Sustainable Sand Management Control and Solutions - Balancing Performance, Costs, and Environment

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Evaluation of Particle Velocity in Gas Stream Flows using High-Speed Camera and CFD-DEM Simulation

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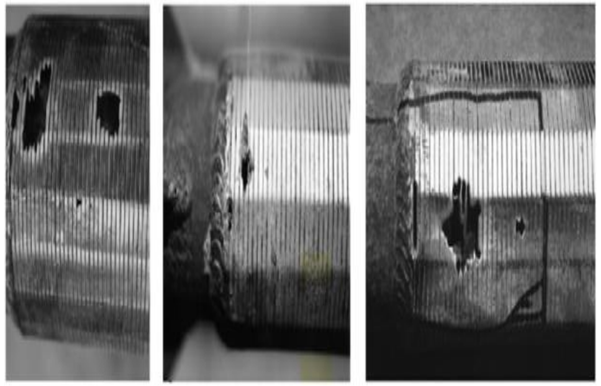
Introduction: Gas Erosion Effects

- In the oil and gas industry, sand production during drilling is a major issue. Uncontrolled sand in the extracted fluid can damage equipment and disrupt production.
- Mechanical sand screens, like wire-wrapped and premium mesh screens, help reduce sand production. However, they can become eroded and flawed over time.
- **Particle velocity evaluation** has been conducted to study particle movement in gas systems and understand how potential erosion occurs and affects the equipment
- Factors: Velocities, Particle Size, and Attack angles

[1] Erosion of sand screen Matanovic et al.,



[1] Abduljabbar, Abdullah & Amadi, Azubuike & Mohyaldinn, Mysara & Ridha, Syahrir & Taha, Obai & Alakbari, Fahd. (2024). Sand Screens Application and Performance for Sand Control: A Review of Selection Criteria, Screen Materials, and Causes of Failure. Heliyon. 10. e30731. 10.1016/j.heliyon.2024.e30731.

Gas Sand Screen Erosion Test (GSSET)

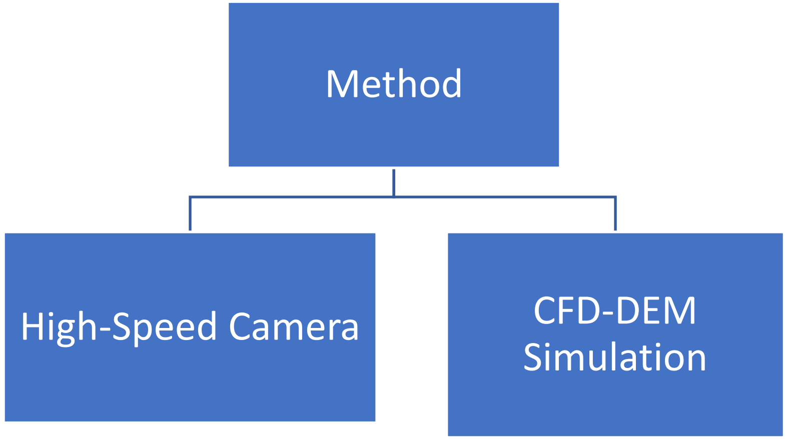
- Conducted erosion testing using in-lab equipment called the Gas Sand Screen Erosion Test (GSSET).

- Measures erosion using repeated impacts, where the nozzle directly blasts a gas stream with abrasive or granular particles onto a test specimen.

- Parameters:

I. **Air Flow Rate (L/min)**
II. **Particle Size Distribution (PSD)**
III. Sand Injection Rate (G/Min)
IV. Time Taken (Hours)

GSSET Equipment



Particle Size Distribution (PSD) Analysis

SPE International

SPE workshop

- The dry sieve method was employed to classify the particle sizes of ceramic beads.
- The size of the beads was determined using a dry sieve, ranging from 45 µm to 2000 µm opening size.
- The cumulative weight of each sieve is measured and the desirable targeted size of the ceramic beads was selected.

Particles	Ceramic Beads
Particle Size Distribution, PSD	• 63 – 150 µm • 150 – 212 µm • 250 µm

Mechanical dry sieve equipment

Note: Dry-sieve analysis was performed as per ISO 1350-2 (2006) in this work.

