Geophysical Research Abstracts
Vol. 13, EGU2011-12157, 2011
EGU General Assembly 2011

Volcanic Ash versus Turbine Ingestion Test Sands: Thermal Stability Experiments

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Volcanic eruptions are an inevitable natural threat. The range of eruptive styles is large and short term fluctuations of explosivity or vent position pose a large risk not necessarily confined to the immediate vicinity of a volcano. Explosive eruptions rather may also affect aviation, infrastructure and climate, regionally as well as globally. The 2010 eruption of Eyjafjallajökull (Iceland) drastically brought into common awareness how volcanic activity can disrupt air traffic and thereby affect every day's life. The presence of solid particles in the air ingested in jet turbines may cause harm as it can lead to 1) abrasion upon impact and 2) deposition on surfaces upon being heated up.

Particles suspended in the atmosphere may have different origins, including volcanic ash, aeolian sand, or incineration residues, each of them having different chemical and physical characteristics. To date, aircraft turbine operability has mostly been investigated – amongst other tests – through the ingestion of sands whose grains have different mineralogical nature. Due to high cooling rates, volcanic ash is usually made up of glass, i.e. an amorphous phase lacking crystallographic order. Glass and crystal behave very differently to heating up. Glass will soften – and accordingly change shape or stick to surfaces – at temperatures as low as 700 °C, depending on the chemical composition. The melting of crystals however requires the breaking of strong crystallographic bonds and therefore leads to higher melting temperatures. Accordingly, the effect of ash on the operational reliability of aircraft turbines may not be judged solely based on knowledge commonly derived from mineral sand ingestion testing.

In order to investigate the behaviour upon heating, we performed a series of experiments at ten temperature steps between 700 and 1600 °C. We used three different samples: 1) Ash from the explosive phase of Eyjafjallajökull; 2) MIL E-5007C test sand (MTS), and 3) Arizona Test Dust (ATD). MTS and ATD are commonly used for aircraft turbine testing. Experiments have been performed on two different grain sizes, < 63 and $90<x<125$ μm, respectively. Samples have been removed from the furnace after 30, 60, or 120 minutes, respectively, and subsequently investigated for signs of sintering or melting. The visual characterisation of the samples revealed the following results: Sintering starts between 850 and 900 °C for the volcanic ash, at 1000 °C for the fine ATD, at 1100 °C for the coarse ATD, and at 1200 °C for MTS. We observed complete melting at 1050 °C for the volcanic ash, at 1200 °C for the fine ATD, at 1400 °C for the coarse ATD, and at 1600°C for the MTS sample. We are presenting thin section and microprobe data to document this sintering process. Additionally, we performed Differential Scanning Calorimetry measurements to more precisely constrain the mineralogical weakening temperature of the different samples. In fact, high values of viscosity may obscure a noticeable sintering of the samples during the time of the experiments. For the ash samples, weakening starts at around 700 °C.

These experiments clearly show the distinction between the behaviour of volcanic ash from Eyjafjallajökull and the two investigated non-volcanic sand samples conventionally used for turbine testing.