Two-phase Liquid-Solid flows in Rock fractures - Geothermal Applications

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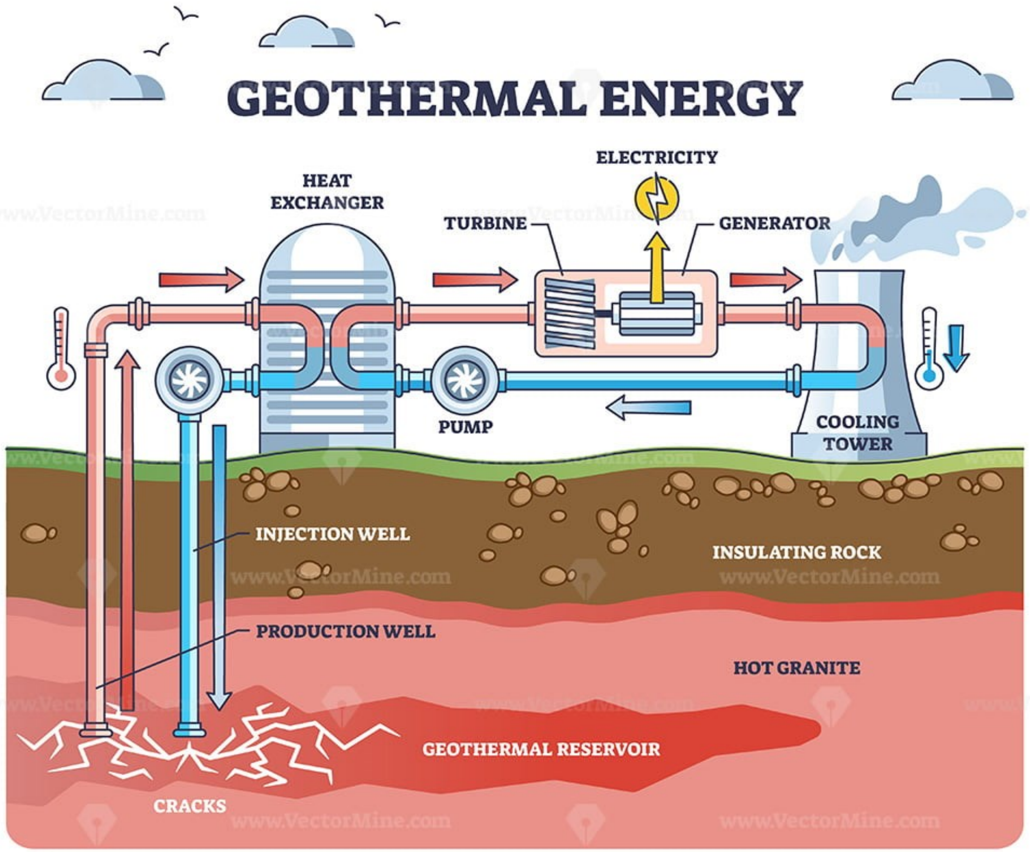
Outline

- **Introduction**
  - ❑Geothermal Applications
  - ❑CFD Codes
  - ❑Rough-Wall Fractures
- **Results**
  - **Star CCM + / Rocky-Fluent solver**
    - ❑Smooth channel fracture
    - ❑Fracture coverage
    - ❑Characteristics in time
    - ❑Particle displacement in time
- **Conclusions and future work**

Introduction



1. https://www.energy.gov/

Purpose

- Fracking the rock formation and keep it open for hot water flow.

Fracturing Procedure

- Drilling a horizontal well in the targeted formation and inserting a steel pipe with holes into the wellbore.
- Pressurized liquid and proppants are injected into wellbores.
- The targeted formation fractures.
- Injection process is ceased, and the fracking liquids is drained.
- Proppants in fracking fluid penetrates rock fractures and keep them open allowing hot water flow back to surface.

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Motivation

- Experimental field studies are expensive
- Numerical studies with a realistic fracture geometry are scarce
- The effect of proppant's properties on the fracture coverage and heat transfer is not fully understood

Objectives

- Develop a computational model for proppant flows in rock fractures
- Assess the facture coverage and heat transfer under different conditions

Solution Methods

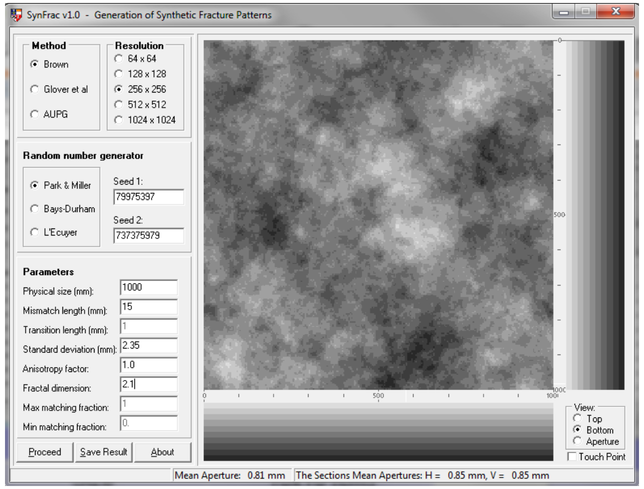
- Computational models
  I. Star CCM + solver
  II. Rocky-Fluent solver

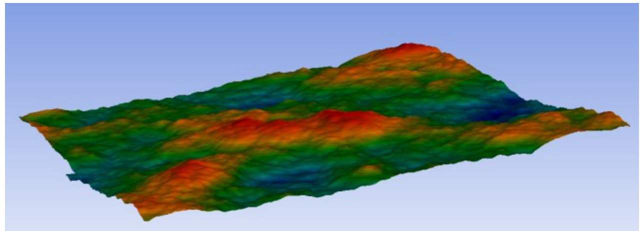
Introduction - Rough wall Fracture, CFD-DEM Code

