Simulation of Proppants Motion and Placement in Realistic Rock Fractures Using Ansys-Fluent-Rocky Code

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Outline

- **Introduction**
  - ❑Hydraulic fracturing
  - ❑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**

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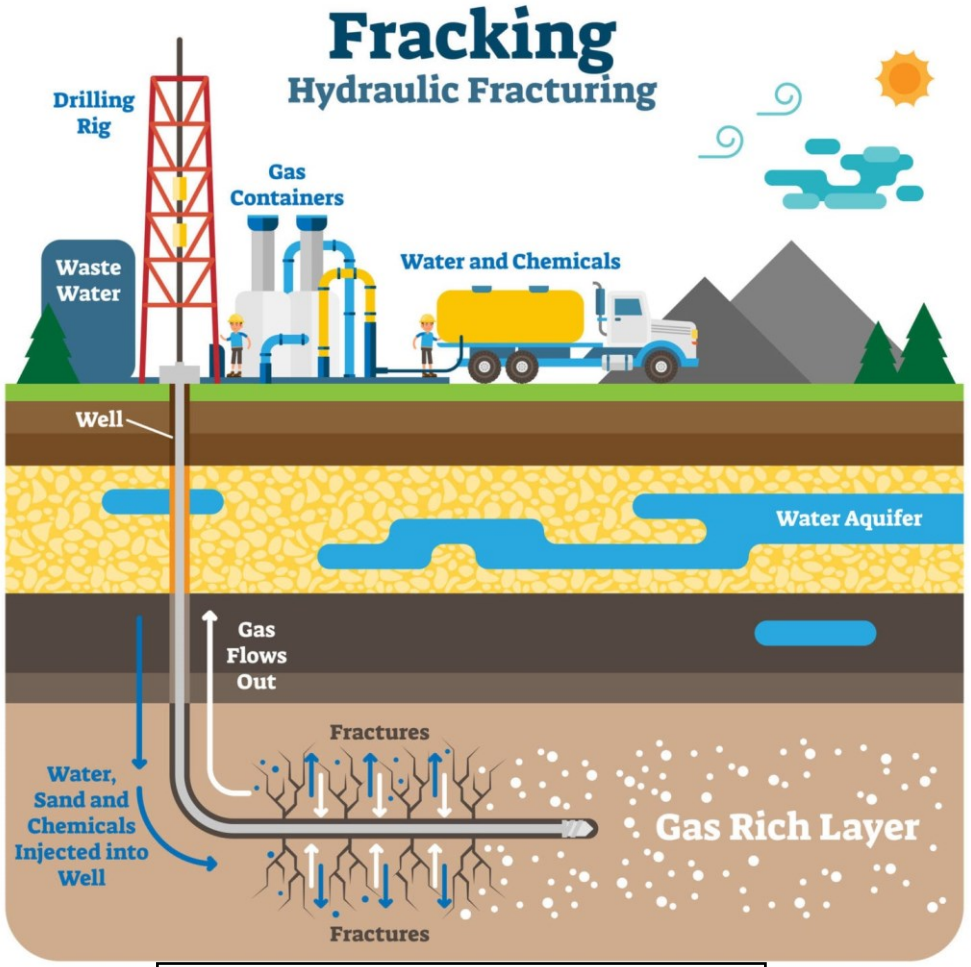
Introduction - Hydraulic Fracturing



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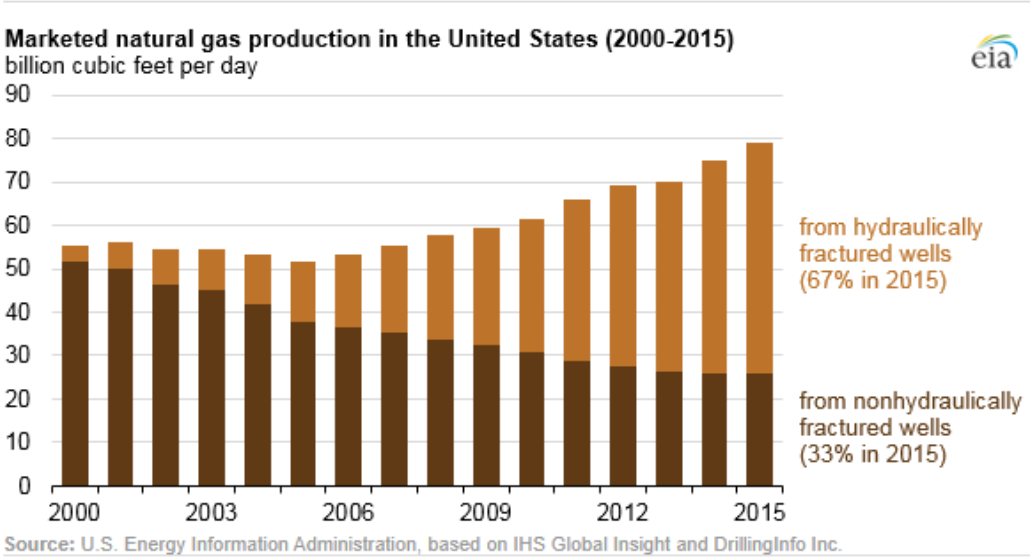
Purpose

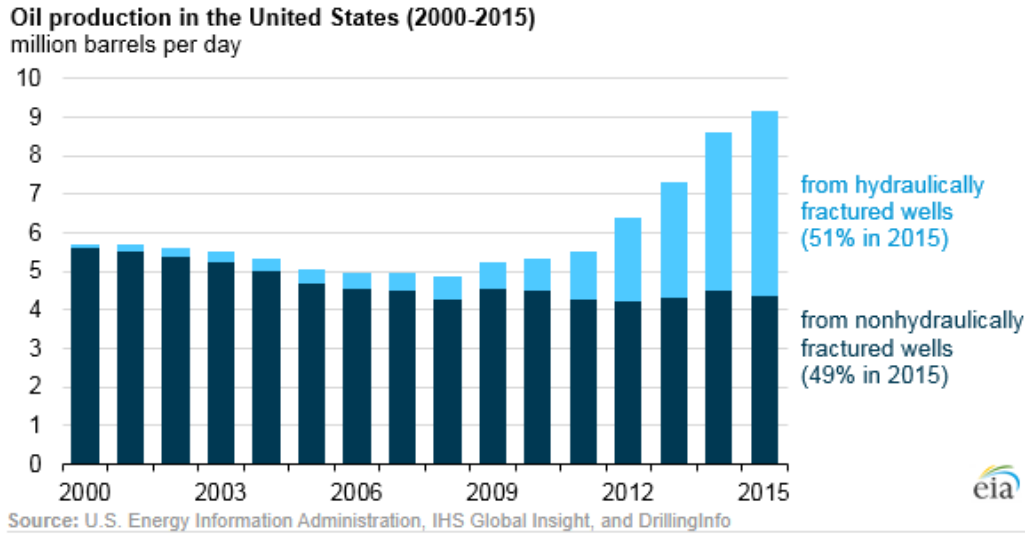
- Releases petroleum or natural gas trapped in shale rock formations.

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.
- Proppant keep the rock fractures open and allows gas/oil production

Introduction - Hydraulic Fracturing





Why it is important?

- Shale gas production increased from 4% in 2005 to 24% in 2012.
- 300K hydraulically fractured wells in 21 states in 2015.
- Fracking generated 67% of natural gas and 43% of crude oil in 2015.
- In 2013 at least 2 million oil/gas wells were fractured.

