Adhesion of Volcanic Ash Particles under Controlled Conditions and Implications for Their Deposition in Gas turbines

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14th December, 2015, Cambridge

1. The Volcanic Ash Problem

Jet engines can be damaged by ingestion of volcanic ash (VA), if it adheres to solid surfaces after passage through the combustion chamber

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Criteria are needed for VA adhesion, based on both ash characteristics and conditions in the engine

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Systematic adhesion testing, and associated CFD modeling, is required, using a range of conditions and types of ash (composition and particle size)

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This should allow identification of combinations of conditions (“softness” of particles, impingement velocity, substrate roughness etc) for adhesion

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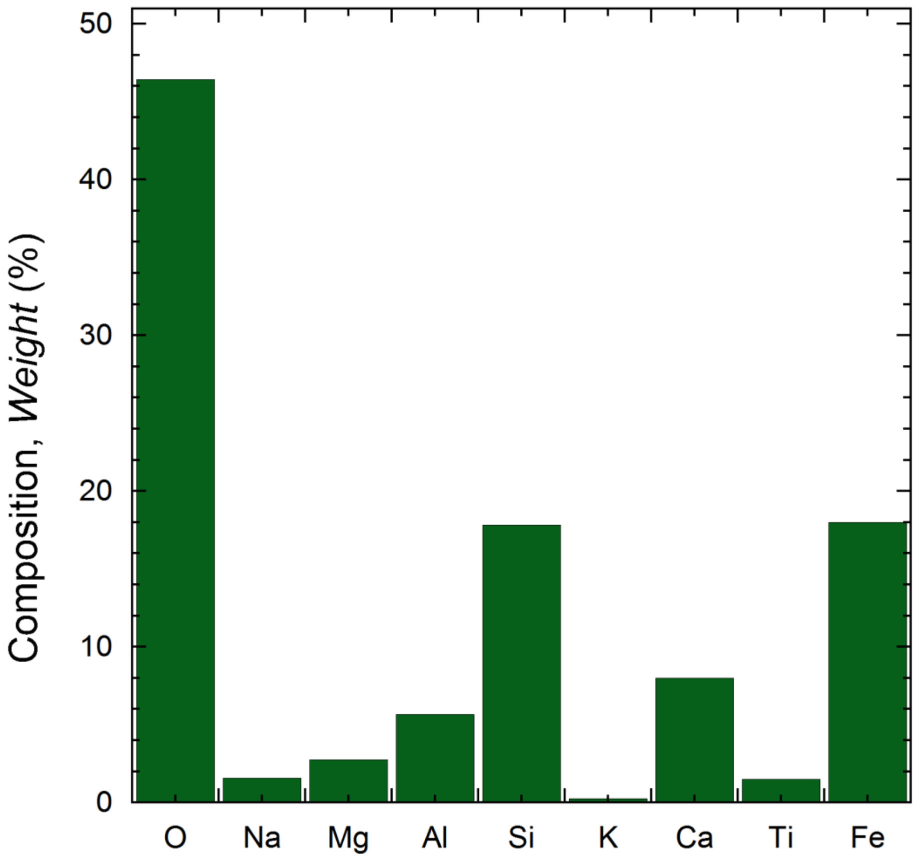
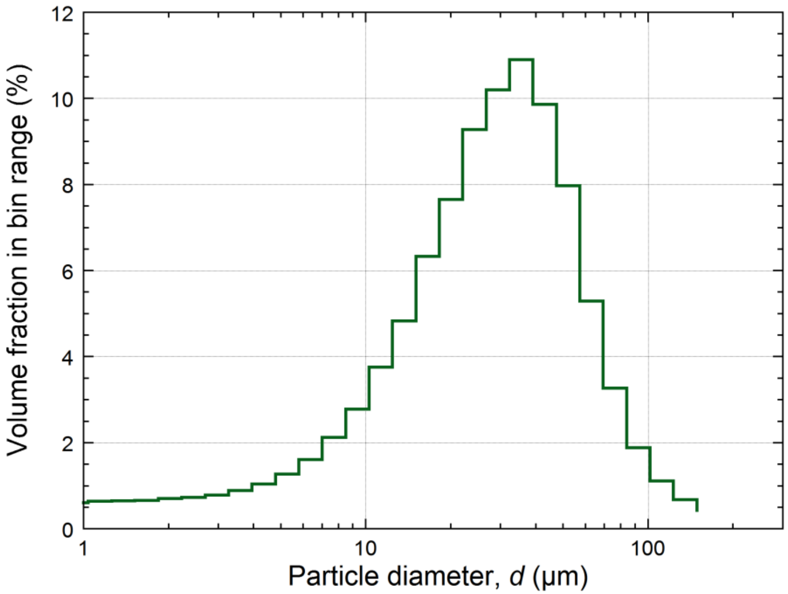
Such criteria can then be used to predict the likelihood of adhesion in real engines for a given ash type, or at least to classify the level of danger

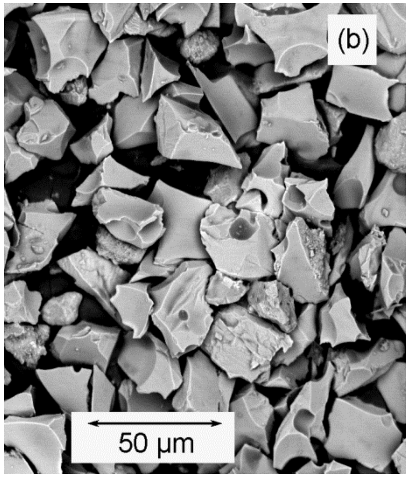
2. Laki Volcanic Ash: Composition and Particle Size

