Breaking the ice with Clean Sky innovations

Ice accumulating near engine inlets and on wing leading edges can alter the aerodynamic laminarity of an aircraft, producing drag, reducing lift, and significantly lowering performance. This results in the burning of extra fuel to compensate for a lack of lift and propulsion. Left unchecked, a build-up of ice on aircraft wings and engines can be hazardous to the aircraft.

Pre-flight procedures at airports during winter seasons such as the spraying of wings with de/anti-icing fluid are commonplace. But in flight, at altitude, onboard means are necessary to ensure that ice cannot build up on critical external surfaces. Hence, airplanes have built-in systems to either mechanically remove accumulated ice, using expandable ‘boots’ on the wing’s leading edges, or by applying heat to melt the ice near engine inlets. Unsurprisingly, these systems consume lots of energy and add weight to the aircraft when flight in icing is only a portion of the total flight time.

Clean Sky has been working on innovative, lightweight, alternative ways to address ice accumulation using lower power consumption, less weight and greater efficiency, in line with the ACARE targets and the ambitions of the European Green Deal. Two projects in particular, PIPS and InductICE, have developed promising technologies that could help boost Europe’s leadership in this niche yet highly important aspect of aircraft operational safety.

PIPS (Passive Ice Protection System), which concluded in December 2020, is a capillary pumped closed loop system without moving parts (less maintenance) which transfers the heat from the engine area to the engine air inlet where ice can potentially accumulate. While on the wing leading edges, InductICE uses contactless electromagnetic induction (very similar to the system used for induction hobs in domestic kitchens) to heat up a metal mesh embedded in the composite material of the wing’s leading edge.

These proof of concept projects were put through their paces in a third project, IIPS (Integration of Innovative Ice Protection System), which tested PIPS and InductICE under representative conditions in icing wind tunnels.

Harnessing space age technology with PIPS

In PIPS, the idea of transferring heat from the engine to the areas surrounding the engine air intake that are prone to icing is inspired by a concept first used in orbiting satellites in the early days of the space race, to self-regulate their temperature.

‘It’s a technology which has been used since the end of the 1960s in the space domain, but not so much on earth, and especially not at all in aeronautics, because it’s quite delicate and is affected by gravity and acceleration,’ explains PIPS Coordinator Romain Rioboo, Design Engineer at Euro Heat Pipes (EHP). ‘When you’re in space, without any vibration, without any gravity, you can control everything, and it can work perfectly for 30 years without any maintenance. But on an airplane which vibrates and accelerates, it’s much more challenging.’

PIPS, which is led by EHP and supported by Ecole Nationale Superieure de Mecanique et D’Aerotechnique, uses the heat (that would otherwise be wasted) from the engine, so it’s free in terms of cost and from an energy point of view – the only ‘cost’ is weight (the system weighs a little bit less than 10 kilos). It’s a virtually passive system that uses a two phase maintenance-free ‘closed loop’ heat transfer system by means of a capillary pump.
Rioboo explains that ‘the advantage of this system is that it works independently, and the efficiency is very high.’

**Touchless wing heating**

Turning to the wings, the InductICE project (Efficient, Modular and LightWeight Electromagnetic Induction Based Ice Protection System) which ended in December 2019 under the coordination of IK4-Ikerlan, took an innovative approach to wing ice protection with a system that aligns with the trend towards aircraft electrification. The InductICE system is based on the use of thin heated elements embedded in the wing structure and coils inside the structure made from lightweight Litz wire conductors. Due to the geometrical distribution of the coils, along with phase-shifted current distribution, a uniform magnetic field is generated, which produces a consistent heating pattern at the front of the wing. The system was initially tested at IK4-Ikerlan’s facilities, and was also later tested in the Icing Wind Tunnel at Cranfield University and at RTA Austria within the framework of the I3PS project.

**Putting both systems to the test**

Clean Sky’s I3PS project recently reached completion, having put PIPS and InductICE technologies through their paces. The I3PS consortium was led by SONACA, supported by Euro Heat Pipes, IK4-Ikerlan, Rail Tech Arsenal (RTA) and Cranfield University.

‘One of the topic manager’s (Airbus Defence and Space) main objectives in I3PS was to take the PIPS and InductICE technologies and integrate them into relevant reference structures, and then demonstrate them in an ice wind tunnel to determine whether these innovative systems can be applied to future aircraft,’ explains Maxime Henno, Project Coordinator for I3PS at SONACA.

