THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Ansys Rocky Tutorial

Bulk Material Characteristic Testing III: Drawdown Test

Developed and curated by the Ansys Academic Development Team

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Ansys Software Used

This case study uses Ansys Rocky™, the particle dynamics simulation software.

Summary

This tutorial will cover the setup and execution of a simulated drawdown test used in bulk material calibration. This test is performed to determine the angle of repose and shear angle of a bulk material.

Prerequisites

It is recommended to complete the Bulk Material Characteristic Testing I and II tutorials before this exercise. This can be found on the Ansys Education Resources site.

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1. Introduction

To understand the importance of calibrating bulk material for handling and processing refer to the Angle of Repose Test Ansys Innovation Course here.

The test we will focus on for this tutorial is the *Drawdown* test, which aims to determine the static angle of repose (AOR) and shear angle (internal friction angle) of a bulk material. As a reminder, the static AOR refers to the angle from the horizontal plane a material forms after it has reached a point of static equilibrium, whereas the shear angle refers to the angle formed between the horizontal plane and the direction of the maximum shear stress in the material.

Compared to the two previously explored calibration methods, the drawdown test is a more recent application for determining material characteristics. This test can be used in addition to one or both of the former tests for more calibration parameters, or it can be used as a standalone calibration method.

This test involves two boxes; the top with a small opening to allow material to fall through when opened, and a lower box to catch the material fallen through. In physical lab testing, this opening will be created by the fast removal of a small plate to prevent preferential drawdown from one side of the box. This is mimicked as closely as possible in the tutorial by the instant removal of a geometry, i.e., the plate. The shear stress from the material in the top box forms the shear angle, and like the Static Angle of Repose Test, the lower box fills with material to form the static AOR.

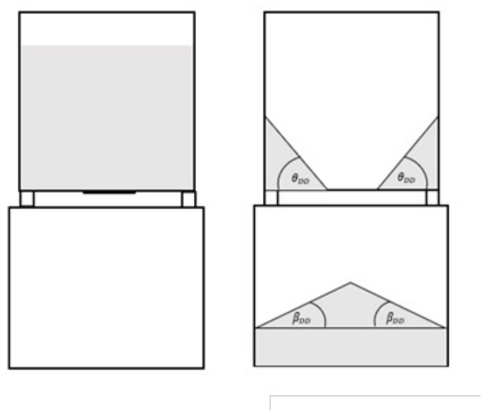


Figure 1: Drawdown test before and after the gate is opened

The drawdown test is often seen as an important test in bulk material calibration for DEM simulations as it offers a wide range of material properties. These include the AOR, shear angle, mass flow and mass difference or residual mass as it may be known in some cases. Replicating the aforementioned properties through calibration of DEM parameters, means that the model accurately captures the behavior for the materials.

This test can also be used to represent a hopper or bin discharge, and determine the arching properties of the material, which relates to the particle-to-particle adhesion. Arching of a material, typically occurs in those with higher moisture and/or fines content, sometimes known as unfavorable materials. The term ‘unfavorable’ refers to materials that act in a way in which is much more difficult to process, and handle compared to most bulk materials seen. These materials are typically the result of having high moisture and/or fines content, that increase cohesiveness and reduce particle flow.

The following paper further discusses calibration and its importance using the drawdown test and many other methods, particularly with unfavorable materials.

1.1 Further Readings

Carr, M, J., Roessler, T. & Otto, H. et al. (2019) "Calibration procedure of Discrete Element Method (DEM) parameters for cohesive bulk materials". Proceedings of the 13th International Conference on Bulk Materials Storage, Handling and Transportation (Gold Coast, Queensland, Australia. 09-11 July, 2019) p. 693-707. Barton, A.C.T.: Engineers Australia

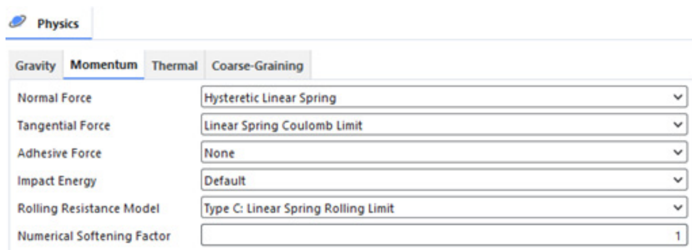
2. Exercise: Simulating Drawdown Test

Download the three .stl files uploaded with this lab document, *Bottom_Box*, *Gate*, and *Top_Box*.

