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Analysis of the behavioral characteristics of detergent powder using Rocky-Ansys Fluent two-way coupling

Ansys Fluent has a variety of particle analysis methods, but sticky particles are particularly difficult to analyze. Rocky, a specialized particle analysis program that can analyze various shapes and sticky particles, and ductile analysis are needed. This analysis attempts to understand the behavior of sticky detergent powders according to flow velocity using Rocky-Ansys Fluent two-way coupling.

When powdered washing detergent is used, water enters the detergent drawer and injects the detergent into the washing machine. As shown in Fig. 1, as the detergent powder gets wet and adheres, the adhesion increases, and the powder remains in the detergent drawer.

While Ansys Fluent has several particles analysis methods, most particle analysis methods are not suitable for this case. Therefore, a method that uses Rocky-Ansys Fluent coupling, a specialized particle analysis program, is required. Rocky can implement both spherical and non-spherical particles, as well as particle stacking and sticky particles. In addition, Ansys Fluent coupling can be implemented very easily, and the flow analysis grid can be greatly reduced. If many particles are present, the GPU can be used to dramatically shorten the analysis time.

In this article, we delve deeper into the analysis of the behavioral characteristics of detergent powder according to water flow velocity using Rocky-Ansys Fluent two-way coupling. This analysis was conducted to determine the possibility of interpretation without precise conditions.

Fig. 1 – Phenomenon of residual detergent powder

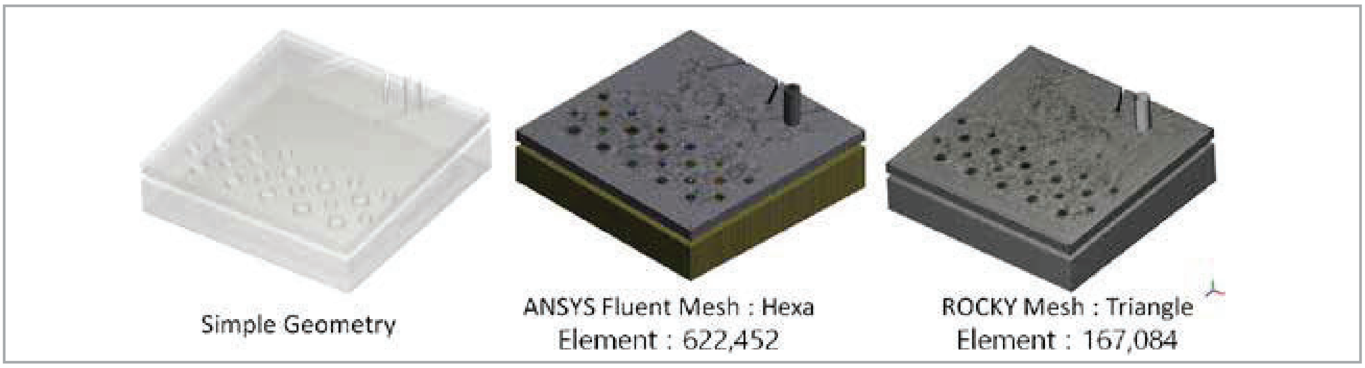

Fig. 2 – Simple geometry and mesh

Geometry and mesh

As shown in Fig. 2, the behavior of detergent powder is determined using simple geometry. By creating an Ansys Fluent case file, Rocky can use a boundary in the Fluent case. The grid is a full hexahedral type and about 620,000 elements. In Rocky, the surface grid is about 170,000 elements and the quadrilateral grid is automatically converted to a triangular one.

Ansys Fluent configuration for coupling analysis

There are two ways to conduct Rocky coupling. If only one fluid is present, it is set to a single phase and treated with porous using volume fractions of the particles. If two or more fluids are present, a multiphase model must be used, and only the Eulerian model is possible. This case requires a three-phase analysis using the Eulerian model since water, air, and detergent particles are present. The realizable k-e model and scalable wall function were used for the turbulence model, and the turbulence multiphase model was set to dispersed.

Configure Ansys Fluent as follows for two-way coupling:

1. 3D double precision
2. Transient
3. Gravity
4. Dispersed turbulence model for multiphase (using the Eulerian model)

The properties of each fluid use Ansys Fluent's default values for water and air. The properties of the particles are set by Rocky. Particle density is set the same way and viscosity is not required, so use the default value or set it to 0.

The input sets the velocity inlet condition where the velocity is 2m/s and 5m/s, respectively. The output sets the relative gauge pressure to 0Pa in the pressure outlet condition.