Sand Erosion Test Parameters

High-Speed Camera

Test Parameters	
Particles	Ceramic Beads
Particle Size Distribution, PSD	• 63 – 150 µm • 150 – 212 µm • 250 µm
Air Flow Rate	• 50 L/min • 75 L/min

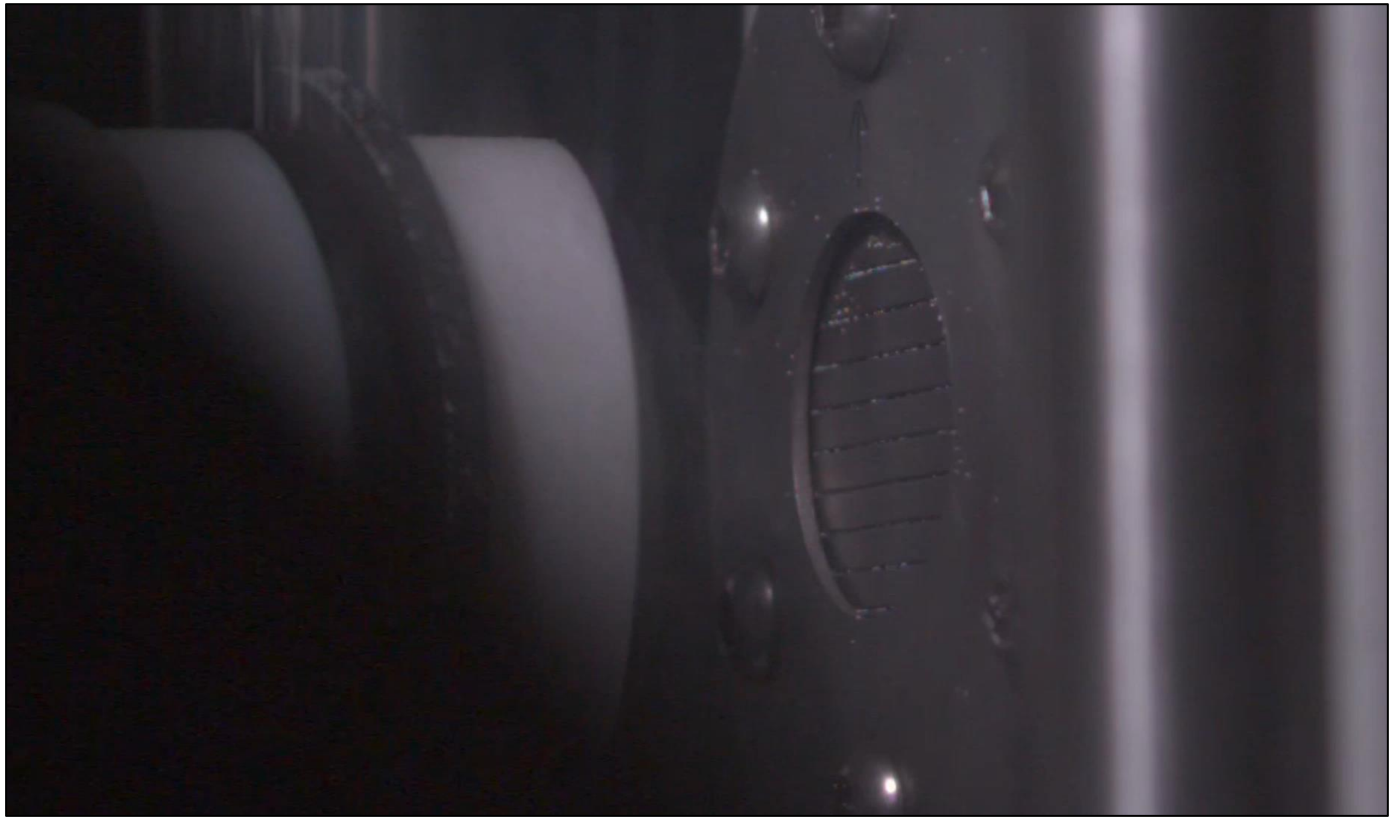
CFD-DEM Simulation

Simulation Input Parameters	
Particle Diameter	120 – 160 micron
Feeder Rate	2.5×10^{-5} kg/s (1.5 g/min)
Pipe Inner Radius	11.05 mm
Pipe Length	3.8 m

