PROVIDA (PROtection against Volcanic ash Induced Damage in Aeroengines) Project

Minutes of the 2nd Progress Meeting
Cambridge, 10.00am, 18th June 2014

Attending

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2.1 Welcome & Introduction

The meeting started with a tour of some of the facilities in the Department, including the Process Area, X-Ray Diffraction, Mechanical Testing and the Gordon Lab. Introductions were made, including SJ & SG via telelink from ARCI (Hyderabad).

2.2 Apologies for Absence

There were none.

2.3 Minutes of last meeting (9th April 2013)

TWC explained that the last meeting took place soon after the grant announcement was made, over 12 months ago. Some of the material in the minutes is now slightly outdated. Furthermore, the consortium involved in the project is now considerably larger, with several industrial and other organisations that were not originally involved in the proposal now participating. Nevertheless, the minutes of the last meeting were noted and it was agreed that an updated Gantt chart would be produced.

It was later agreed that a new umbrella name (PROVIDA) would be used to describe the overall activities of the group now participating in the project.

2.4 Update on contractual & technical situation at Cambridge

TWC reported that CT has been employed on the project as a post-doc in Cambridge since March 2014, which is the formal start date of the project. YS is currently carrying out a short term Masters project and it's planned that she will start a PhD in October 2014 (with the studentship primarily supported by the Ultra-Precision Manufacturing CDT in Cambridge). JD is not directly supported on the project , but will be providing modelling support through an arrangement with EasyJet.

Experimental work has already started at Cambridge, and the Combustion Chamber Simulation Rig (based on a plasma torch in a vacuum chamber) is now fully operational. Preliminary experiments have been carried out (injecting Laki ash) and some provisional conclusions drawn - see §2.7 below.

2.5 Update on contractual & technical situation at Cranfield

SG reported that the contract agreement is in place and payments will shortly be made (via Cambridge). HT is employed as a post-doc and new PhD is due to start soon. The focus of the work at Cranfield is on modelling, particularly of the impingement of hot particles on solid substrates. Some information regarding the conditions and material properties of primary interest will shortly be supplied by Cambridge.

2.6 Update on contractual & technical situation at ARCI, Hyderabad

SJ reported that they are still negotiating with DST and formal approval has been obtained from them. SG is in post and there is one more position to fill. It was noted that TWC will visit Hyderabad in November, partly to give a talk at an International Thermal Spray conference. SJ emphasised that, while travel funds may be limited, the Indian partners aim to visit the UK at some stage. (There are in any event plans for a workshop in Cambridge sometime over the next year or two, and hopefully all partners will attend this: a possible time is Easter 2016.) SJ noted that all of the facilities required for the work at ARCI are already in place.

2.7 Summary of recent work at Cambridge

A presentation was made by CT, concerning VA deposition in a customized tubular set-up simulating the conditions in a turbine combustion chamber. Five VA types have been identified for detailed study - Hekla (100% glassy), Askja (85%), Laki (70%), Eyja (40%) and Eldgja (25%). Values of T_g and T_m have been obtained for these (using a novel procedure with a dilatometer, as well as conventional DSC) and there have also been some milling, sieving and particle size analysis operations. Thermal and velocity fields within the tube have also been studied experimentally. High deposition rates (up to 15%) have been observed for small (25 μm) particles of Laki ash, particularly on rough surfaces. The presentation will shortly be uploaded to the PROVIDA website. It was noted that numerical modelling of particle flight histories in the set-up will be instigated soon. TWC also gave a presentation, focussed on the damage to coatings (promotion of spallation) that can be caused by the presence of CMAS (particularly VA). This was part of a presentation to be given in late June at the TBC IV conference (http://www.engconf.org/conferences/materials-science-including-nanotechnology/thermal-barrier-coatings-iv-2/).

2.8 Priorities of Monitor Coatings regarding the project

A presentation was made by SSC. This included an overview of the company profile. It has recently become part of the Messer Group (Castolin Eutectic). Monitor have an interest the project, particularly relating to TBCs and other coatings in gas turbines, and have offered support when appropriate concerning supply of coated samples etc.

2.9 Priorities of Rolls Royce regarding the project

A presentation was made by RC, focussing on the interests of Rolls Royce in characterising damage from ingested VA particles. A map was presented of exposure time against the VA burden of ingested air, on which lines can be drawn representing specified dosage levels. Areas of the map can in principle be identified as representing different expected severities of damage, although it has to be recognised that factors affecting the likelihood of particle adhesion, notably particle size and softening temperature, will probably be relevant. Nevertheless, the usefulness of the concept is clear, and such maps can now be populated with at least a few particular aircraft incidents (for which the severity of damage is approximately known).

RC also gave a brief update on VERTIGO (www.vertigo-itn.eu), which is a large EU (FP7) project that started in January 2014 and will run for 4 years. It has a broad remit, with 20 european institutions involved, and is largely focussed on improved understanding of volcanic eruptions. It was noted that good awareness of the activities of other relevant projects, such as that one, is likely to be helpful.