Open the Ansys Rocky software[1] and create a new project using the ***New Project*** icon, and save to an appropriate location.

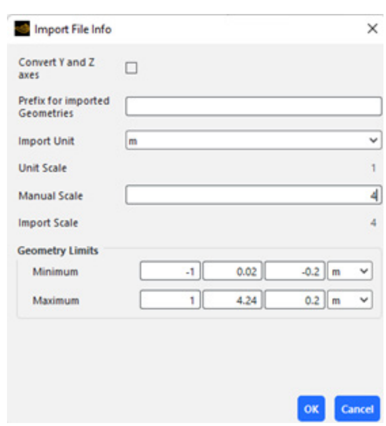
2.1 Physics

Similarly, to the previous tutorials, set the ***Rolling Resistance Model*** under the ***Momentum*** tab in ***Physics*** to the following settings shown below, while leaving all others as default.



2.2 Geometry

Import the three geometry files supplied with this document and set the ***Manual Scale*** as 4, leaving the rest as default. It is important to check the ***Minimum*** and ***Maximum Geometry Limits*** to ensure it is in the correct units.

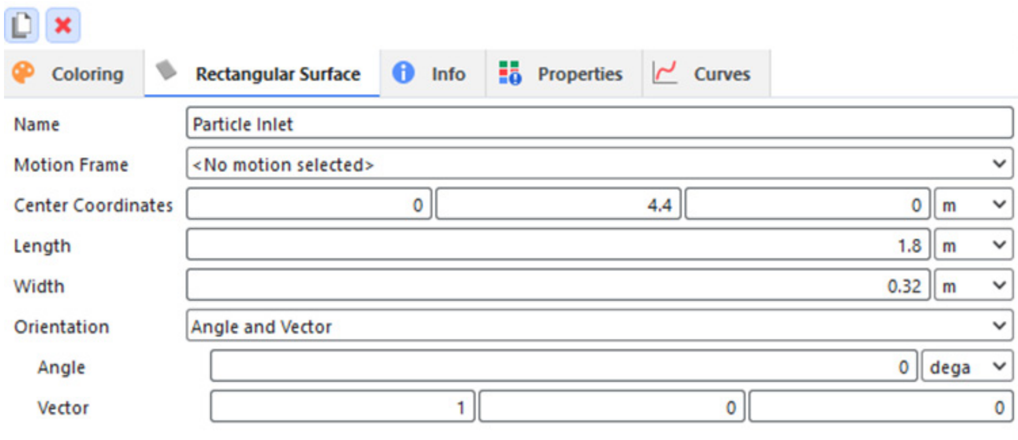


1 This resource was made with the Ansys Rocky 23R2 release. Interface may look different, depending on which release you are using.

Open a new 3D workspace to view the imported geometry and set the geometry ***Transparency*** to 70.

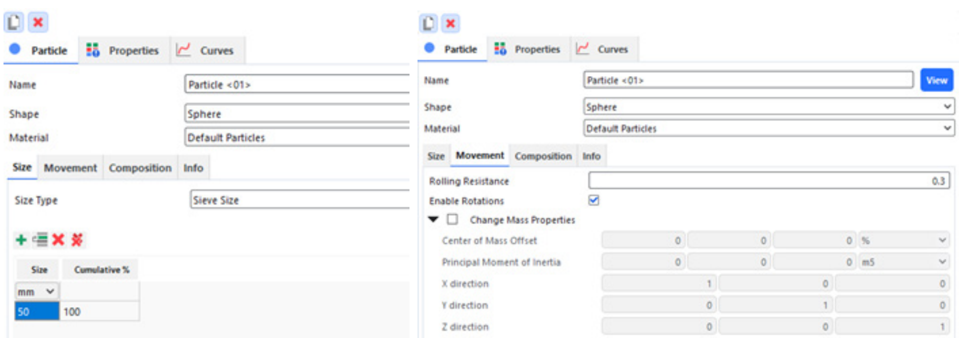
2.3 Inlet Creation

Create a surface a surface using the ***Create Circular Inlet option***. Under the ***Circular Surface <01>*** tab, define the ***Name***, ***Centre Coordinates***, ***Length*** and ***Width*** of this new surface as the following. This surface will be defined as an inlet in a later step.