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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 is not fully understood

Objectives

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

Solution Methods

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

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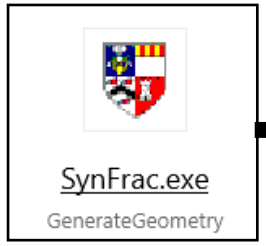
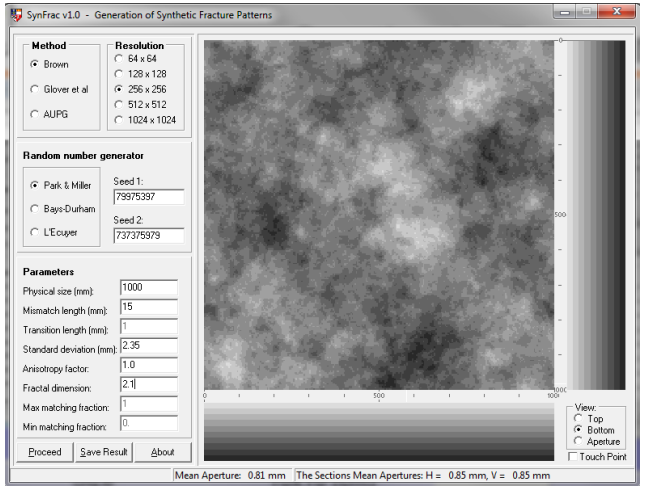
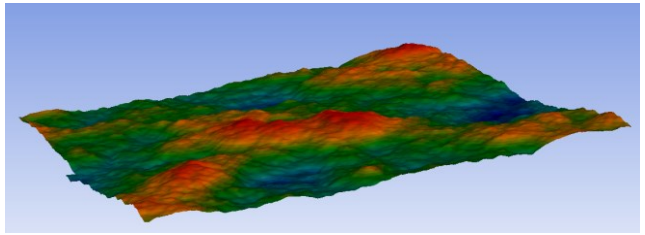
Introduction - Rough wall Fracture, CFD-DEM Code



Simulation
CFD-DEM solver





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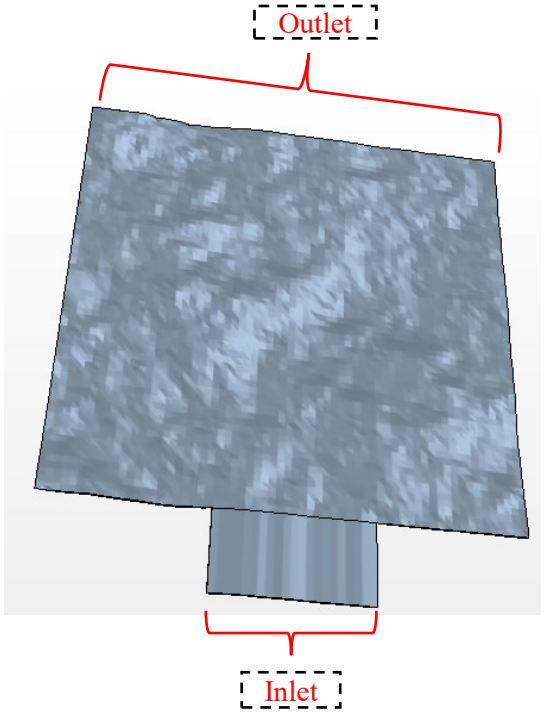

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Simcenter
STAR-CCM+

Rocky-Fluent

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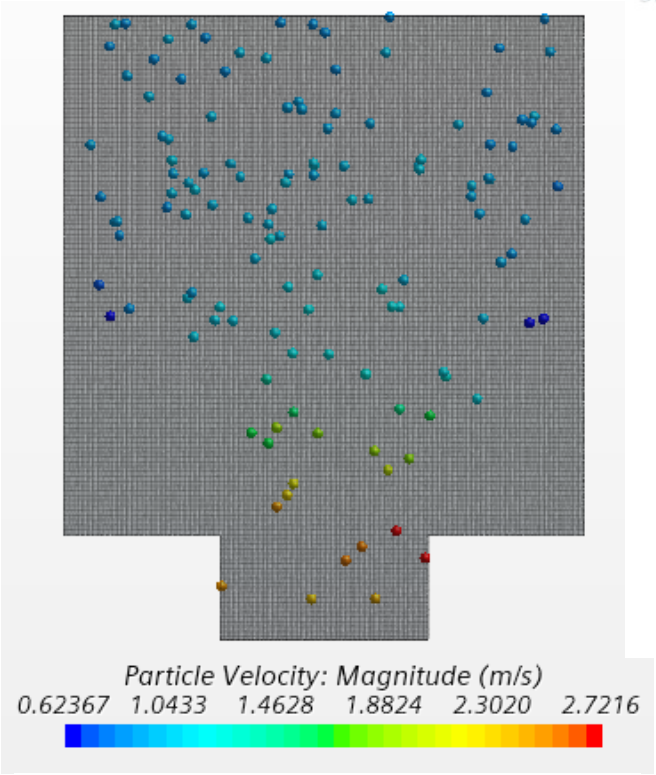
Star CCM +, Smooth channel fracture

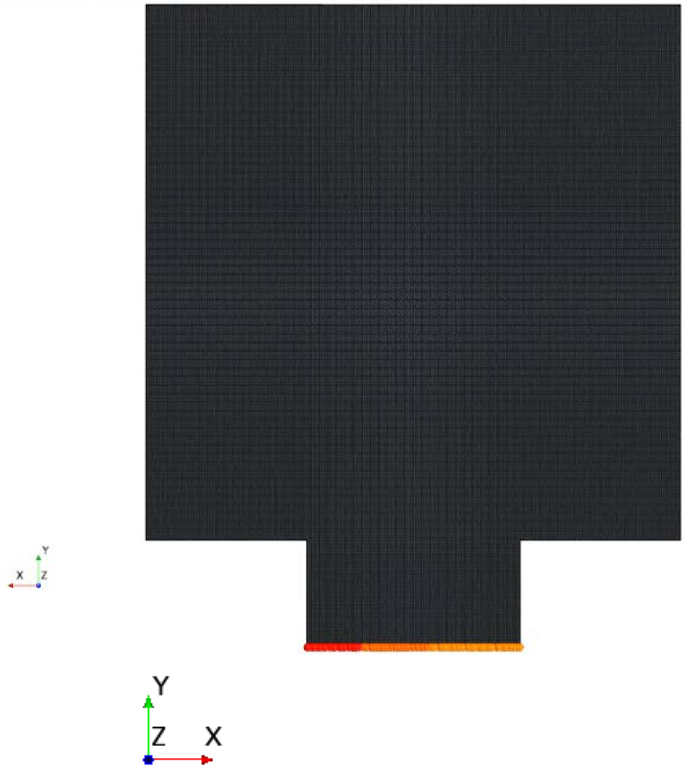
- Smooth walls
- Fracture Dimension = 100 × 100 × 0.4 mm
- Slick water + sand
- Gravity in –Z direction
- 1000 Particle per second
- Inlet pressure = 10 m^2/s^2 normalized by the fluid density

