Modelling industrial multiphase flows with STAR-CCM+

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Contents

Validation of the Eulerian multiphase (EMP) model in chemical and process applications
  – Slurry pipe flows
  – Stirred vessels
    • Solid-liquid
    • Gas-liquid

Interphase transfer of chemical species in STAR-CCM+ v7.02

Granular flow model in STAR-CCM+ v7.04
Horizontal slurry pipe flow experiments

Phase 1 - water
Density = 997.6 kg/m³
Viscosity = 8.887e-4 Pas

Phase 2 - silica particles
Density = 2650 kg/m³
Diameter (d) = 90 - 480 µm
Volume fraction (vf) = 0.0918 - 0.273

Pipe diameter (D) = 51.5 - 495 mm
Pipe length (L) = 10 m
Slurry velocity (V) = 3.0 - 5.4 m/s


Uniform solids concentration
Measurement plane 1 m
V
g
L=10 m
D
Settling of particles along the pipe

Liquid velocity

Particle volume fraction
Comparison with measured data

**Uniform solids volume fraction (vf) and slurry velocity (V)**

- d=90 μm, vf=0.19
  - D=103mm, V=3 m/s
- d=165 μm, vf=0.189
  - D=51.5mm, V=4.17 m/s

**Measurement plane**

- L=10m

**Graphs**

- For d=90 μm, vf=0.19:
  - Position [0.0, 1.0, 0.0] (m):
    - Volume Fraction of Solid
    - Experimental vs. STAR-CCM+

- For d=165 μm, vf=0.189:
  - Position [0.0, 1.0, 0.0] (m):
    - Volume Fraction of Solid
    - Experimental vs. STAR-CCM+
Comparison with measured data

- For $d=270 \, \mu m$, $v_f=0.2$, $D=51.5mm$, $V=5.4 \, m/s$
- For $d=480 \, \mu m$, $v_f=0.203$, $D=51.5mm$, $V=3.41 \, m/s$
- For $d=165 \, \mu m$, $v_f=0.0918$, $D=51.5mm$, $V=3.78 \, m/s$
- For $d=165 \, \mu m$, $v_f=0.273$, $D=495mm$, $V=3.46 \, m/s$

**Graphs:**

- Experimental data points and STAR-CCM+ simulations plotted against volume fraction of solid.
Solid-liquid stirred vessel

Solid-liquid system
1 ft tank D = H, flat base
single 6 blade PBT d = 0.5T
C/H = 0.25, 4 baffles

Liquid:
Water-salt solution
ρ_l = 1150 kg/m^3
μ = 4.5e-3 Pas

Solid:
Glass particles
d_p = 3.075 mm
ρ_p = 2485 kg/m^3

Measurement line for velocities at h/H = 0.2
Comparison of vertical solid concentration

Experimental

STAR-CCM+
Comparison of liquid velocities

Liquid Velocities

- $U_z$
- $U_r$
- $U_{\theta}$

Experimental vs. STAR-CCM+

$r/R$ vs. $U/U_{\text{tip}}$

Velocity of Liquid (m/s): 0.0000 to 2.5000
Comparison of solids velocities

Solids Velocities

- $U_z$ Experimental
- $U_z$ STAR-CCM+
- $U_r$ Experimental
- $U_r$ STAR-CCM+
- $U_{\theta}$ Experimental
- STAR-CCM+

Velocity of Solid (m/s)

0.0000 0.50000 1.0000 1.50000 2.0000 2.5000

0 0.5 1

$r/R$
Gas-liquid system
D=2ft, torispherical base
3 impellers
4 blade PBT up pumping d=0.5D
2 Rushton turbines d=0.5D
C1/D=0.3, C2/D=0.64, C3/D=0.96
4 baffles,
N=280 rpm
2 gas spargers located between PBT and lower Rushton turbine
Liquid: Water
Gas: Air,
superficial gas velocity:
0.0184-0.201 m/s
Liquid velocity and gas volume fraction

Gas superficial velocity 0.201 m/s
Gas cavities behind impeller paddles

Gas superficial velocity 0.201 m/s
Effects of increasing gas injection rate

Gas superficial velocity:

- $U = 0.0184 \text{ m/s}$
- $U = 0.0448 \text{ m/s}$
- $U = 0.0835 \text{ m/s}$
- $U = 0.1175 \text{ m/s}$
- $U = 0.201 \text{ m/s}$
Comparison of gas holdup

Gas holdup [%] vs. Superficial velocity [m/s]

- Experimental
- STAR-CCM+

Graph showing a comparison of gas holdup between experimental and STAR-CCM+ data points.
Interphase transfer of chemical species in STAR-CCM+ v7.02

- Allow chemical species transfer between phases: gas dissolving into liquid, gas release from liquid.

- Aimed for chemical, process, oil & gas, water, food...

- Applications: bubble columns in chemical process, aeration tanks in water treatment, gas release in oil & gas risers, aeration in bio-reactors...
Oxygen transfer in aeration tank in water treatment

Volume fraction of air

Oxygen in air

Water

Air injector

Oxygen in water

Oxygen level at water surface and exit
Granular flow model in STAR-CCM+ v7.04

- Kinetic theory model for granular flows.

- Particle-particle collisions represented by a granular temperature equation derived from kinetic theory.

- Suitable for dense particle flows such as fluidised beds.

- Aimed for chemical, process, oil & gas, water, food, cement, mineral, pharmaceutical, agricultural...

- Applications: fluidised bed reactors, sand and slurry transports, solid handling...
Fluidised bed

Solution Time 0.01 (s)
We will continue to validate the Eulerian multiphase (EMP) model against industrial applications.

We will continue to develop new capabilities in STAR-CCM+
- Chemical reaction model (v7.04)
- More turbulence model options (v7.04)
- Multi-particle phases granular model (v7.06)
- Coupling with liquid film model (v7.06)
- Non-Newtonian model (v7.06)

We will continue to improve user experience of the models
- Robustness of models
- Clear model description in user manual, tutorial examples