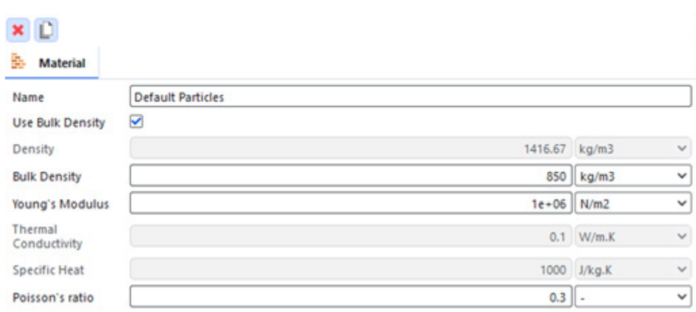
2.4 Particle Creation

Create a new particle and under the ***Size*** tab, define the ***Size*** and under the ***Movement*** tab define the ***Rolling Resistance*** to the following and leave all else default.



2.5 Particle Material Definition

To define parameters for the particles just created, select ***Default Particles*** under the ***Materials*** tab. You will need to define the ***Bulk Density*** and ***Young's Modulus*** as follows.



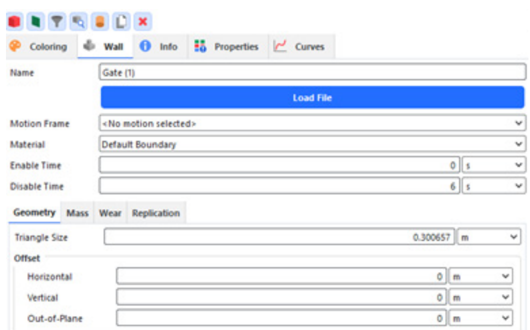
2.6 Material Interaction Definition

For this simulation we will only be changing the ***Default Particle*** to ***Default Particle*** interactions as we are only interested in the interparticle interactions. Define the ***Static Friction*** and ***Dynamic Fiction*** for this ***Default Particle*** to ***Default Particle*** interaction as follows, while leaving all other parameters as default.

2.7 Gate Movement

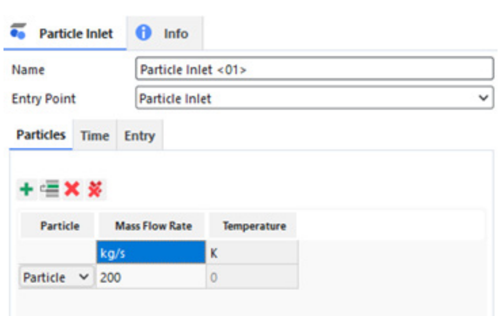
To simulate the Gate opening to allow the particles to fall through it is most effective to disable the geometry at a specific time.

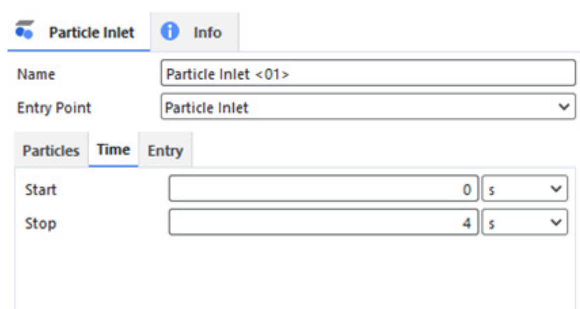
To do this navigate to the ***Geometry*** tab and select the ***Gate*** and then the ***Wall*** option. Now change the ***Disable Time*** to the following and leave all the rest as default. This will allow the Top Box to fill and hold particles for *6 seconds* then the Gate geometry will be removed and allow the particles to fall through.



