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Analysis on High-Pressure Water Separator

Long Chen, Xingjuan Zhang*, Chao Wang and Chunxin Yang

School of Aeronautic Science and Engineering, Beihang University, Beijing, China

Abstract

High-pressure water separator (HPWS) is one of the most important components of airplane environmental control system (ECS). Through introducing the Wall-Film Splashing Model into the simulation process, the trajectories of droplets, pressure drop and water separation characteristics under different condensed water contents are researched with Ansys-Fluent. Comparison with the experiment has proved that the Wall-Film Splashing Model can improve the accuracy for HPWS's simulation. Meanwhile, modeling results verified that the existence of splashing is the main cause of the relative low water separation efficiency of the HPWS. So it's of great importance to improve the design process and manufacture technique of the separation section of the HPWS in order to increase its efficiency.

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Keywords: Water separator; Environmental control system; Droplet breakup; Pressure drop characteristics; Separation efficiency

Nomenclature

D	Diameter of the water separator, m	m	Mass flow rate of condensed water, kg/s
C_D	Drag coefficient	P	Pressure of the air, kPa
ϕ	Resistance coefficient	T	Temperature of the air, K
g	Gravity acceleration, m/s2	v_i	Gas phase velocity, m/s
G	Total mass flow rate, kg/s	u_i	Liquid phase velocity, m/s
Re	Reynolds Number	ΔP	Pressure drop, kPa

* Corresponding author. Tel.: +86-10-82339617.
E-mail address: zhangxingjuan@buaa. edu. cn

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Greek Symbols

η	Water separation coefficient	ρ	Density, kg/m^3
σ	Surface tension force, N/m		

Subscripts

in	Inlet of water separator	*out*	Gas outlet of water separator
CW	Condensed water, (g/(kg•air))		

1. Introduction

Air cycle refrigeration system (ACRS) is the most popular system style of the commercial airplane ECS. HPWS is one of the key components of ACRS, and is widely applied in the commercial airplanes, such as Boeing 757/767/777/787 and Airbus320/330/340/380, etc.[1-2].

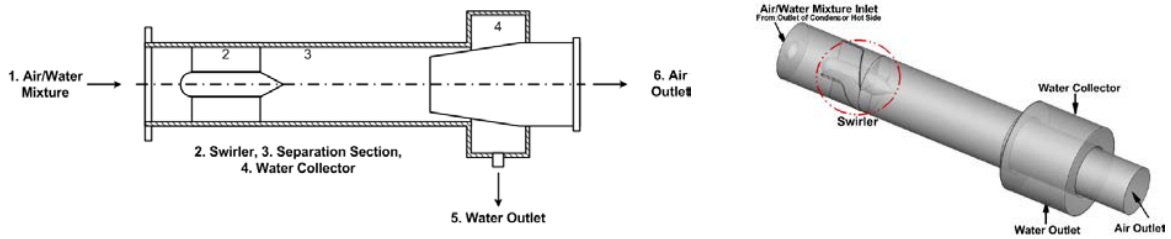
Published research work around the HPWS has been carried out. Hoyt et al.[3] who worked at NASA researched the efficiency of a cyclone water separator with the Euler Two Fluid Model and got some detail characteristics data. Yang[4] tested water separation performance for a type of HPWS. Results show that different swirl angles significantly influence the water separation efficiency, and the water efficiency fluctuates greatly. Wang[5] and Dang[6] studied a HPWS through experimental research and computational analysis. Results show that the diameters of particles are in the range of 30 to 50μm, and the water separation efficiency and pressure drop is respectively about 85% and 20 kPa at the design condition. Research also shows that only when the water separation efficiency is higher than 95%, the outlet of turbine is not limited by the freeze point and could work reliably. Liu[7] optimized and modified the structure of a HPWS which efficiency can reach 95% by theory analysis. Zhang[8] simulated a HPWS and found that its efficiency is higher than 95% when the particle diameter is bigger than 8μm.

All the above-mentioned researches assume that the droplets will run into the collector with the shell force of the air after hitting the wall. While during the practical applications, the droplets splash easily after they impact the solid wall. Big droplets splash into small ones which run out of the HPWS with the main air flow, and therefore the water separation ability of HPWS is decreased. That's why the deviation between the simulated values and the experimental ones exist. In this paper, the Wall-Film Splashing Model is introduced to simulate the phenomenon of droplet splashing. With the comparison between the simulated results and the tested results about water separation efficiency and resistance characteristics, the model's accuracy is verified.

2. Methods

2.1 Typical Structural of the HPWS

As shown in Fig 1(a), HPWS is composed of 6 parts: air/water inlet, swirler, separation section, water collector, water outlet and air outlet. Herein, the swirler and separation section are two key components which influence the performance of HPWS. The 3D perspective drawing is shown in Fig 1(b).



(a) Structural Diagram (b) 3-D Perspective Drawing

Fig. 1. High Pressure Water Separator