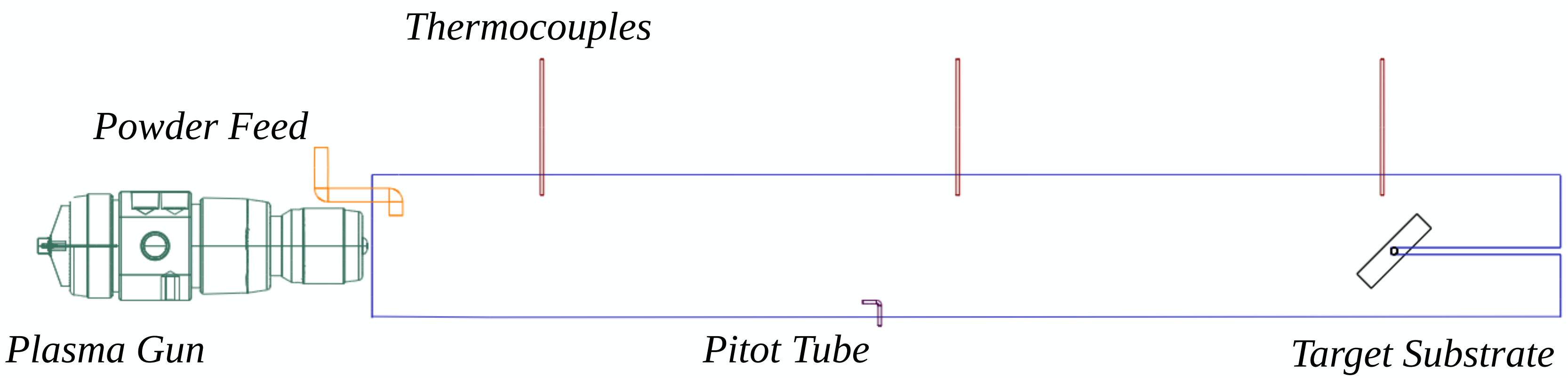
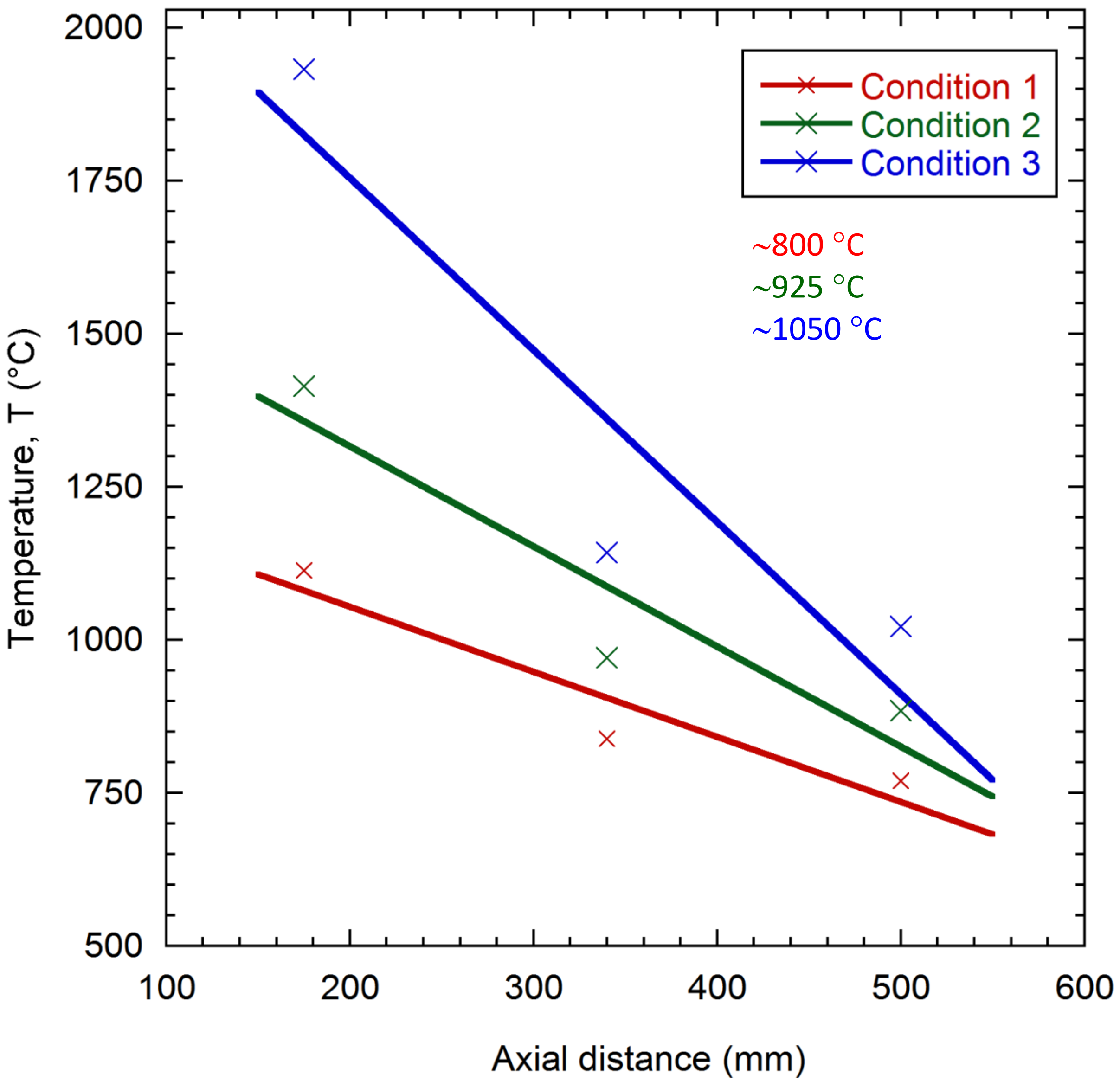
Summary of Recent Modelling Work at Cambridge

J. Dean, C. Taltavull, P. Earp & T. W. Clyne

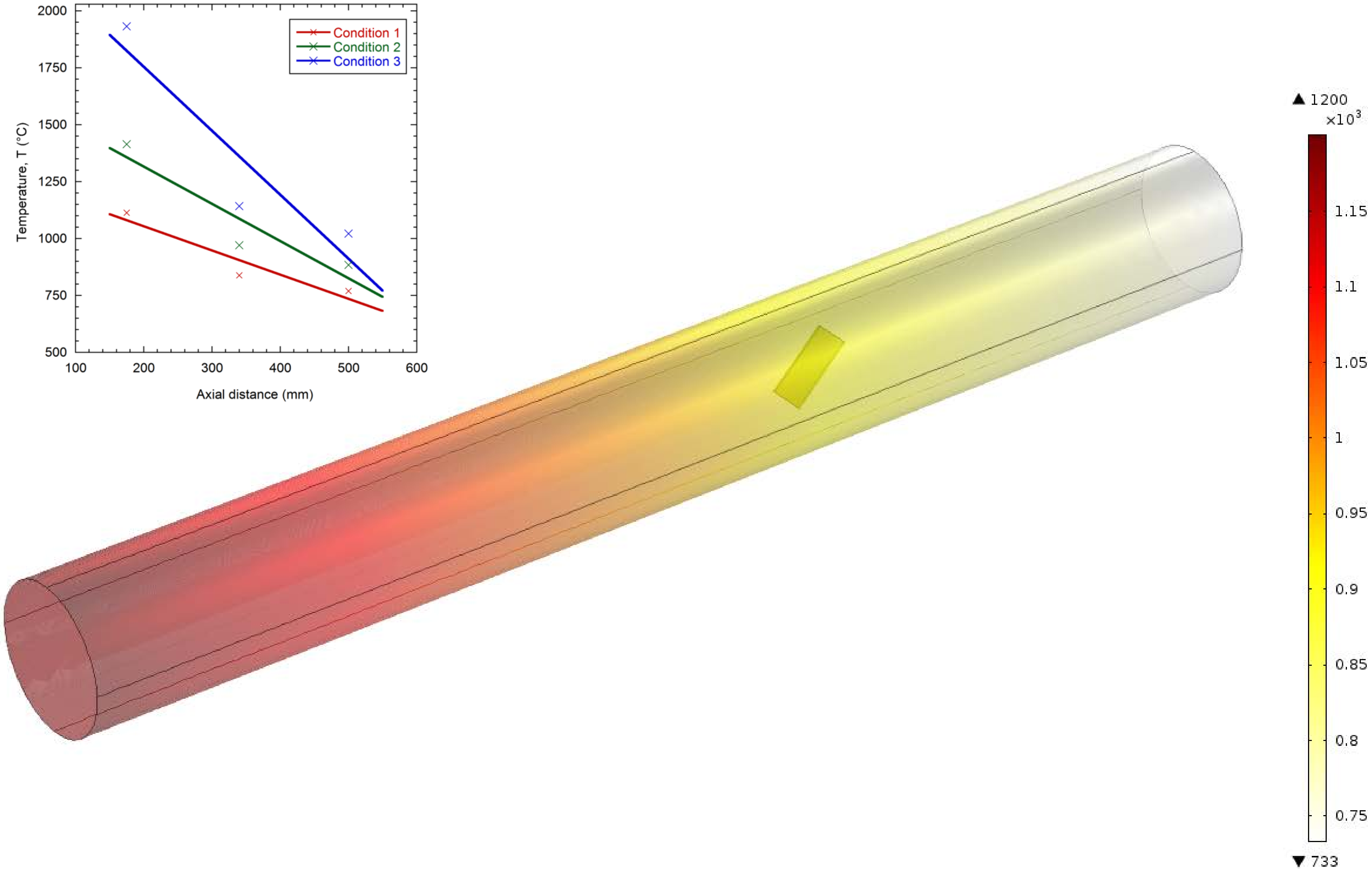
Experimental Overview



Experimental Data – Thermal Fields



Modelling – Thermal Fields – Condition 1



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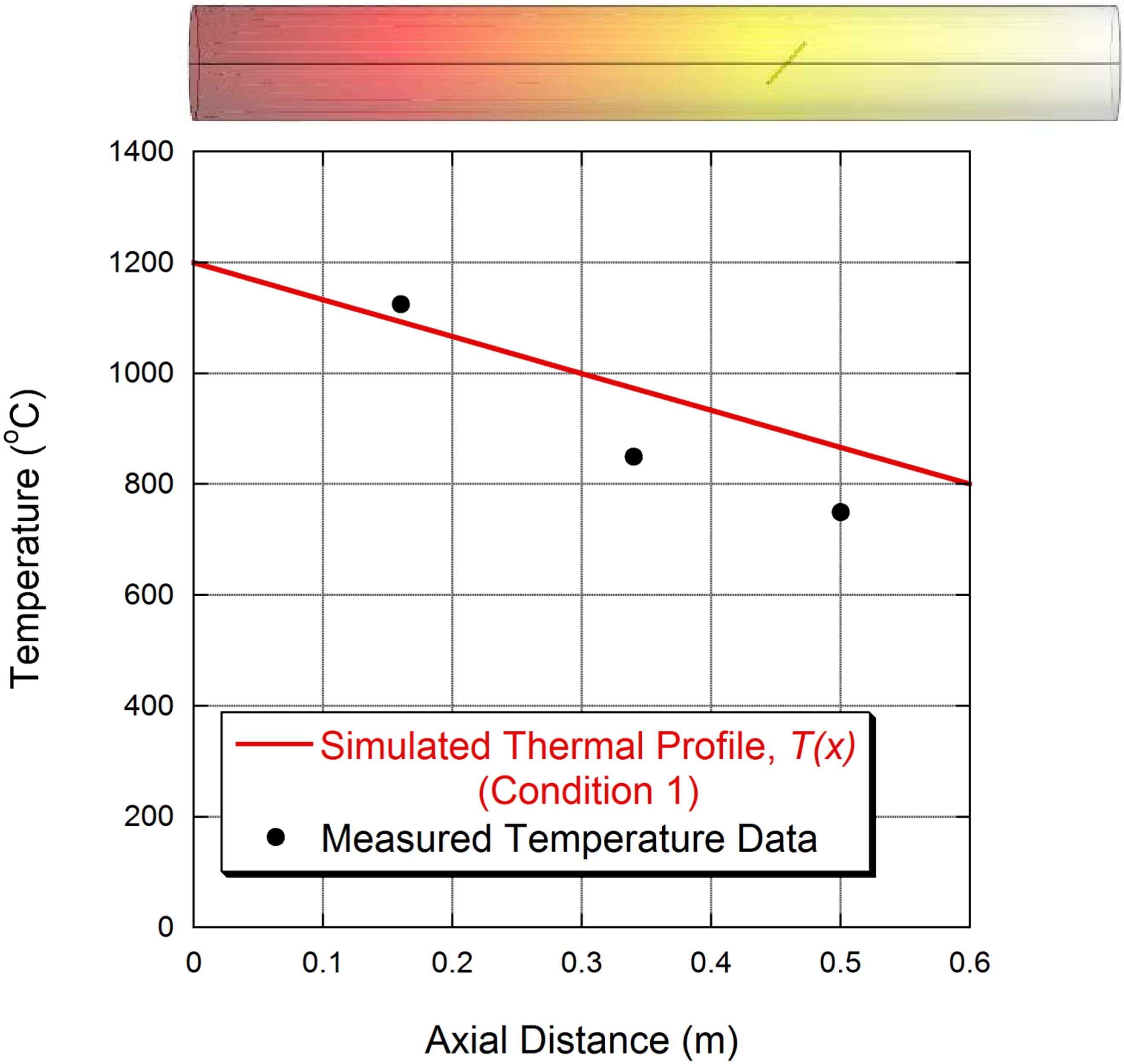
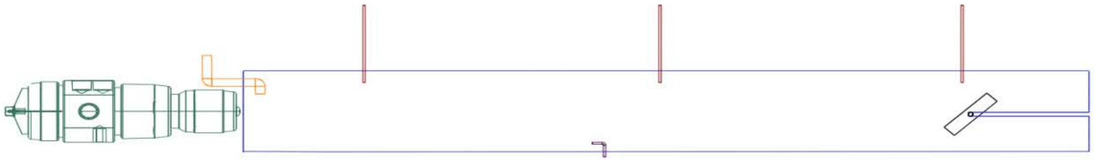