Composition



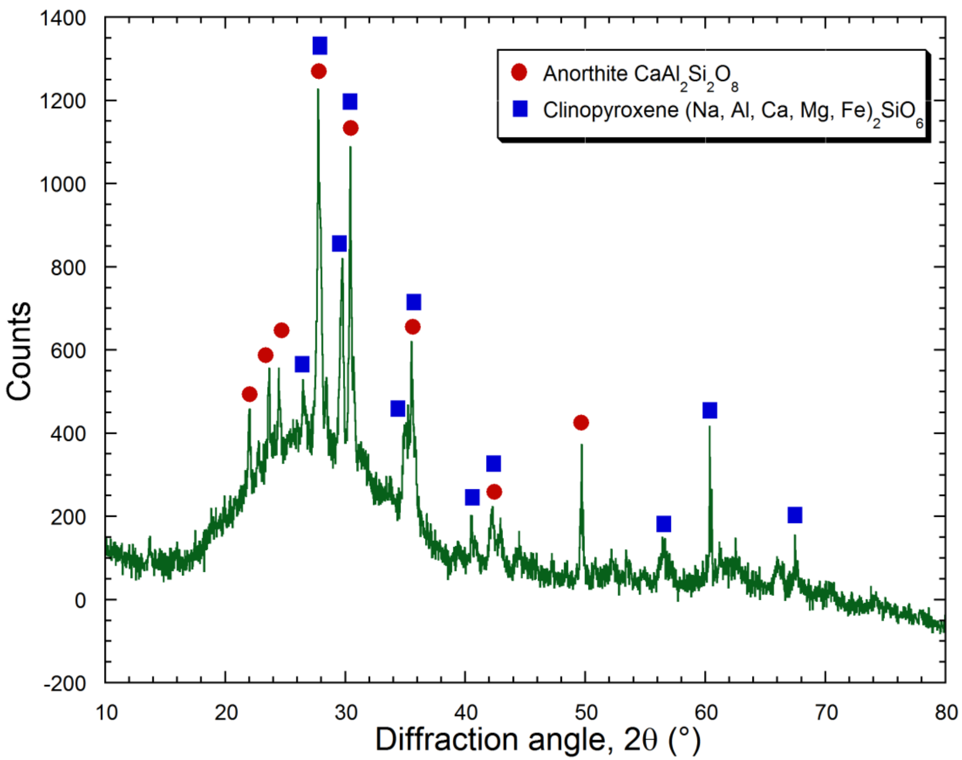
Particle size distribution (PSD)





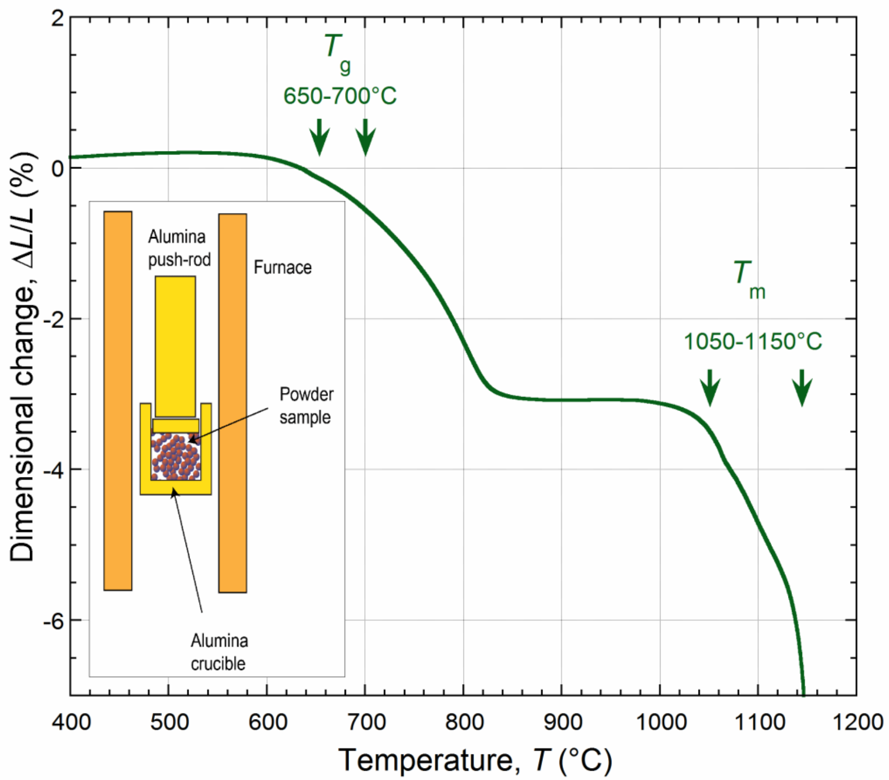
3. Laki Volcanic Ash: Amorphous Content and Softening T