Particle Distribution

Particle distribution after 5s



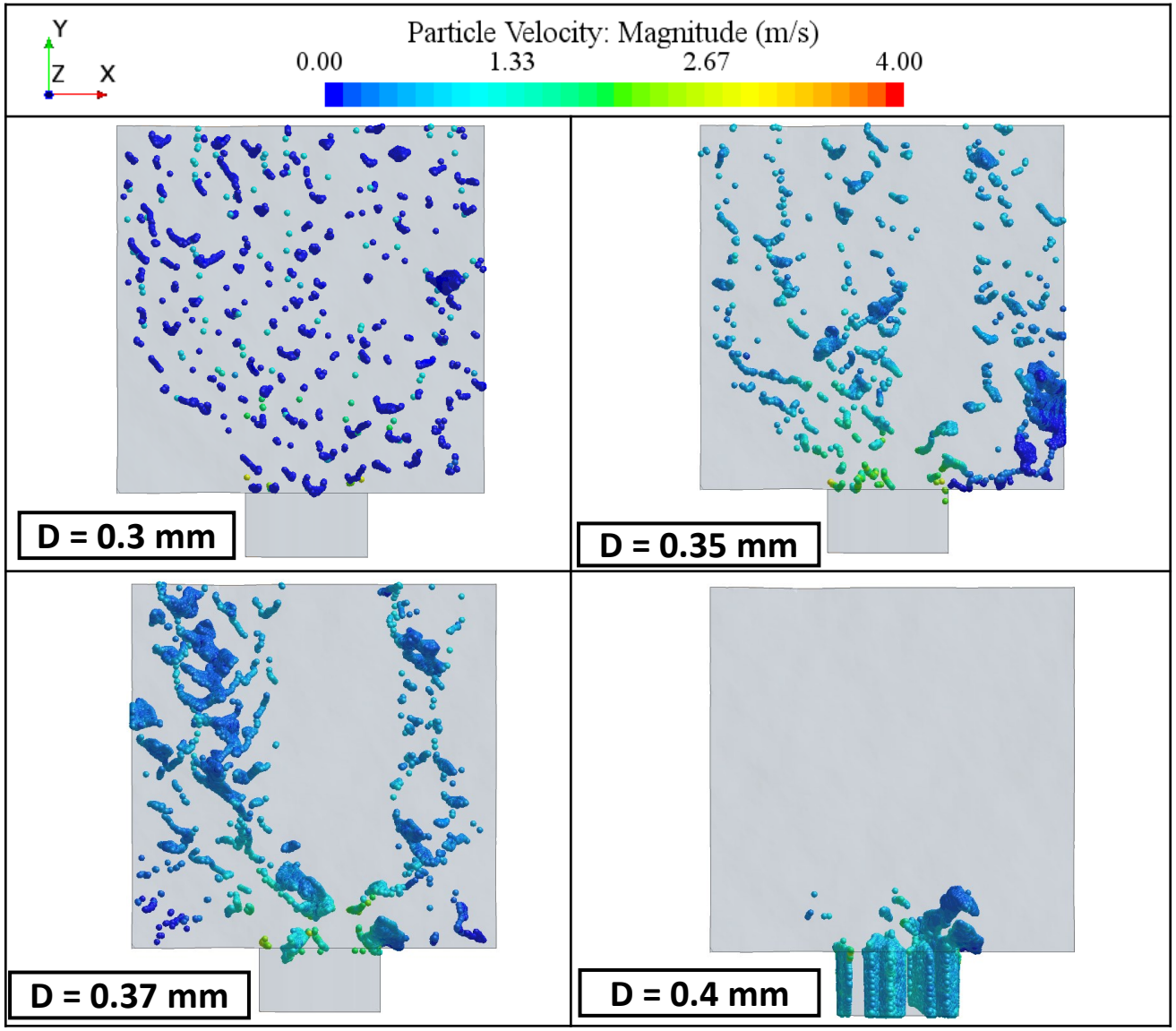
Movie of particles displacement



Star CCM +, Mean Aperture size = 0.4 mm

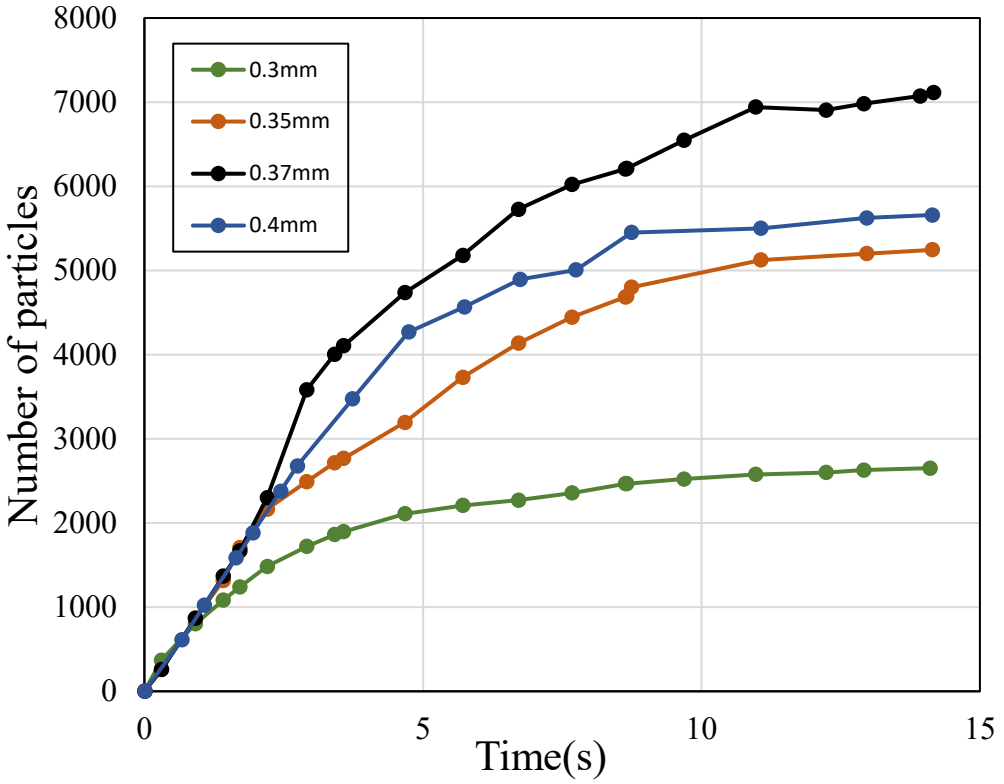
- Mean Aperture size = 0.4 mm
- Gravity in –Z direction
- Fracture Dimension = 0.1 × 0.1 m
- Slick water + sand
- 1000 Particle per second
- Inlet pressure = 10 m^2 / s^2 normalized by the fluid density

Fracture Coverage

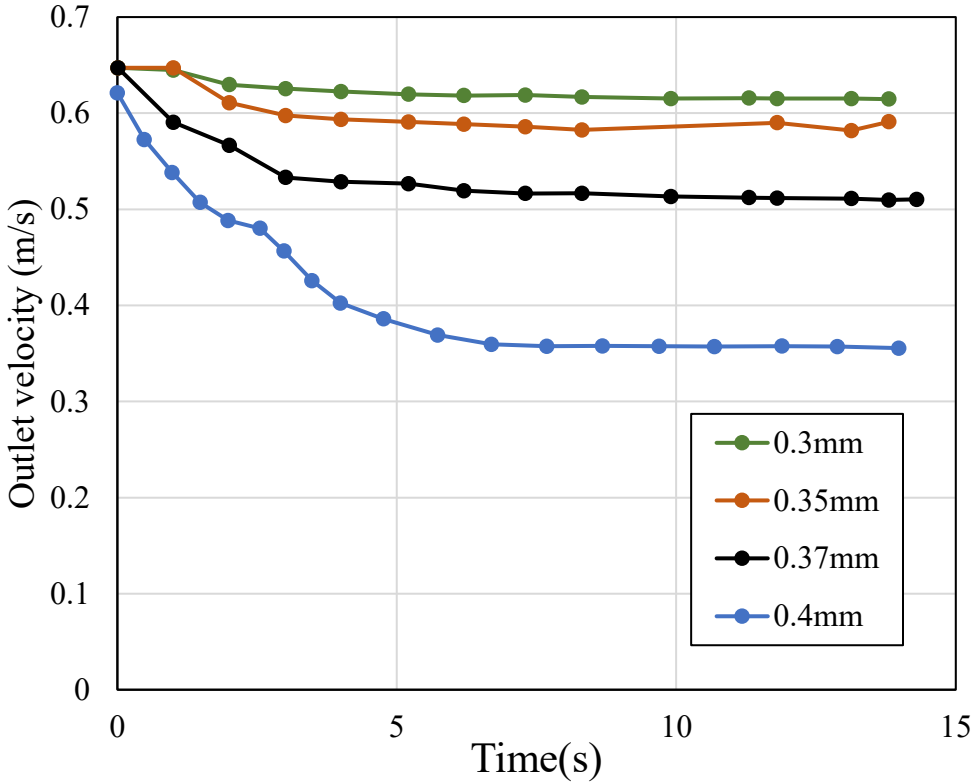


Star CCM +, Mean Aperture size = 0.4 mm

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
- Slick water + Sand
- 1000 Particle per second
- Inlet pressure = 10 m^2/s^2 normalized by the fluid density

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- Slick water + sand
- 1000 Particle per second
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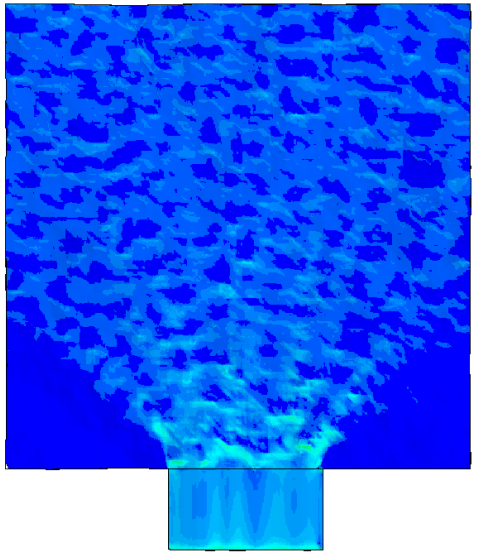
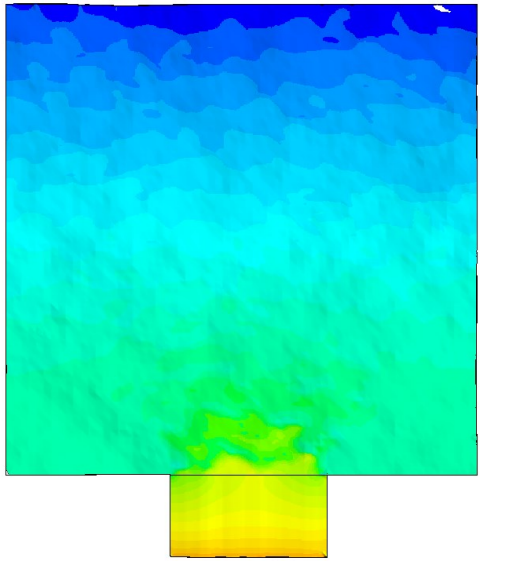
Velocity and Pressure Contours