The wall is set to stationary and non-slip conditions. In solution method, pressure is set to body force weighted, transient formulation is changed to bounded second order implicit, and the default values are used for the rest. Standard initialization is used, and air volume fraction is set to 1. Finally, save the case file. This case file is available to Rocky, so it is not necessary to create a separate surface mesh for Rocky.

Rocky configuration for coupling analysis

Rocky settings for stacking of detergent powder

After stacking the detergent powder, water is added into the washing machine. First, it is necessary to stack the detergent powder using Rocky: the stacked state is the initial condition. After coupling with Ansys Fluent, the behavior of the detergent is analyzed when water enters.

The normal force hysteretic linear spring model is used by adding the Leeds Contact Model and the tangential force uses the Linear Spring Coulomb Limit Model. To consider the sticky properties of the particles, use the Leeds Contact Model among the adhesive models. To consider rolling resistance, select Type C: Linear Spring Rolling Limit. Gravity (-9.81m/s^2) was set in the Y direction, and heat transfer was not considered. The detergent powder particles are spherical and have a size of 0.3mm. The total mass input is 5g, and the rolling resistance is set to 0.2.

The density of detergent powder is 2,100kg/m^3, and the bulk density is 1,260kg/m^3. Bulk Young's modulus is 0.1GPa, and Poisson's ratio is 0.2.

The detergent drawer is plastic, the density is 1,100kg/m^3, Young's modulus is 3GPa, and Poisson's ratio is 0.2. It establishes particle-particle interactions and particle-wall interactions. The static and dynamic friction of the particle-particle interactions is 0.55, and the coefficient of restitution is 0.1.

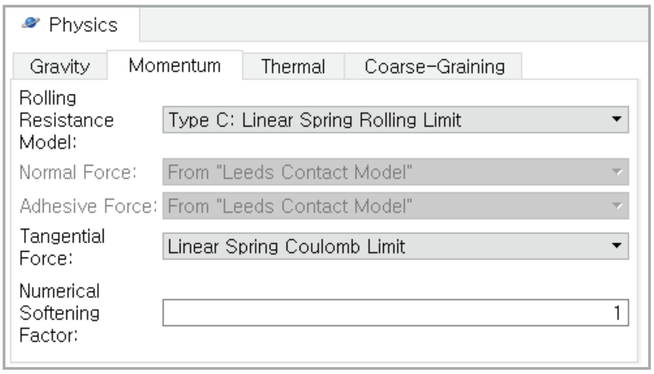

Fig. 3 Momentum of Physics

For the adhesive force, the damping ratio was set to 0 and the surface energy was set to 0.0003j/m^2. The static and dynamic friction between the particle-wall interactions is 0.2, and the

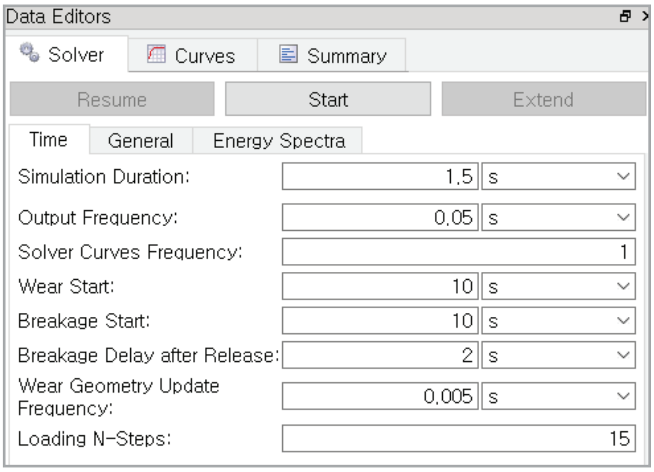

Fig. 4 Solver setting

coefficient of restitution is 0.1. The analysis time is 1.5 seconds, and the analysis is performed using the GPU (Tesla P100).

During the analysis, stacking particles can be checked for each time as shown in Fig. 5. When the stacking is complete, save the 1.5 second result as an initial condition, as shown in Fig. 6. We configure the coupling with Ansys Fluent from the initial conditions saved.