SynFrac.exe
GenerateGeometry

MATLAB R2018b
App

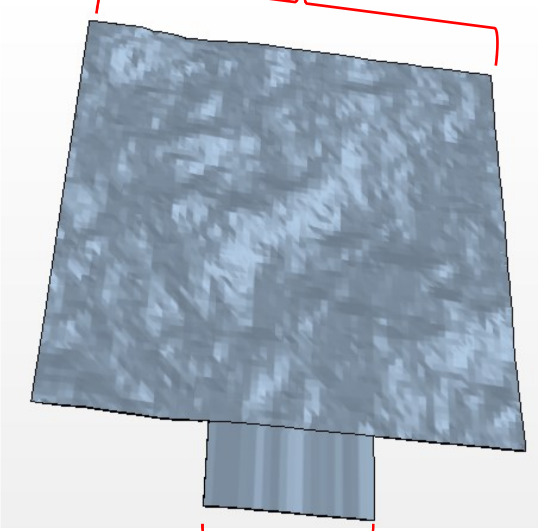
Simulation
CFD-DEM solver





.frt file

Outlet



Inlet

.srt file

2020
Simcenter
STAR-CCM+

Ansys
ROCKY
ADVANCED SOLUTION PARTNER
Rocky-Fluent

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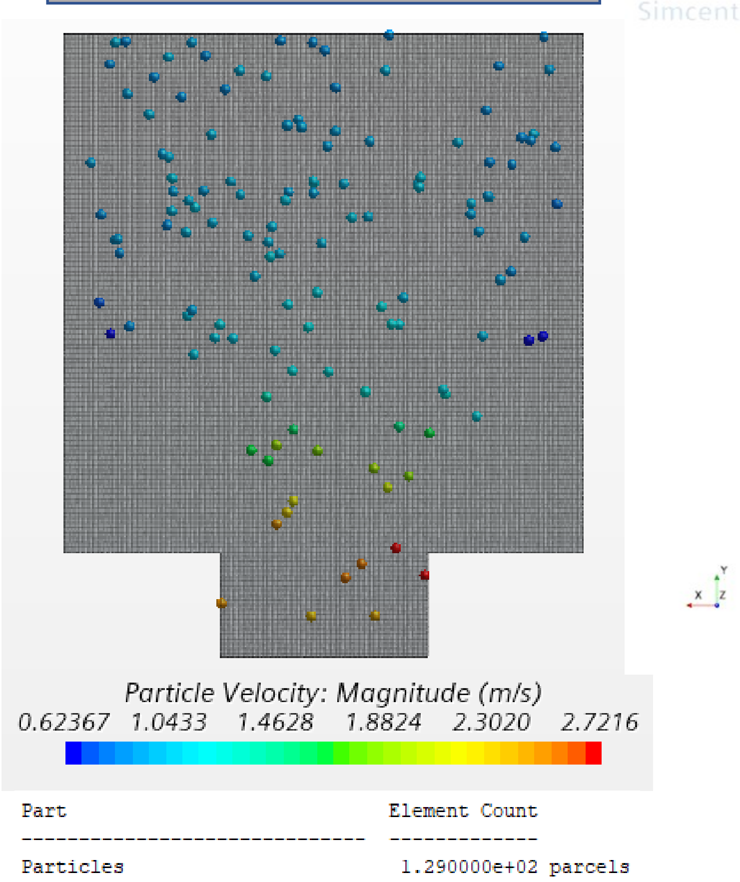
Star CCM +, Smooth channel fracture

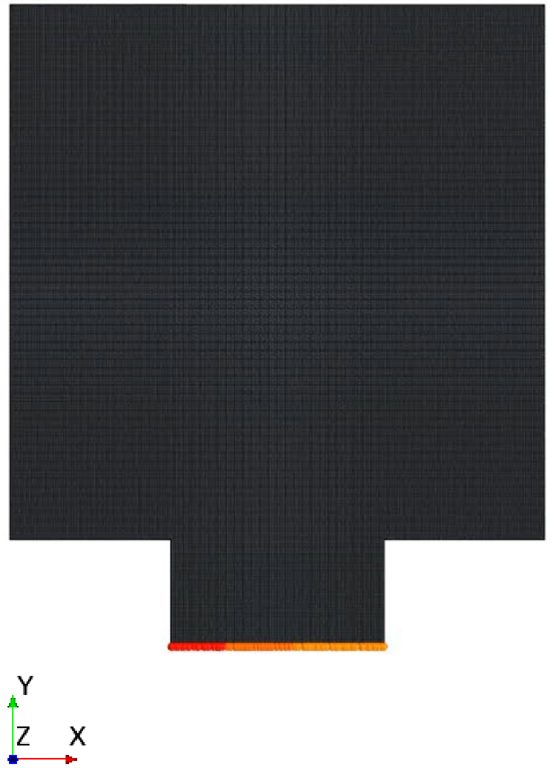
- Smooth walls
- Fracture Dimension = 100 × 100 × 0.4 mm
- Slick water + sand
- Gravity in –Z direction
- 1000 Particle per second
- Inlet pressure = 10 $m^2/\ s^2$ normalized by the fluid density

Particle Distribution

Particle distribution after 5s



Movie of particles displacement



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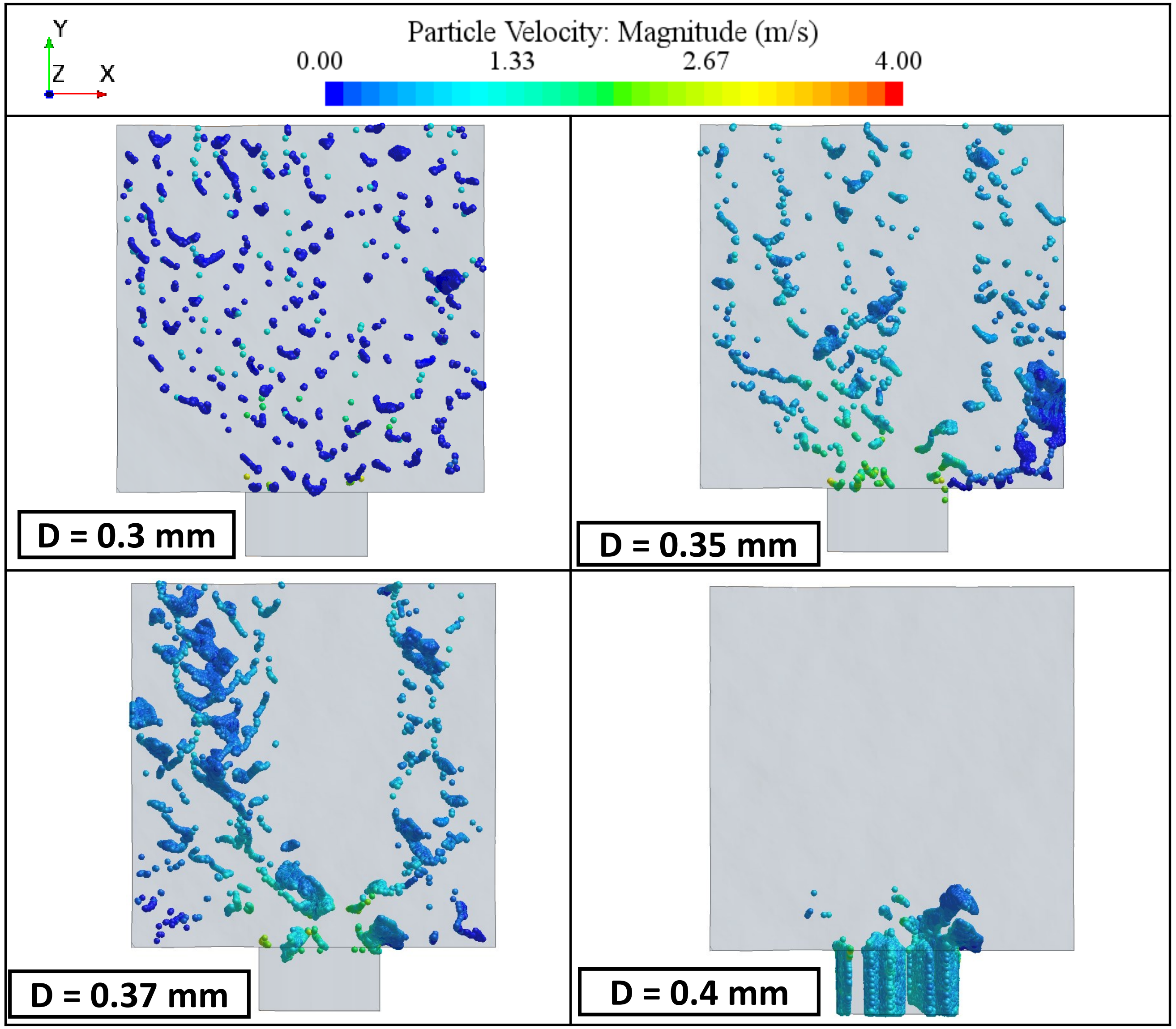
Star CCM +, Mean Aperture size = 0.4 mm

- Mean Aperture size = 0.4 mm
- Gravity in –Z direction
- Fracture Dimension = 0.1 × 0.1 m
- Slick water + sand
- 1000 Particle per second
- Inlet pressure = 10 m^2 / s^2 normalized by the fluid density