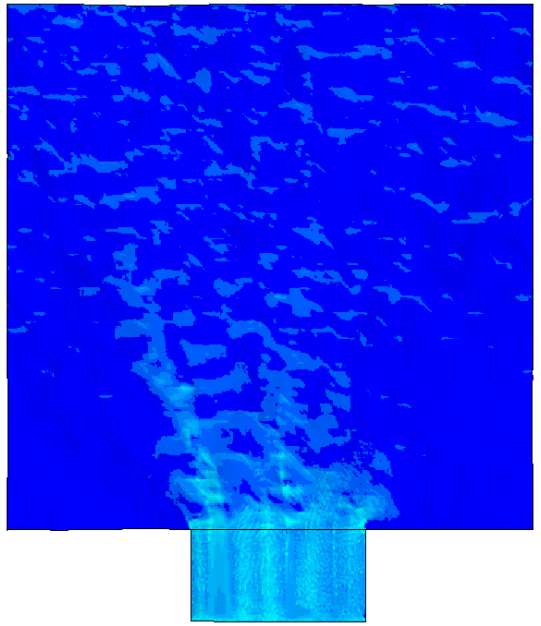
Velocity Contours D = 0.3 mm



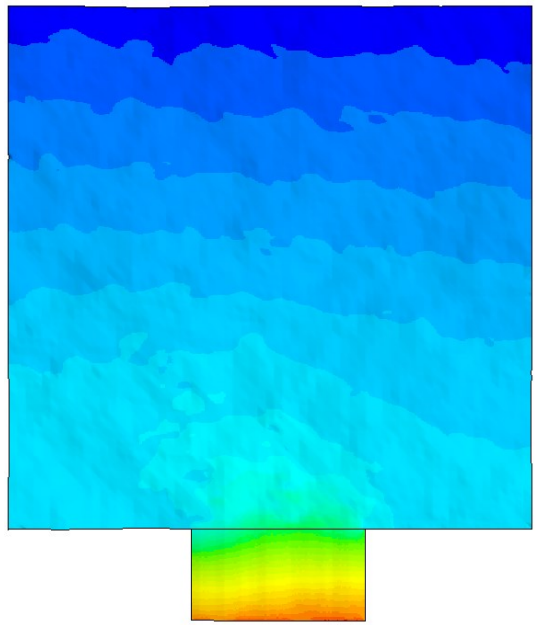
Pressure Contours D = 0.3 mm



Velocity Contours D = 0.4 mm



Pressure Contours D = 0.4 mm



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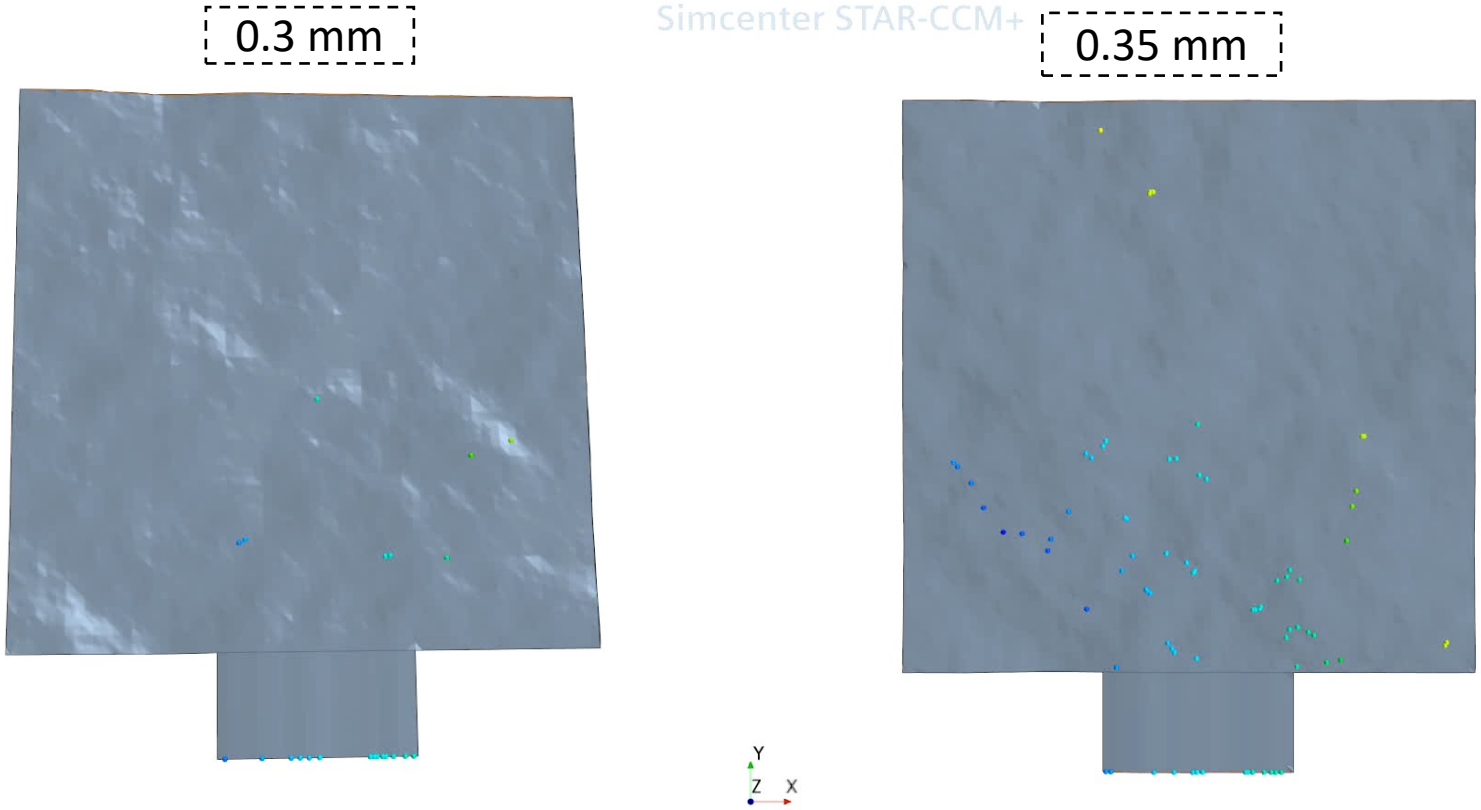
Star CCM +, Mean Aperture size = 0.4 mm

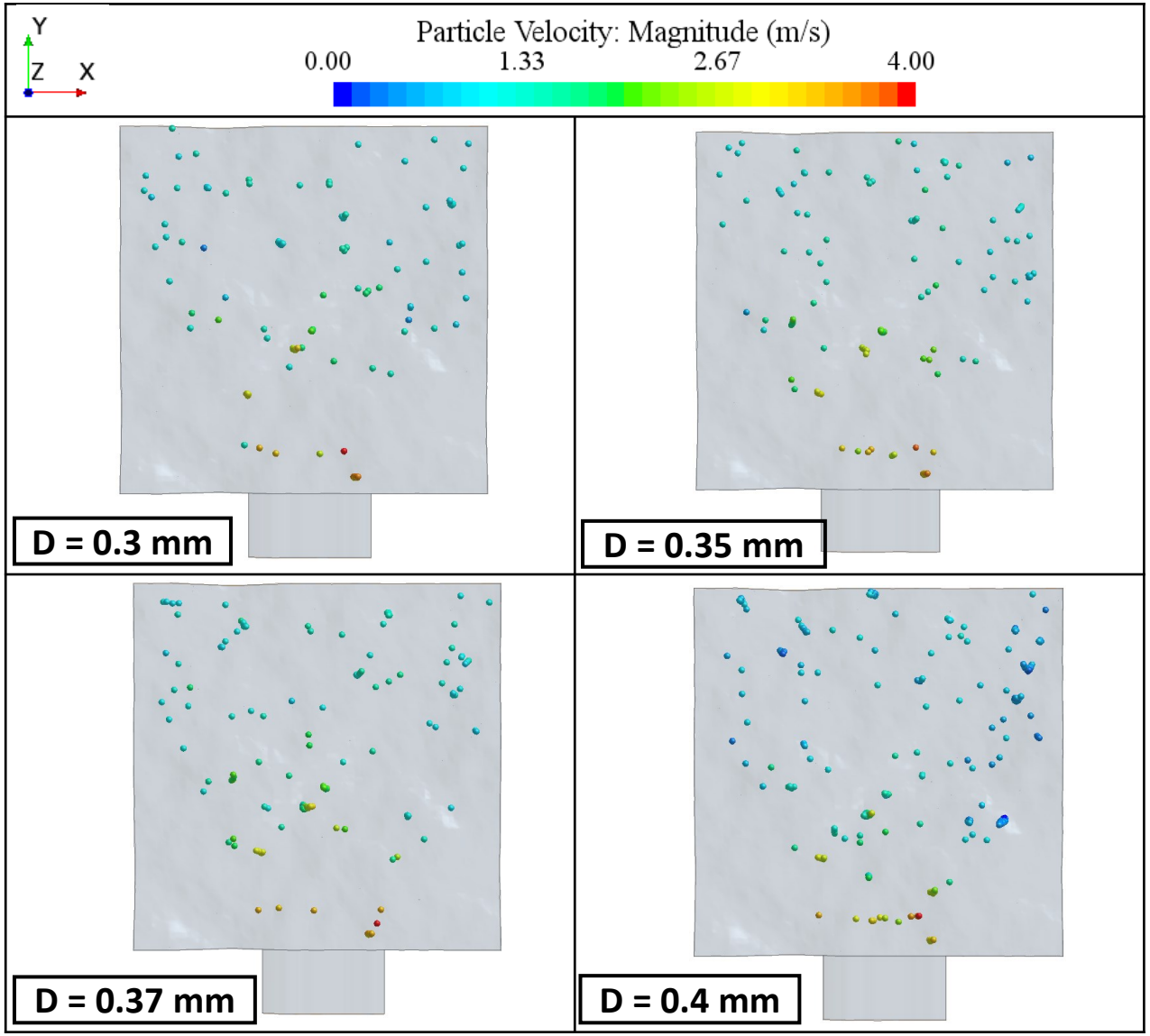
Movie of particles injection and displacement over time for two of the considered cases