Modelling – Velocity Fields – Condition 1



Re > 10,000 (Turbulent flow model)

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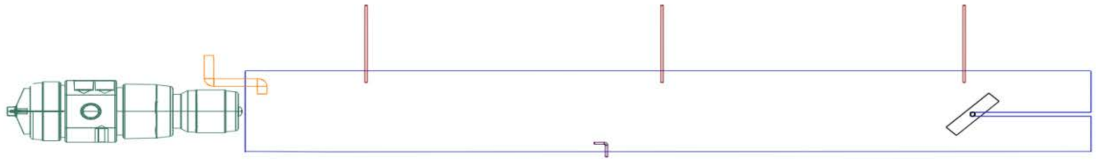

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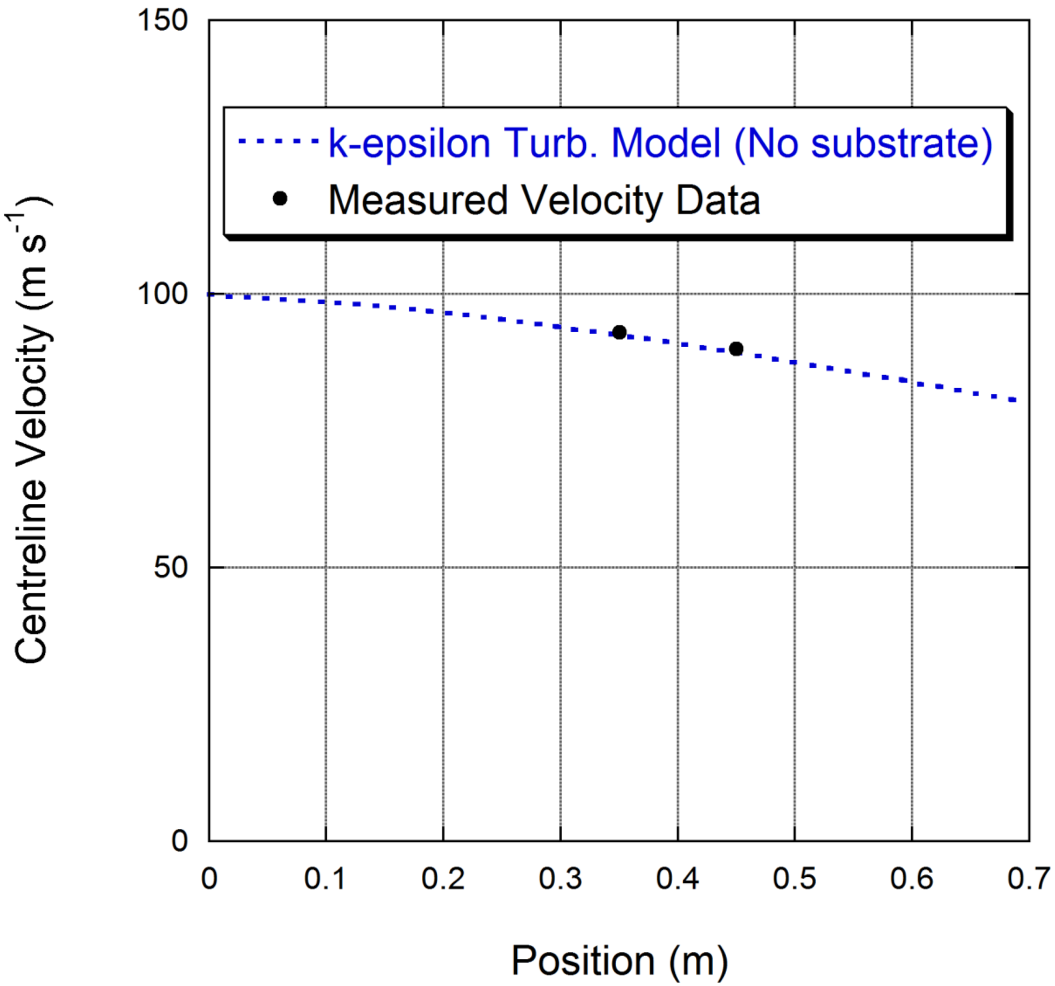

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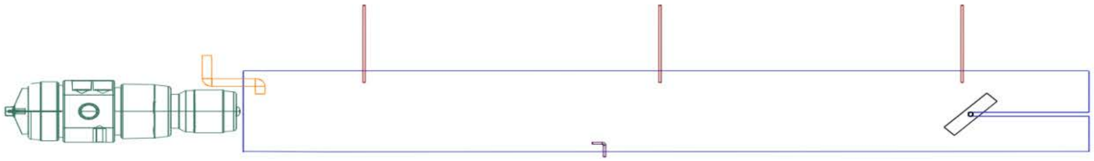

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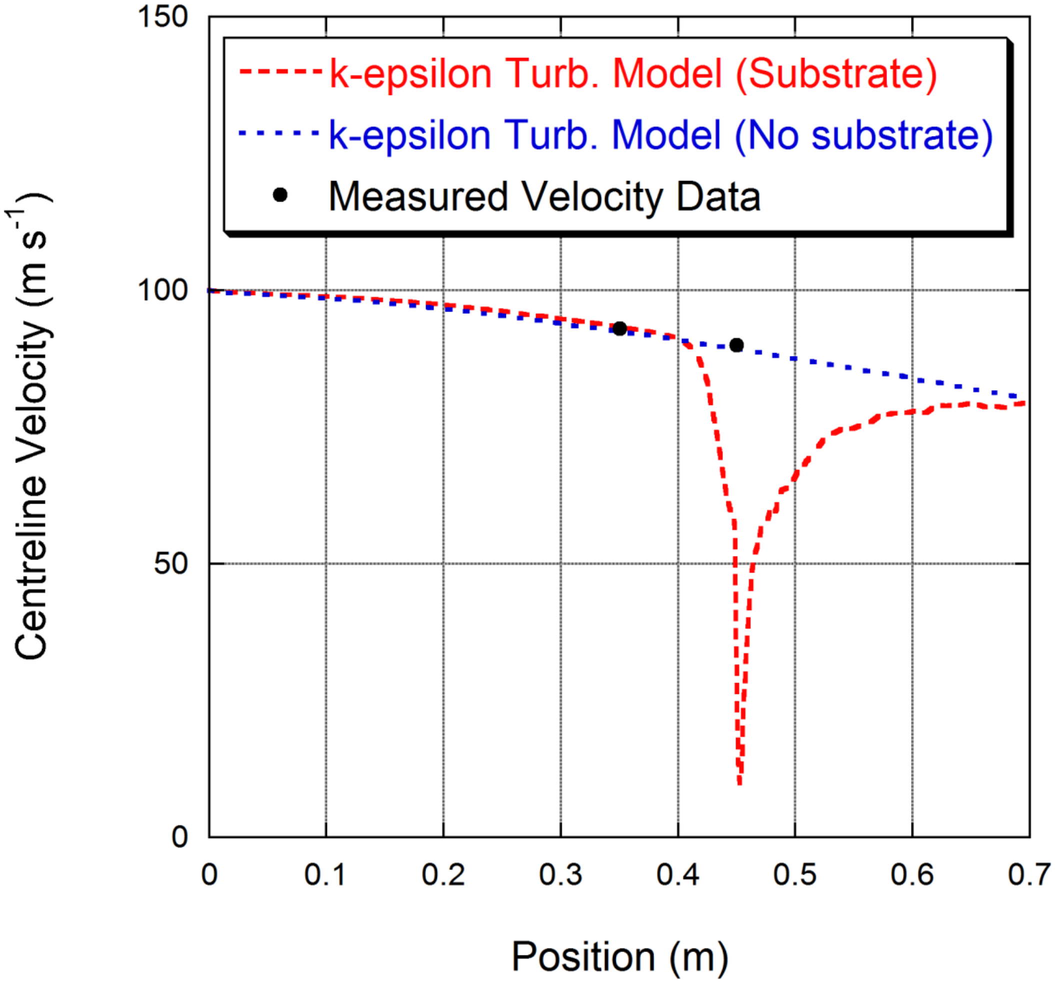