Particle Velocity Measurement

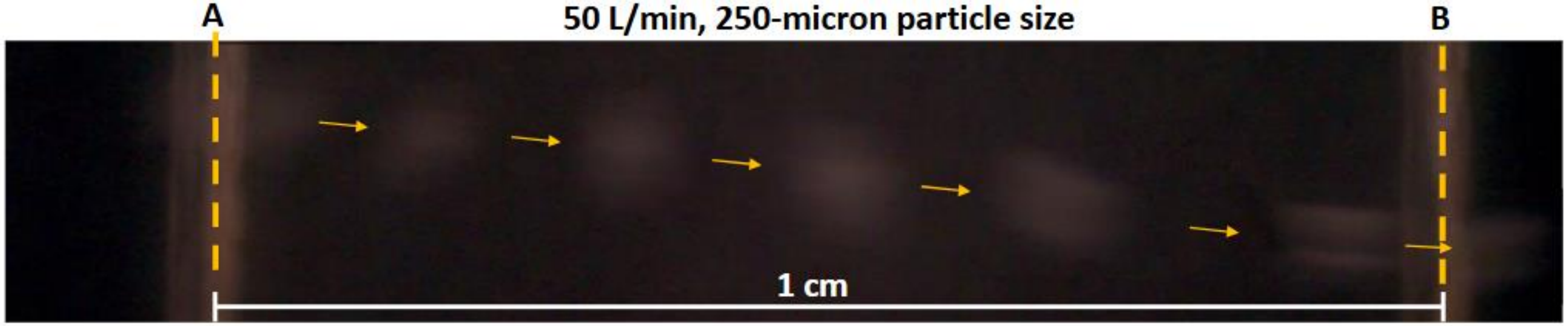
- **<u>High-speed camera</u>** at 3030 frames per second (fps).
- The **<u>high-speed camera</u>** focuses the interaction between the pipe outlet and the impact of ceramic beads onto the screen.
- The time taken for the particle to travel <u>1 cm</u> was measured – shorter time means faster particles.
- The velocity of the particles can be calculated using the formula.

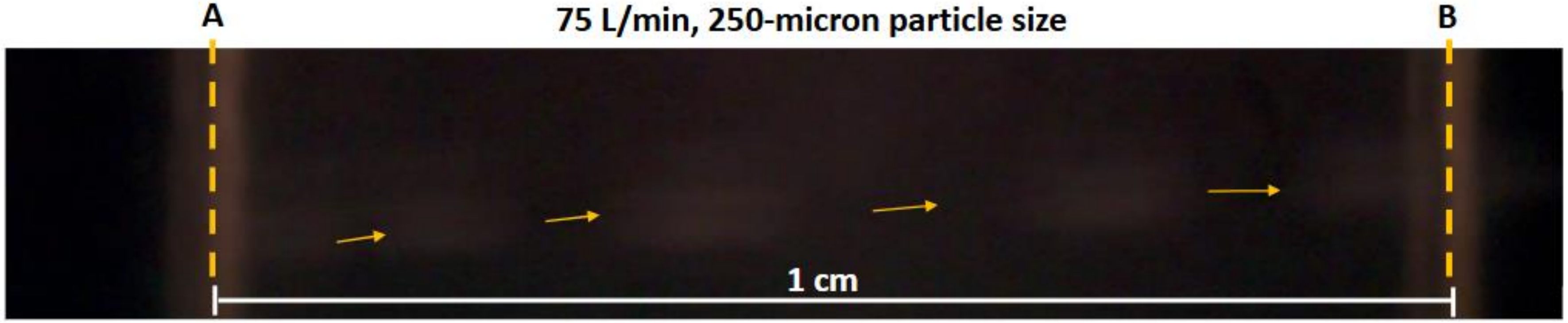
$$Velocity, V = \frac{Distance}{Time}$$



Video recording of particle movement impacting the screen where the nozzle directs a gas stream with ceramic bead particles onto a test specimen.