Fracture Coverage



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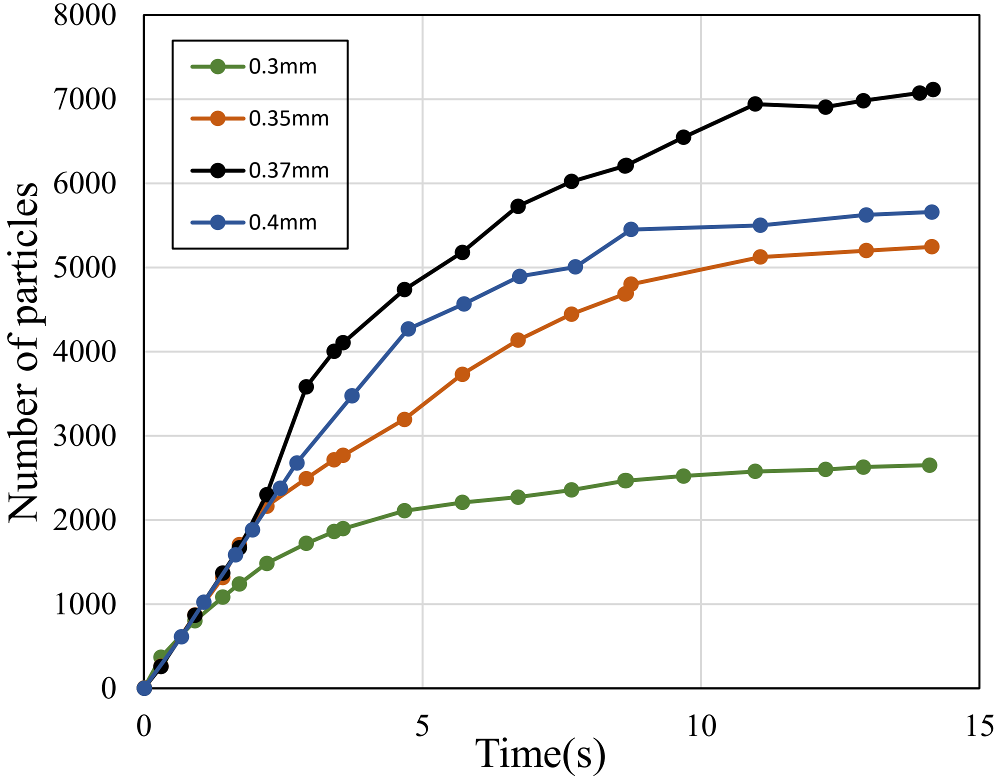
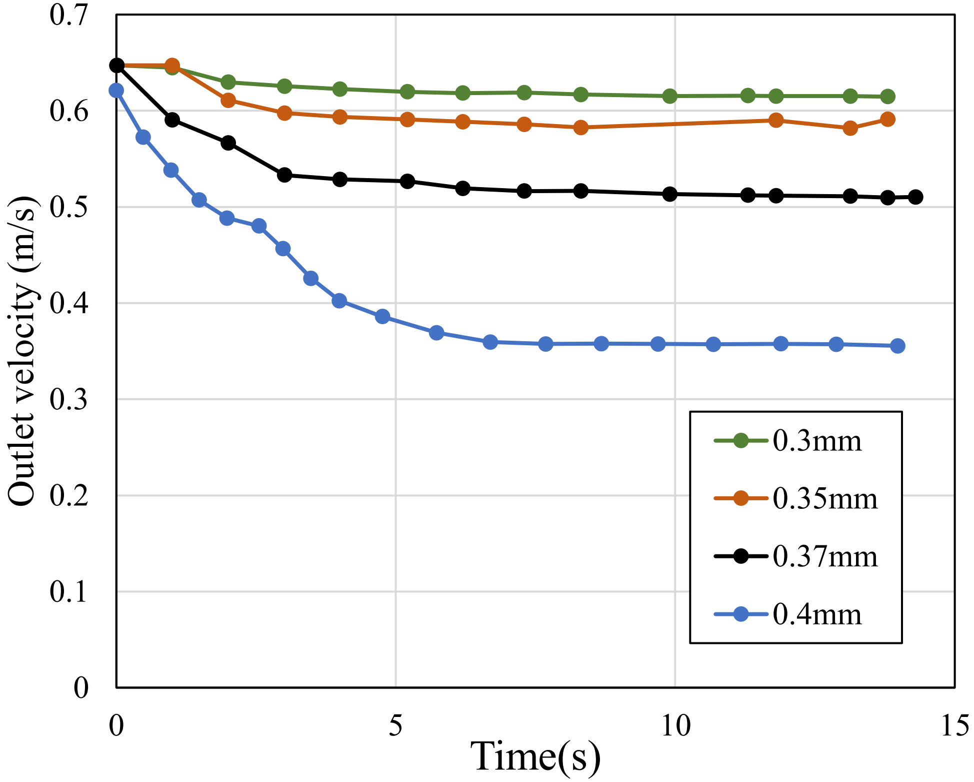
Star CCM +, Mean Aperture size = 0.4 mm

Number of particles in the fracture over time



Fluid flow velocity at the outlet of the fracture



- Mean Aperture size = 0.4 mm
- Gravity in –Z direction
- Fracture Dimension = 0.1 × 0.1 m
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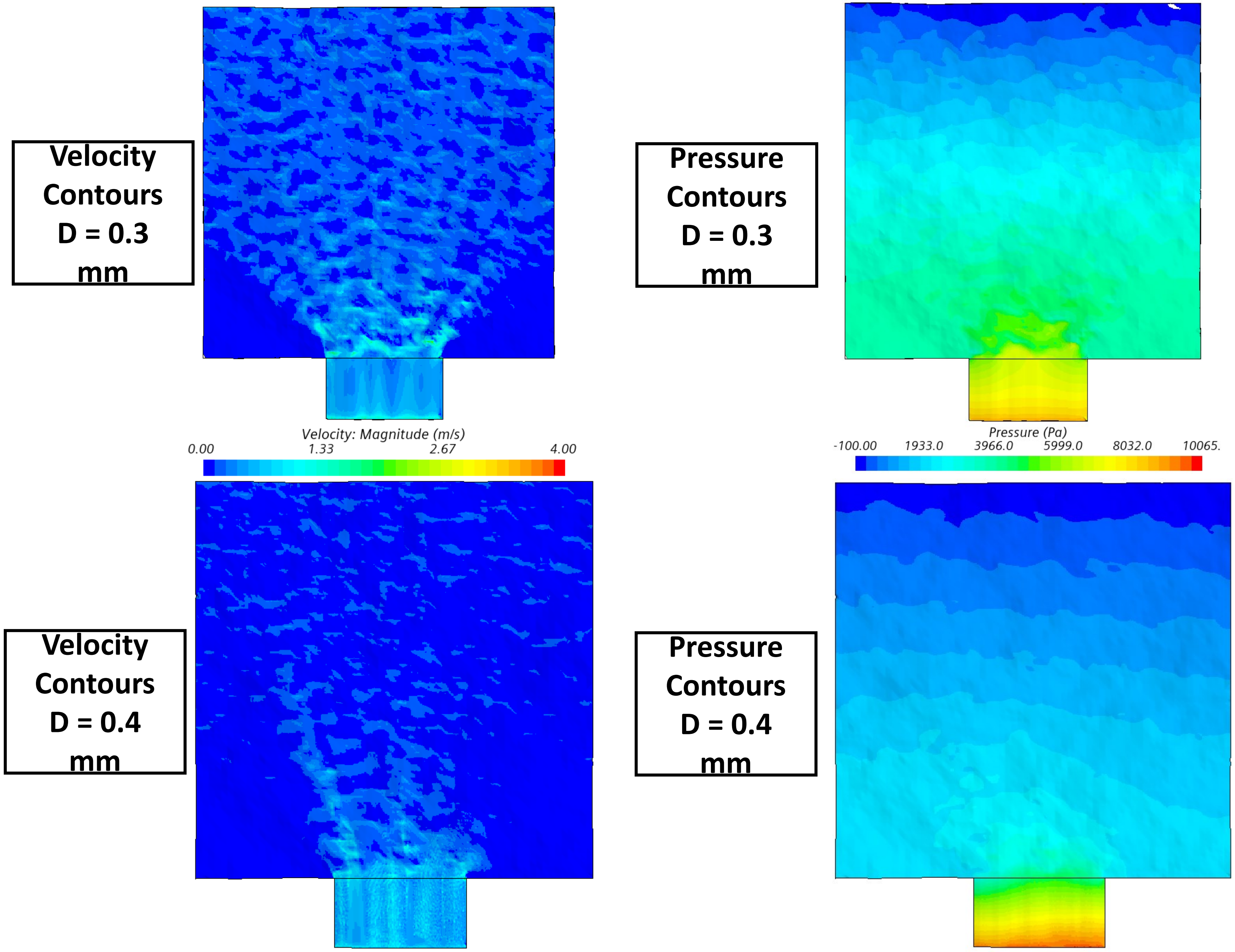
Velocity and Pressure Contours

