Aircraft Icing

Mathematical Analysis of Crystal and Droplet Impacts

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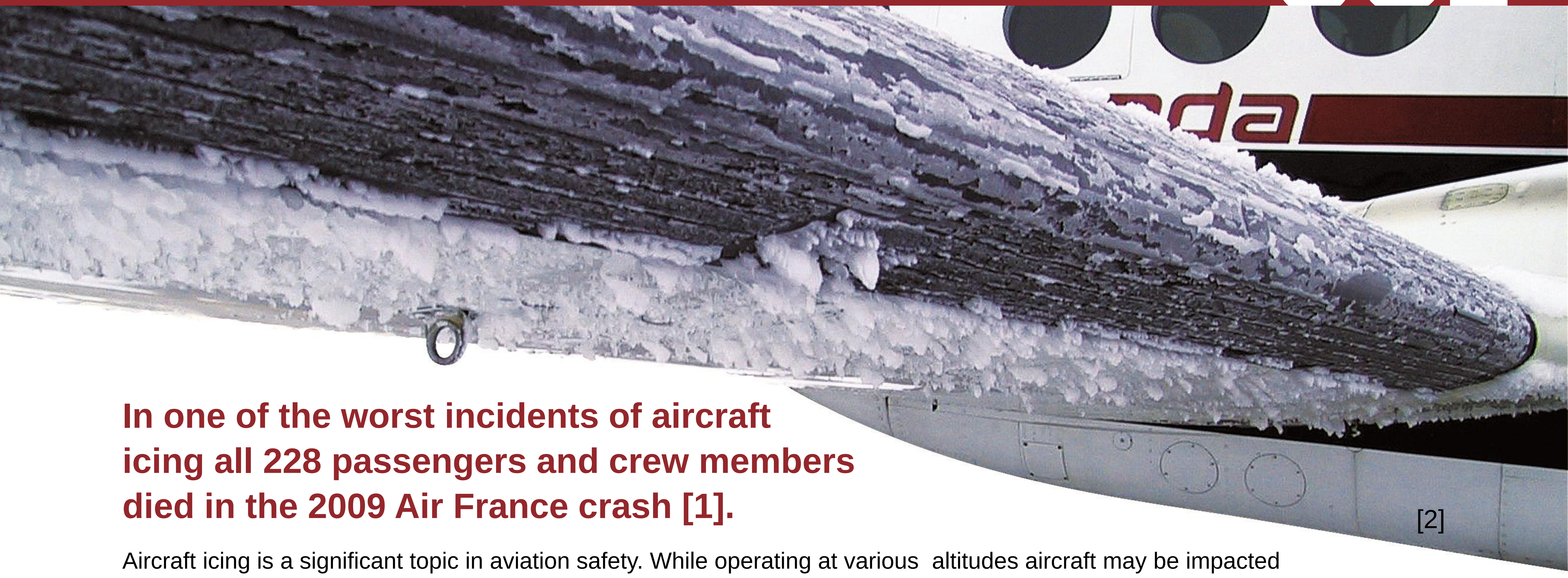

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In one of the worst incidents of aircraft icing all 228 passengers and crew members died in the 2009 Air France crash [1].

Aircraft icing is a significant topic in aviation safety. While operating at various altitudes aircraft may be impacted by atmospheric ice crystals or droplets leading to the formation of ice on wings, engines or vital components. This can degrade the performance of the aircraft and its systems, potentially leading to a system failure. Whilst progress has been made in recent years, icing continues to be a contributory factor in aviation accidents and incidents. Presented is an overview of research into mathematical modelling for icing conditions, produced in collaboration with AeroTex UK LLP.

Ice crystal modelling

Key dynamics: Each crystal may have a different shape and size that affects how it responds to the airflow.

Modelling: Forces and moments may act upon each crystal differently depending on its shape and orientation [3]. Thus, nuanced modelling of each one’s velocity, rotation and orientation is used to find its impact location.

Industrial application: Ice crystals are a problem for heated parts of an aircraft, such as engines and pitot tubes, where they are likely to begin to melt and freeze, degrading performance and potentially causing a system failure.

Skimming droplets and ice crystals

Key dynamics: When droplets impact a warm surface or ice begins to melt, a thin layer of liquid may form. When a subsequent crystal or droplet impacts this layer the physical response is significantly different to that of a dry surface.

Modelling: It is important that the force and pressure involved are carefully studied to accurately model the response of the particle, namely its subsequent rotation, skimming rebound and velocity upon exiting the water layer [5].