‘In the IWT it’s possible to vary the parameters and control the weather conditions in a way that cannot be done in flight testing where the weather is beyond anyone’s control,’ he explains.

In relation to PIPS, Rioboo reported: ‘Testing in our lab went well, but when we went to the icing wind tunnel the prototype was able to transport enough power to de-ice two of the three parts which had to be de-iced, however there wasn’t enough heat allocated to the engine lip due to a design problem for which the root cause has already been found. So we still have work to do on the design of the condenser, but from all other aspects it was OK.’

As part of I3PS, the InductICE system had to be integrated inside the structure of a composite wing. This was achieved by embedding a metallic thin mesh inside the composite layup which was carried out on two demonstrators, first tested in Austria at RTA near Vienna, and then later at Cranfield’s icing wind tunnel.

The induction architecture using the metallic mesh gives the advantage of eliminating the physical hard connection between the power supply and the heating elements. Therefore, explains Henno, ‘in terms of integration, you don’t have to go through the structure – and therefore you don’t have to cut through the aircraft skin in order to install wires – the structure and the system can really be separate. Also, another advantage is that you can have this kind of technology on composite structure, and this is an important point because aircraft are going more towards composites.’

Full-scale air inlet demonstrator after icing tests, fitted with a passive diphar ©Sonaca

Copyright 2021 – Clean Sky 2 JU – Belgium White Atrium, 4th floor, Av. de la Toison d’Or, 56-60 – 1060 Brussels

www.cleansky.eu
But the use of composites also presents a challenge in this specific circumstance. Whereas conventional wing structures are manufactured from metal (which is good for heat transfer), composite material has poor conductivity. To overcome this issue the mesh was installed close enough to the external surface of the structure to be able to transfer enough heat to melt the ice – but not too much, for another challenge is to generate just the right amount of heat to melt the ice without overheating the resin that holds the fibres together within the composite material. The induction technology also brings the possibility of dual use of the mesh used for direct impact lightning protection.

‘There’s a maximum temperature of the composite material which is about 120 degrees Celsius,’ cautions Henno. ‘Above this you have deterioration of the composite material and you don’t have the same mechanical features of the structure, which of course, on the wing leading edge serves a very important function – not just for obvious aerodynamic requirements – but also for the protection of the wing against bird strikes. The leading edge functions as a bumper for the wing, which also houses the fuel tanks. It’s important that in the case of a bird strike the fuel tanks aren’t punctured.’

One way to solve this is to design a system which can resist higher temperatures, which can run to 180 to 200 degrees without threat to their structural integrity, however these are more costly and difficult to handle at the manufacturing stage.

**Overall achievements**

Altogether, three testing models were constructed: one for the PIPS capillary pump, and two for the InductICE induction technology, comprising a de-icing system of a wing leading edge for a mid-size aircraft and an anti-icing system for the flap of an unmanned aircraft.

‘These tests showed that the principle of heating by induction can be used for ice protection and overall integration between the different elements was appropriate, but certain aspects raised showed the need for improvements in terms of maturity prior to application,’ says Francisco Redondo, Senior Expert Environmental Systems at Airbus Defence and Space.

In relation to the PIPs project, Clean Sky Project Officer Francesco Paolo Mancini reports that the project is ‘on the right path – it’s a very good result because it was the first time this kind of de-icing system was used and tested in an ice wind tunnel, and they saw that the system was able to transport more than eight kw permanently, as well as above 10 kw intermittently, which is what they were aiming at.’

The PIPS consortium is currently in the process of patenting its system – a testament to the value of Clean Sky in facilitating the transition of a concept from a very low TRL to TRL6, with a potential exploitation path towards industrialisation.

Regarding InductICE, Mancini says that ‘basically, the objectives have been reached, with 90-98% of the generated power reaching the metallic mesh, and they managed to build a modular, flexible and lightweight solution. And although not everything was reached, it’s a very big step forward.’

Although the results from PIPs, InductICE and i3PS do not support any specific demonstrator, what is important to note is that the promising results from these projects will provide sufficient data to support application on actual aircraft, and with further technical work, could become competitive technology approaches for ice protection.

‘This is one of the most rewarding aspects of working in Clean Sky,’ concludes Redondo. ‘The working experience is excellent, always with an open spirit and people willing to support. While Clean Sky is a research and innovation programme, the pressure related to production type programmes was not present at all times, the limitations given by processes and procedures are much less penalising. All these aspects made inspirational ideas a resource which could be further developed.’