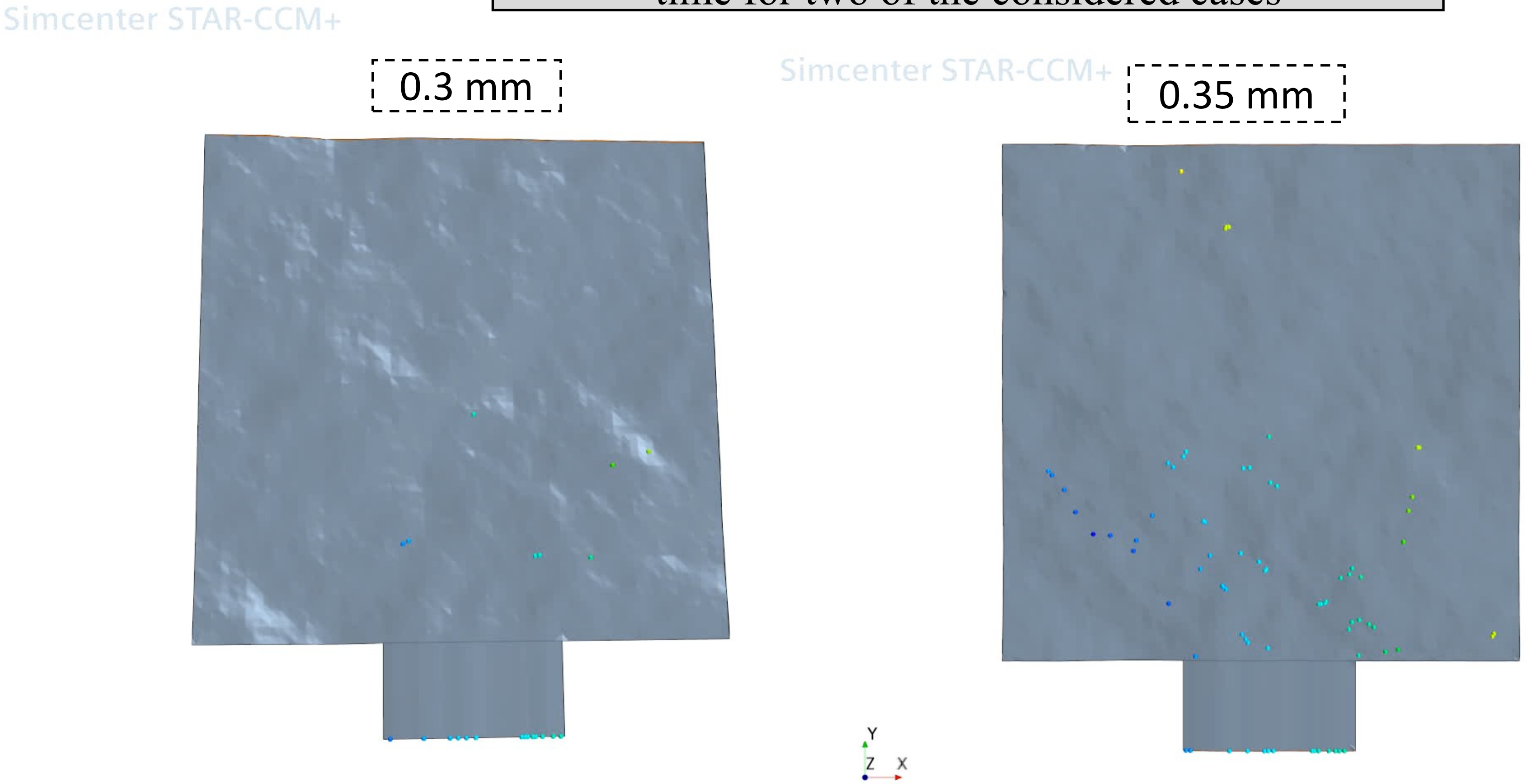


Star CCM +, Mean Aperture size = 0.4 mm

Movie of particles injection and displacement over time for two of the considered cases

0.3 mm

0.35 mm



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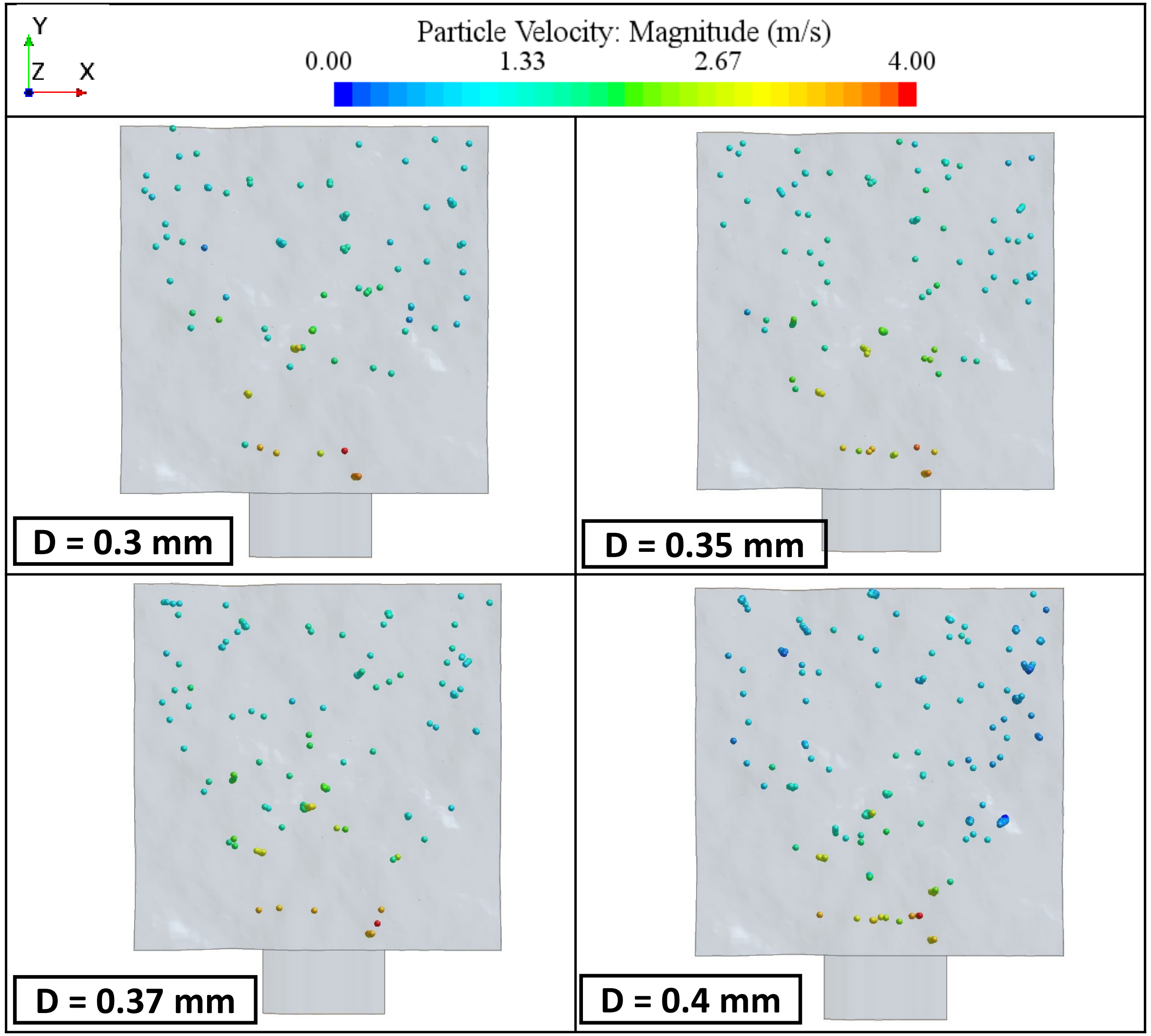
Star CCM +, Mean Aperture size = 0.8 mm