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

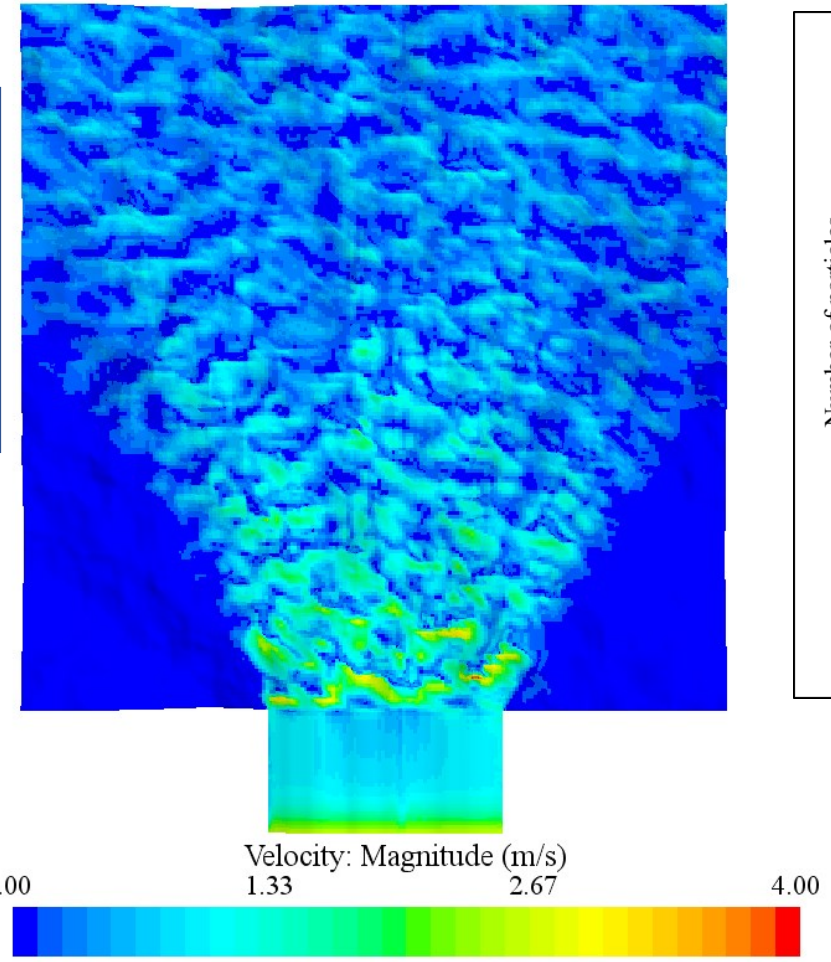
Fracture Coverage



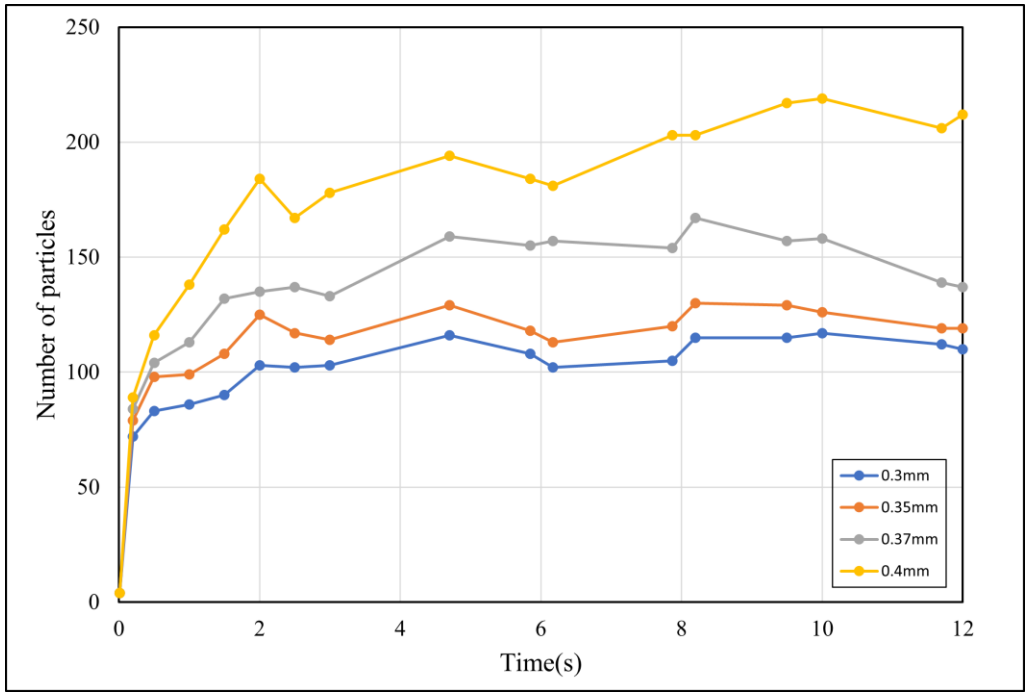
Star CCM +, Mean Aperture size = 0.8 mm

- 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



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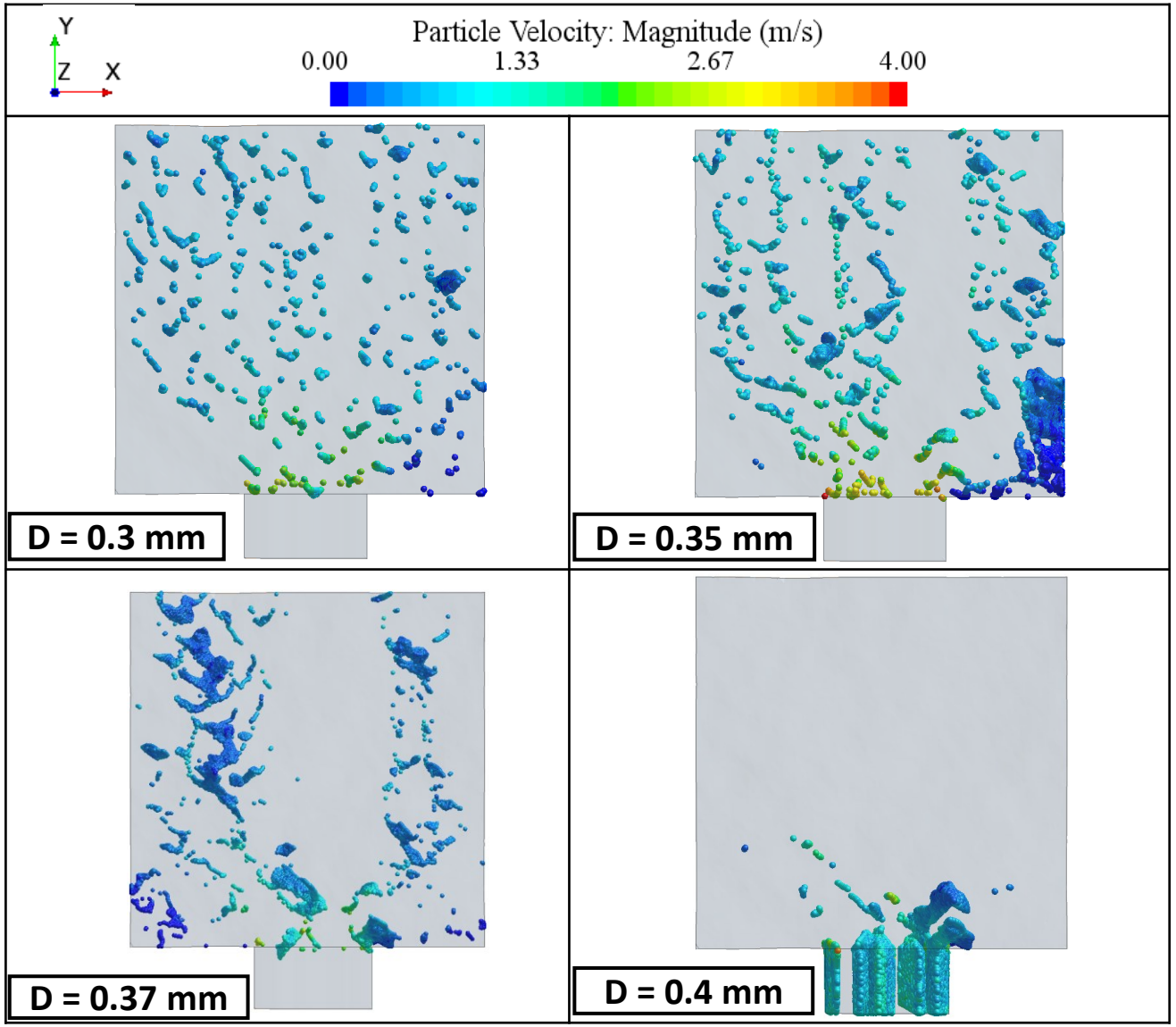
Star CCM +, Vertical fracture

