



Thermal protection layer destroyed, sensors blocked

09 October 2014

The effects of volcanic ash on aircraft engines

Volcanic ash can cause serious problems for aviation. Under Project VolcATS-Vehicle (Volcanic Ash Impact on the Air Transport System), researchers from the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) are investigating the effects of volcanic ash on aircraft. The focus of the work is on the impact of ash on engines, and its effect on the performance of aircraft due to contamination of flight data sensors and navigation and communications equipment.

The results of these investigations should help with estimates of the risk potential for aircraft. The data acquired on loss of thrust, for example, will influence the design of future experiments and also be used for computer simulations. "The threshold value for air traffic is currently an ash concentration of two to four milligrams per cubic metre. However, one significant factor is the amount of ash encountered during the course of a flight," says Hendrik Lau, Project Manager for VolcATS-Vehicle. "In our investigations, we want to determine in which areas ash is harmful to engines."

The eruption of Icelandic volcano Eyjafjallajökull in 2010 and similar eruptions around the world have demonstrated how worldwide air traffic can be significantly disrupted by this kind of natural phenomena. The effects of ash particles on critical components of an aircraft, such as the combustion chambers, compressors and sensors, are still not sufficiently understood and need to be investigated in greater detail.

Artificial volcanic ash

The DLR Institutes of Materials Research, Flight Systems and Propulsion Technology are contributing to the VolcATS-Vehicle project. The work packages are focused on the direct impact on the engine, the engine blades and the combustion chambers. In addition, the institutes are working on the development and thermophysical characterisation of artificial volcanic ash for use in realistic tests, and the analysis of known aviation incidents associated with volcanic ash.

To scientifically investigate the different combinations under realistic conditions, various test stands and test methods have been developed. With these, the different operating phases and temperatures of an engine can be realistically simulated.

Ash in the engine

Volcanic ash mainly damages aircraft engines as a result of the erosion caused by sharp-edged particles and by the presence of molten ash. The clogging of fuel nozzles, cooling air holes and turbine flow cross-sections poses an additional problem. Radio interruptions and effects on navigation systems are also reported in flights through volcanic ash clouds. In addition, the pitot tubes used to measure velocity have been contaminated by volcanic ash.

The level of damage depends heavily on the actual geometry of the particles, their concentration, the operating conditions of the engine, and the physical and chemical properties of the ash. While erosion by volcanic ash is largely comparable to erosion caused by desert dust, there has been almost no understanding to date of what damage volcanic particles can cause in the combustion chamber and on high-pressure turbine blades.

To guarantee efficient, clean combustion, the temperatures inside modern turbines are far above the melting point of steel (flame temperatures of 2000 degrees Celsius or more). Therefore, components with a particularly high thermal load such as combustors and turbine blades are equipped with a layer of ceramic thermal protection. This protective layer has a columnar structure that makes it flexible, and it can adjust to the temperature-related expansion of the underlying metallic structure. Because of its complex chemical composition, volcanic ash has a melting range rather than a melting point, which can start at just 900 degrees Celsius. Softened like honey, it can be baked onto the ceramic protective layer, stripping the columnar structure of its flexibility and thus reducing the thermal shock resistance of the insulation. With an enamelled pot, the compact enamel (ceramic) flakes off if the pot is deformed; similarly, a heat insulation layer that has been compacted by molten volcanic ash flakes off as the turbine blade expands and contracts during the various flight phases. Consequently, unprotected metallic surfaces on the turbine blades come into contact with the hot gas flow and can become molten in places. This localised melting causes the turbine blades to lose their optimum aerodynamic shape, leading to loss of performance and increased fuel consumption. In extreme cases, the turbine can fail.

The VolcATS and iVAR projects

DLR is combining its research work on the effects of volcanic ash on air traffic in the VOLCANic Ash impact on the air Transport System (VolcATS) project as well as the Increased Volcanic Ash Resistance (iVAR) project. VolcATS includes a satellite-supported process that quickly determines and predicts the distribution of ash in the air and contributes to flexible air traffic management so that ash-free and hence safe regions for commercial aviation can be approved. In addition, the still inadequately understood effects of volcanic ash on aircraft engines are being investigated, and an ash warning system for commercial airliners is being designed.

Participants include the DLR Institutes of Atmospheric Physics, Flight Guidance, Materials Research, Propulsion Technology, Flight Systems and Air Transportation Systems, together with DLR Flight Experiments. During the Eyjafjallajökull eruption in 2010 the airspace over Germany was able to be re-opened on the basis of measurement flights performed by the DLR Falcon. The Falcon is the only research aircraft in Europe that is legally able to fly at high altitudes and over long distances in volcanic ash clouds.

Under Project iVar, which is being conducted in collaboration with the Physics and Environmental Measurement Techniques Laboratory at the University of Applied Sciences in Düsseldorf, the turbine blades of a small gas turbine have been coated with commercially available, flight-tested and also potential future thermal insulation layers. In a test system similar to a wind tunnel, specified volcanic ash concentrations are evenly dispersed into the intake air of the turbine, thus creating the conditions in the turbine of flying through an almost realistic volcanic ash cloud. This enables the damaging effect of volcanic ash particles on a jet engine to be investigated under the most realistic test conditions possible.

Contacts

Michel Winand
German Aerospace Center (DLR)
Corporate Communications
Tel.: +49 2203 601-2144
Michel.Winand@dlr.de

Dr Hendrik Lau
German Aerospace Center
Institute of Materials Research
Tel.: +49 2203 601-2343
Hendrik.Lau@DLR.DE

Detail of a melted turbine blade



If unprotected metal surfaces of turbine blades come into contact with the hot gas flow, they can undergo local melting.

