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The physico-chemical properties of volcanic ash: Does size matter?

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Explosive volcanic eruptions can inject large quantities of volcanic ash into the atmosphere. Fine-grained volcanic ash has the potential to stay in the atmosphere for days, weeks or even months. Suspended particles in general but volcanic ash in particular can negatively affect air traffic in a plethora of ways. Since the 2010 eruption of the Icelandic volcano Eyjafjallajökull, several experiments were carried out to determine the impact of volcanic ash on jet engines. There are two strings of experiments, those using natural volcanic ash and those using chemical equivalents in the Calcium-Magnesium-Aluminum-Silicates system (CMAS). Natural ash collected from the ground exhibits a range of grain sizes (from submicrometer up to hundreds of microns) as a function of distance from the source volcano. As the residence time of particles in the atmosphere depends on their size and density it becomes obvious that this ground collected ash does not necessarily represent the material which might be ingested into a jet engine. Additionally, it needs to be considered, that only particles <20 μm are expected to enter the combustion chamber of a jet engine (Vogel et al. 2016) where they will soften and/or melt and possibly attach to substrates, negatively influencing the functionality of the engine. Larger particles, however, are believed to stay in the bypass flow. These considerations lead to the question of a changing composition, hence changing properties, of the ash in dependence of their grain size.

Here, we present results on experiments using pristine volcanic ash from the 1 February 2014 eruption of Tungurahua volcano, Ecuador. We subdivided the bulk sample in four grain size fractions (<10, <32, 63-90, 125-180 μm) and constrained the grain size dependence on chemical and mineralogical changes as well as the melting behaviour. It turned out that particles <10 μm (PM10 fraction) show a significant enrichment of glass on the expense of the mineral phases (labradorite, augite, enstatite). Since the glass phase will be the first to soften upon heating in the combustion chamber of a jet engine, its increased presence within the PM10 fraction leads to an increased sticking potential on exposed surfaces (e.g., turbine section within a jet engine). The melting behaviour was evaluated based on four characteristic temperatures through an analysis of images obtained with a heating microscope (optical dilatometer). In consequence of outgassing effects, influencing the 2D-shape of ash samples <63 μm upon heating, the flow temperature was re-defined to improve measurement accuracy.

Our results clearly demonstrate the grain size influence on the phase composition of the Tungurahua ash as well as the determination of characteristic melting properties, determined with the heating microscope.

Reference

Vogel, A. et al., 2016. Volcanic ash ingestion by large gas turbine aeroengine: fan-particle interaction, Geophysical Research Abstracts, 18, EGU2016-15419.