Results: High-Speed Camera Recording of 250-micron Particle

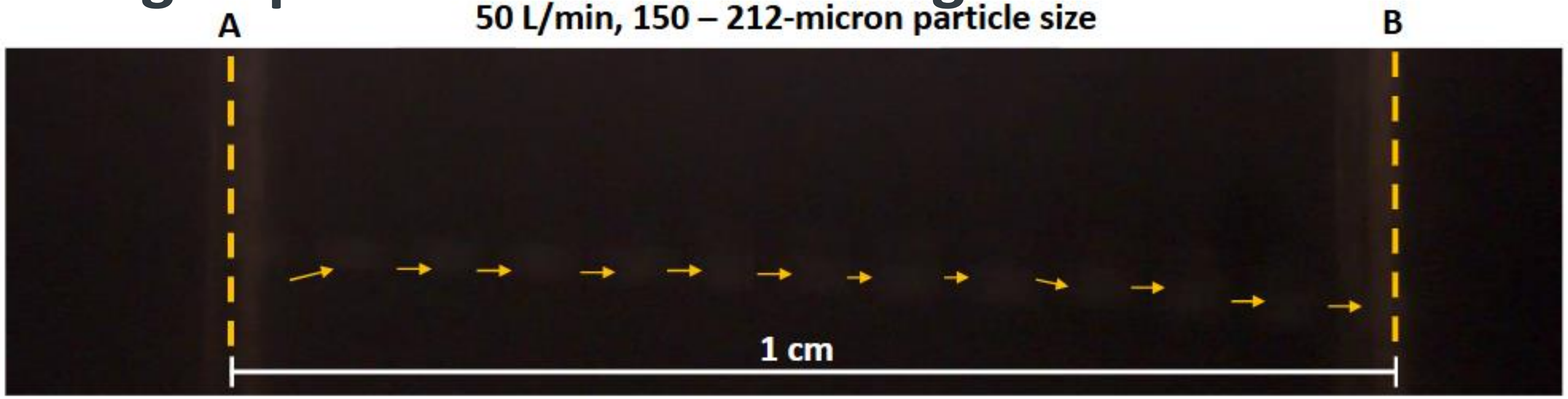


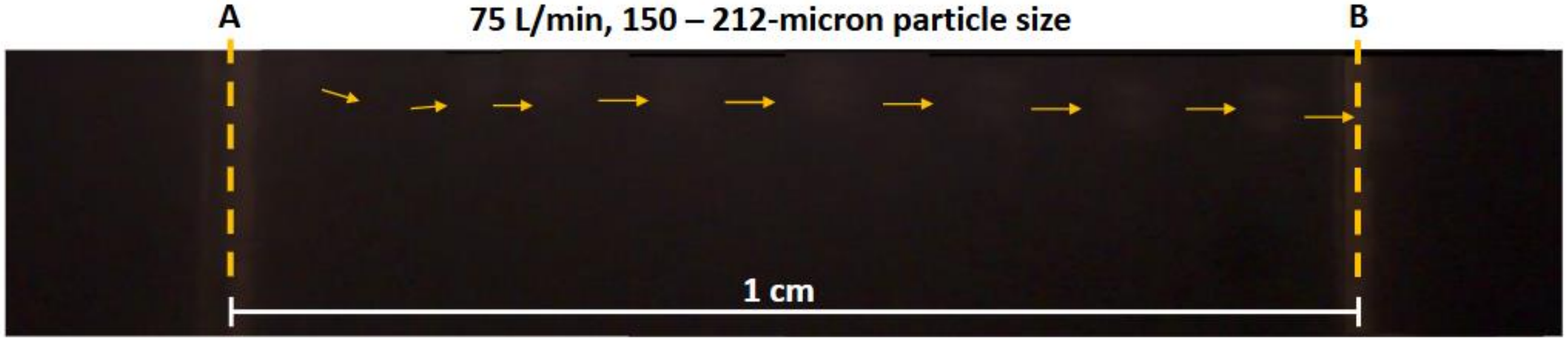


Air Flow Rate (L/min)	Particle Velocities (m/s)	Projected Particle Velocity at 1700 L/min (m/s)
50	1.59 – 2.81	54.22 – 95.69
75	1.04 – 3.79	23.68 – 85.86

[2] N. Manning, "SPE-191942-MS Performance of Ceramic Sand Screen for High Rate Gas Application-Gas Sand Screen Erosion Testing," 2018.