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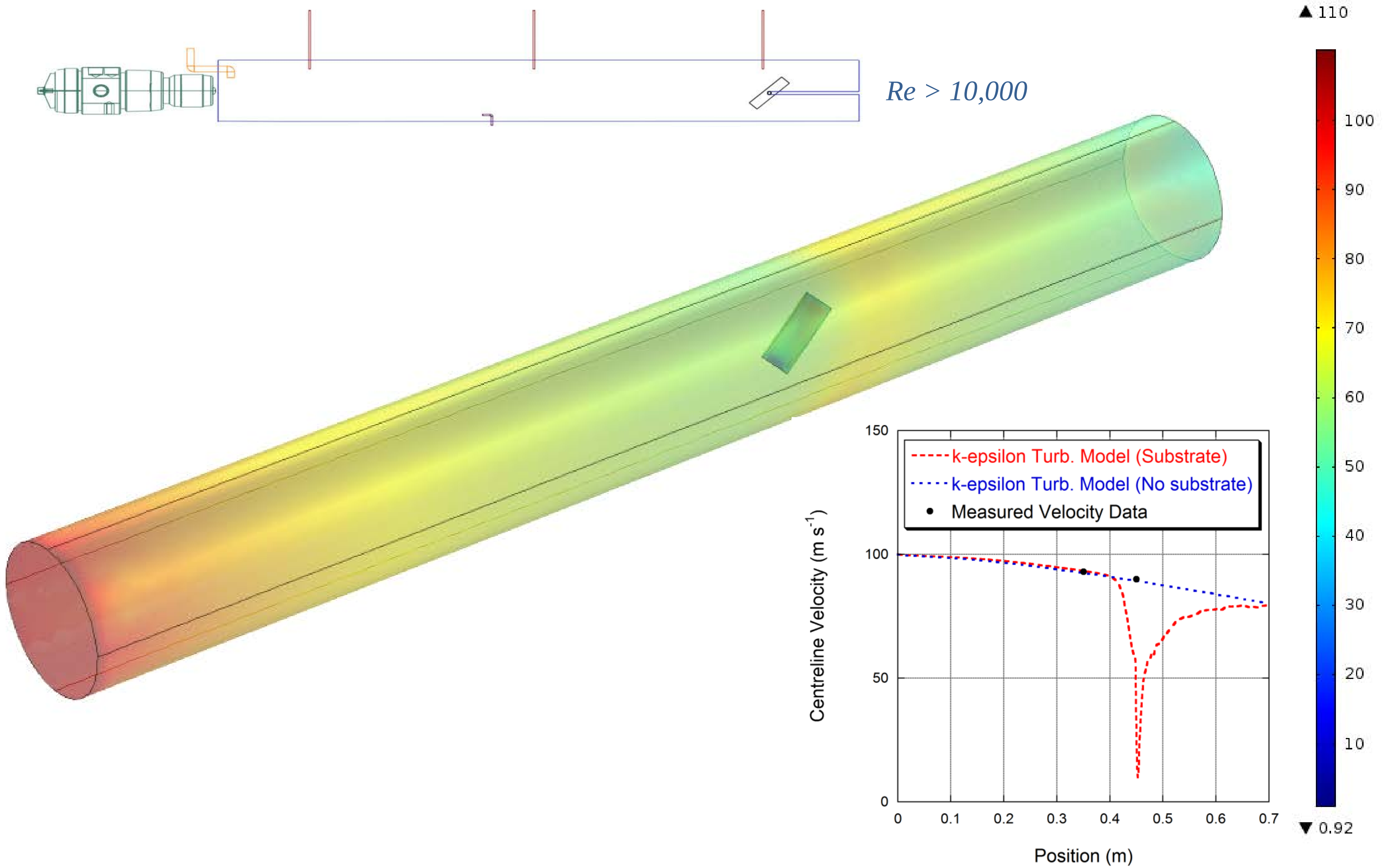
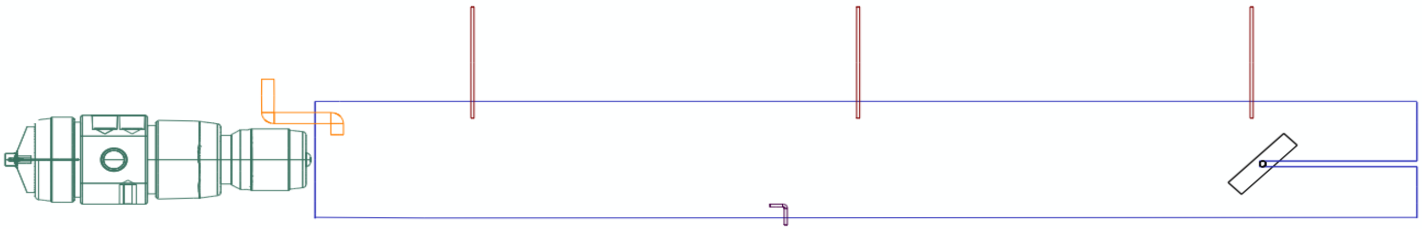


Modelling – Particle Trajectories – Condition 1



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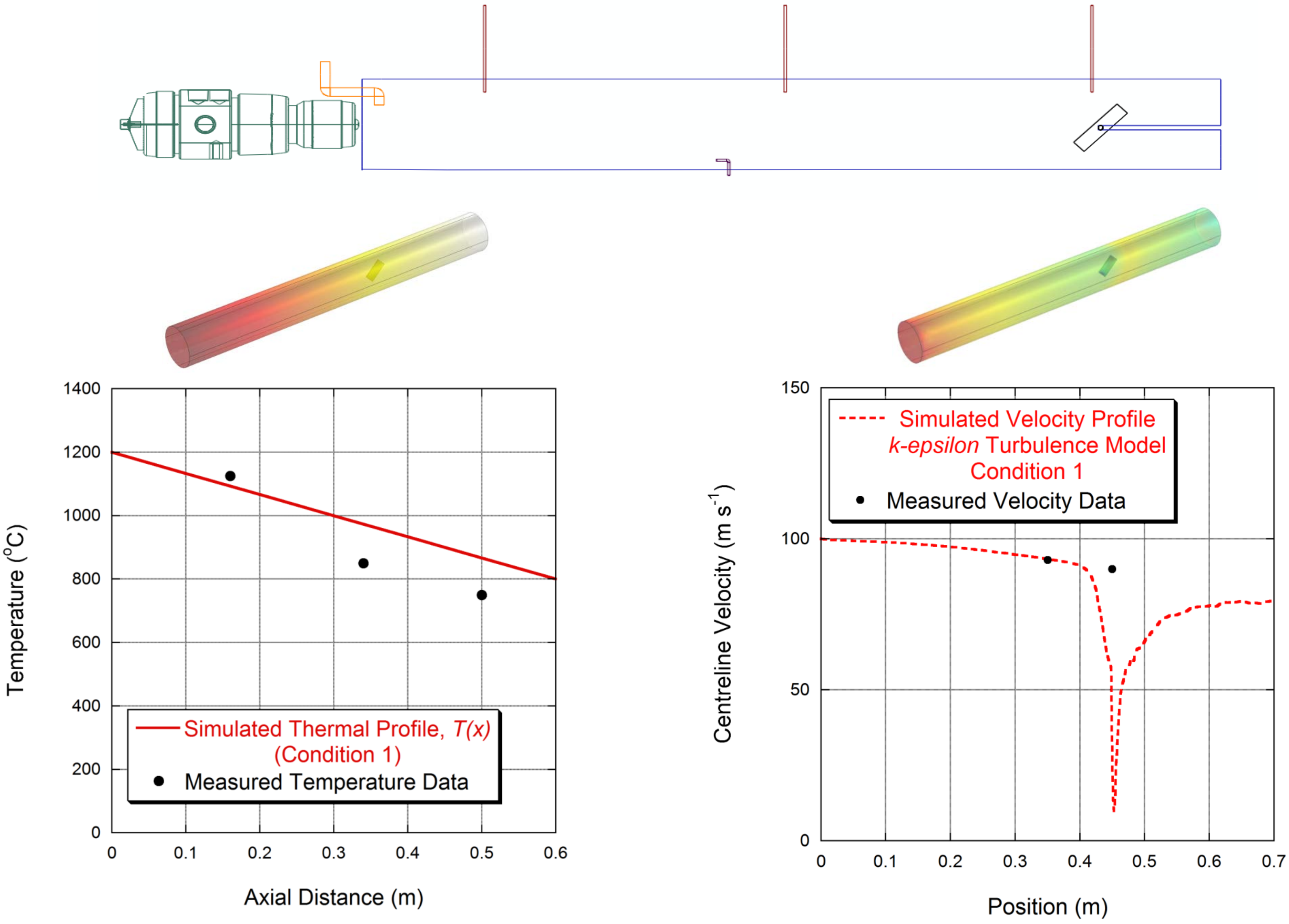

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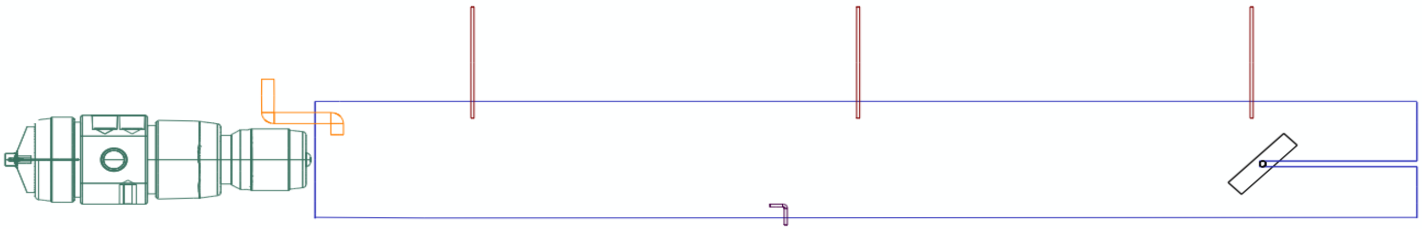

Particle Properties:

Density = 2400 kg/m^3
Diameter = 25 μm
Specific Heat Capacity = 800 J/kg/K
Latent Heat = 0 J/kg (Laki = 70% amorphous)

Temperature Field

Fixed *T(x)*

Velocity Field

Computed *V(x)* using k-epsilon turbulence model, coupled with fixed *T(x)*

Boundary Conditions

Initial particle velocity = 1 m/s (*x*-direction)
Gravity included
Convective heat transfer = Specified *h*, ambient *T* = Fixed *T(x)*
Drag law = *Haider-Levenspiel* with specified particle *sphericity*

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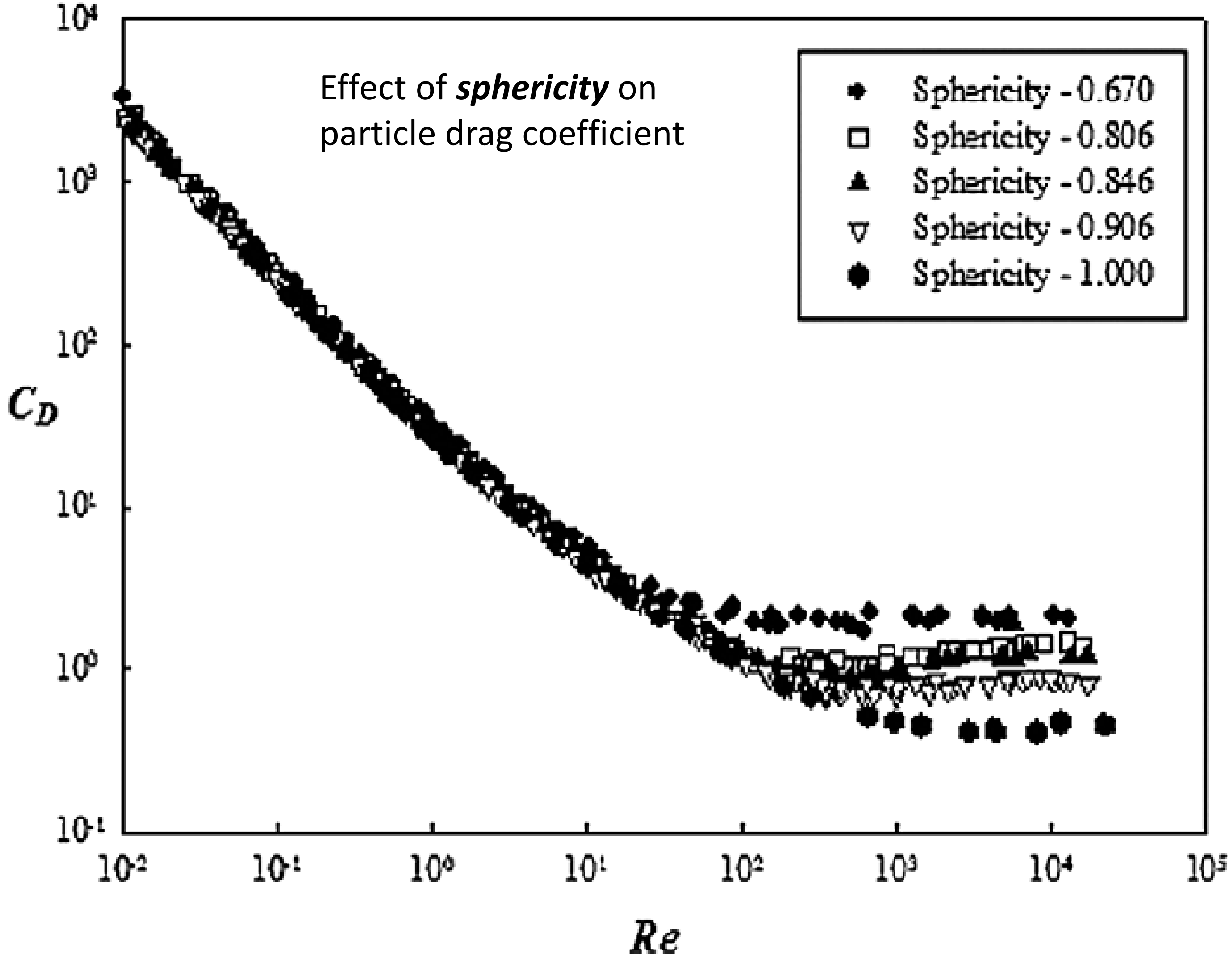

Drag Correlations for Particles of Regular Shape, Advanced Powder Technology, Vol. 16, No. 4, 363-372. 2005

