High temperature properties of airborne dusts and their behavior in aircraft engines

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Introduction:

Every year, an estimated 2,000 million tonnes of dust is carried up into the atmosphere, mainly during sand and dust storms. This dust presents a major hazard to modern aircraft engines, which operate at extremely high temperatures that are close to the melting points of many of the minerals in the dust. This hazard is similar to that encountered when aircraft fly through volcanic ash clouds. Particles entrained into the air intake of a turbine engine may be heated to temperatures of over 1200 °C. If they melt they may clog up the cooling holes in the turbine blades or react with the blade material and cause various degrees of engine damage, leading to a shortened service life of the engine, and potentially engine failure. The hazard is greatest during take-off, when the engine runs at its hottest, and large concentrations of particulates are more likely to be present in the air either due to uplift of sands and dusts by local turbulence from the aircraft engine, or because of wind-generated sand and dust storms (Image 1). It is recognised by the aviation industry that this hazard is likely to get worse as future climatic variability and extremes result in an expansion of dusty environments, as well as more frequent and severe sand and dust storms. At the same time, engine operating temperatures are likely to be higher in the future than they are today. Despite this, there is currently a lack of detailed knowledge of how different compositions of dusts will behave in this high temperature environment.

Project Summary:

This PhD will involve building up a model of how complex natural mineral dusts will behave at the extremely high temperatures encountered in aircraft engines. The research will follow on from ongoing Rolls Royce-sponsored research to assess the likely mineralogy and particle size distribution of airborne dusts from a number of key airport locations. The project will begin by investigating the properties of individual minerals, and will then progress to simple binary and ternary mixtures, followed by multi-component mineral mixtures. One of the key questions to investigate is the extent to which unconsolidated mineral mixtures interact with each other during the melting process: does each component melt at a different temperature, or is there a eutectic melting point? Properties will be measured using: differential scanning calorimetry (DSC), to measure the temperatures of devolatilisation and melting reactions; high temperature furnace (up to 1700 °C), to freeze the samples at different stages of the melting process to enable a more detailed study of the chemistry and textures of the melting reactions; X-ray diffraction (XRD), scanning electron microscopy (SEM) and electron probe microanalysis (EPMA) of partially melted samples to determine the nature of the reactions taking place; Fourier transform infrared (FTIR) spectroscopy and EPMA of the glasses (= quenched melts) to determine if any of the volatiles released during melting (H_2O, CO_2, S, Cl) are incorporated into the melt. Further experiments in the high-temperature furnace will include sample encapsulation to prevent vapour loss and thus mimic the water vapour-rich atmosphere in aircraft engines, and experiments to investigate the interaction of the melting minerals with the ceramic thermal barrier coatings used in real engines.

This project will be suitable for a student who has a first degree in geology, chemistry or materials science. The student will be trained in using the above experimental and analytical equipment, all of which is available in the School of Earth and Environmental Sciences at the University of Manchester. The studentship will include a placement at Rolls-Royce, which will involve learning about engine operation and examining contamination on engine components following operation in dusty environments. The supervisory team of both earth *and* atmospheric scientists, together with the input of experts at Rolls-Royce, make this an exciting project which will have impact in the aviation industry, where it will inform engine damage models and hence the cost of ownership for aircraft engine manufacturers.

Image 1:

A dust storm at Nyala Airport, Sudan (by UA-320, http://spotters.net.ua/file/?id=65312&size=large, via Wikimedia Commons)

References

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