Modelling and Simulation

SSM

Latest state of the art technology

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BEHAVIOUR OF THIXOTROPIC MATERIALS

- Flow behaviour difficult to predict
  - NON-NEWTONIAN RHEOLOGY

Newtonian Fluid

- Increase in Temperature decreases viscosity

Thixotropic Alloy

- Viscosity decreases much faster
  - Viscosity of multiphase alloy greatly influenced by liquid fraction
- Control of liquid fraction + Injection rate
  - Avoid: Premature freezing

    Porosity

Typical die filling process (Thixocasting)

- Viscosity: drop in orders of magnitude (Shear thinning)
- Concurrently liquid phase solidify
  - ➡ Increase in viscosity
- Competition of shear thinning and solidification effects during filling stage

- **Shear rate history important factor in design and casting processes**
  - **Viscosity decreases over time after applied shear rate**
- **Ideally viscosity should be:**
  - **High enough – Turbulent flow**

  BUT !!!

  - **Low enough – Allow all section to fill before solidification**

NUMERICAL MODELLING

Modelling a thixotropic material

- Complex thermo-mechanical behaviour
- Depending on loading condition phase deformation can be classified as:
  - Homogenous
  - Heterogeneous
- Two approaches to model SSM behaviour:
  - Two phase
  - One phase - classical and homogenous medium both liquid and solid phase same velocity

- Thixoforming process
  - No significant macroscopic segregation occur
  - Partially liquid/Solid phase treated as one phase
- One Phase model
  - Wider volume solid fraction 0 – 1
  - Implementation in Power Law Cut-Off Model (PLCO) of Procast

Assumptions of the PLCO Model

- Isotropic material model
- Pure viscoplastic behaviour
- Pressure independent
- Homogenous deformation

Fluid Flow Model

- Navier-Stokes model
- Non-Newtonian viscosity function
- Shear thinning (cut off method) approximated by a Power Law Function

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LATEST DEVELOPMENT

IN THE NUMERICAL MODELLING FIELD

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2-Phase Model

- **Macrosegragation central problem…influences final cast component**
- **Result of slow interdendritic flow & driven by thermo-solutal convection**

2 PHASE MODEL IMPLEMENTATION

Generally the influence of solid motion is considered negligible in the fluid flow

➢ The 2 Phase Model

- Mushy zone considered as an effective two phase continuum
- Solid material behaviour: incompressible viscoplastic – obey constitutive power Law type equation –
- Macroscopic flow rule is viscoplastic
- Solid continuum seen as a deformable compressible porous medium
- Liquid Phase intrinsically – Newtonian Behaviour

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Mass $$\frac{\partial}{\partial t}(g_k \rho_k) + \nabla \cdot (g_k \rho_k \boldsymbol{v}_k) = \Gamma_k$$

Momentum $$\nabla \cdot (g_k \boldsymbol{\sigma}_k) + \boldsymbol{M}_k + g_k \rho_k \boldsymbol{g} = \frac{\partial}{\partial t}(g_k \rho_k \boldsymbol{v}_k) + \nabla \cdot (g_k \rho_k \boldsymbol{v}_k \times \boldsymbol{v}_k)$$

Energy $$\frac{\partial}{\partial t}(g_k \rho_k h_k) + \nabla \cdot (g_k \rho_k h_k \boldsymbol{v}_k) + \nabla \cdot \left\langle \boldsymbol{q}^k \right\rangle = Q_k$$