Crystalline/amorphous content

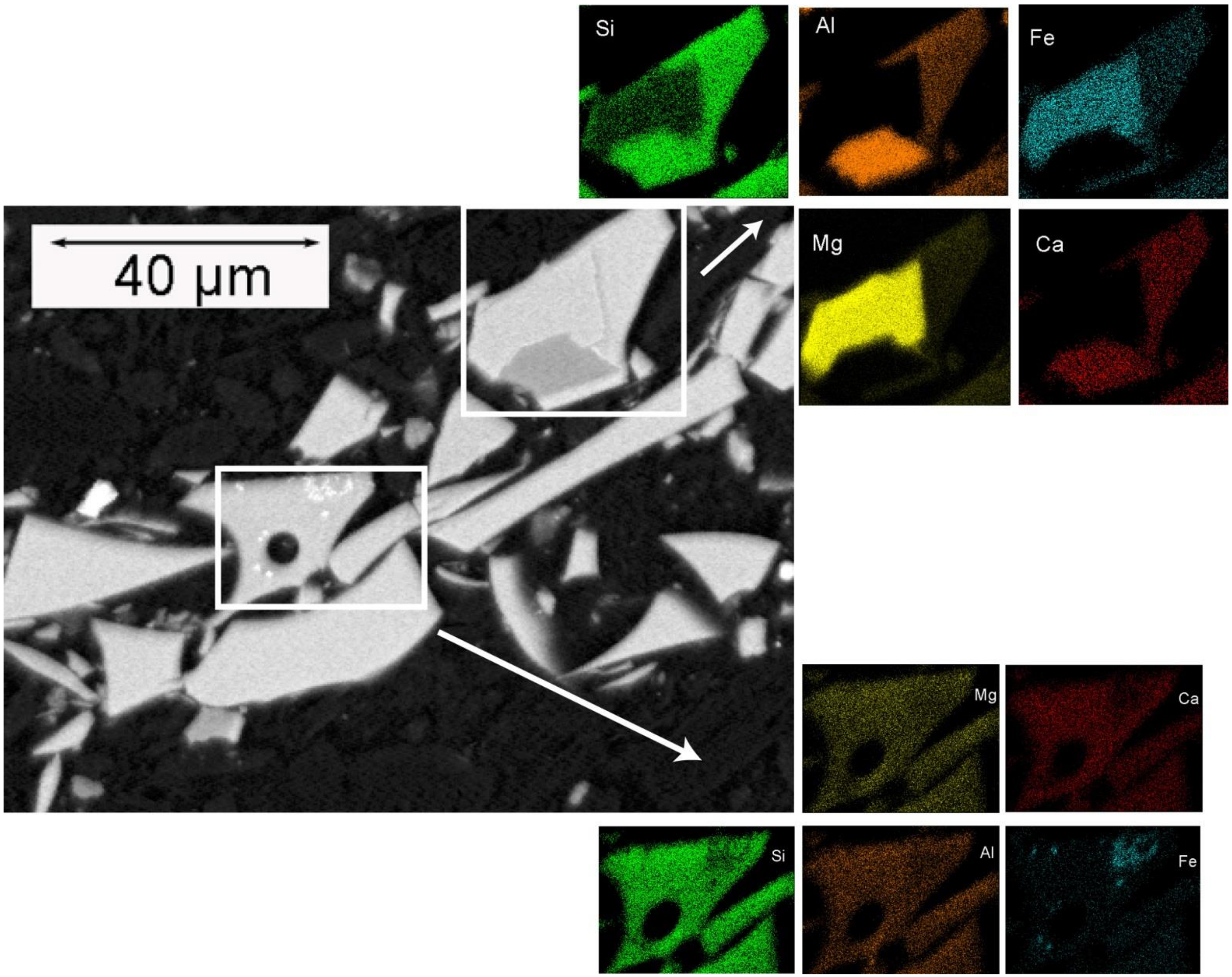


80% amorphous
20 % crystalline
(60 % Clinopyroxene+ 40% Anorthite)

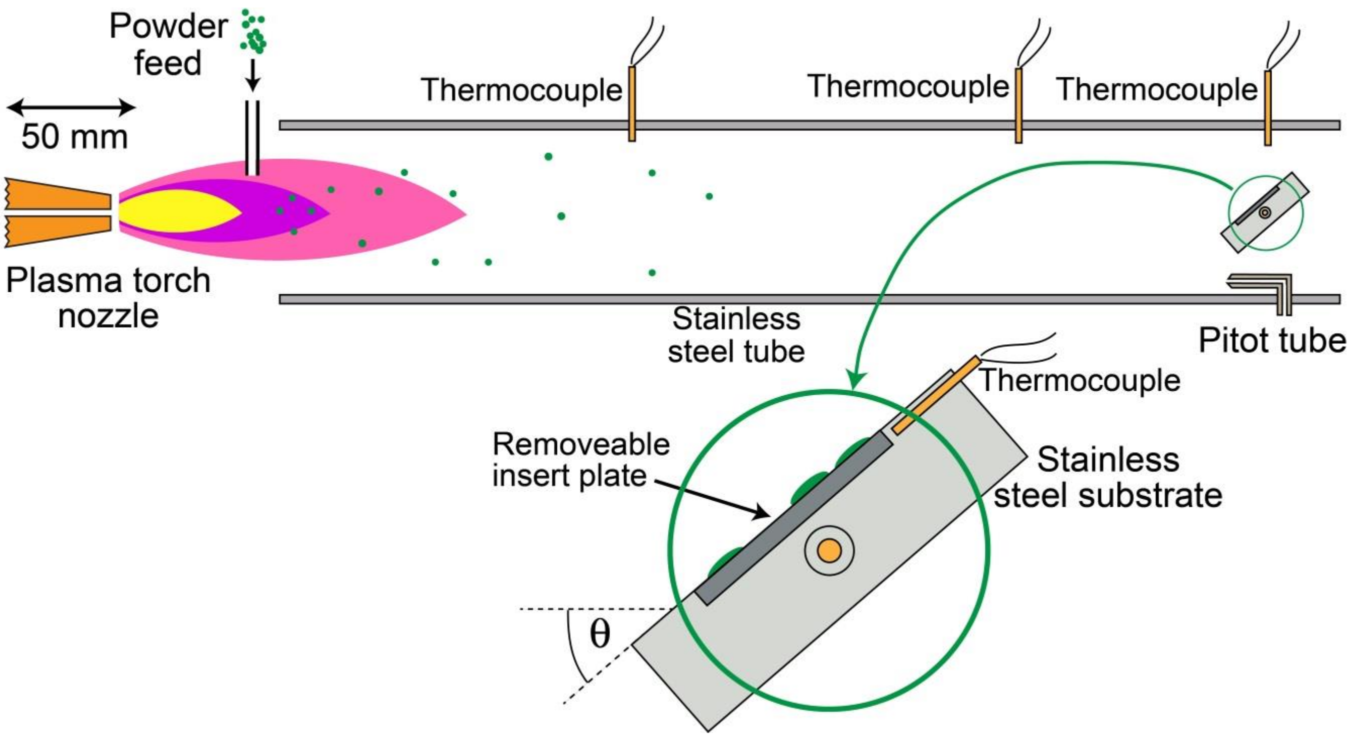
T_g & T_m



4. Laki Volcanic Ash: distribution of amorphous content



5. Experimental Approach to Exploring Adhesion of VA



Control over:

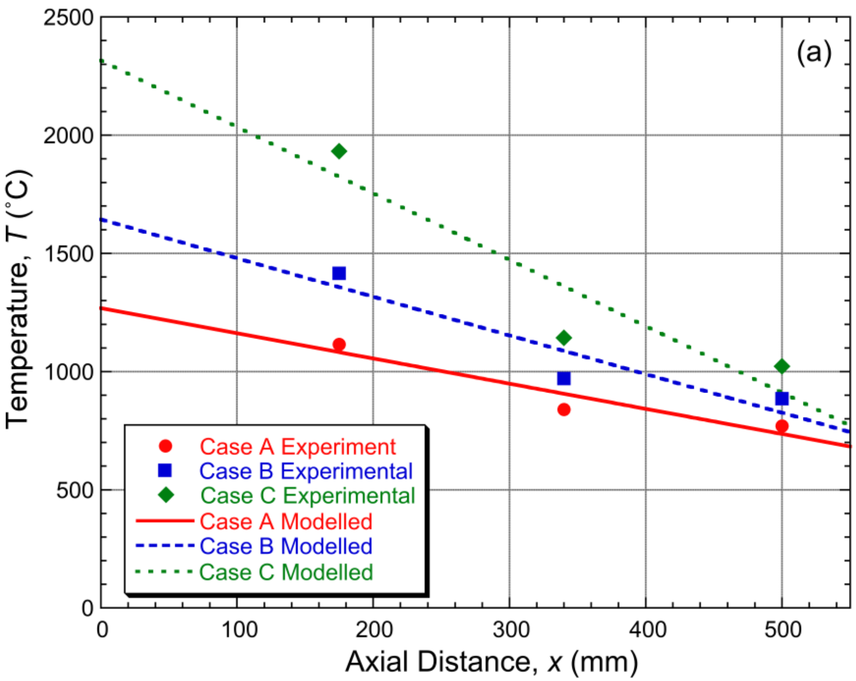
1. Thermal field
2. Velocity field
3. Substrate position

Measure:

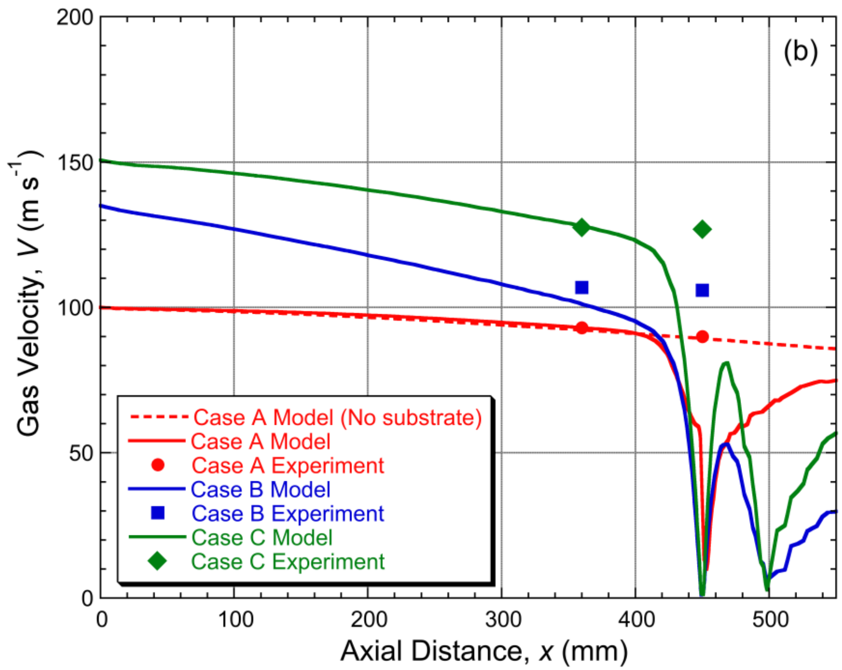
1. Mass Fraction of Particles incident on the Substrate that Adhere to it

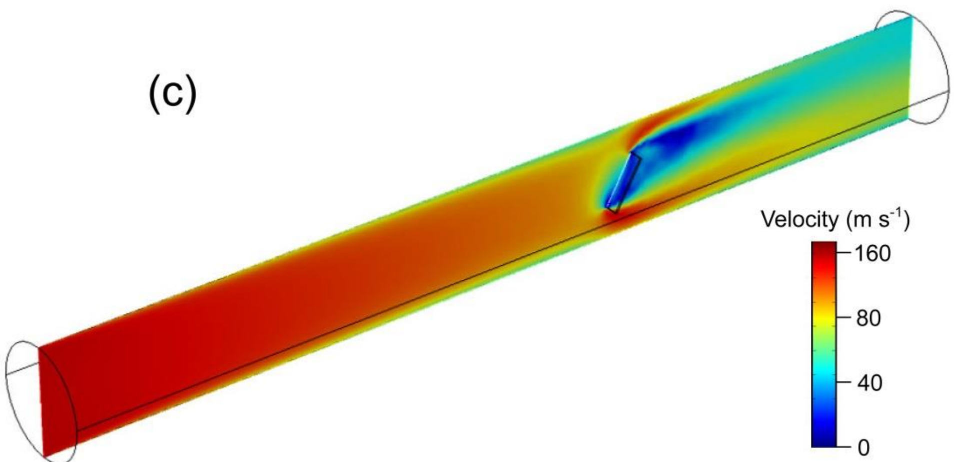
6. CFD Modeling: Velocity and Thermal Fields