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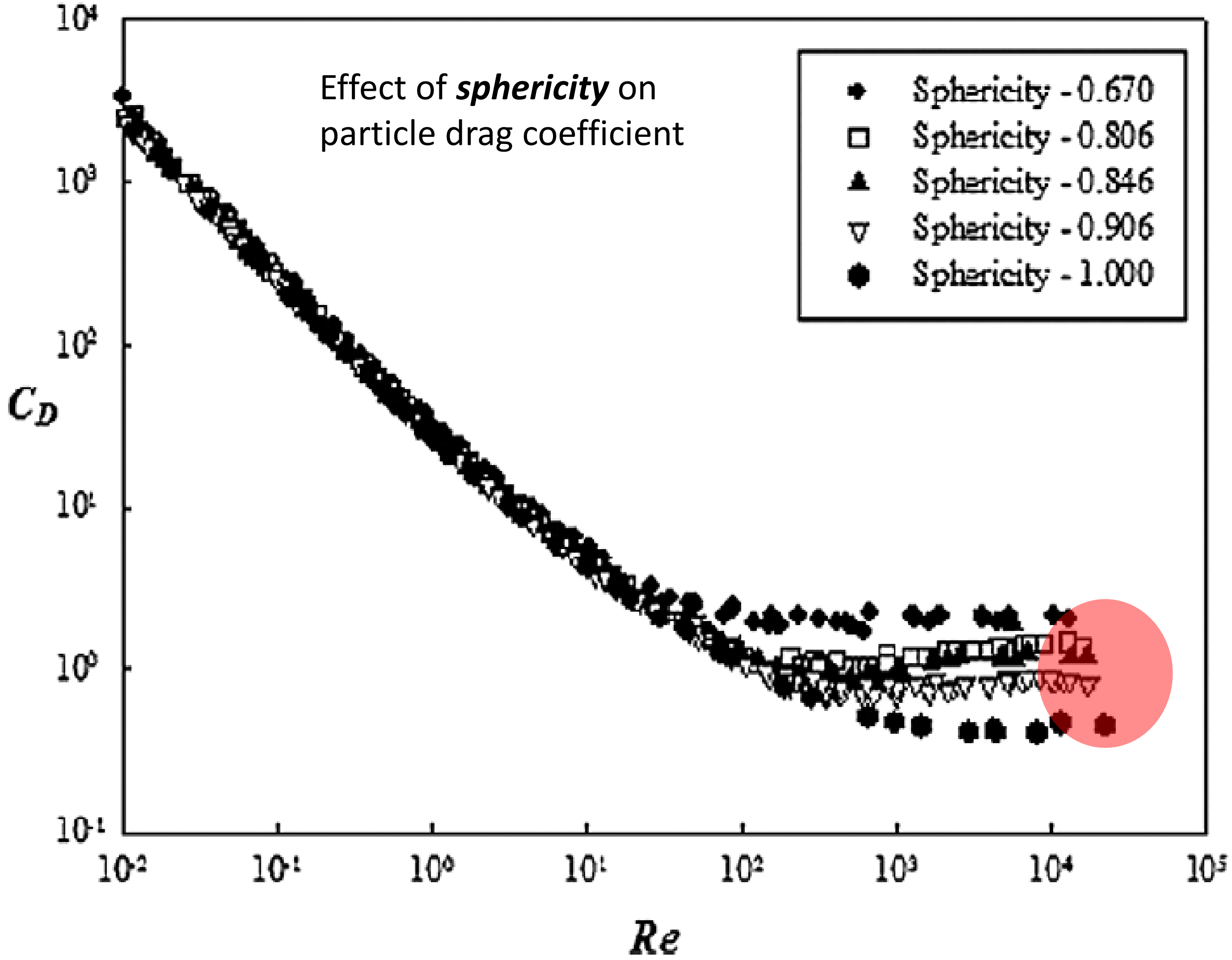

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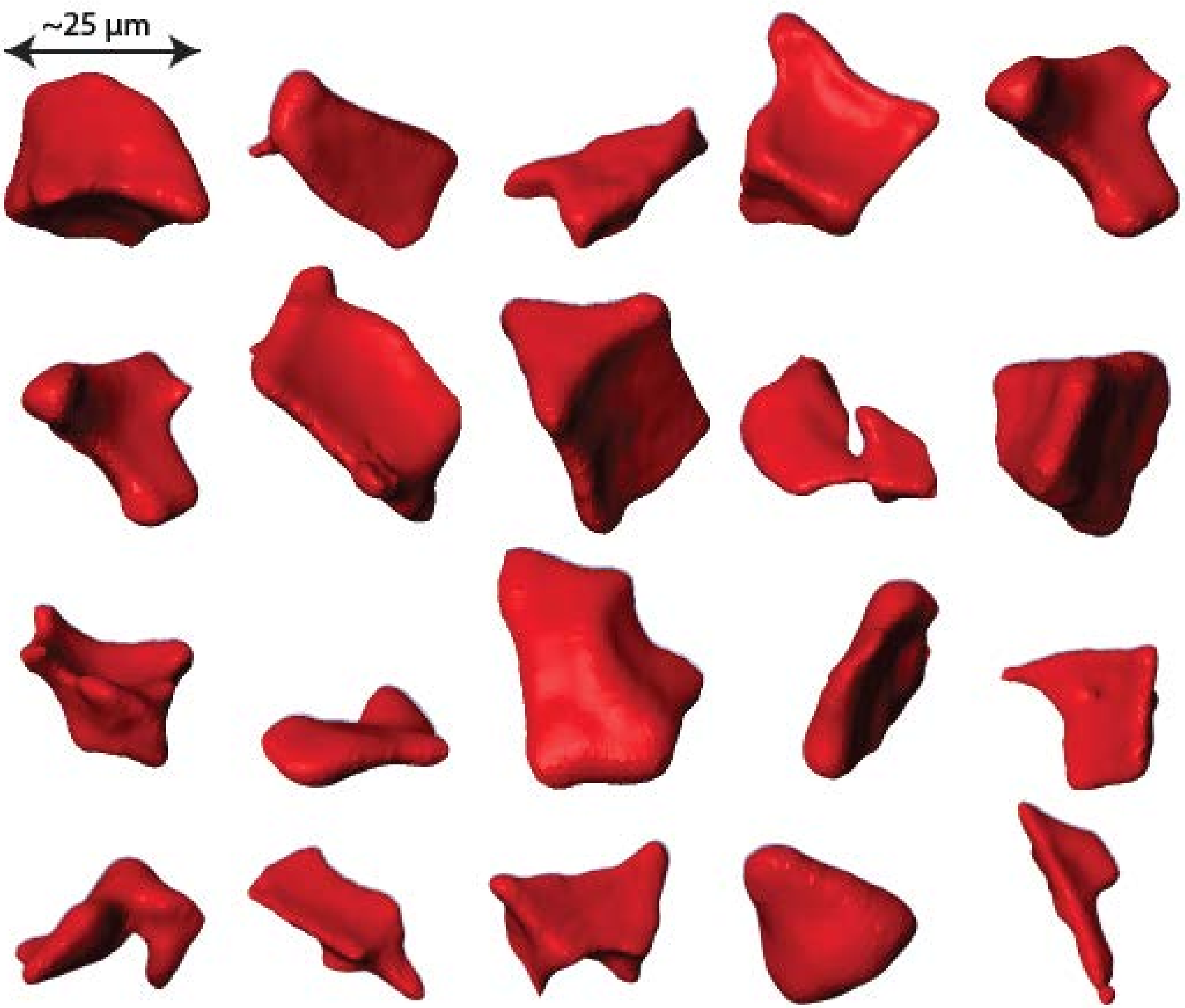
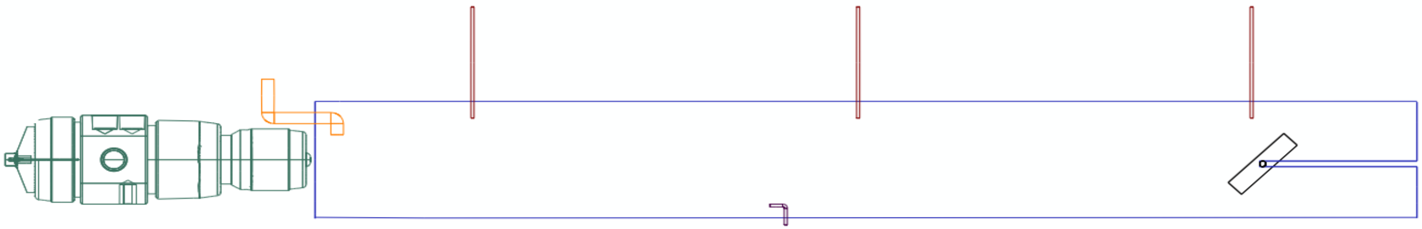


Outcomes:

Sphericity = 0.73

Aspect Ratio ~ 1.5

Modelling – Particle Trajectories – Condition 1



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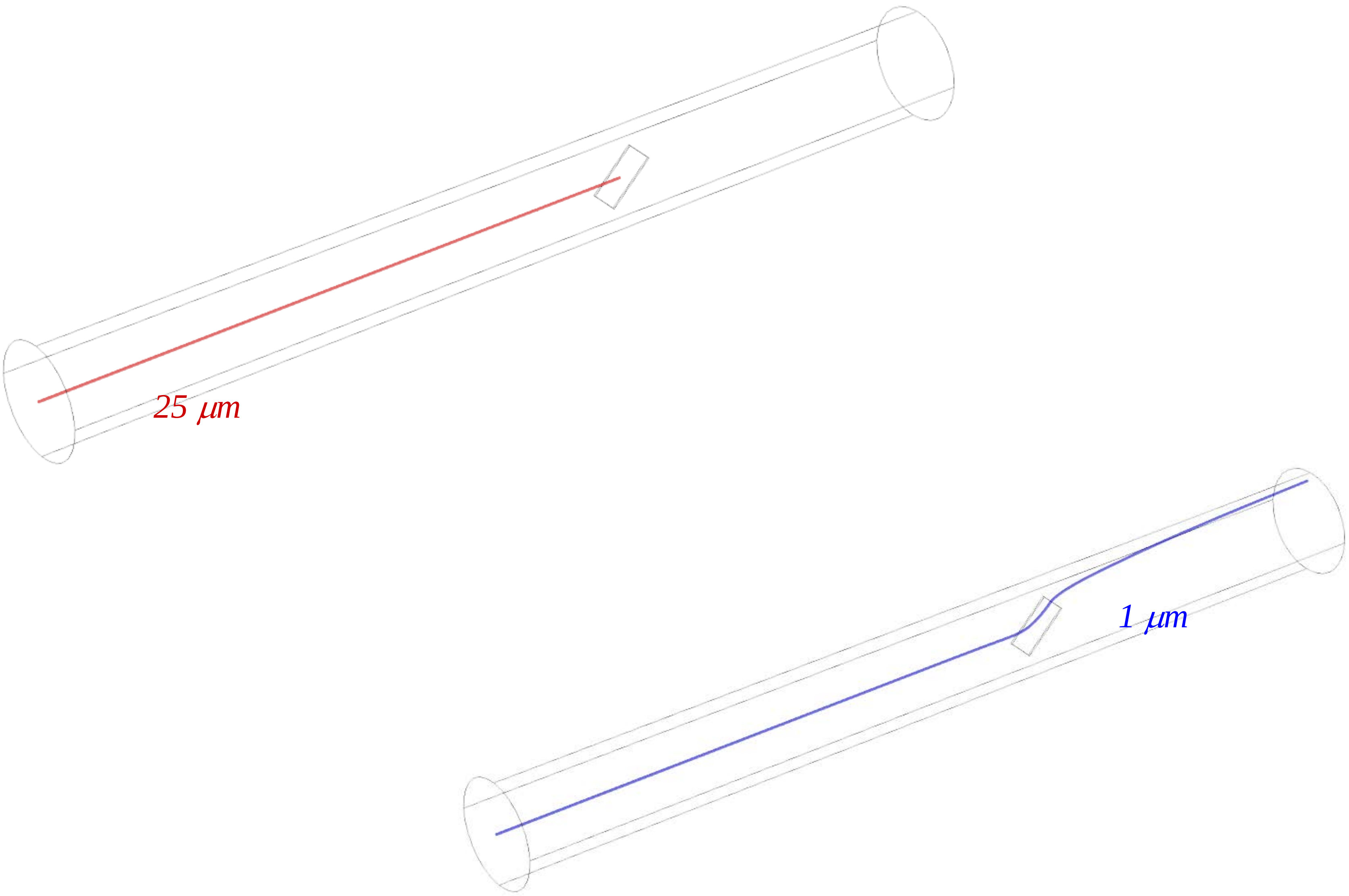