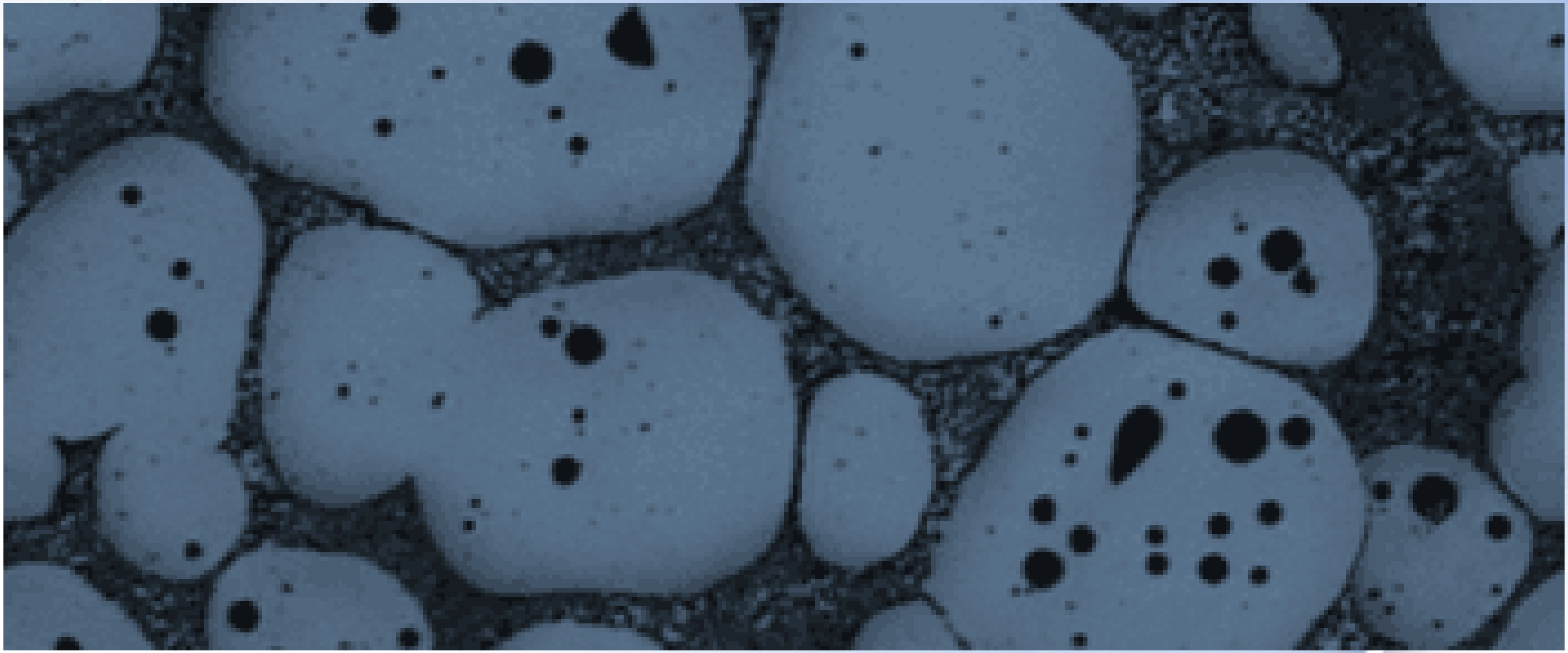
Liquid/Momentum $$\nabla \cdot \boldsymbol{\Sigma}^{l} - g_l \nabla p_l + \boldsymbol{M}_l^d + g_l \rho_l \boldsymbol{g} = \rho_l \frac{\partial}{\partial t}(g_l \boldsymbol{v}_l) + \rho_l \nabla \cdot (g_l \boldsymbol{v}_l \times \boldsymbol{v}_l)$$