Thermal Field



Velocity Field





Section of 3-D Velocity Field

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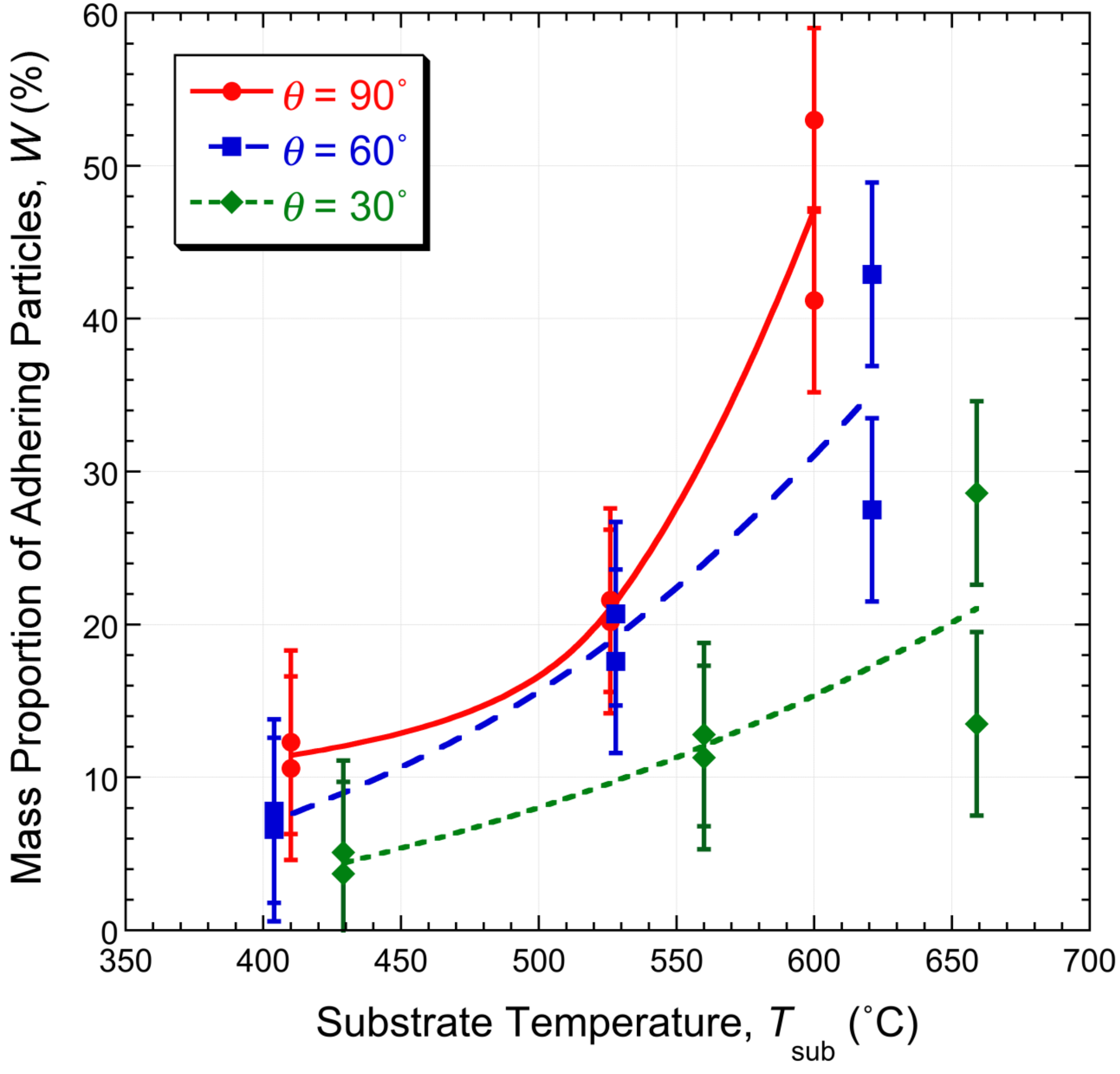
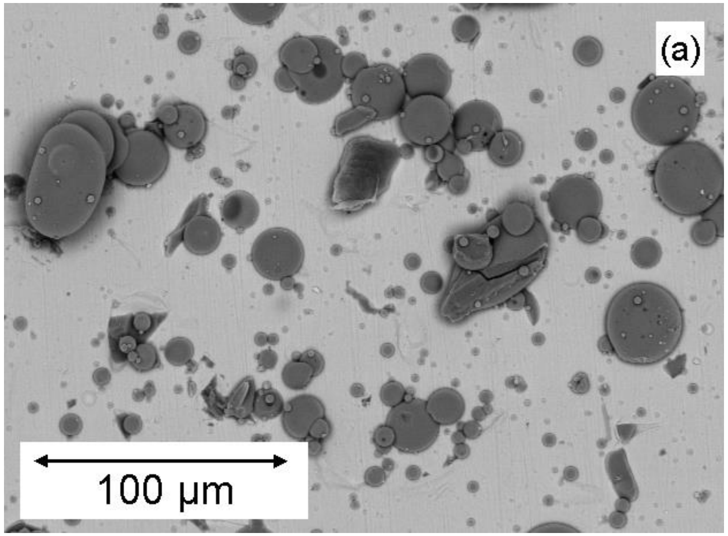
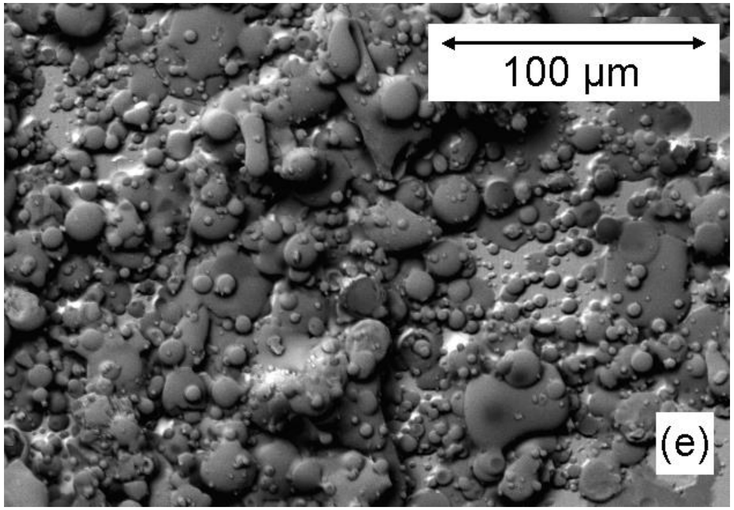
7. Measurement of Deposition Rate for Laki VA