- Mean Aperture size = 0.8 mm
- Gravity in –Z direction
- Fracture Dimension = 0.1 × 0.1 m
- Slick water + sand
- 1000 Particle per second
- Inlet pressure = 10 m^2 / s^2 normalized by the fluid density

Fracture Coverage



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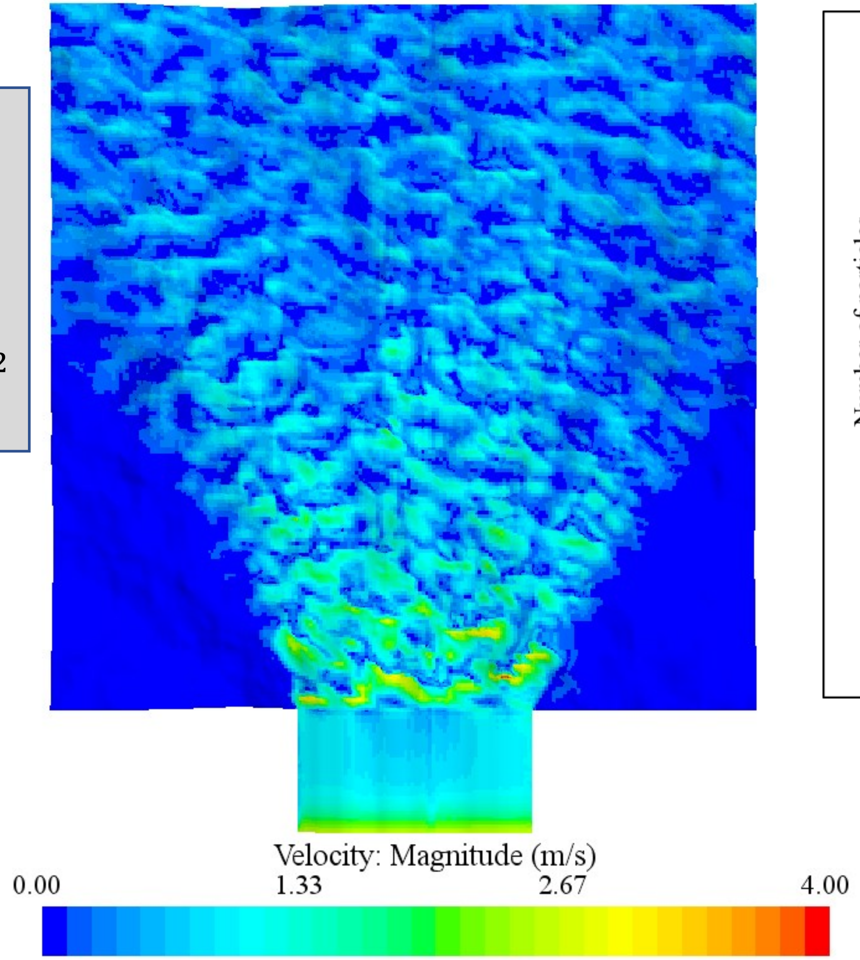
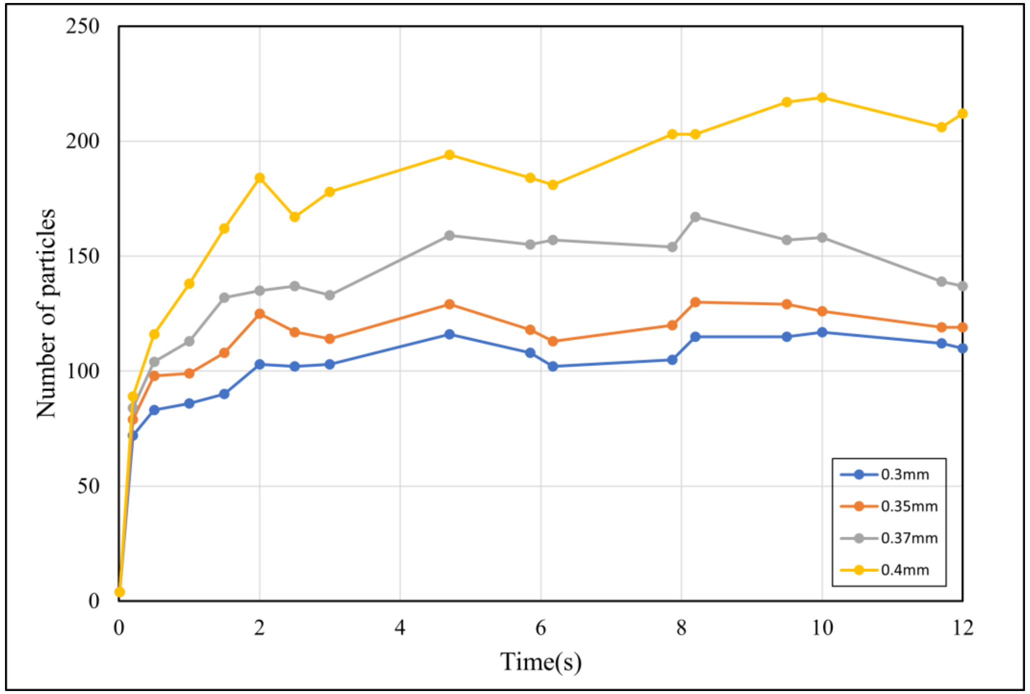
Star CCM +, Mean Aperture size = 0.8 mm

- Mean Aperture size = 0.8 mm
- Gravity in –Z direction
- Fracture Dimension = 0.1 × 0.1 m
- Slick water + sand
- 1000 Particle per second
- Inlet pressure = 10 m^2 / s^2 normalized by the fluid density