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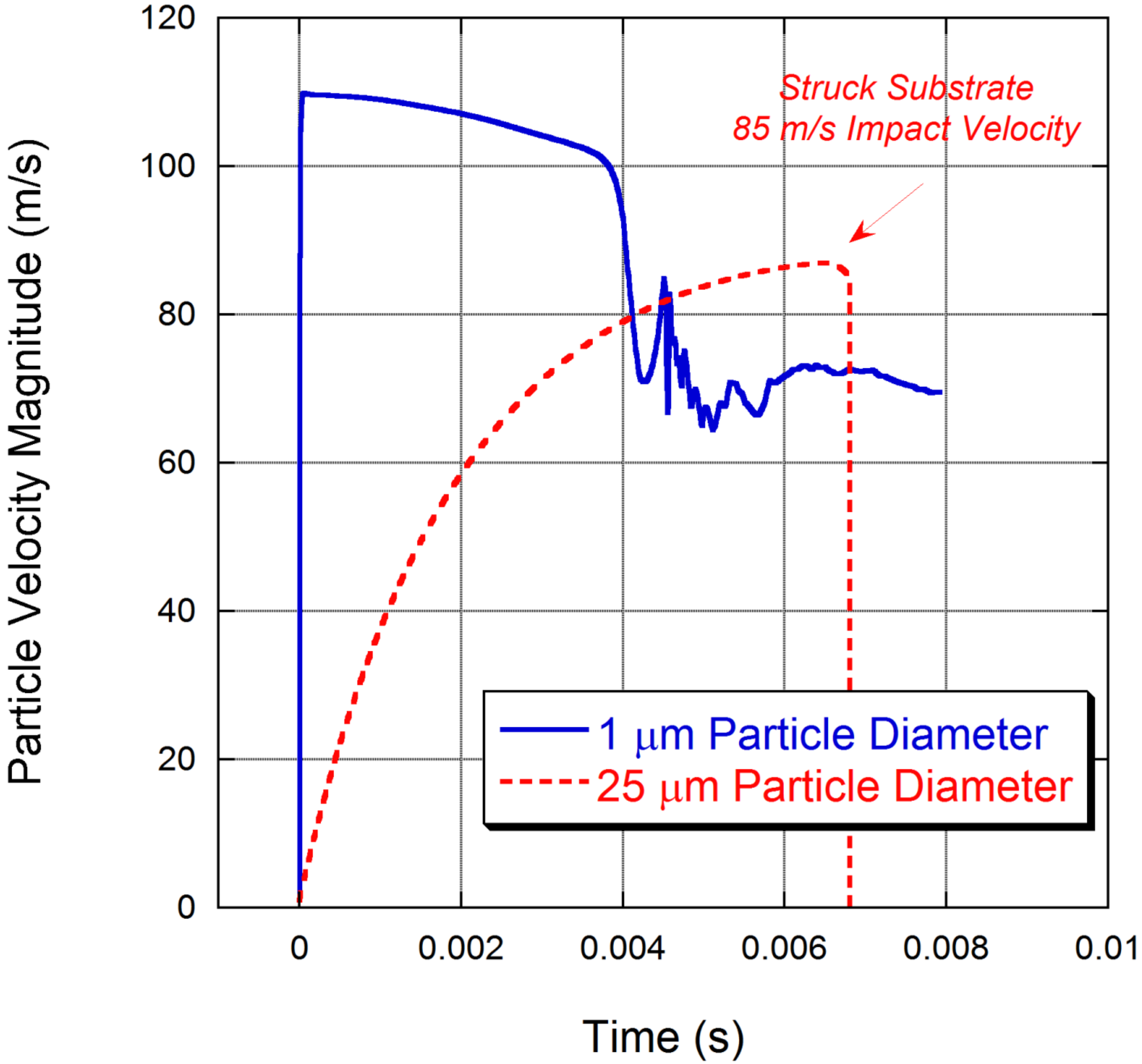

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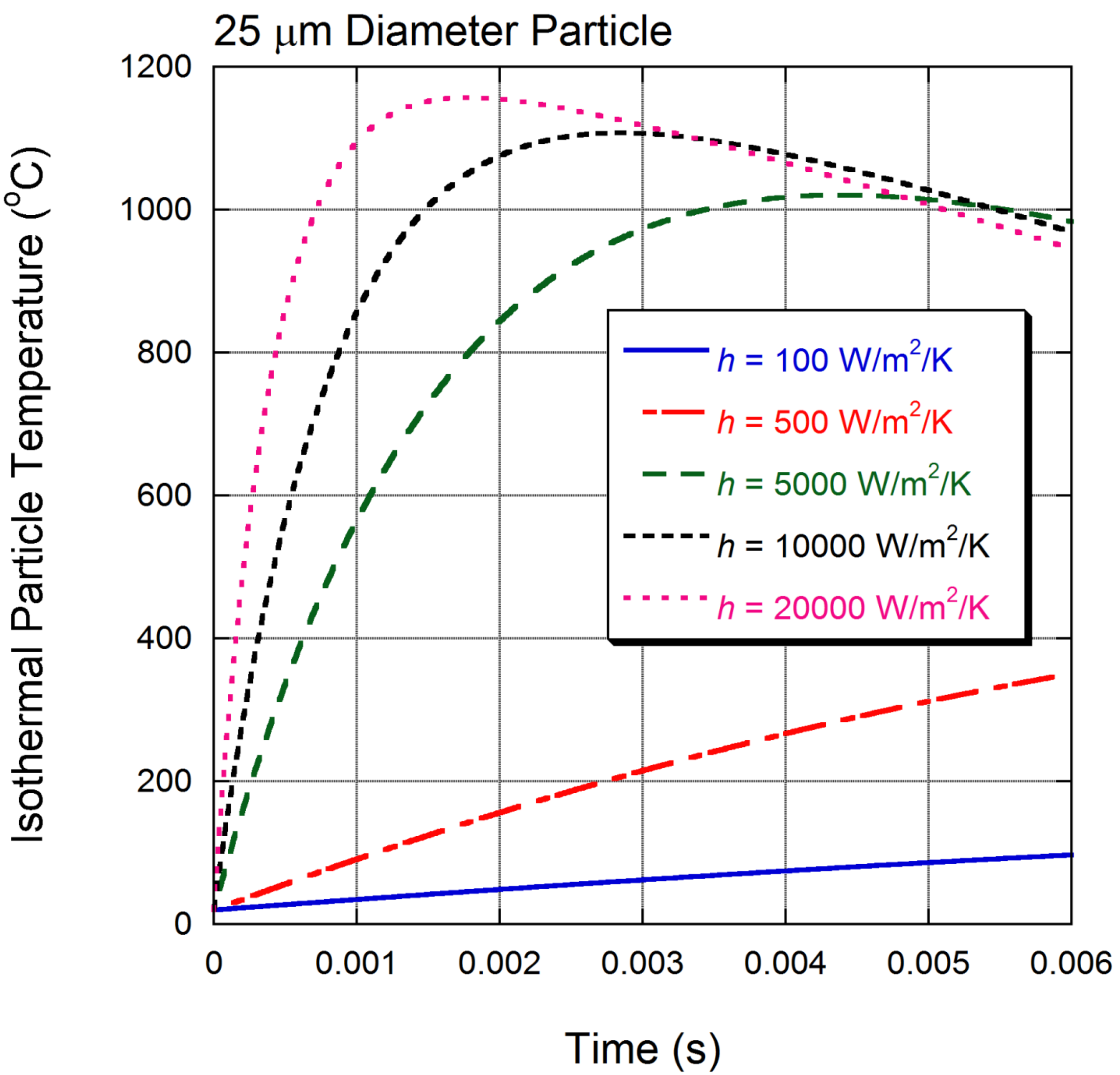

Modelling – Particle Trajectories – Condition 1

Which value of h to use?

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Which value of *h* to use?

$$\mathrm{Re}_p = \frac{\left|U_f - U_p\right| \rho_f D_p}{\mu_f}$$

$$\mathrm{Pr} = \frac{Cp_f \mu_f}{k_f}$$

$$Nu_p = 2 + a\,\mathrm{Re}_p^b\,\mathrm{Pr}^{1/3} = \frac{hD_p}{k_f}$$

$$4500 \le h \le 8700 \quad \mathrm{W\ m^{-2}\ K^{-1}}$$

Principles of Gas-Solid Flows, Liang-Shih Fan & Chao Zhu, Cambridge University Press, October 2005, p.512-513

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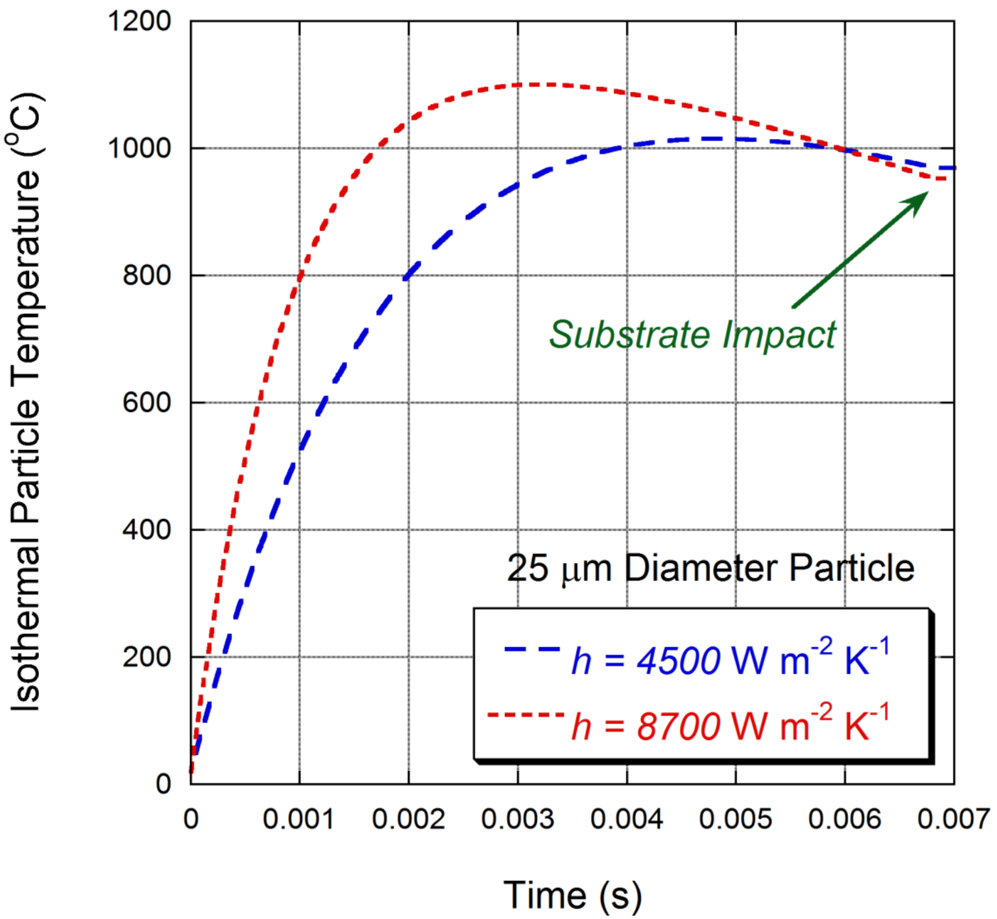

