexity of a varying retention ratio into the calculation procedures.

In this paper, different analytical models were employed to evaluate the ozone removal efficiency inside airplane cabin and ECS, where different flow conditions and deposition mechanisms were considered for different ozone transportation stages according to the general configuration of civil airplane ventilation system. As for ozone retention inside ECS, DPM was employed and extended to numerically investigate the ozone spread inside ECS. For ozone retention inside cabin, where the ozone reaction on all the in-cabin surfaces were considered, the steady analysis of basic cabin with recirculated passage were built and validated.

2. Method

The entire transportation process, starting from the bleed airport of engine, going through the ozone converters in most cases and the ECS until reaching the supply port of cabin, could be divided into two parts to separate the serial effects of all the components to ozone removal, that is, ECS and cabin. In this section, we combined the analytical model for cabin with DPM for ECS to evaluate the ozone removal efficiency for airworthiness certification.

2.1. Ozone retention model for cabin

For a typical cabin, the ozone will enter with the fresh air from outside firstly, then the deposit would react with some chemical substance inside the cabin, and then be exhausted. Figure 1 demonstrated a typical ozone transportation process for a cabin with recirculated air.

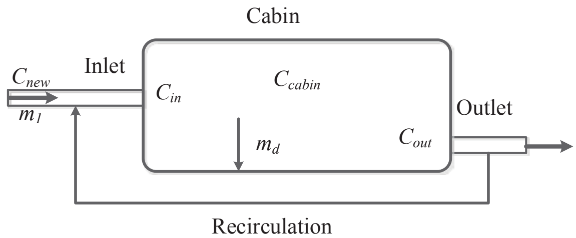

Fig. 1. General ozone transportation process in cabin