Results: High-Speed Camera Recording of 150 – 212 micron Particles



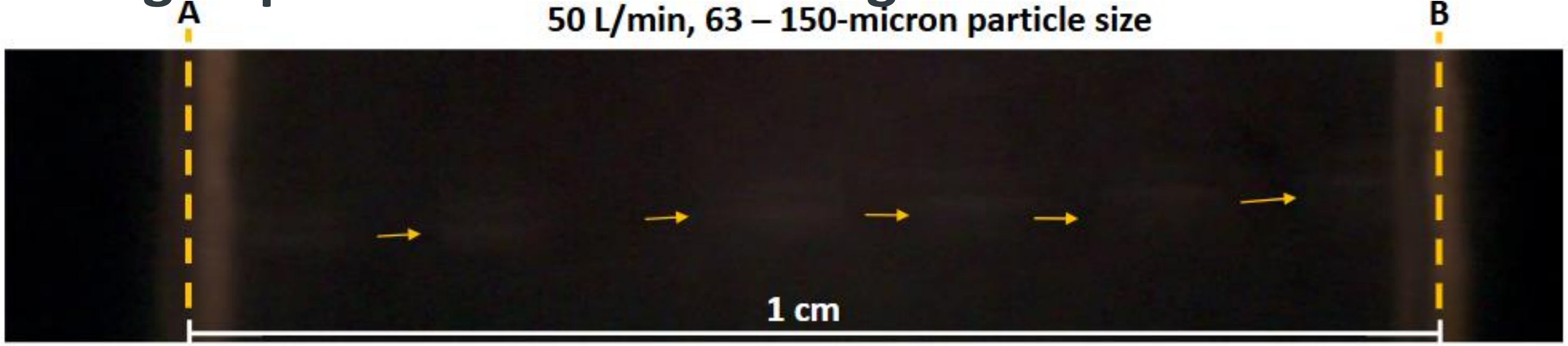


Air Flow Rate (L/min)	Particle Velocities (m/s)	Projected Particle Velocity at 1700 L/min (m/s)
50	2.02 – 3.03	68.68 – 103.03
75	1.89 – 4.33	42.93 – 98.12

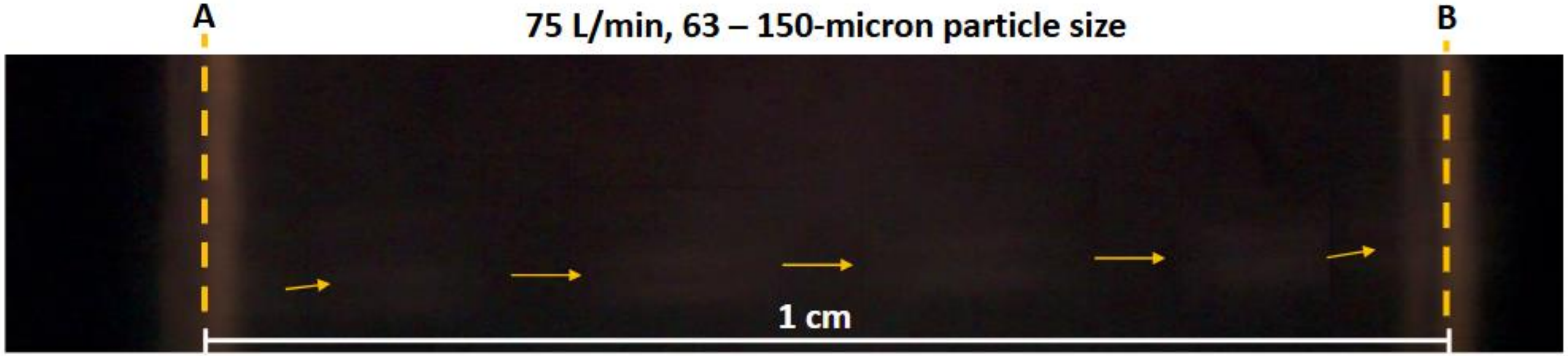
[2] N. Manning, “SPE-191942-MS Performance of Ceramic Sand Screen for High Rate Gas Application-Gas Sand Screen Erosion Testing,” 2018.