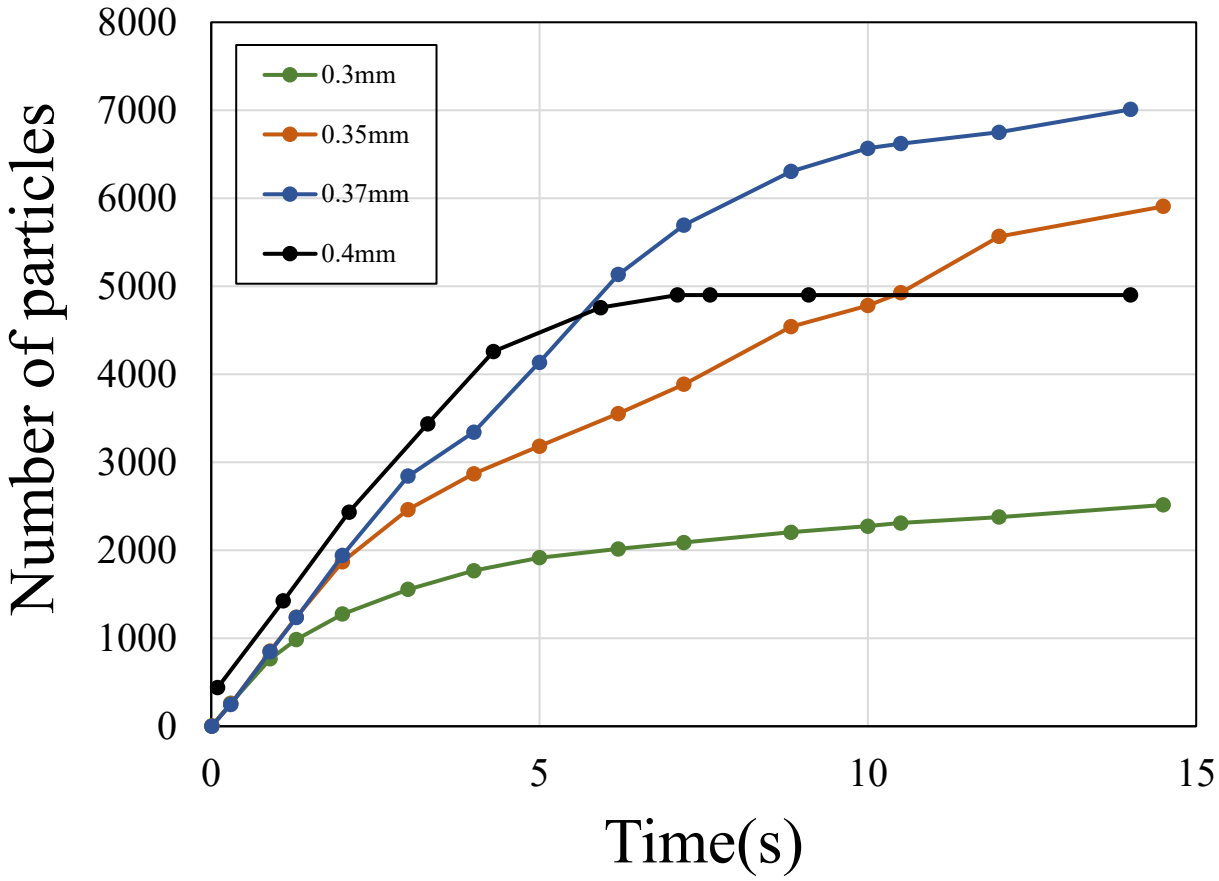
- Gravity in –Y direction
- Mean Aperture size = 0.4 mm
- Fracture Dimension = 0.1 × 0.1 m
- Slick water + sand
- 1000 Particle per second
- Inlet pressure = 10 m^2 / s^2 normalized by the fluid density

Fracture Coverage



Star CCM +, Vertical fracture

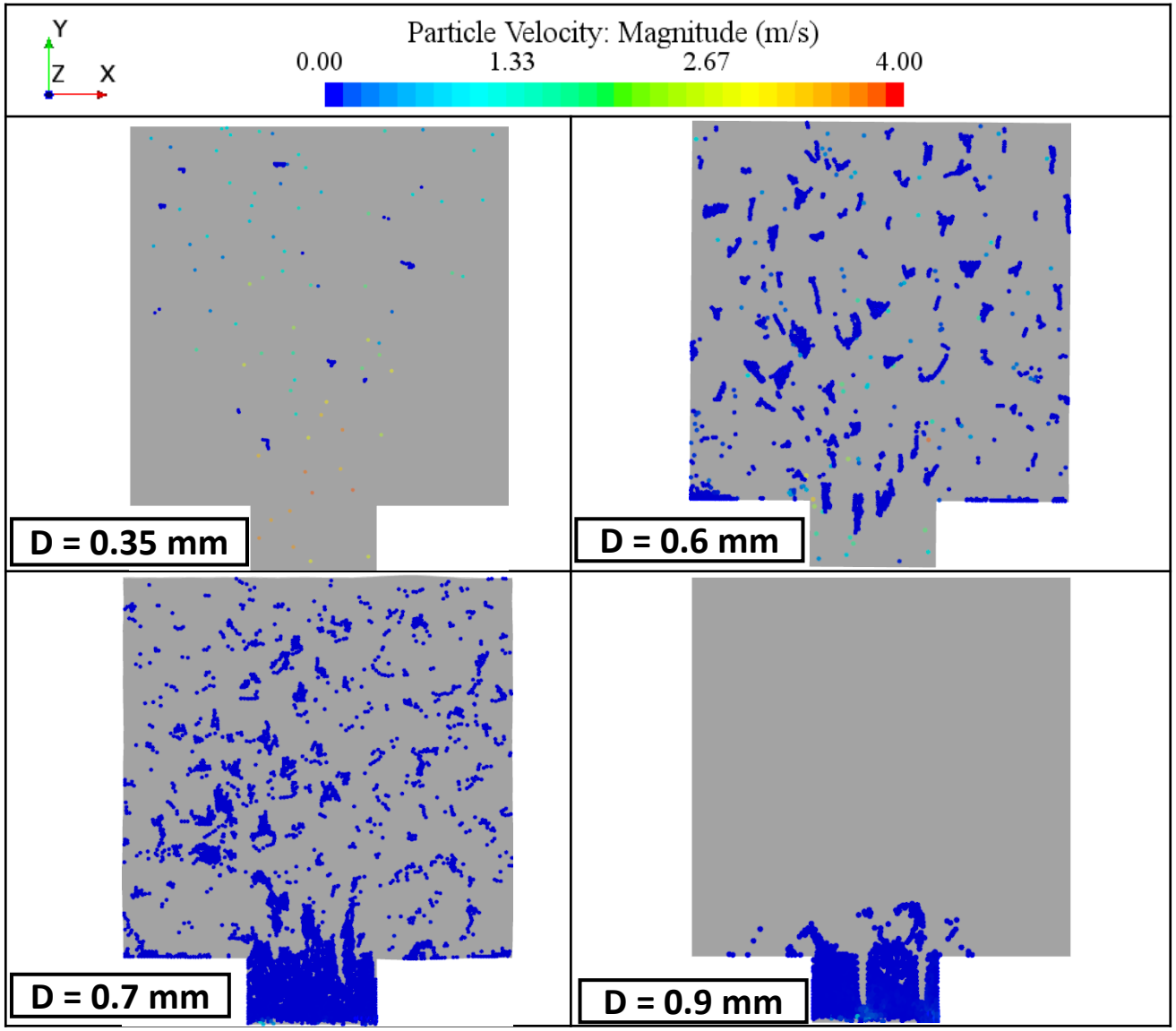
- Gravity in –Y direction
- Mean Aperture size = 0.4 mm
- Fracture Dimension = 0.1 × 0.1 m
- Slick water + sand
- 1000 Particle per second
- Inlet pressure = 10 m^2 / s^2 normalized by the fluid density