θ= 90°/ Substrate T ~ 400°C

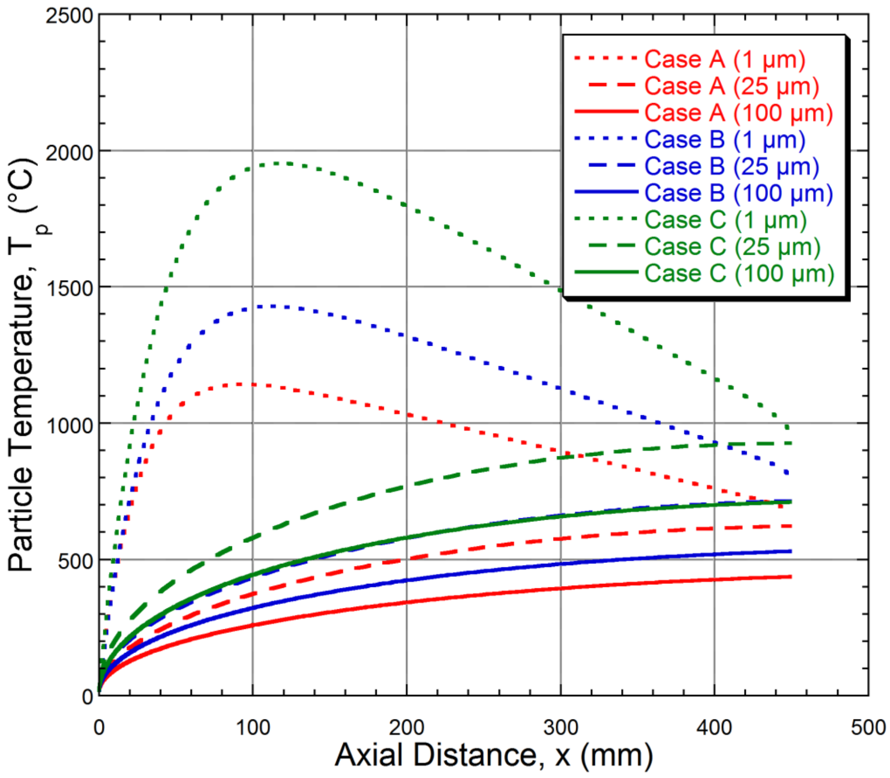


θ= 90°/ Substrate T ~ 600°C

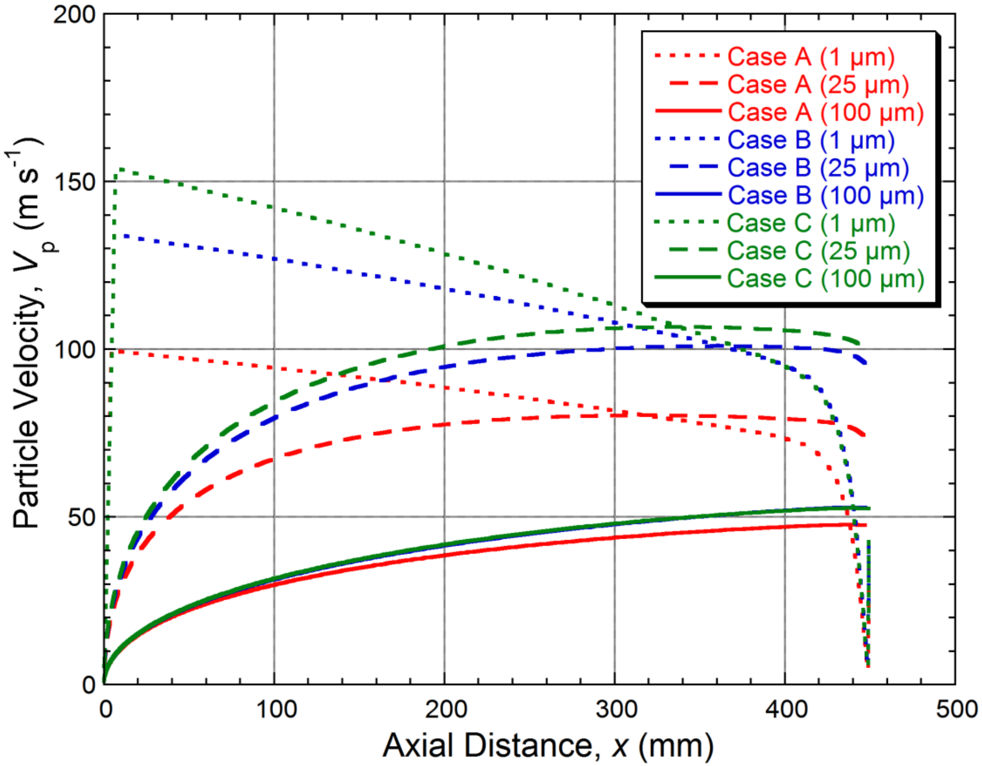


8. CFD Modeling: Particle Histories during Flight

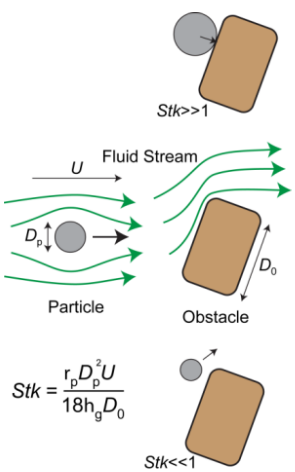
Particle Thermal Histories

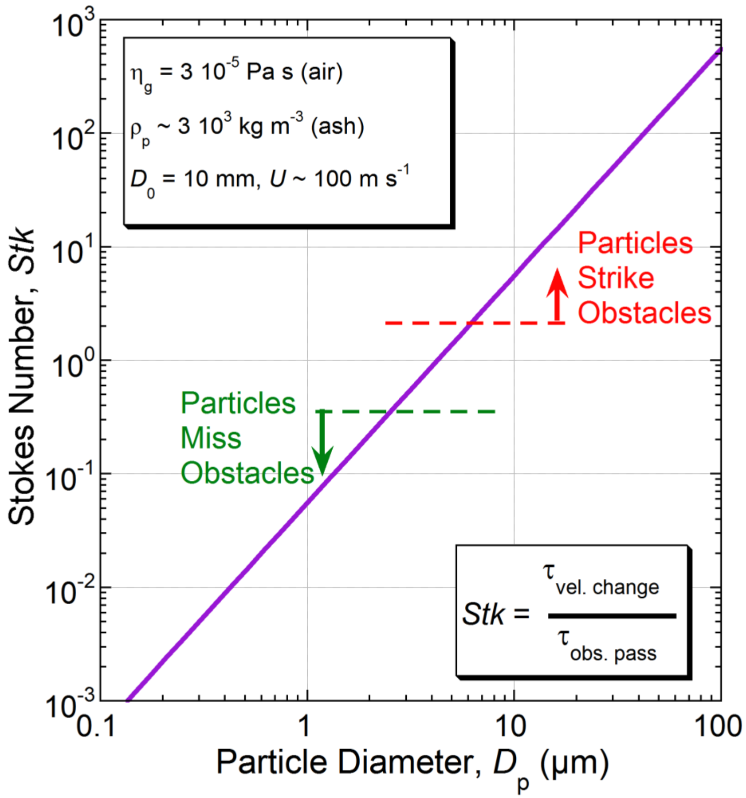


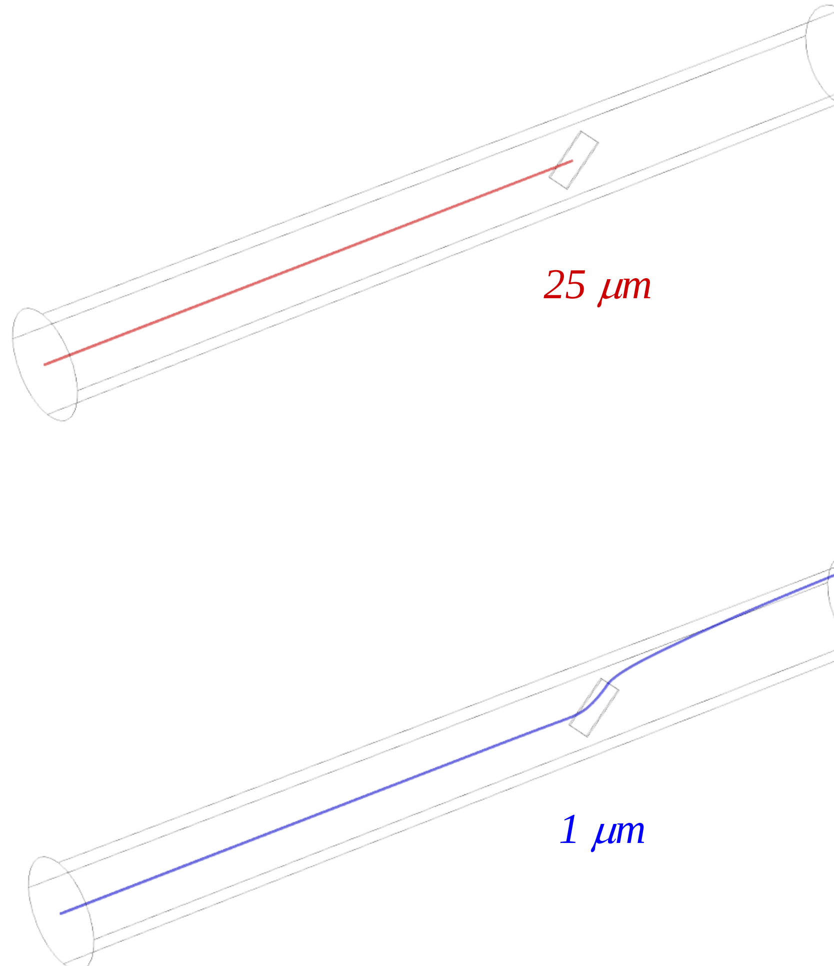
Particle Velocities Histories



9. CFD Modeling: Particle Striking the substrate