Results: High-Speed Camera Recording of 63 – 150 micron Particles

50 L/min, 63 – 150-micron particle size



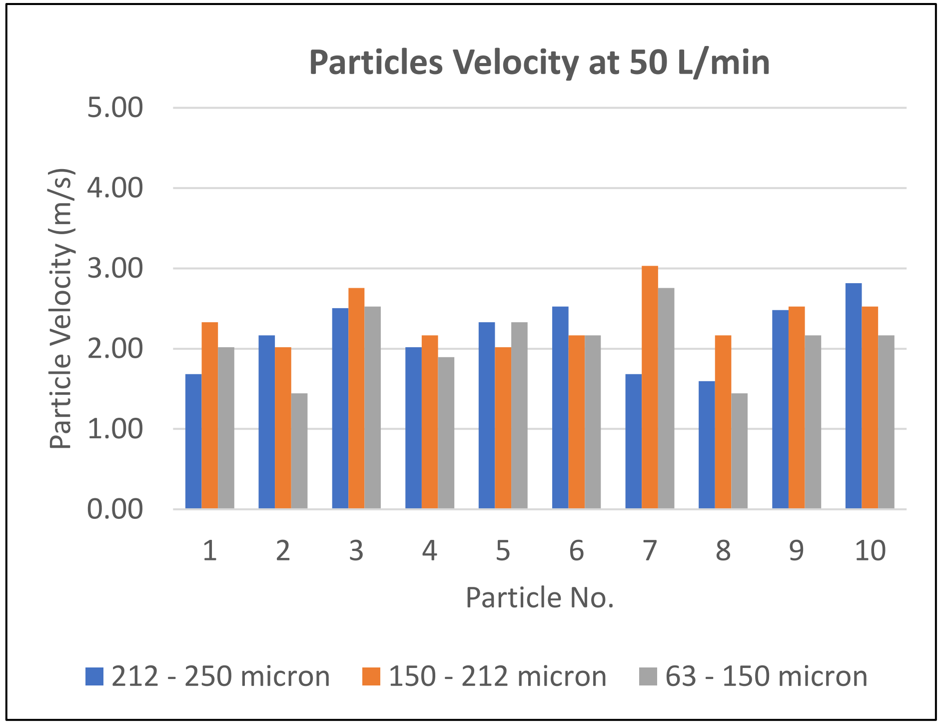
75 L/min, 63 – 150-micron particle size

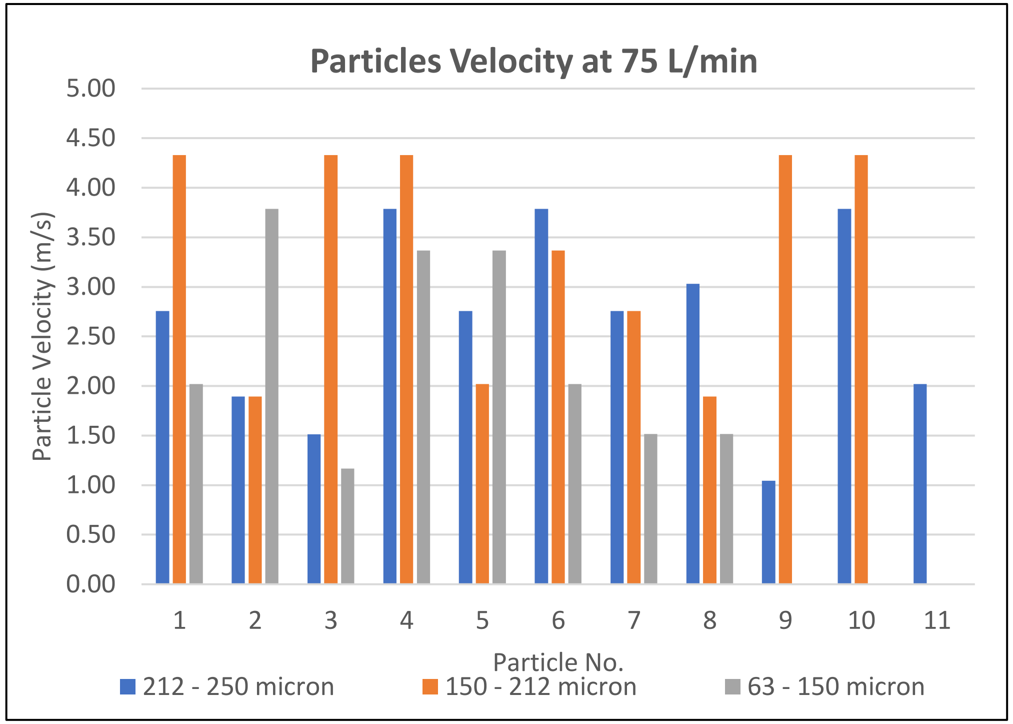


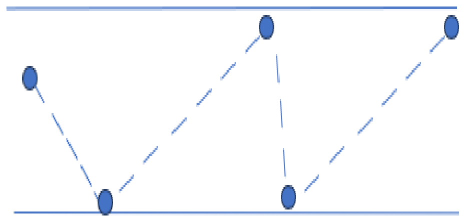
Air Flow Rate (L/min)	Particle Velocities (m/s)	Projected Particle Velocity at 1700 L/min (m/s)
50	1.44 – 2.75	49.06 – 93.66
75	1.17 – 3.79	26.42 – 85.86

[2] N. Manning, "SPE-191942-MS Performance of Ceramic Sand Screen for High Rate Gas Application-Gas Sand Screen Erosion Testing," 2018.

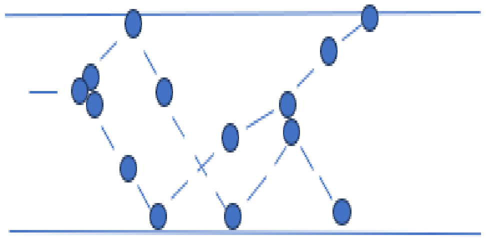
Results: Comparison of Particles Velocity at 50 L/min and 75 L/min







Particle-wall Interaction



Particle-particle Interaction

- Particle velocity at 50L/min flow rate show more consistent for all size range. At lower flow rate, it suggested particle-wall interaction had occurred.
- At flow rate 75L/min it is observed that the particles velocity at all size range of ceramic beads are inconsistent and fluctuate. It suggested that particle-particle interactions has occurred at higher flow rate and gives higher velocity.