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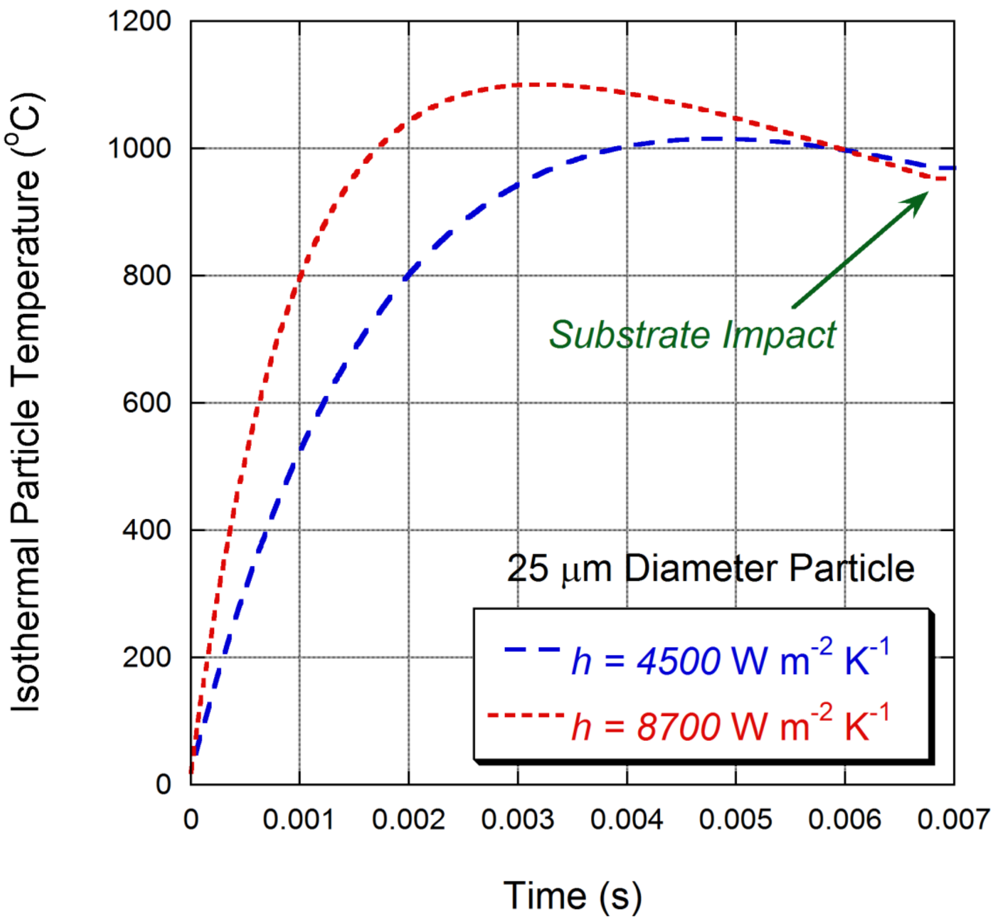
Modelling – Particle Trajectories – Condition 1

Which value of *h* to use?

Local variations in *h*?



Modelling – Particle Trajectories – Condition 1

Is the isothermal particle assumption valid?

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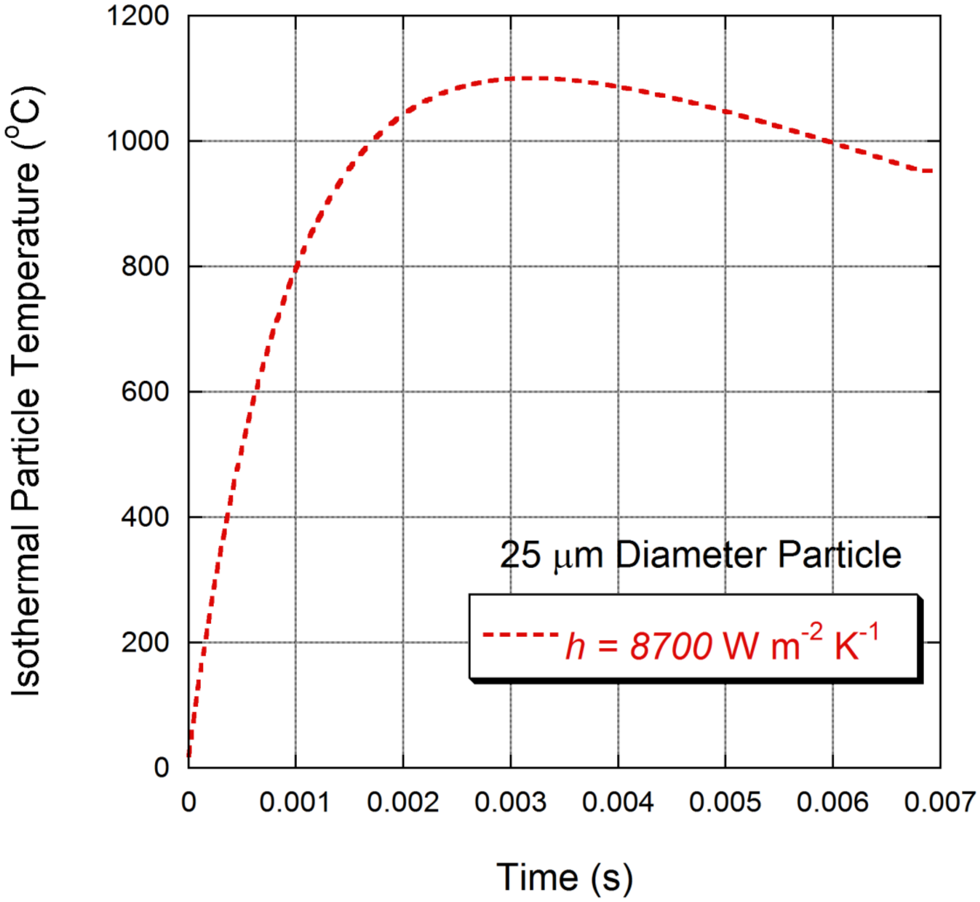

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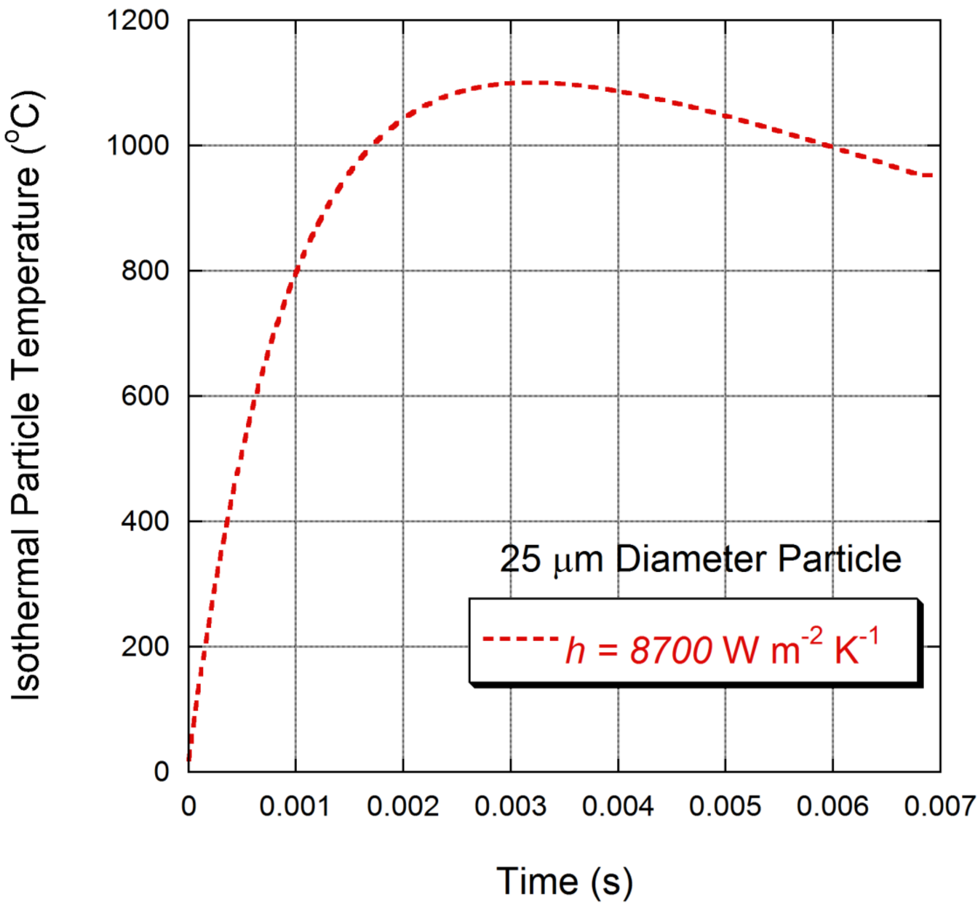

Specify the COMSOL-predicted $T_p(t)$ as a thermal boundary condition in ABAQUS and compute the non-isothermal particle temperature history