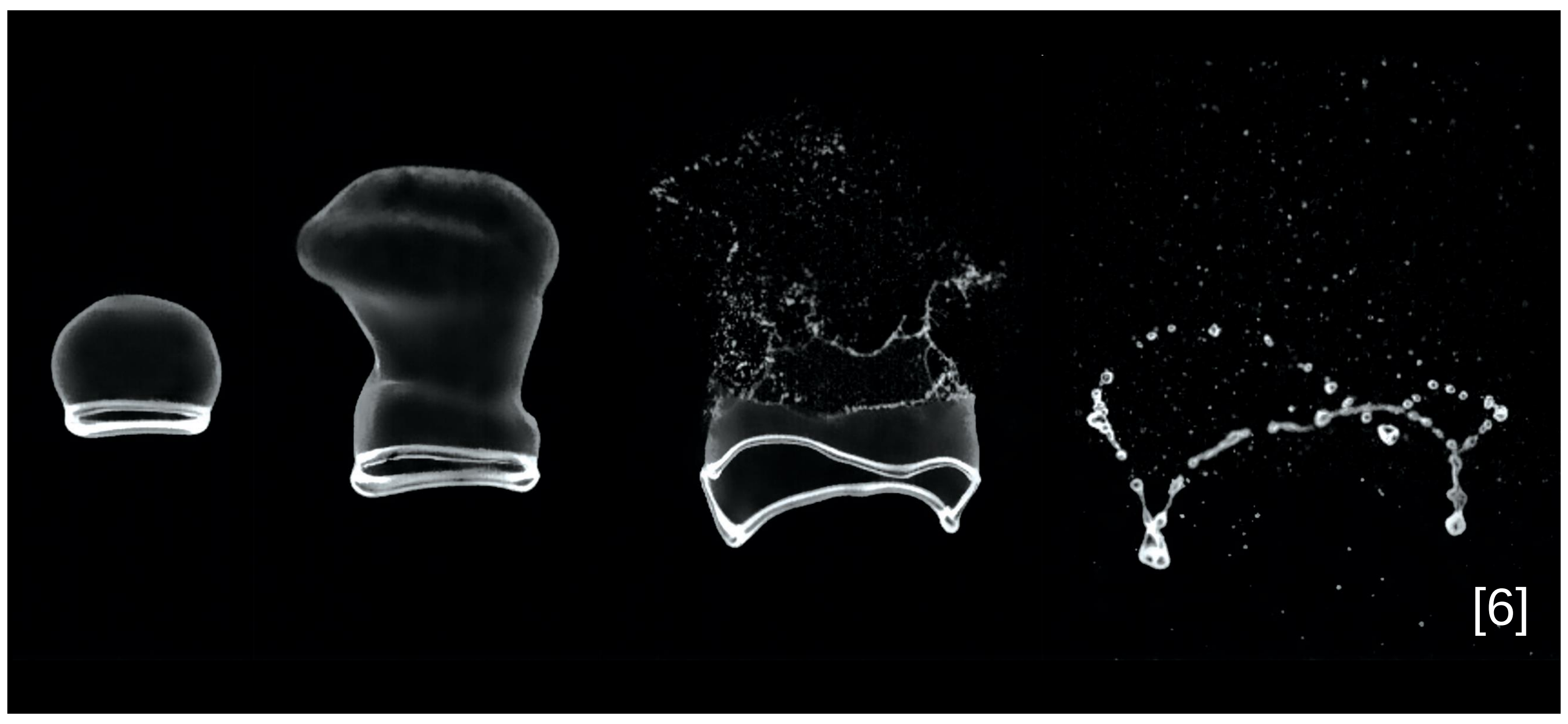
Industrial application: Such modelling informs the physical understanding of how particles interact with water on aircraft components and how particles progress after impact.

Supercooled Large Droplet (SLD) modelling

Key dynamics: SLDs are large, deformable droplets that exhibit phenomena unseen in traditional icing conditions [4].

Modelling: As a droplet deforms in response to pressure changes around an aircraft, it may break-up into smaller droplets. Alternatively, it may remain large, bouncing or splashing on impact. Modelling of these dynamics is crucial since they allow for droplets to potentially cause ice accretions on unprotected parts of the aircraft.

Industrial application: SLD icing is a big issue for regional aircraft and business jets, thus new certification requirements were introduced specifically for these conditions. However, it is still difficult to demonstrate compliance because icing tunnels cannot currently replicate the required conditions; thus, better modelling is a significant step towards improved safety.



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Conclusions

This work is of scientific and industrial importance, providing: insight into the relevant physics; new methods for modelling complex dynamics; and, the implementation of new methods into industry. Currently the presented scenarios are not widely modelled nor accounted for reliably. By enhancing the discussed aspects, the range of real-world scenarios that can be modelled within industry have been extended, impacting key areas of the aviation industry such as certification, and important societal problems of aviation safety and environmental impact (through improved aircraft efficiency).

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AeroTex UK
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