Velocity Contours D = 0.3 mm



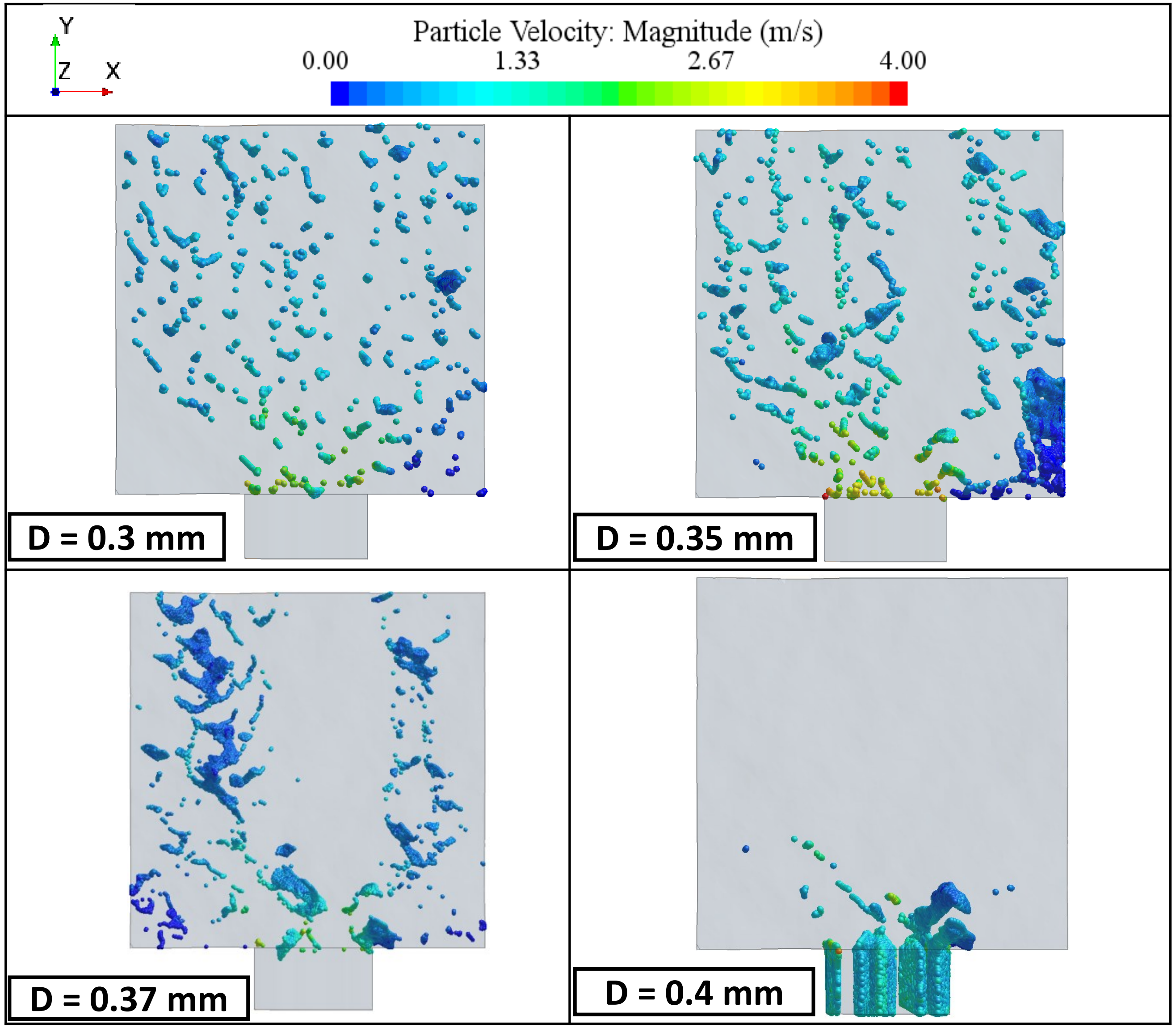
Number of particles in the fracture over time



Star CCM +, Vertical fracture

- Gravity in –Y direction
- Mean Aperture size = 0.4 mm
- Fracture Dimension = 0.1 × 0.1 m
- Slick water + sand
- 1000 Particle per second
- Inlet pressure = 10 m^2 / s^2 normalized by the fluid density

Fracture Coverage



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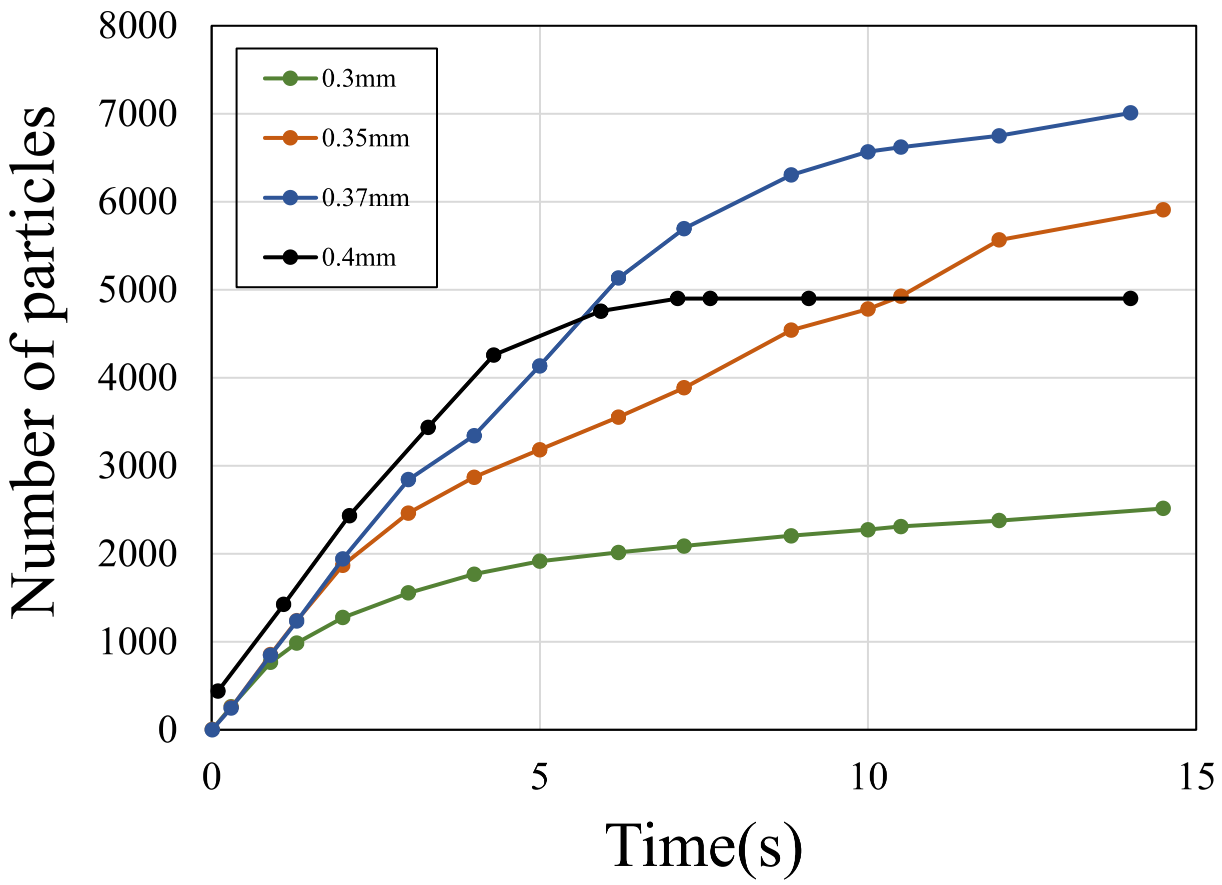
Star CCM +, Vertical fracture