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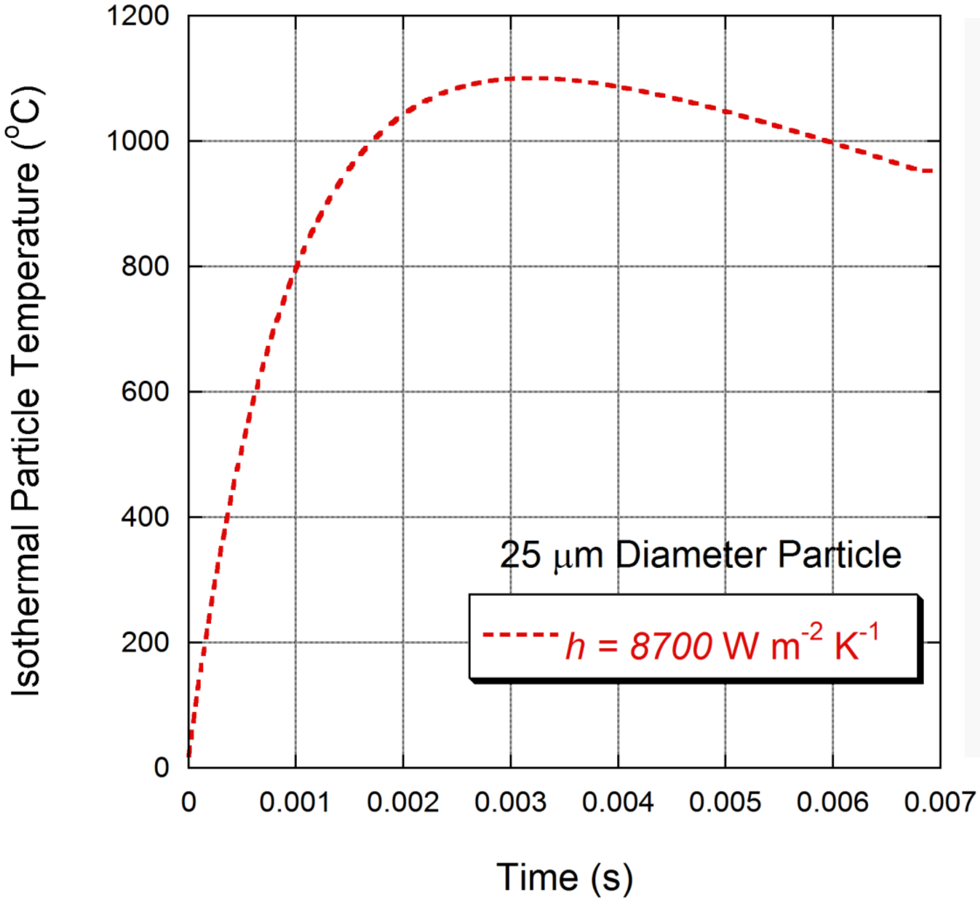
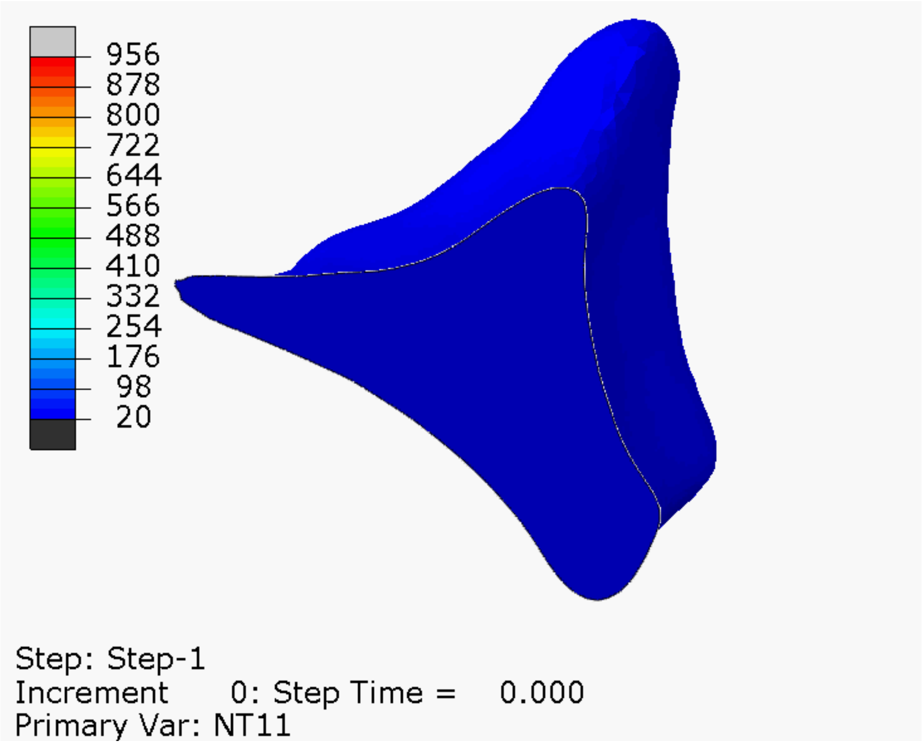
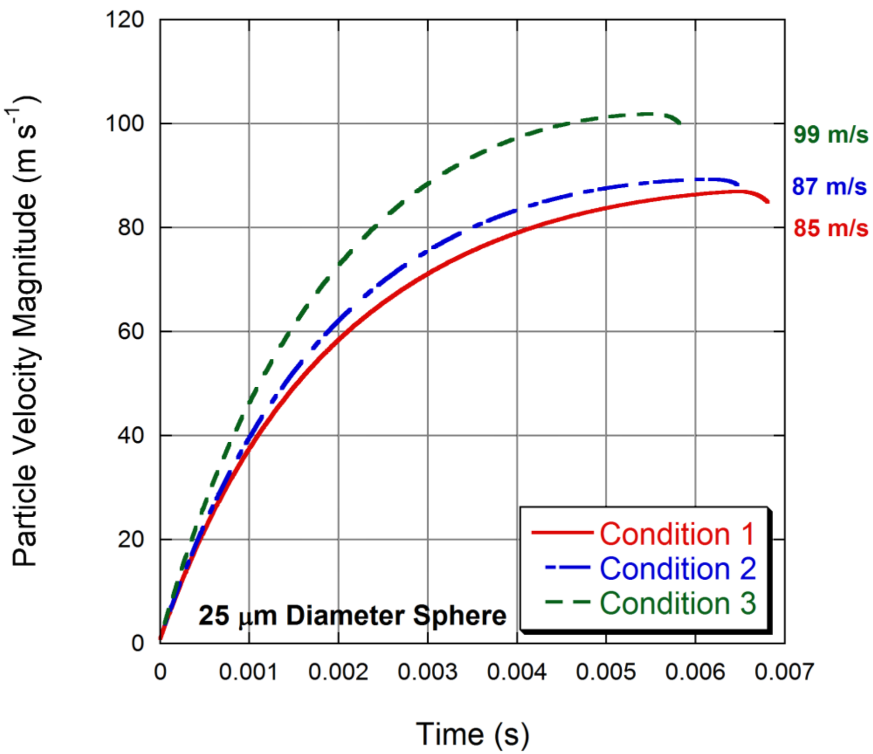
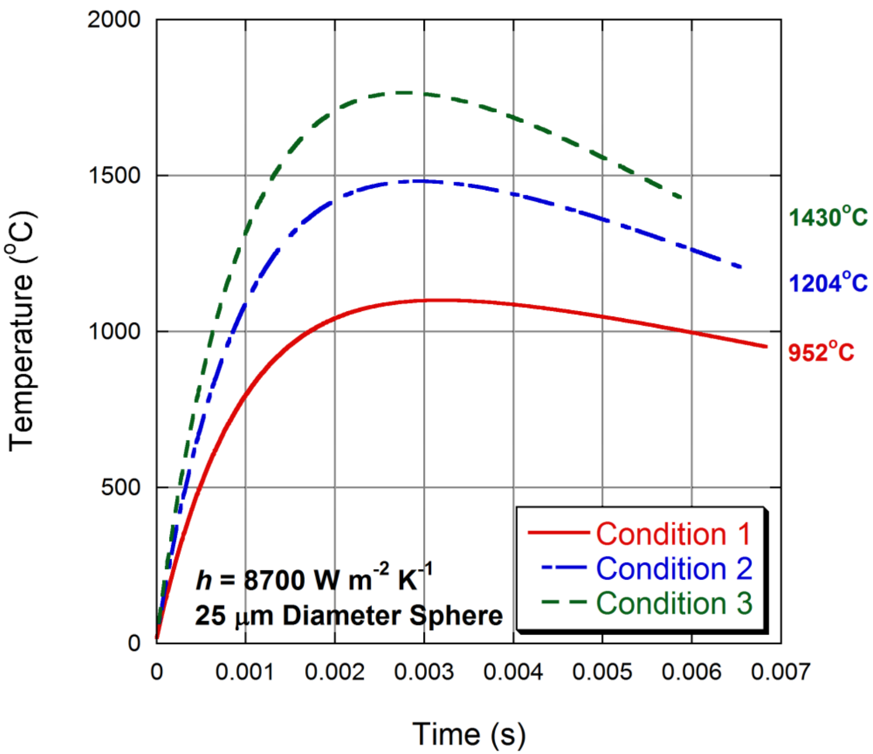




Modelling – Particle Trajectories – Condition 1, 2 & 3





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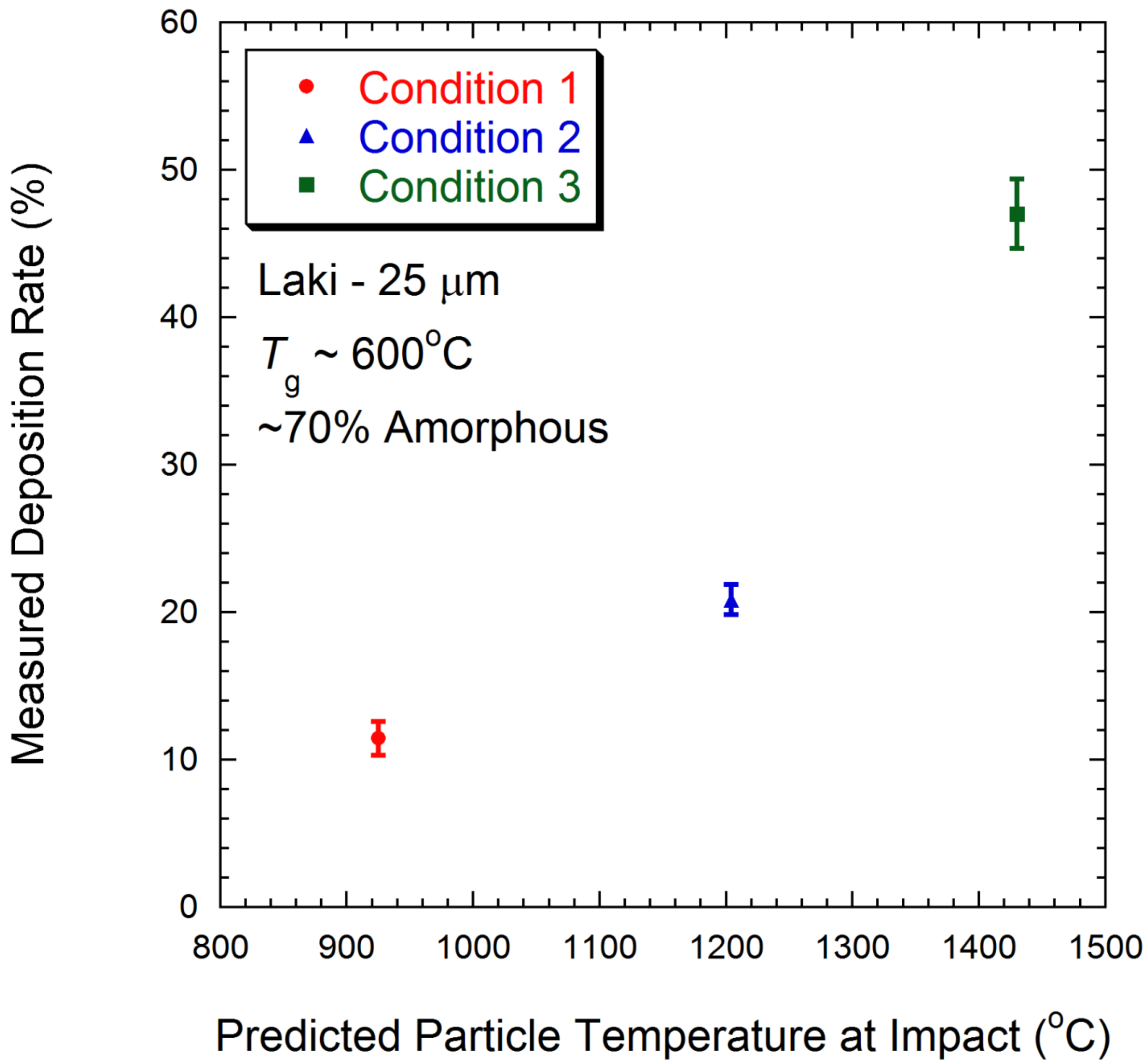

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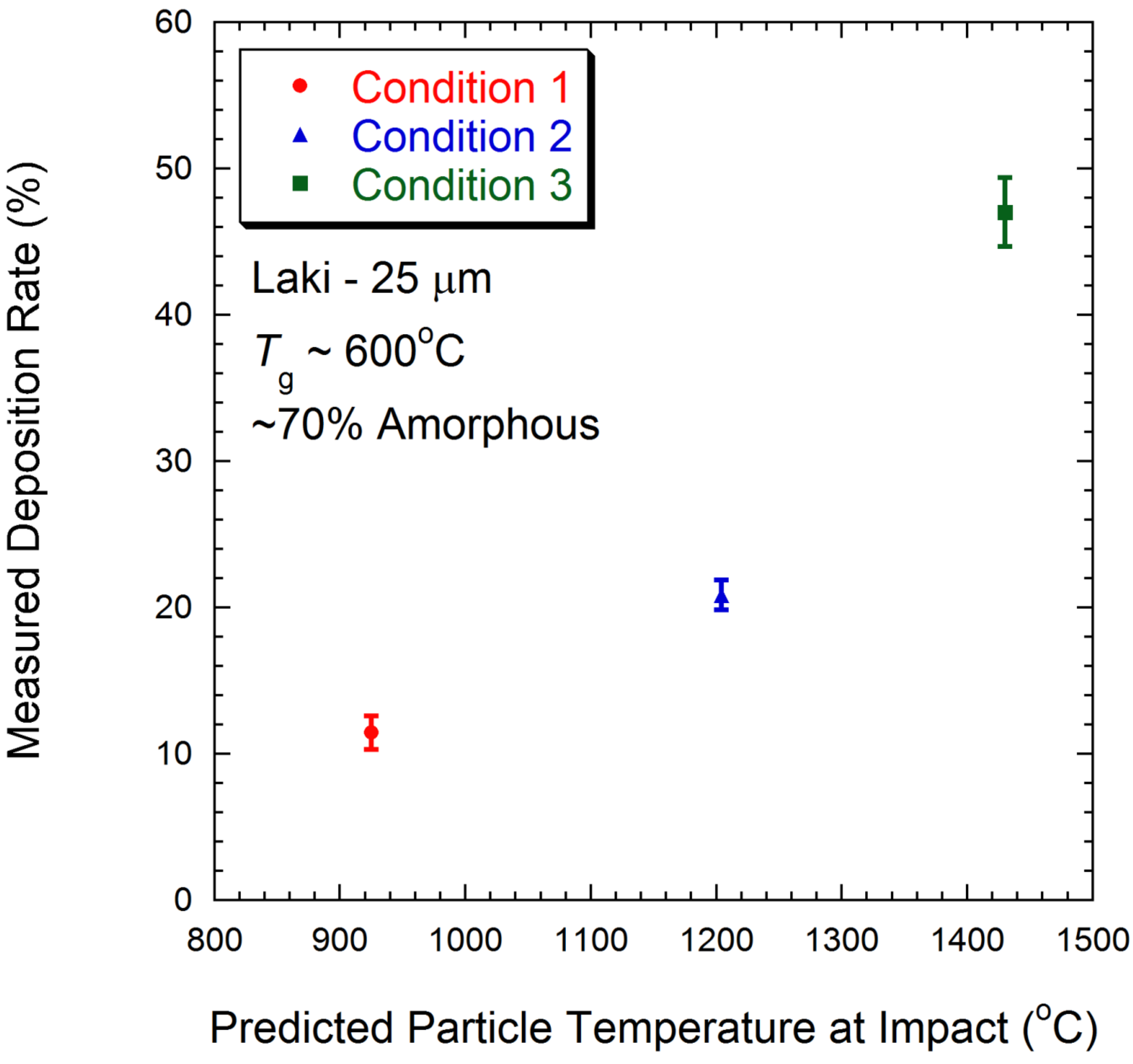
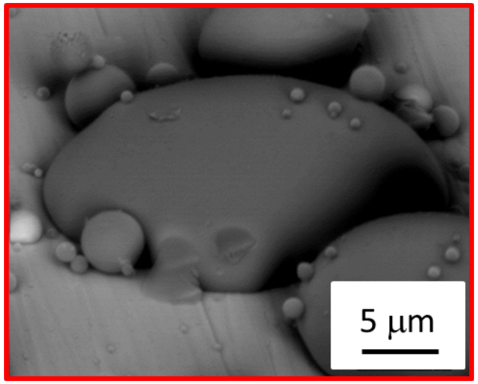
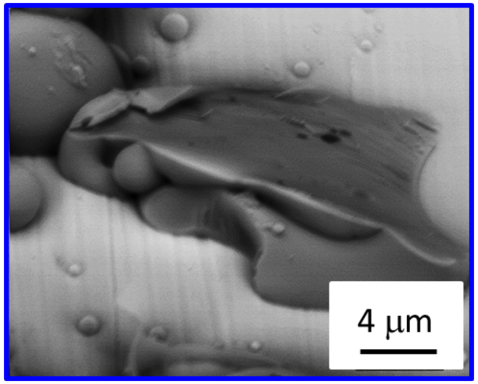
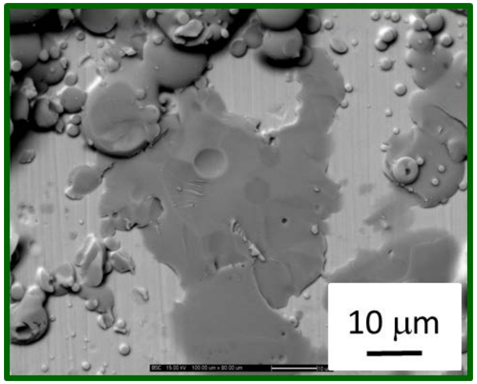




