8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

NUMERICAL SIMULATION OF ICING ROUGHNESS GROWTH

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Key Words: *CFD, In-flight icing, Beads, Roughness*

ABSTRACT

The paper presents a numerical model aimed at the prediction of ice roughness growth during in-flight icing phenomena. The roughness shape is determined through the analysis of the behaviour of the water layer flowing over the icing surface, with special regard to the transition between still beads, flowing rivulets and continuous film.

A correct prediction of the roughness level has a huge impact on the accuracy of ice accretion codes [1], since roughness affects boundary layer development and heat transfer, determining the final ice shape. Although experimental evidence clearly shows that roughness is a time- and space-varying phenomenon, it is normally taken into account simply through a single value. Such value is usually an equivalent sandgrain roughness height, obtained from empirical correlations as a function of temperature, liquid water content, droplet medium volumetric diameter and aircraft speed. In this approach, most of the actual physics of the problem may be lost. Furthermore, no attempt is made at the evaluation of the roughness effect induced by the shape and flow pattern of liquid water layer, which can evolve in the form of a collection of still or moving droplets, or as rivulets and as a continuous film.

The shape of liquid water layer on the iced surface has also other important effects: the effective area exposed to evaporation is enhanced by beads or rivulets, and the evaporative heat fluxes are consequently affected. The importance of the actual surface exposed to evaporation in the heat transfer process was already proved in different application fields [2][3], and is a relevant issue when dealing with the simulation of anti-icing and de-icing systems. Furthermore, the water layer build up is an unsteady process, adding complexity to the picture. In particular, continuity and energy equations are affected by the time-dependent dynamics of water: beading causes water retention during the first stages of ice accretion.

In the proposed paper, the evolution of the water layer and its effect on ice roughness is numerically modelled. The model is developed as an add-on of a comprehensive finite element suite, FENSAP-ICE [4], devoted to the analysis of ice accretion prediction within a fully 3D CFD framework. In particular, the model is embedded within FENSAP's ICE3D module, and is based on the experimental observation made by

Hansman and Turnock [5], who studied the surface water behaviour during glaze ice accretion, and on the experimental data from Anderson and Hentschel [6] on surface roughness during ice accretion.

The model was validated through the comparison to experimental measurements of roughness reported by Anderson et al. [6], showing encouraging agreement, despite the high uncertainty of experimental roughness evaluation. As an example, the time evolution of computed and experimental maximum roughness are compared in Fig.1.

Furthermore, the typical experimental roughness height profile, which is close to zero around the leading edge and increases further downstream, is also correctly predicted. Finally, the predicted average value for ice roughness, for the large majority of tested cases, falls within the range of the experimental uncertainty.

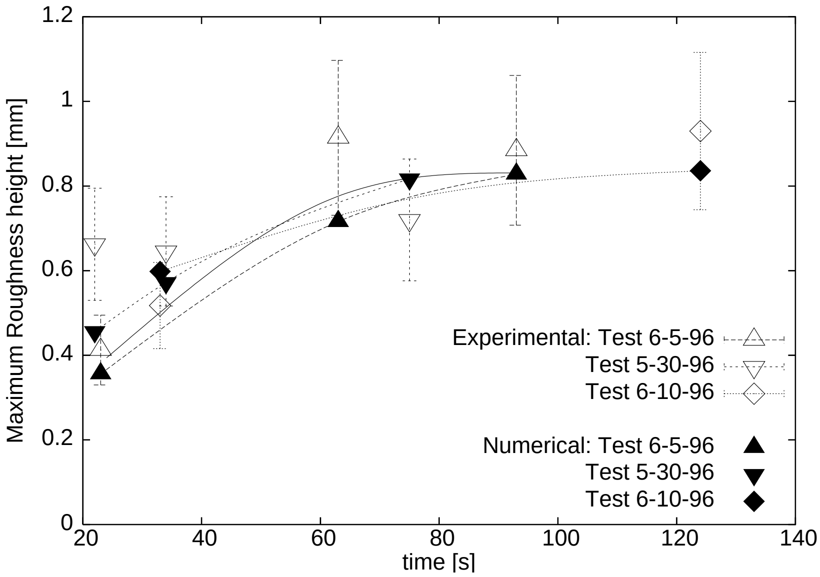

Fig.1 – Numerical and experimental roughness

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