2.8 Inlet Definition

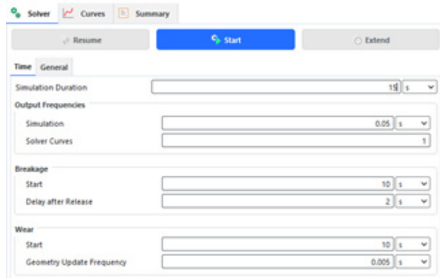
Define the previously made surface as a particle inlet via the ***Inlets and Outlets tab***. In here we will add a particle by selecting the green plus button (***Add***) and select ***Particle*** (the previously created particle) under the ***Particle*** tab and set ***Mass Flow Rate*** to *200 (kg/s).* We also need to define the inlet's ***Entry Point*** and ***Start*** and ***Stop*** under the Time tab to the following, leaving all other values as default.



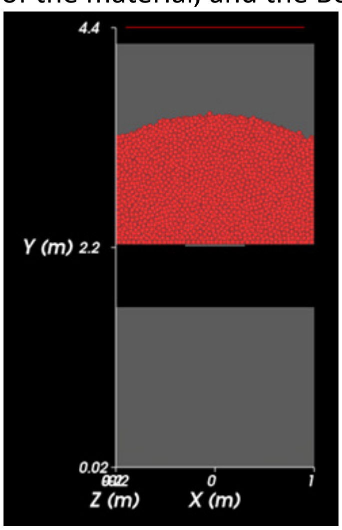


2.9 Solve Simulation

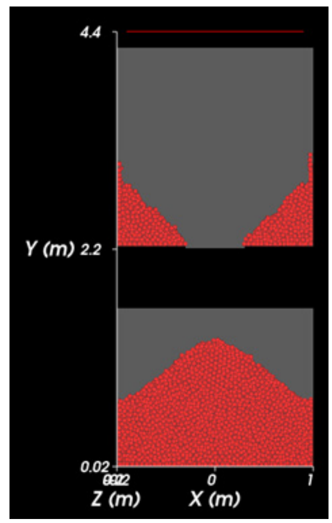
Before you solve the simulation, adjust the ***Simulation Duration*** to the following then select the ***Start*** button. We will leave all of these other values as default for this simulation.



The following is the solved simulation. In the left figure, the material left in the Top Box defines the Shear Angle of the material, and the Bottom Box results in the Angle of Repose.



(a) Before gate opening



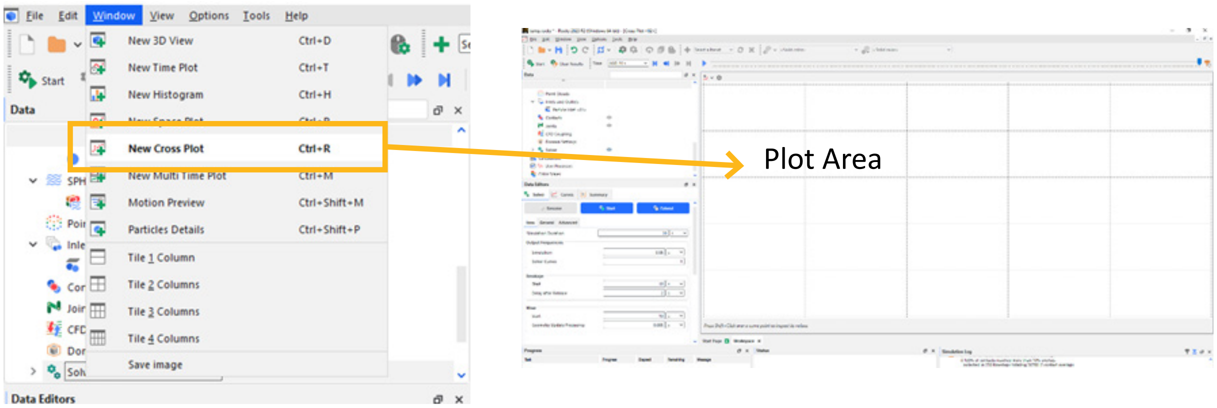
(b) After gate opening

If you wish to remove the axes, right click on the 3D window and deselect ***Bounding Box***. The particle inlet can also be hidden by hiding it in the ***Geometry*** tab.