Results: Summary of Tracked Particle Movement

Flow Rate (L/min)	Particle Size (micron)	No. of Particles	No. of Frames	Time Taken to Reach 1 cm (s)	Particle Velocity (m/s)	Projected Particle Velocity at 1700 L/min (m/s)
50	250	10	11 – 18	0.00355 – 0.00627	1.59 – 2.81	54.22 – 95.69
	150 – 212	10	10 – 15	0.0033 – 0.00495	2.02 – 3.03	68.68 – 103.03
	63 – 150	10	11 – 21	0.00363 – 0.00693	1.44 – 2.75	49.06 – 93.66
75	250	11	8 – 29	0.00264 – 0.00957	1.04 – 3.79	23.68 – 85.86
	150 – 212	10	7 – 16	0.00231 – 0.00528	1.89 – 4.33	42.93 – 98.12
	63 – 150	8	8 – 26	0.00264 – 0.00858	1.16 – 3.79	26.42 – 85.86

- At 50 L/min the particle size of 150 – 212 microns shows a higher velocity of (2.02 m/s – 3.03 m/s).
- At 75 L/min the particle size of 150 – 212 microns shows a slightly lower velocity of (1.89 m/s – 4.33 m/s).
- When contrasted with the same particle size of 150 – 212 microns, the air flow rate at 50 L/min shows the highest velocity compared to 75 L/min.