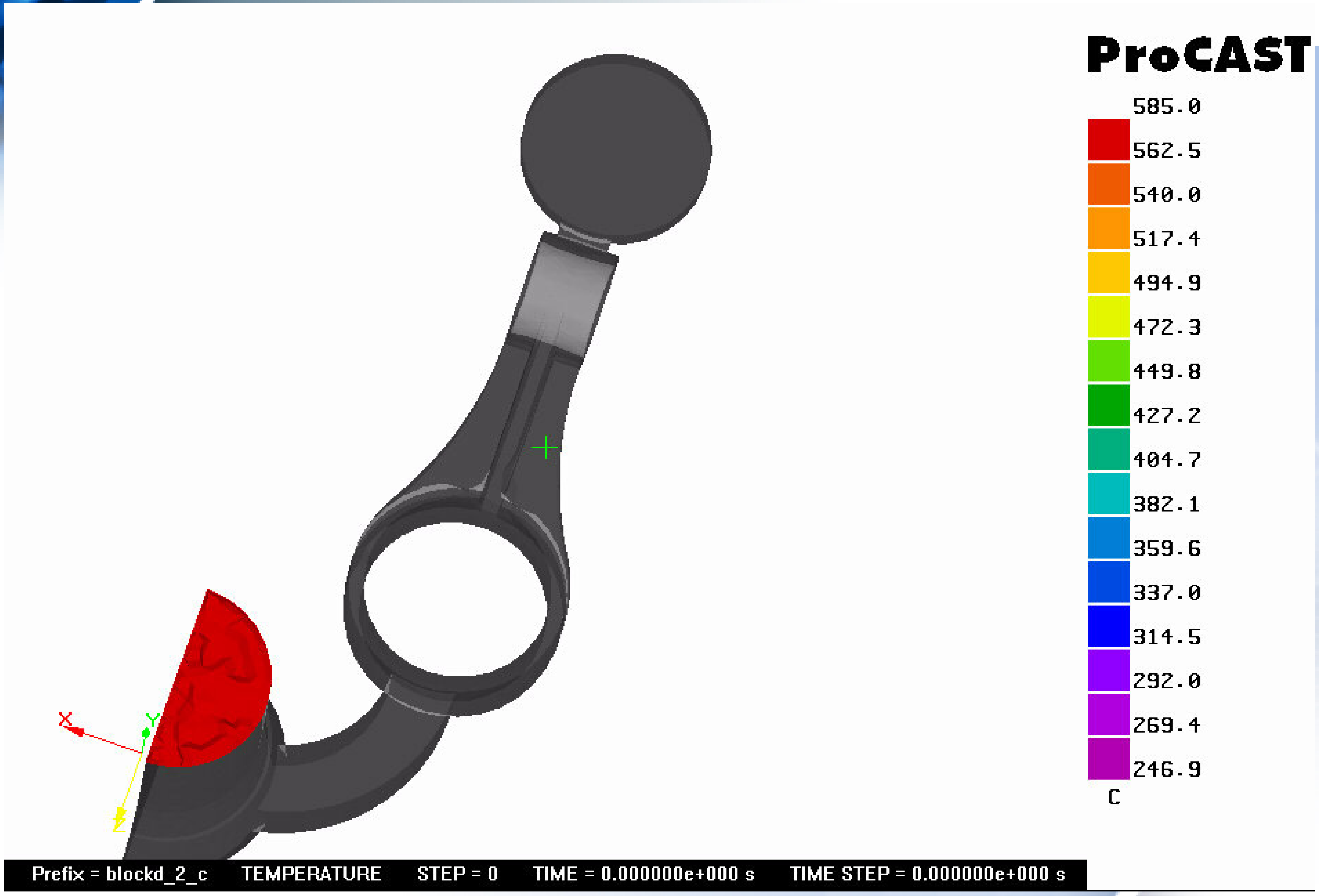
Solid/Momentum $$\nabla \cdot \boldsymbol{\Sigma}^{s} - g_s \nabla p_l - \boldsymbol{M}_l^d + g_s \rho_s \boldsymbol{g} = \rho_s \frac{\partial}{\partial t}(g_s \boldsymbol{v}_s) + \rho_s \nabla \cdot (g_s \boldsymbol{v}_s \times \boldsymbol{v}_s)$$

Mixture/Mass $$(1 - \Delta\varepsilon^{tr})\nabla \cdot (g_s \boldsymbol{v}_s) + \nabla \cdot (g_l \boldsymbol{v}_l) = \frac{\partial g_s}{\partial t}\Delta\varepsilon^{tr}$$

Mixture/Energy $$\langle \rho \rangle \frac{\partial \langle h \rangle}{\partial t} + c_p \nabla T \cdot \langle \rho \boldsymbol{v} \rangle + L(\rho_l \nabla \cdot \langle \boldsymbol{v}^l \rangle - g_l \nabla \cdot \langle \rho \boldsymbol{v} \rangle) - \nabla \cdot (\langle \lambda \rangle \nabla T) = 0$$

