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The Effects of Heat Exchanger on Ozone Retention

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Abstract

There has been an increase in considering the health and aviation safety problem related to bleed air contamination, such as ozone, with the continued growth of aviation transportation. In this paper, the DPM (Distributed Parameters Model) was employed and extended to numerically investigate the ozone spread in HX (Heat Exchanger), the key component of aircraft ECS (Environmental Control System). The equation of mass conservation for each control volume was build, where the flux of the ozone deposited to the surface was determined by its local concentration in air and the deposition velocities, which refers to analogy analysis between mass transfer and heat transfer. The physical surface deposition and chemical reactions between ozone and heat exchanger were both studied with DPM to determine the ozone retention ratio, which could consider the effects of local flow and heat transfer condition with affordable computation burden. This study presented some numerical tools to analyze the ozone problem in airplane ECS and reveals that the ECS may have a significant effect on airplane ozone removal.

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Keywords: cabin air quality, ozone, Heat Exchanger, numerical simulation;

1. Introduction

The modern large commercial aircraft equipped with environmental control system to provide outside fresh air and regulate the temperature, pressure and humidity in the cabin to create a comfortable environment for passengers. The outside air from the bleed air system of engine is directed to the cabin through the ECS, a relative complicated system working under some extreme conditions. The engine bleed air is prone to contamination from outside, or engine oil. The contaminants, such as ozone, solid particle, oil vapor and so on will be transmitted to the cabin

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through the ECS. Such contamination may degrade the quality of bleeding air and be threats to the heath of occupants and safety of flights [1]. Ozone is a strong oxidant among these contaminants, which can cause eye and respiratory irritation effect of short-term exposure at low concentrations, prolonged exposure to high concentrations cause respiratory system diseases[2]. Flight crew and cabin attendants of civil airlines have reported some uncomfortable or partially incapacitating symptoms associated with it. The limits of ozone concentration in aircraft cabin has been regulated in airworthiness standards [3], and corresponding means of compliance has been presented in advisory circulars, such as FAA AC 120-38 [4].

Currently, most researches focused on the final ozone concentration of in aircraft cabin[5], while there is very limited knowledge of the transportation and deposition process of ozone during the whole flow path in ECS of aircraft. ECS in aircraft will generally absorb those contaminants, such as ozone, solid dust particles, oil vapor and gaseous pollutants, as revealed by experiments conducted by UK CAA and Austrian DSTO[8]. HAVC system in building is similar to ECS in aircraft, many authors [6]~ [7] found that the HAVC system will contribute much to the total ozone removal. So ECS will contribute much to the ozone retention in cabin, especially the widely applied component Heat exchangers (HX), there is still short of tools to investigate the ozone retention inside HX.

Analytic methods [9] and numerical methods [10] have been developed for heat exchangers based on the integral parameter model (IPM) to evaluate heat transfer inside HX, and then the ozone transportation could also be analyzed with averaged mass transfer using IPM. However, it has inherent difficulties to characterize the different thermo physical properties of every point inside HX, which usually works in extreme conditions, such as the fouling or wet conditions. CFD based simulations [11] have been broadly utilized in recent years to yield accurate results through solving Navier-Stokes equation with proper flow models, such as wall function, viscosity models and turbulence models. However, huge computational burden caused by complex geometry and unclear deposition mechanism limits its application. The DPM [12] is a reduced-order model for fast CFD analysis with much less computation burden and acceptable precision with the consideration of local thermal physical properties and heat and mass transfer characteristics, which has been validated in the flow and thermal analysis of ducts and HX. Besides that, Yang et al [13] have analyzed ozone retention in ducts with DPM successfully.

This paper extended the DPM further to investigate the ozone spread in HX numerically. It was organized as follows, the DPM model for HX Simulation will be developed firstly in Part II, and where the special numerical tool, DPM, will be introduced briefly with the basic configuration of HX and the theoretic models for such interaction will be presented and validated. More results were given in Part III along with some applications. The conclusion will be drawn at last.

2. DPM model for HX Simulation

2.1. Introduction to DPM

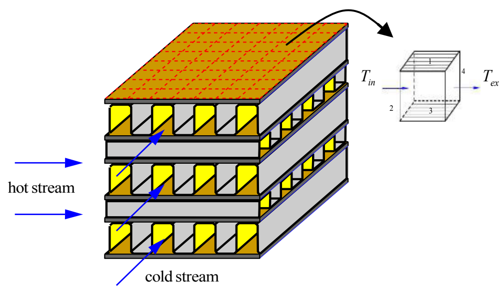

Fig. 1 Mesh generation [12]

The mesh generation method according to different fin surfaces will be illustrated by a rectangle-plain-fined heat exchanger, as shown in Fig.1, where the mesh as the dash line and one of the basic elements acquired is in the right part. It has definite physical significance, where the width and height of element are fin pitch and height, and its length is equal to fin pitch of the other stream passage.