Results: Summary of Tracked Particle Movement

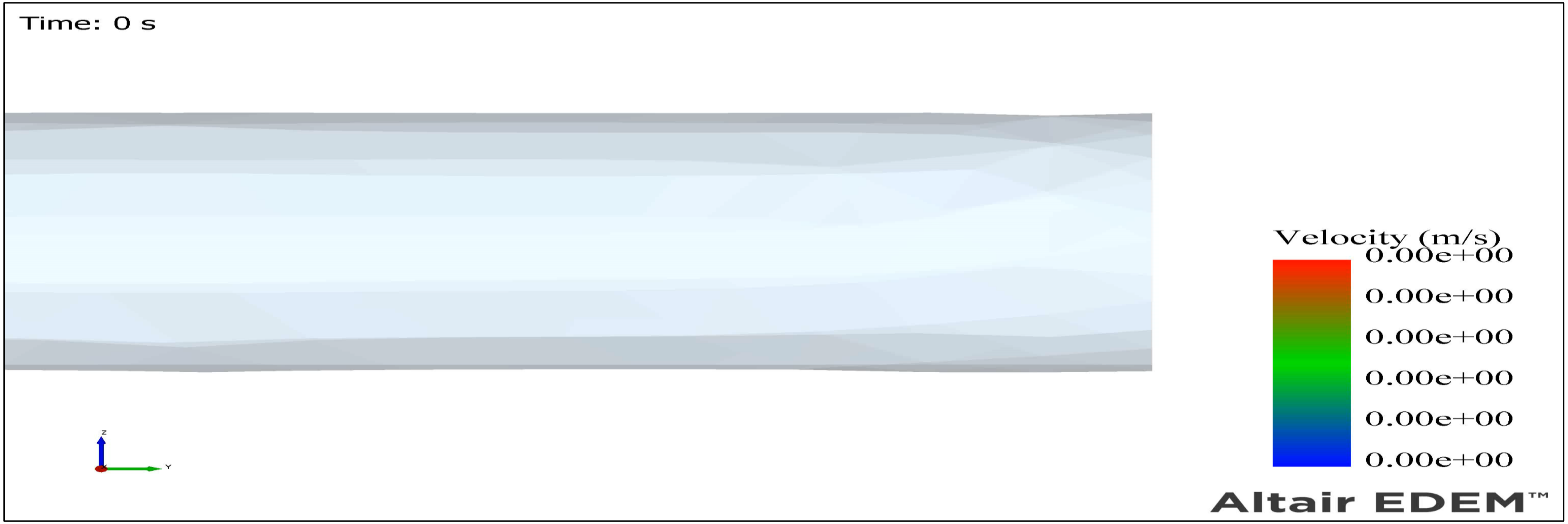
- As seen in the table the inconsistency no. of particles, possibly due to the behaviour of particle movement is somewhat complicated, with higher flow rates that may lead to higher kinetic energy being produced.

- This certainly be due to higher collision and vibration of the particle in the gas stream occurring at the flow rate of 75 L/min.

- Observation with the in-between particle size range, the size of 150 – 212 microns shows the highest, compared to 250 and 63 – 150 microns. This incident is probably due to the momentum effect of the particle within the gas stream flow.

Results: CFD-DEM Simulation for Particle Movement

Video Simulation of Particle Movement via CFD-DEM



Minimum speed: 0.00047033 m/s

Maximum speed: 14.465 m/s

Red Dot = Faster velocity

Blue Dot = Slower velocity

- Particle initial start occurs at 0.8 sec
- Continuously occur every 0.6 sec
- Particle occurrence duration is 0.4sec, during this duration the particle changes from fast to slower

Conclusion

- The study measures the velocity of ceramic beads using gas sand screen erosion test (GSSET) method, which compares the particle velocities at different flow rates and particle size distributions.
- High flow rates can disrupt particle movement, causing more vibrations, collisions, and fluctuations in velocity leading to inconsistent results.
- At different flow rates and particle sizes, the particle-particle interaction, particle-wall interaction, and the angle of the particle movement affect the particle velocity.
- The experiment result determines the movement or motion of ceramic bead particles ranging from different particle sizes and different flow rates in a given specified diameter and length of pipe flowing a stream of gas at a different particle feed per minute.
- CFD-DEM simulates shows that particles can reach a maximum speed of 14.465 m/s and a minimum speed of 0.00047033 m/s with a particle scale ranging in various radius within the size of particles.

Thank you!

Q&A Session