2.10 Priorities of EasyJet regarding the project

A presentation was made by GP, mainly concerning the full scale engine tests that EasyJet plans to carry out in the fairly near future, which will effectively be done within the PROVIDA project. These will be carried out in a large outdoors facility in Cincinatti, with the involvement of GE. Seven (life-expired) engines have been identified. These are all CFM56-3 engines manufactured by GE - see http://www.geaviation.com/press/cfm56/cfm56-3/cfm56-3_19991217a.html. The details of the planned tests were discussed. For each engine, borescope examination can be carried out after each run. However, it will only be possible to dismantle the engine once for more detailed examination. Moreover, once deposition of ash particles becomes substantial in a

particular location, it's likely that subsequent deposition there will become easier. It's therefore likely that reliable information obtainable from each engine will be relatively limited and the tests will need to be carefully planned. In particular, it was agreed that they should cover a range of VA types and particle size distributions. Concerning the latter, it was noted that there may be differences between the size of particles being initially ingested and those reaching the combustion chamber - as a result, for example, of larger particles being centrifuged out into the by-pass air stream and/or being fragmented by impact with the compressor blades. Of course, this will also tend to happen to a similar degree during aircraft flight (although any effect of engine motion through the air will be lost in the tests), but it will not happen in the Cambridge simulation rig, so this may need to be borne in mind when correlating the two types of test. It was agreed that it would be helpful to collect particles passing through the by-pass flow and/or the engine exhaust, although it was recognised that this presents a challenge. Possibly a cyclone collector could be used for a short period (and it was noted that there is one available at Cambridge).

It was agreed that a target date for the full-scale engine trials would be summer 2015. This should allow time for a comprehensive set of experiments to be completed in Cambridge with the simulation rig, and the results from that work to be utilised in selecting the conditions for the engine trials. The quantity of ash required has been estimated and will be of the order of a few kg for each VA type (allowing for some milling and sieving to obtain required particle size distributions). This will be taken into account by MH - see §2.12 below). It was noted that each run would probably be quite short - perhaps of the order of a minute or two.

It was also noted that there would be a meeting in Paris on 8th July, at which some decisions would be made regarding the trials. The possibility of TWC and/or JD attending this meeting will be explored.

2.11 Priorities of Nicarnia Aviation regarding the project

A presentation was made by HT. This focussed mainly on current work being done within the AVOID project (http://nicarnicaaviation.com/technology/avoid/), which includes Airbus (http://videos.airbus.com/video/083304f97c9s.html) as well as Nicarnia and EasyJet. It was explained that current work includes imaging of volcanic ash clouds from the side (eg from an approaching aircraft), as well as from satellites, which offers potential for 3-D mapping of air ash burden densities. Two AVOID imaging systems being fitted to EasyJet planes and further tests have been conducted in Germany. It seems clear that close contact should be maintained between the AVOID and PROVIDA projects.

2.12 Sourcing and Characterisation of Targeted VA Types

A presentation was made by MH, concerning VA samples and a field trip she will be making in August/September 2014 to Iceland, in order to collect relatively large quantities (few kg) of selected ashes for the PROVIDA project. MH provided information about the locations and terrains concerned. Following some discussion, it was agreed that the types on which to focus for this trip will be:

- Hekla (probably H3) - 100% glassy
- Askja - 85% glassy
- Laki - 70% glassy
- Eldgja - 25% glassy

It's therefore been decided to drop Eyja (the 2010 eruption), partly because the site is rather difficult to access. It's felt that the above list covers the range of types quite well. (All of them have a T_g of around 600-700˚C and a T_m of about 950-1150˚C). MH indicated that she felt that visiting these four sites and collecting the quantities concerned (to be posted back to Cambridge) should be feasible in the time available. These ashes will be milled, sieved and analysed, and the same types of sample used in both Cambridge and EasyJet/GE experiments. The expenses for the Iceland trip, which will only amount to a few £k, will be covered from within the PROVIDA project.

RC suggested that VA from Mount Mazama (http://pubs.usgs.gov/fs/2002/fs092-02/) could be included in the PROVIDA project, since it will be used in much US-based work. It was agreed that this would be sensible and RC undertook to supply at least a small quantity of the ash, so that preliminary characterisation work can be undertaken in Cambridge.

2.13 Project Plans, Milestones and Deliverables

TWC briefly summarised the immediate objectives. It was agreed that a modified Gantt chart would be produced, taking account of the expanded scope of the project. This will be done within the next couple of months. It was noted that TWC will be visiting Hyderabad in November, which should provide opportunities for promoting links between the UK and Indian activities.

Date of next meeting

It was agreed that meetings should be held quarterly and that the next one will also take place at Cambridge. The week starting 22nd Sept. was identified as being suitable. The date of Wed. 24th was mentioned, but, following some consultations, that of Tuesday 23rd Sept. is now proposed. This will be confirmed shortly.