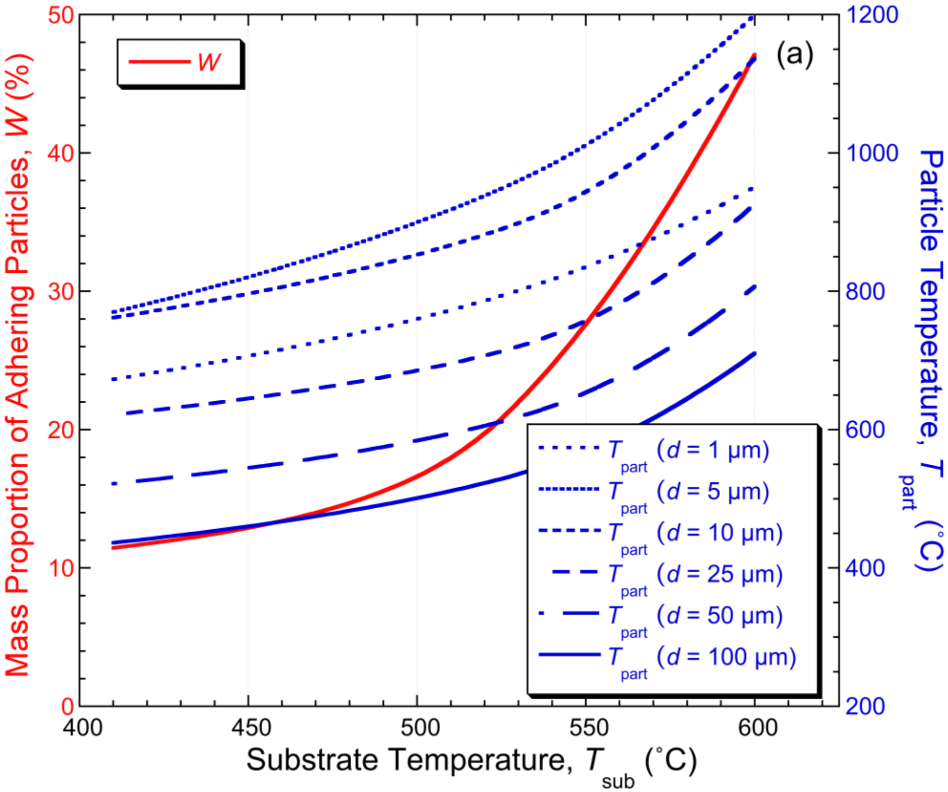




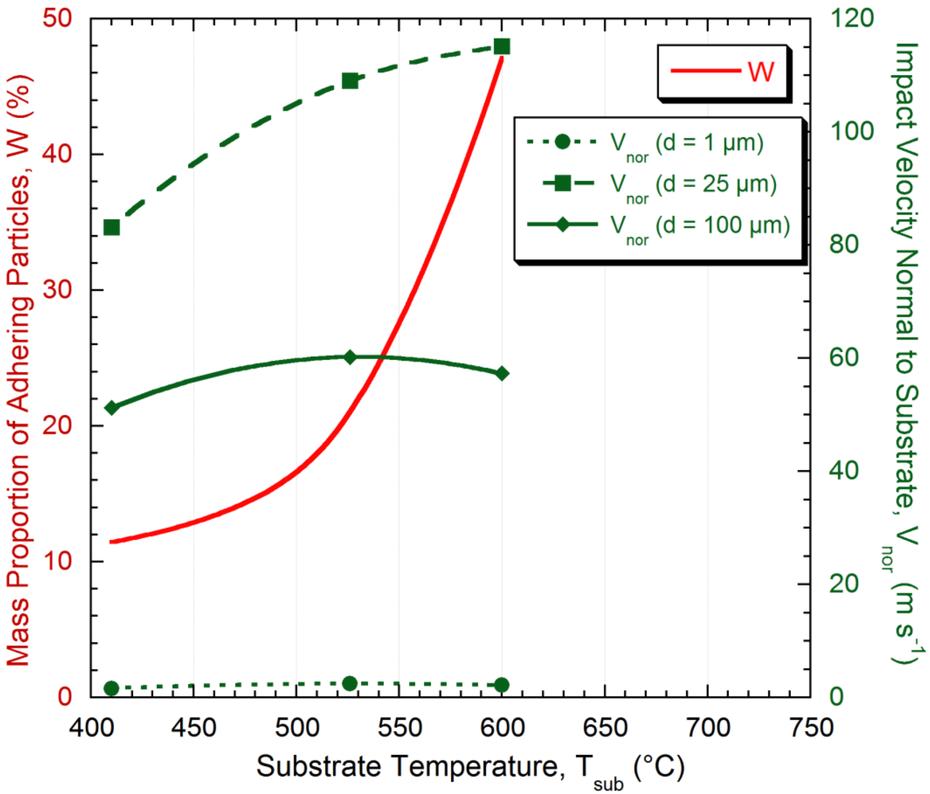


10. Correlation with Experimental Adhesion Characteristics

Particle Temperature influence



Particle Velocity Influence



11. Summary

- Deposition Rate Experiments, in combination with CFD Modeling, have been used to obtain insights into factors affecting adhesion of a typical VA (Laki)

- Particles only need to be >T_g in order to be likely to adhere (and this temperature is often well below T_m)

- Particle Size strongly affects T and V histories: small (<~few μm) particles don't strike substrates and large ones (>~50 μm) don't get hot enough, so intermediate sizes (~ 10-30 μm) are of most concern

- Extrapolation of this methodology to a range of VAs could provide a framework for assessment and prediction of the likelihood of adhesion of these particles into real jet engines.