Credit: DLR (CC-BY 3.0).

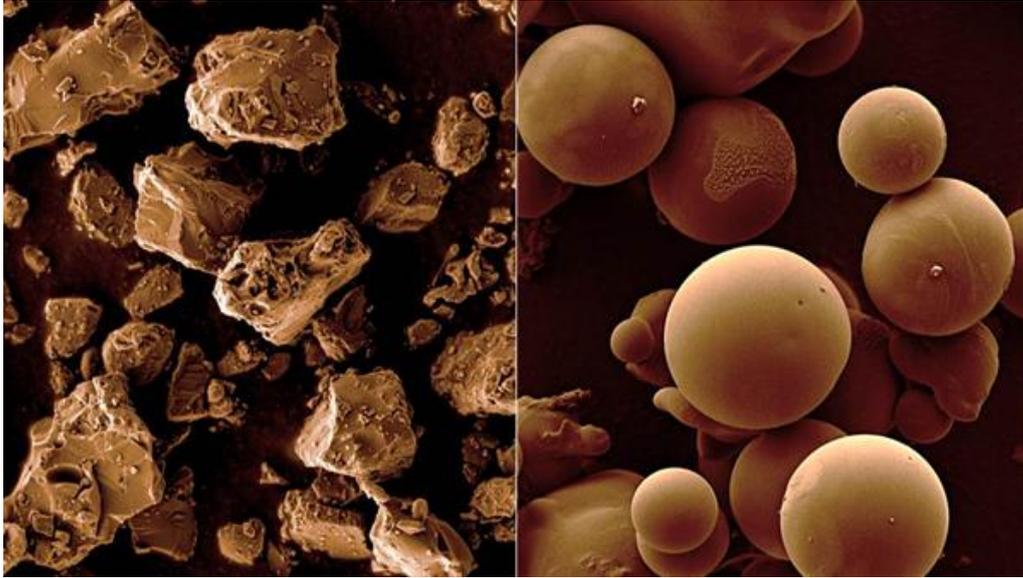
Partially melted turbine blade



The local melting process causes the turbine blades to lose their optimal aerodynamic shape, which leads to a loss of power and increased fuel consumption. In extreme cases, it can lead to failure of the turbine.

Credit: DLR (CC-BY 3.0).

Ash particles under the microscope



Splinter-shaped ash particles from the Eyjafjallajökull volcano (left). When passing through a 1700 degree Celsius flame, the particles quickly convert into melted droplets (right).

Credit: DLR (CC-BY 3.0).

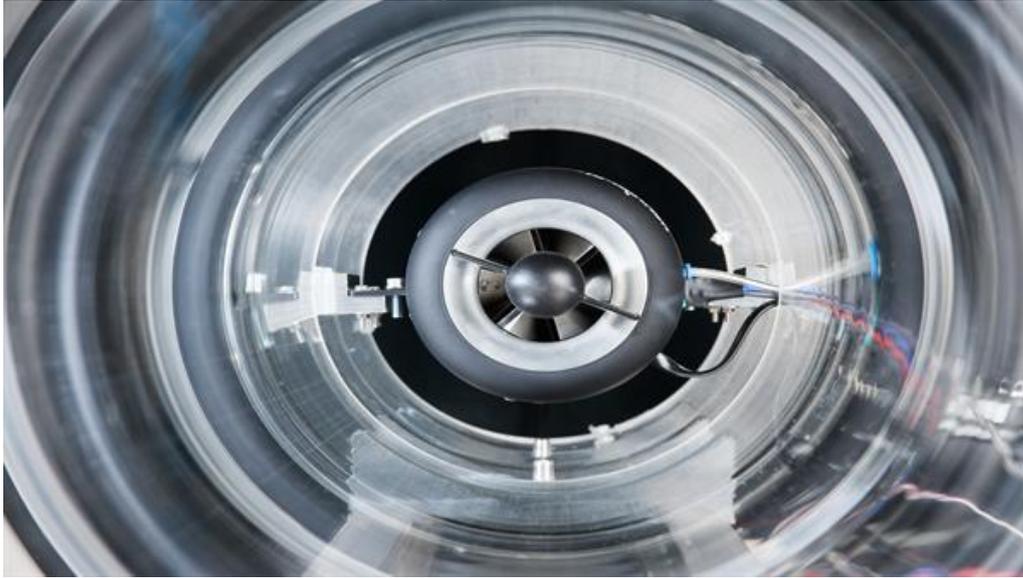
Ceramic coating destroyed by ash



With an enamelled pot, the compact enamel (ceramic) flakes off if the pot is deformed; similarly, a heat insulation layer that has been compacted by molten volcanic ash flakes off as the turbine blade expands and contracts during the various flight phases.

Credit: DLR (CC-BY 3.0).

View of the volcanic ash test facility



Under Project iVar, which is being conducted in collaboration with the Physics and Environmental Measurement Techniques Laboratory at the University of Applied Sciences in Düsseldorf, the turbine blades of a small gas turbine have been coated with commercially available, flight-tested and also potential future thermal insulation layers. In a test system similar to a wind tunnel, specified volcanic ash concentrations are evenly dispersed into the intake air of the turbine, thus creating the conditions in the turbine of flying through an almost realistic volcanic ash cloud. This enables the damaging effect of volcanic ash particles on a jet engine to be investigated under the most realistic test conditions possible.

Credit: DLR (CC-BY 3.0).

Contact details for image and video enquiries as well as information regarding DLR's terms of use can be found on the DLR portal imprint.