PROBLEMS IN UNDERSTANDING AIRCRAFT ICING DYNAMICS

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Abstract

A general discussion of the nonthermodynamic mechanisms present during ice accretion on nonrotating and rotating/flexing aerodynamic surfaces is undertaken. It is shown that competing physical effects do not in general allow a rigorous scaling methodology to be formulated, but suggestions are made which may result in an acceptable approximate scaling scheme. A test program is described which may provide data from which these approximate scaling schemes may be validated.

Nomenclature

A_b	blade cross sectional area
c	blade chord
$C_{\ell\alpha}$	lift curve slope
C_p	specific heat
d	drop diameter
E	modulus of elasticity
f_a	aerodynamic load/length
F	fraction of mass which spashes
h_{fs}	latent heat of fusion
I	moment of inertia
k	thermal conductivity
ℓ	mean spacing between drops
m	blade mass/length
r	droplet radius
R	rotor radius
s	arc distance
t	time
T	thrust
T_a	air temperature
T_f	freezing temperature
U_∞	freestream speed
V_T	tip speed ($R\Omega$)
x,z	Cartesian coordinates
α	angle of attack
γ	contact angle
δ	layer thickness
μ	advance ratio
ρ	density
ρ_b	blade density
σ	surface tension
σ_b	bonding ultimate stress
τ	shear stress
υ	kinematic viscosity
ϕ	incidence angle
Ω	blade rotation rate

Subscripts

a	air
w	water
i	ice
f	freezing

I. Introduction

The desirability of conducting icing tests with subscale aircraft components in an icing wind tunnel has been acknowledged for years. To date, the methodology for these subscale tests has yet to be finalized. The reasons for this are twofold. First, the physical mechanisms effecting the accretion process are still argued among researchers, and are in reality not completely understood. Second, it is extremely difficult to conduct icing scaling tests since the accretion process, by its very nature, has a stochastic component. The ability to measure and control test conditions in an icing tunnel is also difficult. The purpose of this paper is to discuss the scaling of ice accretion and to recommend the types of tests from which scaling laws may be checked. It is hoped that this effort will motivate experimentalists in icing dynamics to undertake the series of carefully controlled tests discussed herein, both to improve the understanding of the dynamics of icing and to determine how quantitatively scaleable are icing tests.

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