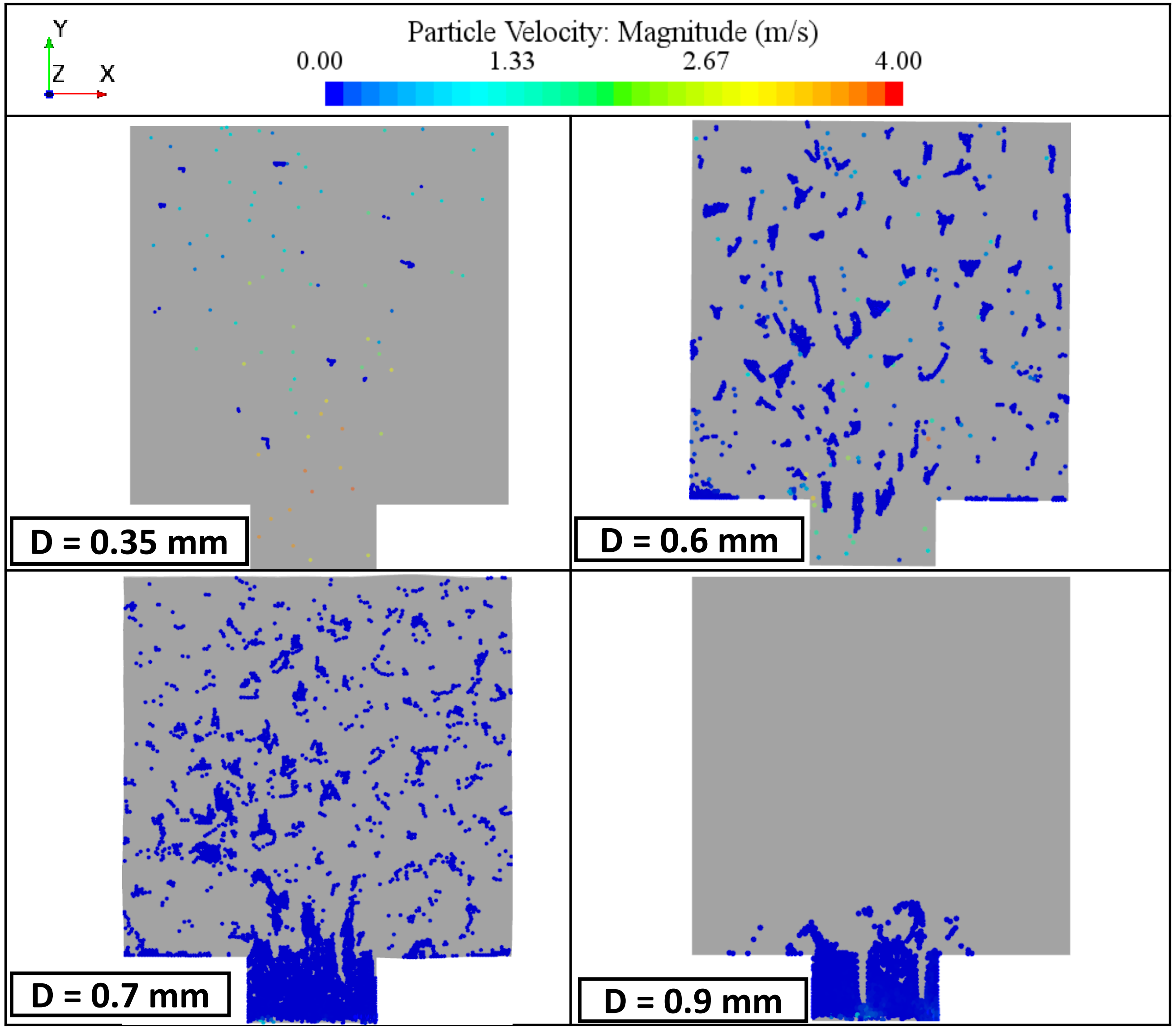
- Gravity in –Y direction
- Mean Aperture size = 0.4 mm
- Fracture Dimension = 0.1 × 0.1 m
- Slick water + sand
- 1000 Particle per second
- Inlet pressure = 10 m^2 / s^2 normalized by the fluid density



Rocky-Fluent, Mean Aperture size = 1 mm

- Mean Aperture size = 1 mm
- Gravity in –Z direction
- Fracture Dimension = 0.1 × 0.1 m
- Slick water + sand
- 1000 Particle per second
- Inlet pressure = 10 m^2 / s^2 normalized by the fluid density

Fracture Coverage



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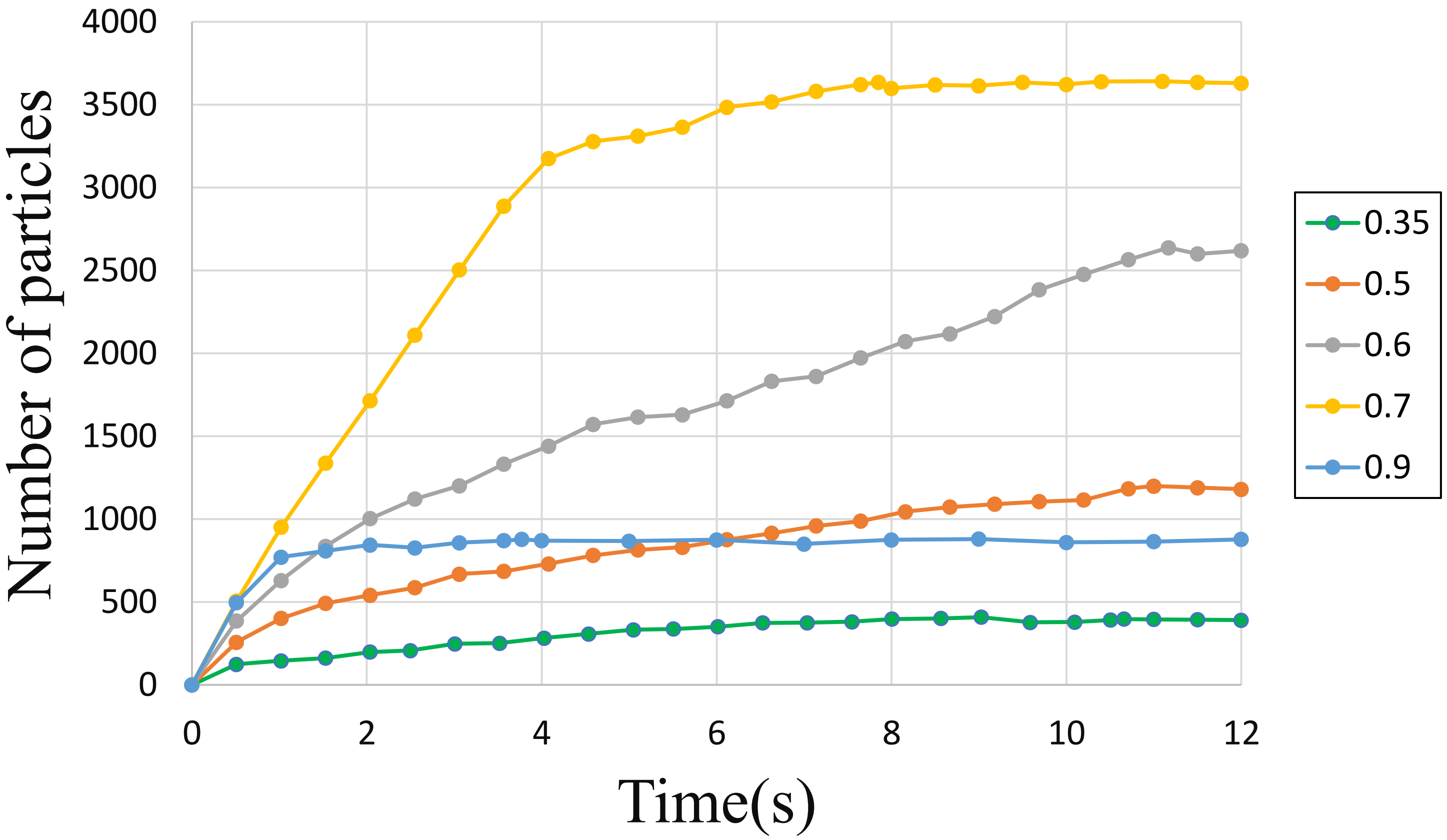
Rocky-Fluent, Mean Aperture size = 1 mm