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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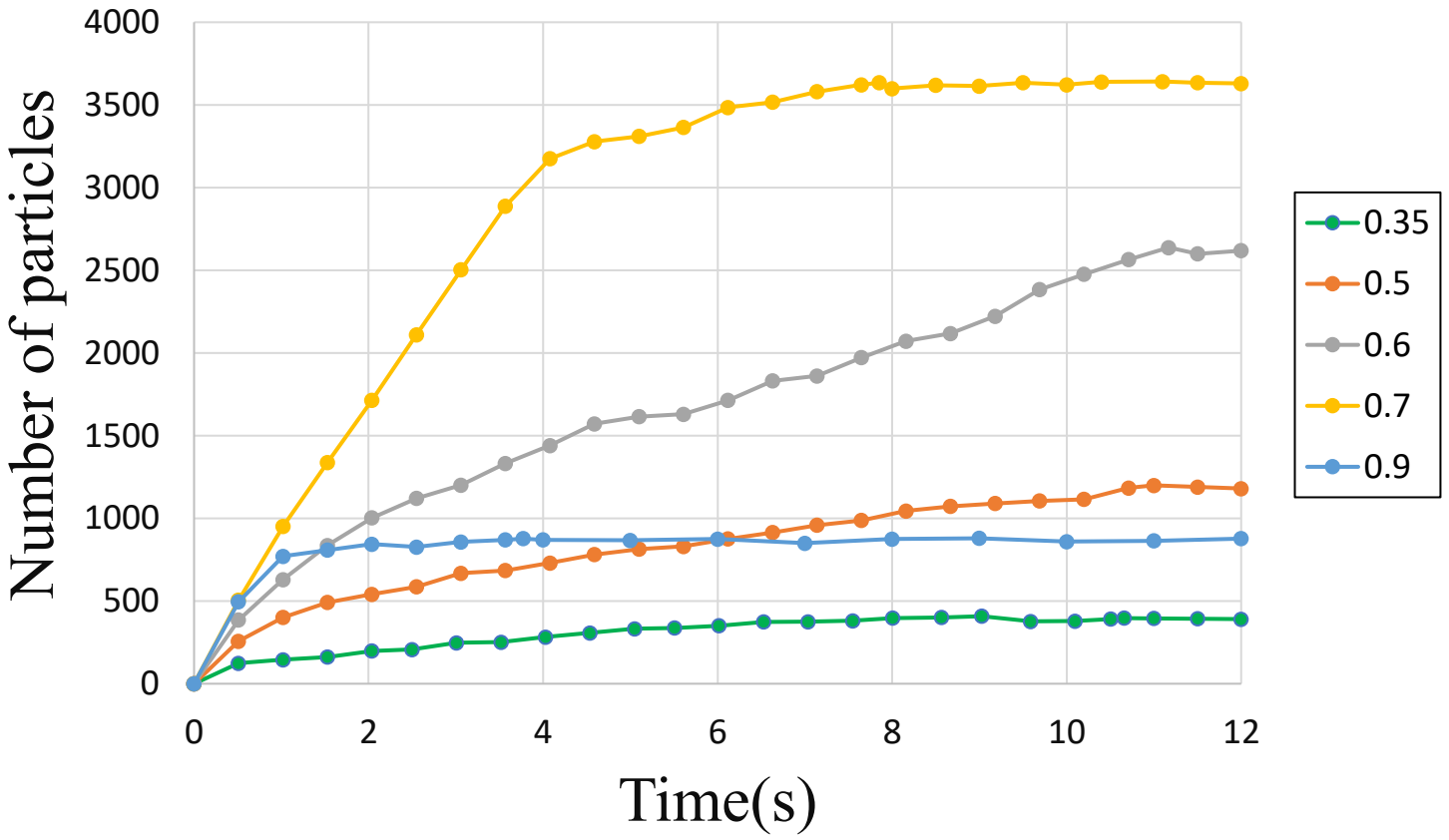
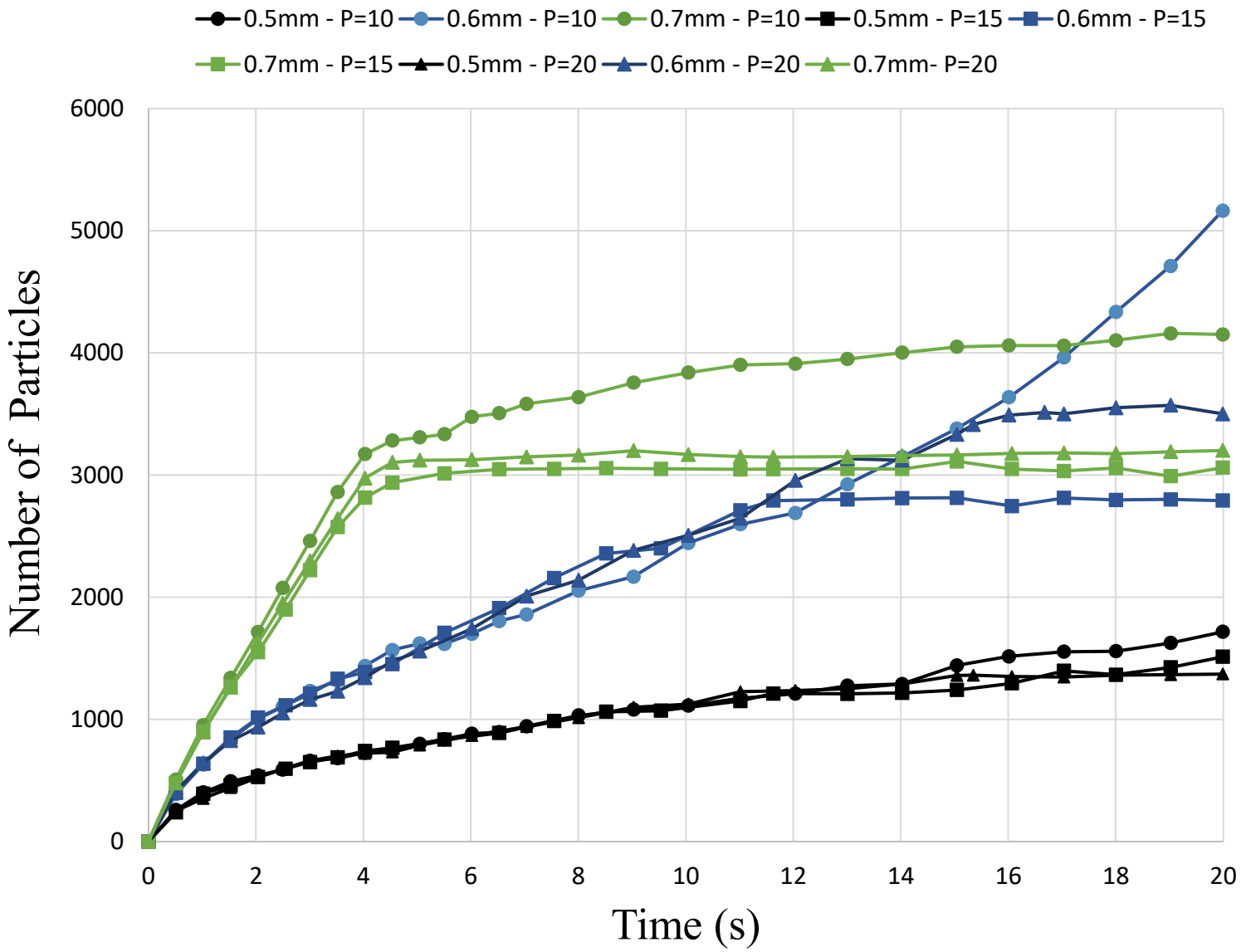
Rocky-Fluent, Mean Aperture size = 1 mm