Microscopic Level





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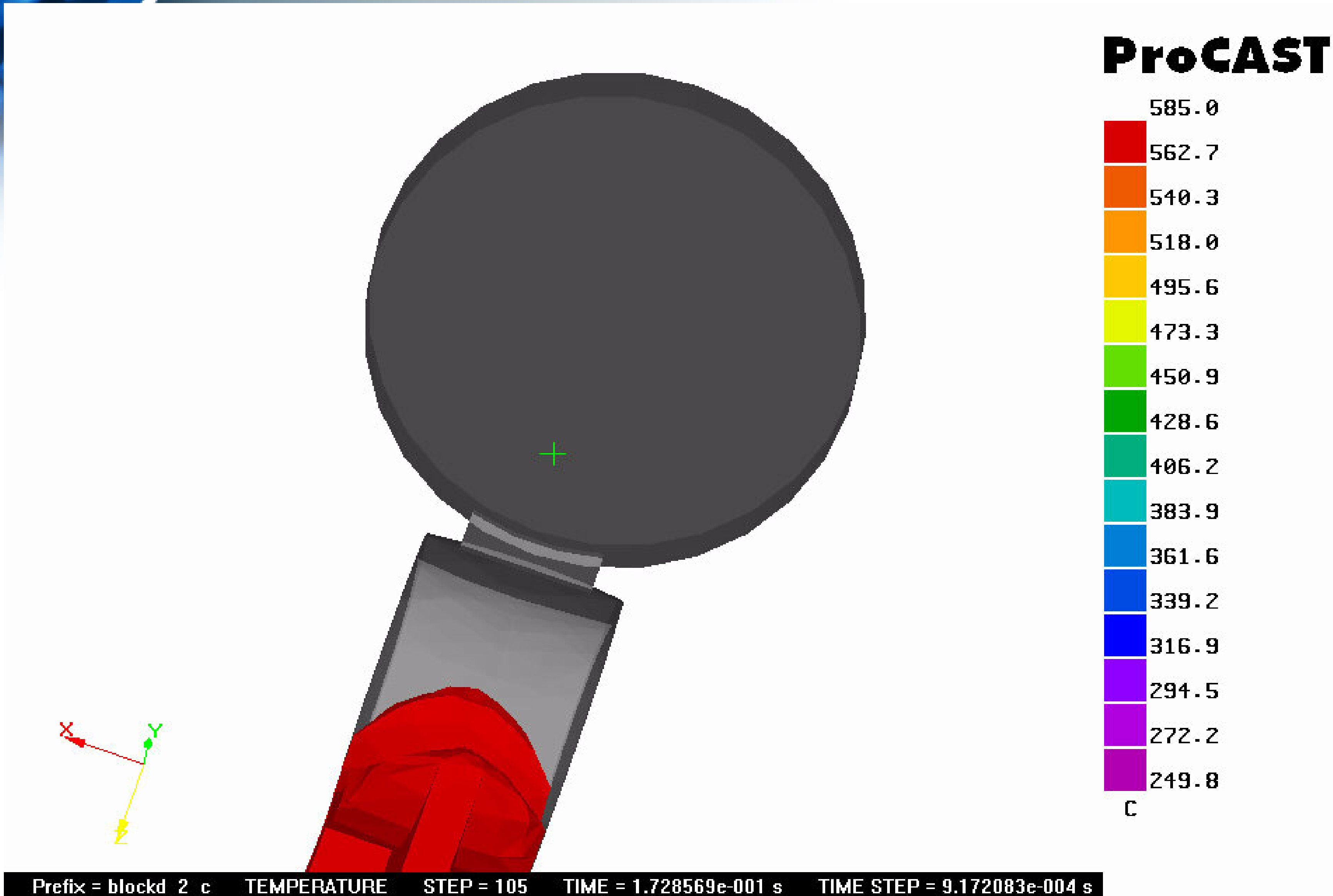
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473.3
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