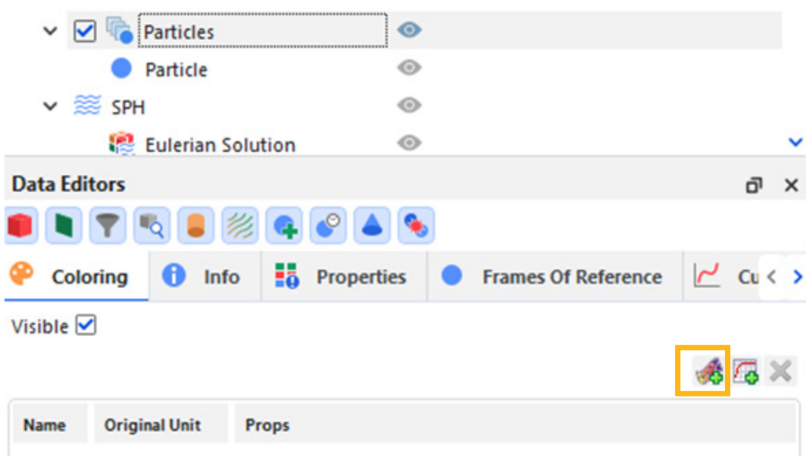
3. Analysis: Estimation of Angle of Repose and Shear Angle

The purpose of this tutorial was to run a simulation of a real test conducted to determine the angle of repose and shear angle of a material. Similar to the *Lifting Cylinder Tutorial*, we will export the shapes as Cross Plots to an image.

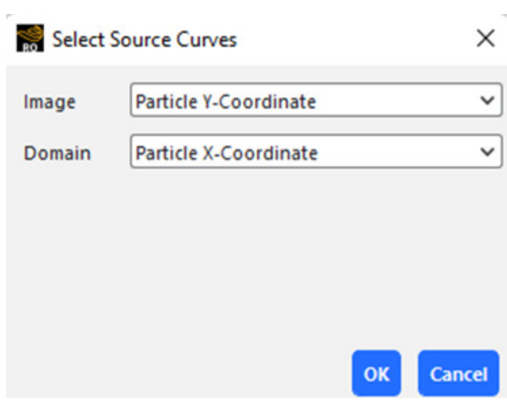
Using the ***Window*** tab, select ***New Cross Plot***.



Now to select the variable to plot, select the ***Particles*** tab and under ***Coloring***, click the small icon shown below.

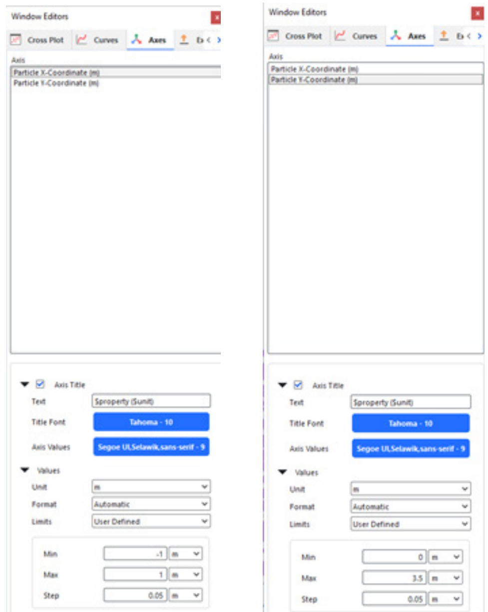


You will then be prompted with a ***Select Source Curves*** window. Define using the drop-down box the ***Image*** and ***Domain*** as follows and select ***OK***.