- Mean Aperture size = 1 mm
- Gravity in –Z direction
- Fracture Dimension = 0.1 × 0.1 m
- Slick water + sand
- 1000 Particle per second
- Inlet pressure = 10 m^2 / s^2 normalized by the fluid density



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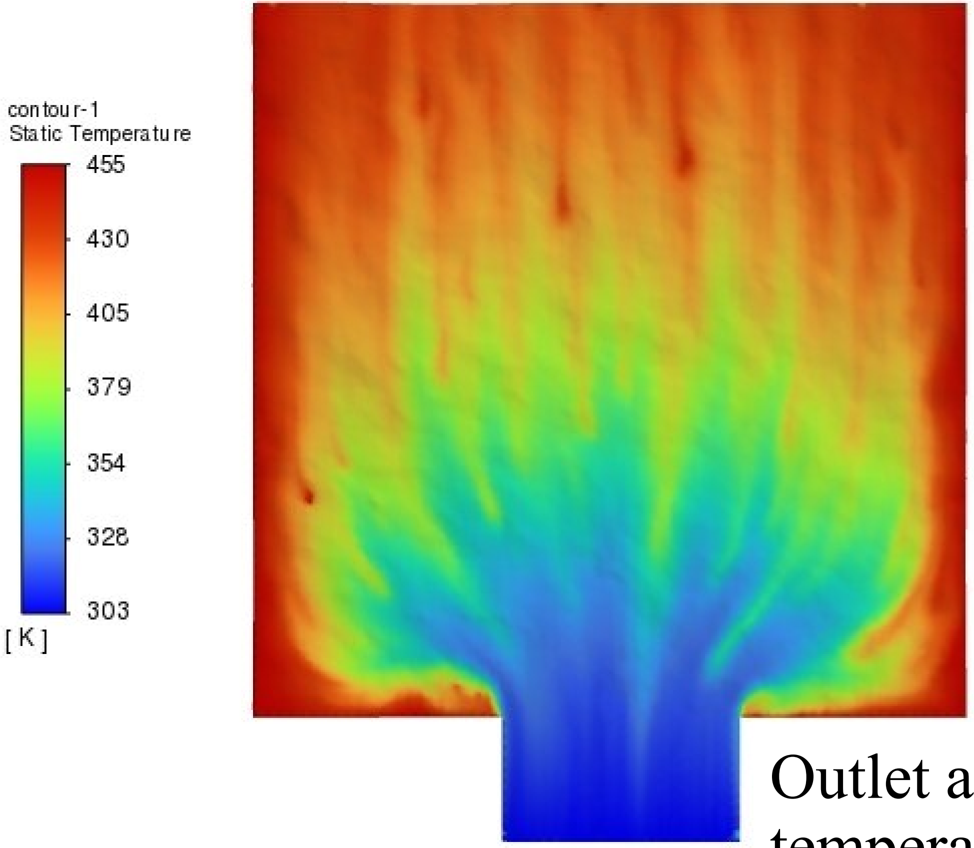
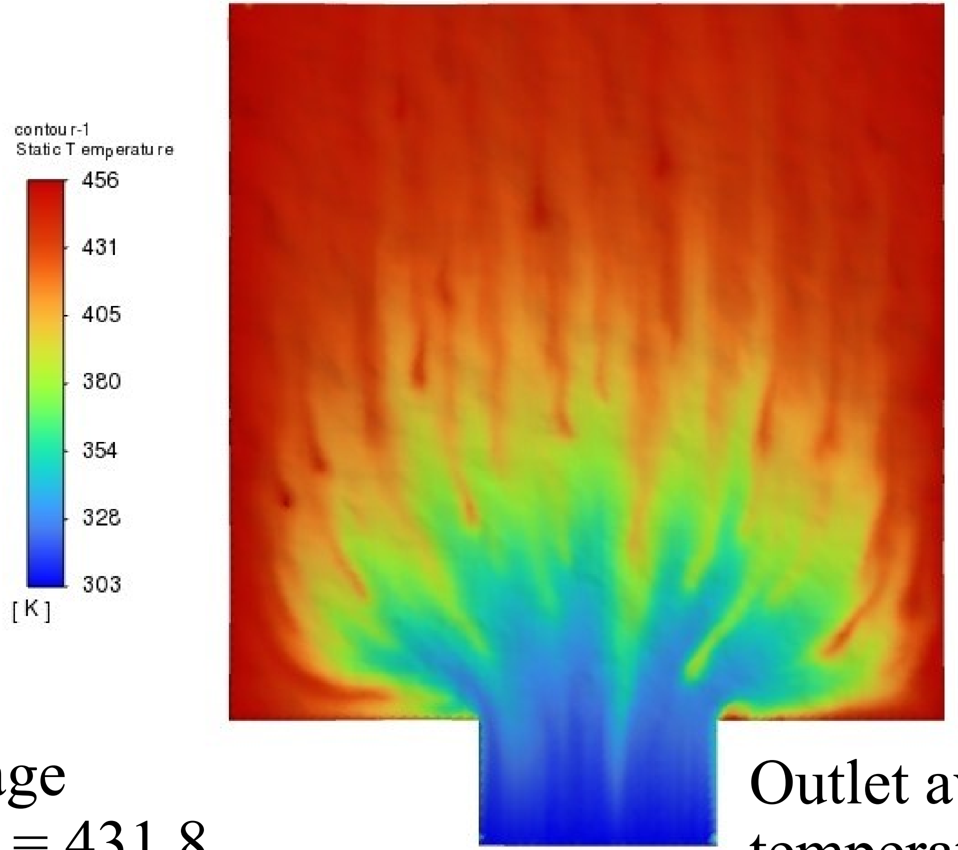
Heat transfer

- Water flow
- Wall temperature = 182 C
- Inlet temperature = 30 C



Outlet average temperature = 431.8

- Nano-fluid (water + Al_2O_3)
- Wall temperature = 182 °C
- Inlet temperature = 30 °C
- C_p = 3706 J/kg°C
- K = 0.6926 W/m·K



Outlet average temperature = 446.5

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Conclusions and Future Study

- A novel procedure to numerically study the proppant transport in fractures with realistic surface roughness was introduced.
- Sample results on effect of particle diameter, inlet pressure, fluid viscosity and shape of proppant on the coverage of the fracture were presented.
- A novel procedure to numerically study the proppant transport in fractures with realistic surface roughness was introduced.

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Future Study

- For the future study, the effect of fracture's characteristics including the mean fracture aperture and proppants properties on fracture heat transfer would be investigated.

Thanks for your attention!

Questions?

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