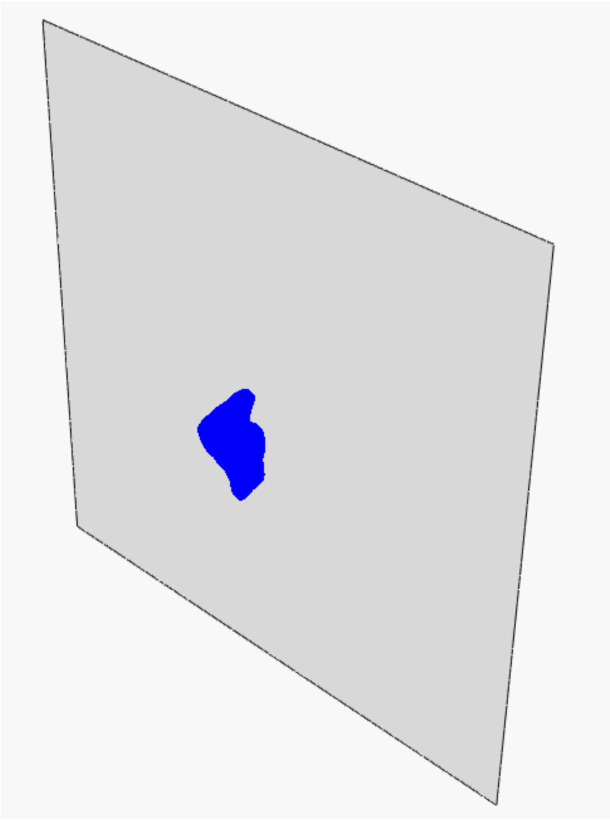


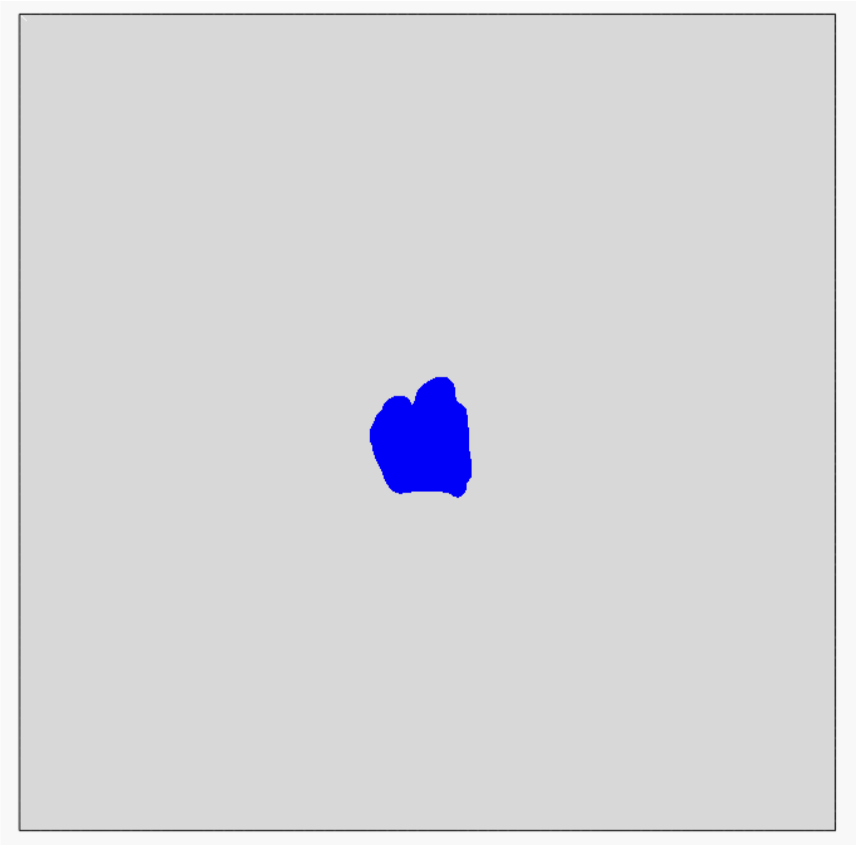


Modelling – Particle Impact Events

Initial Particle Velocity = 85 m/s
Initial Particle Temperature = 952°C

Using Smooth Particle Hydrodynamics (meshless) method to model particles with viscous, fluid-type mechanical behaviour

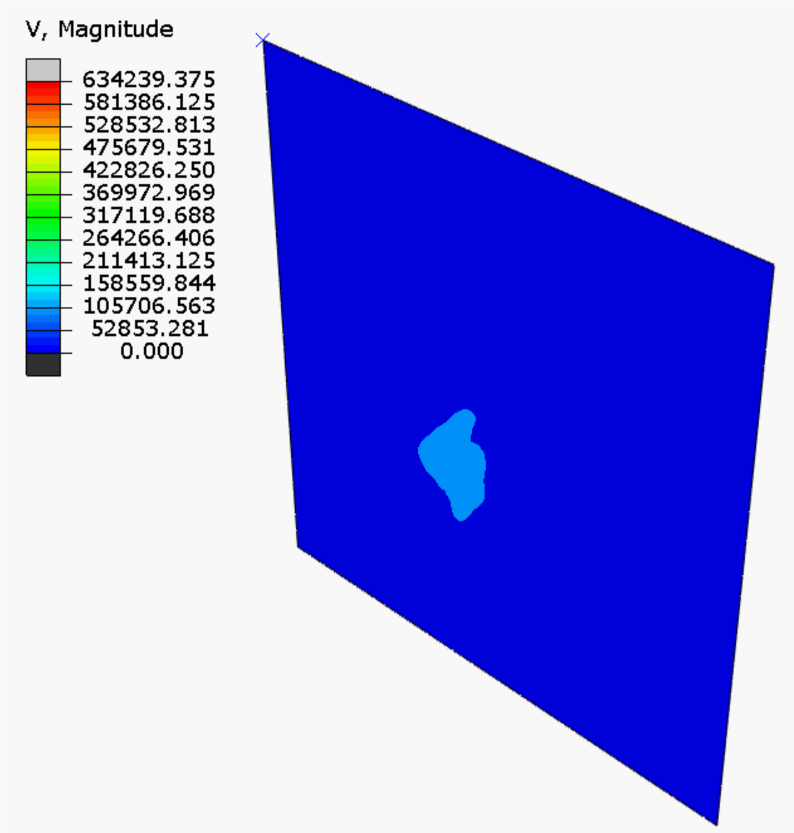


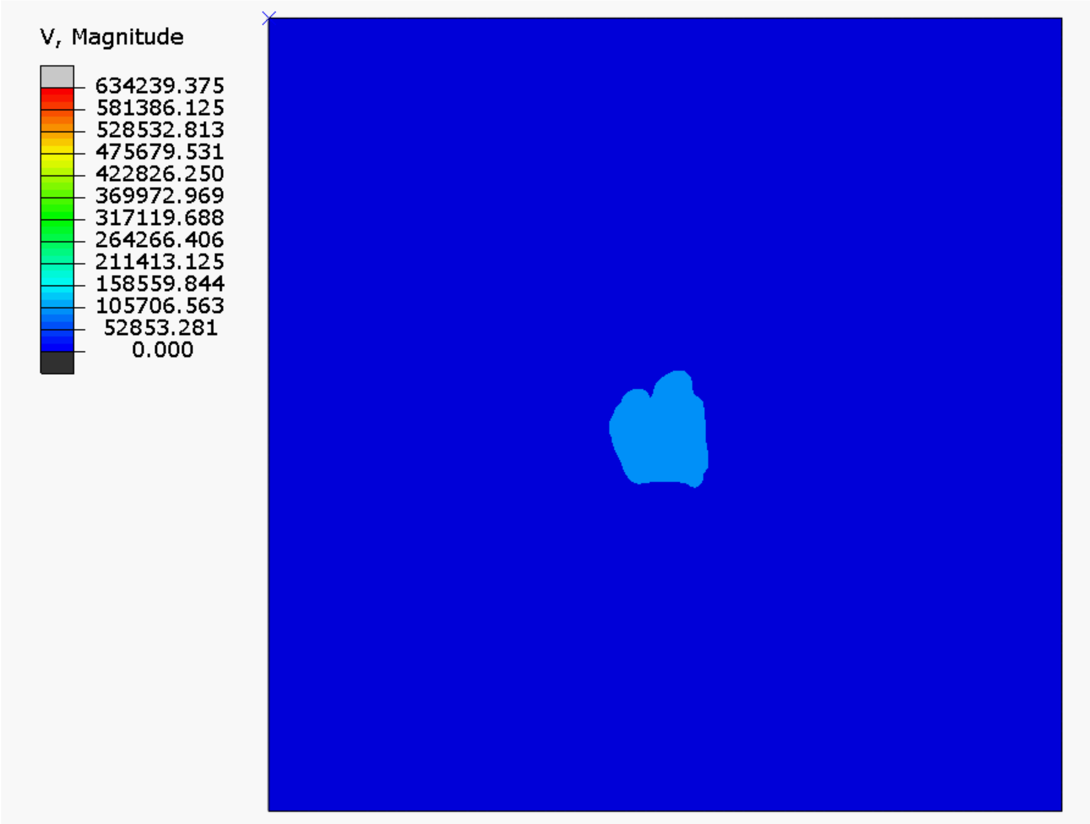


Modelling – Particle Impact Events

Initial Particle Velocity = 93 m/s
Initial Particle Temperature = 950°C

Using Smooth Particle Hydrodynamics (meshless) method to model particles with viscous, fluid-type mechanical behaviour





Conclusions

- Modelled temperature and velocity fields within the ash-injection rig
- Good agreement between modelled fields and experimental data
- Incorporated measured particle sphericity in the Haider-Levenspiel drag equation and simulated the particle trajectories
- Predicted the particle temperature and velocity histories
- Compared predicted T_p at substrate impact point with measured ash T_g values. $T_p > T_g$ for all cases and $T_p > T_m$ of Laki crystalline phases (~30%) for conditions 2 and 3
- Correlated predicted T_p at impact with SEM-observed splat morphologies