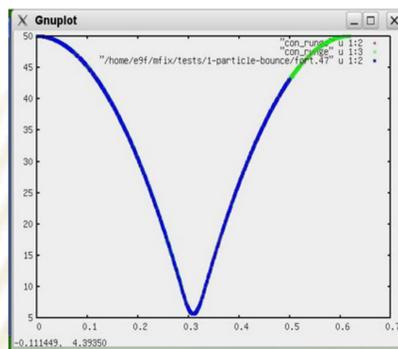
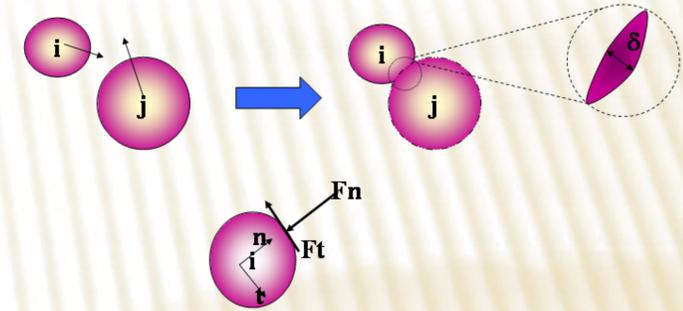


Evaluation of time-stepping schemes for discrete element method (DEM)

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MFIX solution, first order Euler method vs. analytical solution

Introduction

Gas-solids flows are ubiquitous in both nature and man-made processes. Predictive modeling of these flows can help mitigate effects of natural processes and improve the efficiencies of devices such as those employed for fuel production, energy production and energy utilization.

Goal

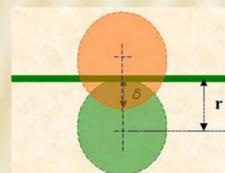
Solve gas-solids flow with accuracy and efficiency

Background

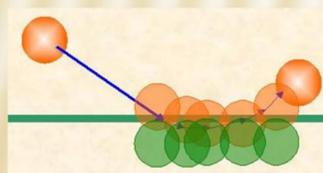
Discrete element method (DEM) considers each individual particle and makes calculations according to Newton's Laws.

Currently the Multiphase Flow Interphase Exchange (MFIX) DEM uses first order scheme to integrate the equations of motion/

In this project we want to evaluate the accuracy and efficiency of MFIX DEM for simple cases and make recommendations for alternate time-stepping schemes.



Wall-particle interaction



Methodology

- ❖ Identify a simple problem with analytical solutions to evaluate different time-stepping schemes
- ❖ First problem identified is the free-fall of an inelastic spherical particle.
- ❖ Second problem is the collision between two inelastic particles (ongoing work)
- ❖ Free-fall case has three phases:
 - ❖ Free-fall
 - ❖ Collision
 - ❖ Rebound
- ❖ Analytical solutions

❖ Free-Fall Stage

$$y'' = -g$$

$$y' = \int y'' dt = -gt$$

$$y = \int y' dt = y_0 - gt^2/2$$

❖ Rebound Stage

$$y'' = -g$$

$$y' = \int y'' dt = -gt + v_i$$

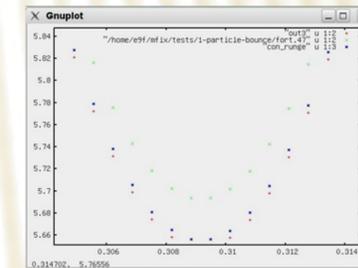
$$y = \int y' dt = r_0 + v_i t - gt^2/2$$

❖ Contact Stage

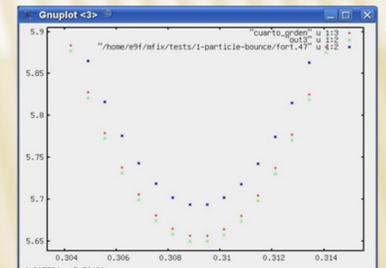
$$y = -\sqrt{2g(y_0 - r_0)} \sqrt{m/k} \sin(\sqrt{k/m} * t) + m * g/k * \cos(\sqrt{k/m} * t) + (r_0 - (m * g)/k)$$

- ❖ Compare free-fall particle cases simulated using MFIX DEM against the analytical solution
- ❖ Evaluate different time-step algorithms, the free-fall equations have been directly integrated using fourth order Runge-Kutta (RK4) and first order Euler method.
- ❖ Determine accuracy and efficiency of different methods would be helpful in determining the time-stepping scheme to be implemented into MFIX DEM.

Results

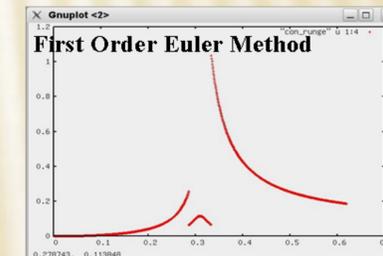


First Order Euler Method, MFIX solution vs. analytical solution (contact region)

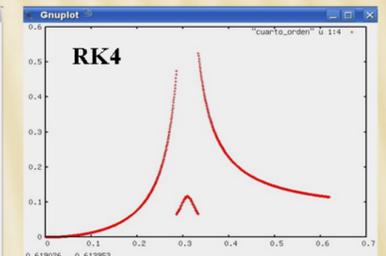


RK4, MFIX solution vs. analytical solution (contact region)

Percent error vs. time



First Order Euler Method



RK4

- ❖ Maximum loss of accuracy error during the contact stage
- ❖ Determine increase order of time-stepping scheme causes error reduction
- ❖ Demonstrate time-step causes error reduction

Conclusion

Increasing the order of the solution scheme or decreasing the time-step size increases the accuracy of the solution.

Future Research

- ❖ Evaluate the computational cost vs. accuracy of different schemes
- ❖ Implement appropriate higher-order schemes into MFIX