- 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



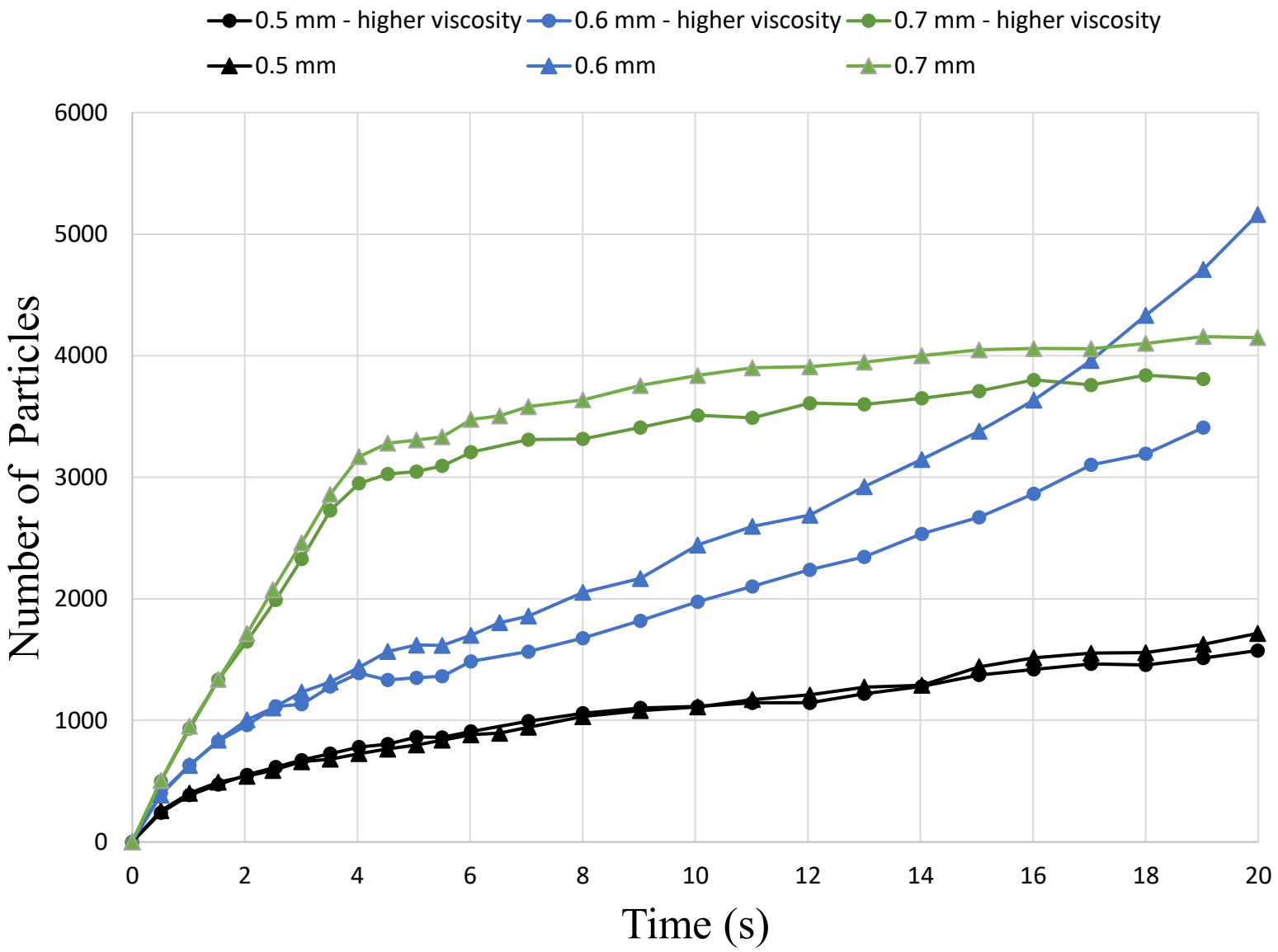
Rocky-Fluent, effect of pressure gradient

- 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, 15 and 20
- $m^2/\ s^2$ normalized by the fluid density



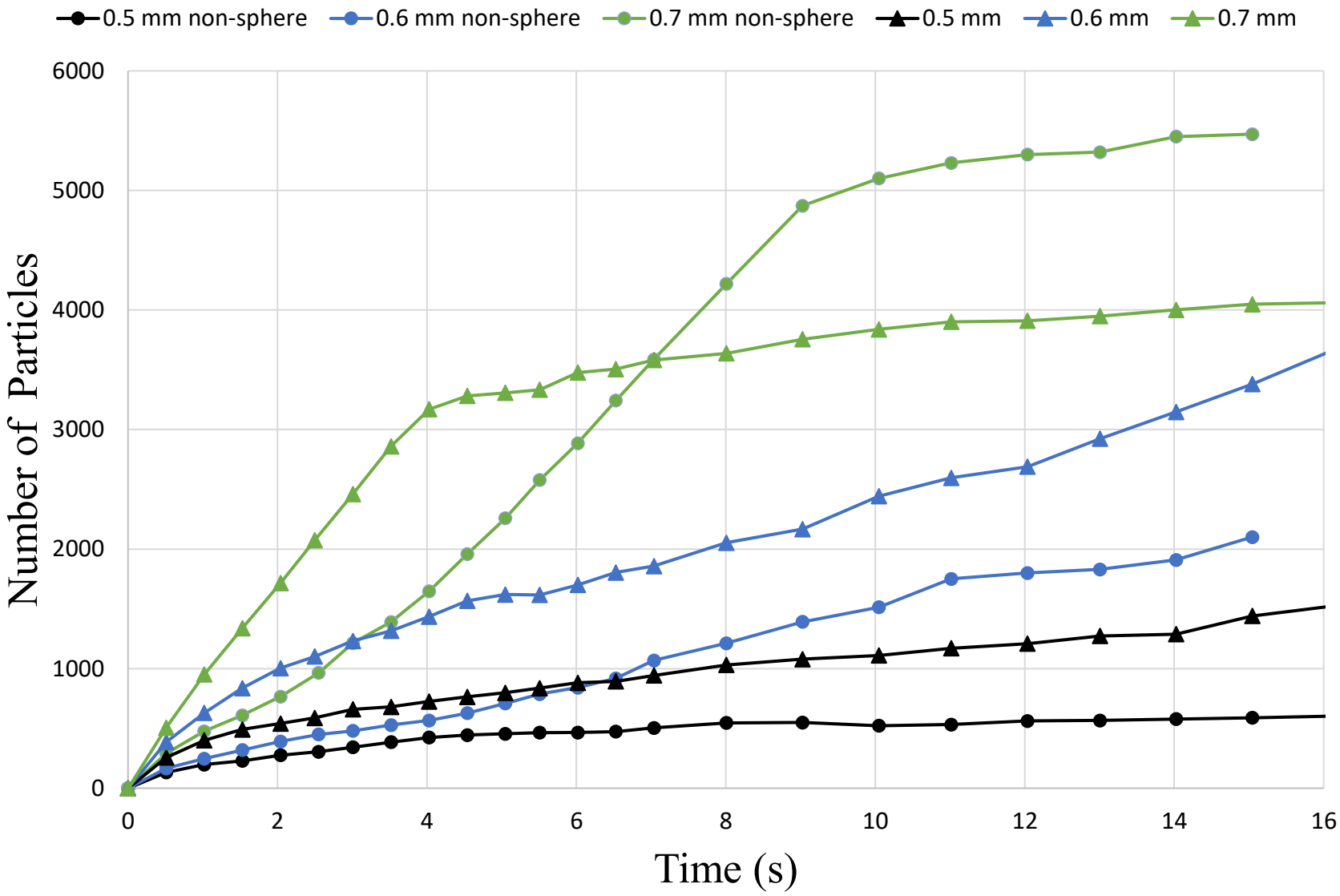
Rocky-Fluent, effect of viscosity

- 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



Rocky-Fluent, effect of shape of proppants

- 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



Conclusions

- 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.
- There was an optimal proppant diameter for a given mean aperture for the maximum coverage. For an aperture height of 0.4 mm the mean diameter was 0.37 mm (92.5%).
- For the mean aperture height much higher than particles diameters the effect of roughness was small.

Future Study

- For the future study, the effect of fracture's characteristics including the mean fracture aperture and proppants properties on coverage would be investigated.
- The effect of gravity direction on the proppants transport and converge will be studied.

Thanks for your attention!

Questions?