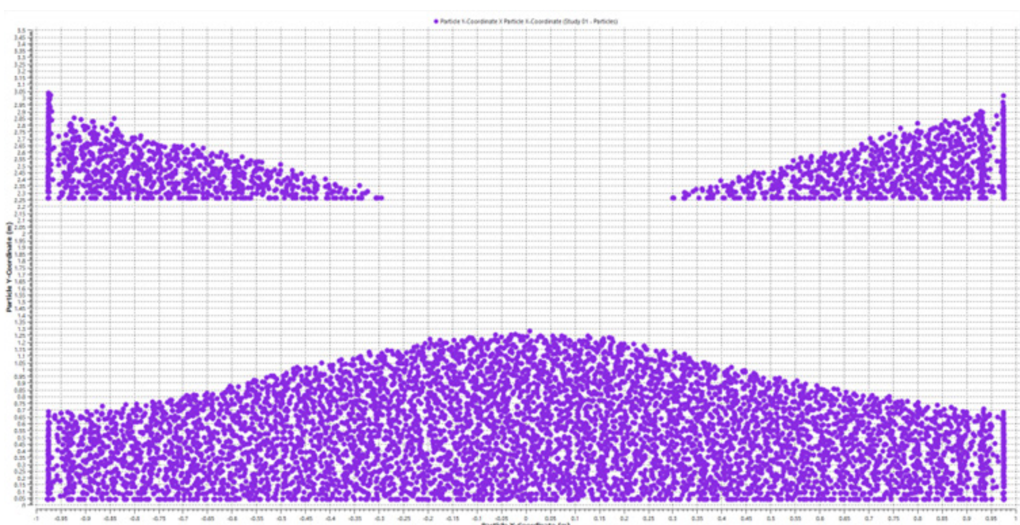


Note: If the current time step you are on isn’t at the end of the simulation, the plot may appear empty or an irregular shape. To fix this, play the simulation to the end or using the Last Time Step button shown below to skip to the end 

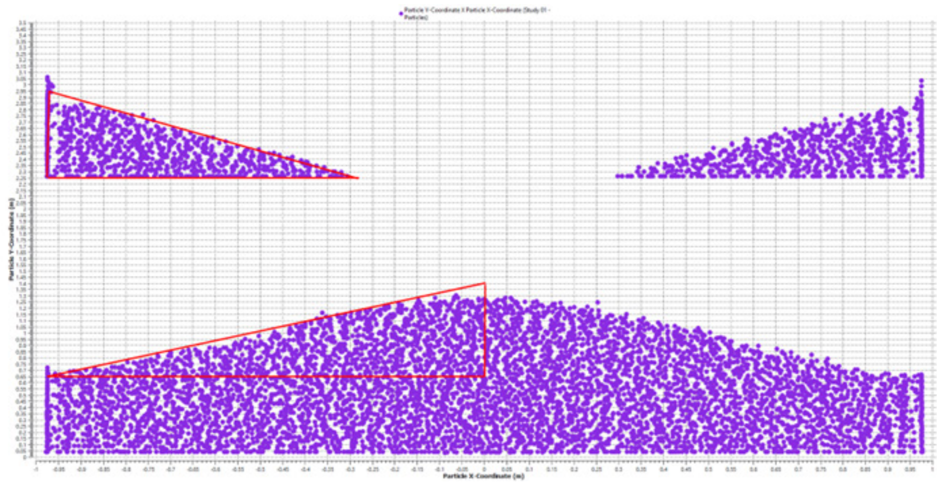
To modify and re-scale the cross-plot, right click in the cross-plot view and select ***Settings***. You will be prompted by a ***Windows Editor*** window. Navigate to the ***Axes*** tab and define ***Particle X – coordinate (m)*** and ***Particle Y-Coordinate (m)*** under ***Axis*** as the following.



If done correctly the cross plot should appear like the following.



Now, to calculate the angle of repose and shear angle, define the following gradients, similarly to the *Lifting Cylinder Tutorial*.



Shear Angle:

$$\theta_{Shear} = \tan^{-1}\left(\frac{2.95 - 2.25}{0.975 - 0.28}\right) \cong 45.2°$$

Angle of Repose:

$$AOR = \tan^{-1}\left(\frac{1.4 - 0.65}{0.975}\right) \cong 37.6°$$

Note: the values you end up with in your project may vary slightly with the ones shown in the tutorial

Now repeat this to complete the following table by changing the particle rolling resistance and particle static and dynamic friction.

Shear Angle		**Particle Rolling Resistance**		
		0.4	0.5	0.6
Particle Static/ Dynamic Friction	0.5			
	0.6			
	0.7			

AOR		**Particle Rolling Resistance**		
		0.4	0.5	0.6
Particle Static/ Dynamic Friction	0.5			
	0.6			
	0.7			

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Document Information

This case study is part of a set of teaching resources to help introduce students to topics focused on particle methods and discrete elements.

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