The flow of an evaporating thin liquid film

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Numerous industrial and natural processes involve the flow of thin liquid films. In certain situations the flow is strongly influenced by evaporation, for example, flow over compact heat exchangers or heat fins and paint drying. The tears which form on wine or brandy glasses are due to evaporation controlled flow, see Figure 1.

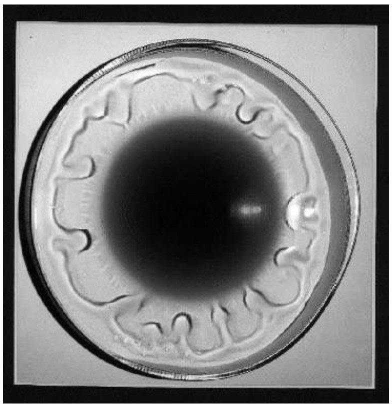

Fig. 1 a) Tear pattern in wine glass b) close up of tears.

Another important industrial application for evaporating flows occurs in the aerospace industry. In cold conditions aircraft frequently fly through clouds of supercooled droplets. These impact on the aircraft surface and can form an ice layer. An accretion of only 0.4mm on the leading edge of an aerofoil can reduce lift by 25%. Alternatively, ice may form on a non-critical surface and subsequently break off, damaging downstream components. Figure 2, shows pictures of ice formed on an aircraft wing and also a turboprop.

Fig. 2 a) Aerofoil with iced leading edge b) Iced turboprop.

Clearly, aircraft icing is extremely hazardous. To combat the problem almost all commercial passenger jets are fitted with some form of anti-icing device. One standard method is to heat the aircraft surface. Since it is too expensive to heat the whole surface, only the regions where droplets will impact are heated. This will prevent the droplets from freezing, however, the droplets are then free to form a liquid film and flow away from the heated region. Once away from the heating the fluid can freeze, consequently all of the impacting fluid must be evaporated.

The focus of this project will therefore be to develop a model for the flow of an evaporating, thin fluid film which is heated from below. The model will be analyzed and related to the problem of evaporation from an aircraft surface. The work will provide information required when designing an anti-icing system, such as evaporation rates and appropriate energy inputs.

This project originated from the ICECREMO aircraft icing project, see http://www.tra3.com/icecremo/, a collaboration between British Aerospace, GKN-Westland Helicopters, Rolls-Royce and DERA (Defence Evaluation and Research Agency).

Background information may be found at:

NASA Glenn, Icing Branch – http://icebox.grc.nasa.gov

Aircraft Owners and Pilots Association (AOPA), Aircraft Icing –
http://www.aopa.org/asf/publications/sa11.html

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