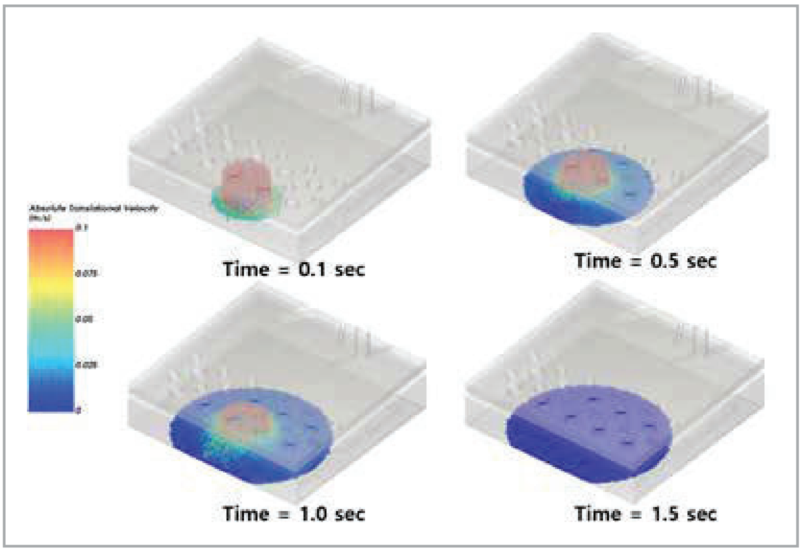

Fig. 5 Stacking particles over time

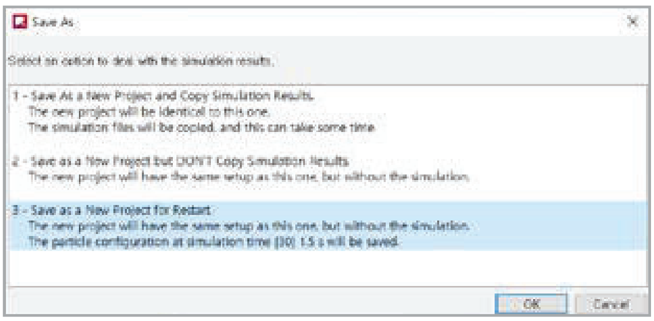

Fig. 6 Save as a new project for restart

Rocky settings for Ansys Fluent coupling

All other conditions are the same as before, so only the CFD coupling needs to be configured. In CFD coupling, select coupling mode as Fluent two way and then select the Ansys Fluent case file. Select drag and virtual mass law from the CFD law and Huilin & Gidaspow from drag law (see Fig. 7).

Turbulence dispersion is similar to discrete random cloud in Ansys Fluent. In the Fluent tab, Rocky phase selects particle phase from secondary. Then select the version of Ansys Fluent to use and enter the number of parallel cores. Configuring Rocky-Ansys Fluent two-way coupling is remarkably simple. Rocky 4.4.3 supports from Ansys R19.2 to Ansys 2021 R1.

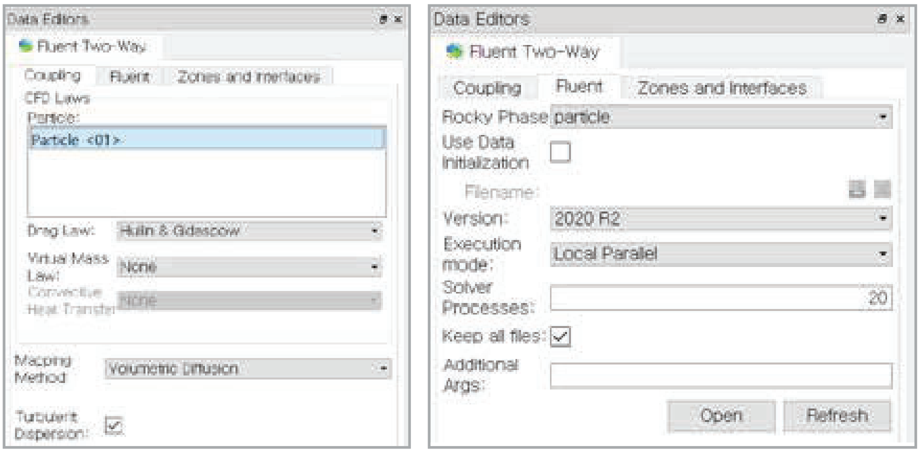

Fig. 7 – Settings for the Rocky-Ansys Fluent two-way coupling

Determine the total analysis time and storage period in the solver and press start. Rocky automatically executes Ansys Fluent (stand-alone) to load the saved Fluent case file, and then exchanges data between them each time.

Results

In Rocky you can only visualize the particle behavior. Ansys Fluent only allows you to view the flow analysis results with the volume fraction of the particles.

EnSight was used to visualize the flow results and particle behaviors together. The particle position over time was exported from Rocky and the Ansys Fluent analysis results were imported into EnSight.

Fig. 8 shows the behavior of the detergent and volume fraction of the water according to the water flow rate over time. When the water flow rate is 2m/s, after 0.5 seconds the water is slow, so the detergent is not washed away, and most of the detergent remains after 5 seconds.

After a little more time, you can see that the water supply has been built up. Because of the low flow rate, the sticky particles cannot be washed down.

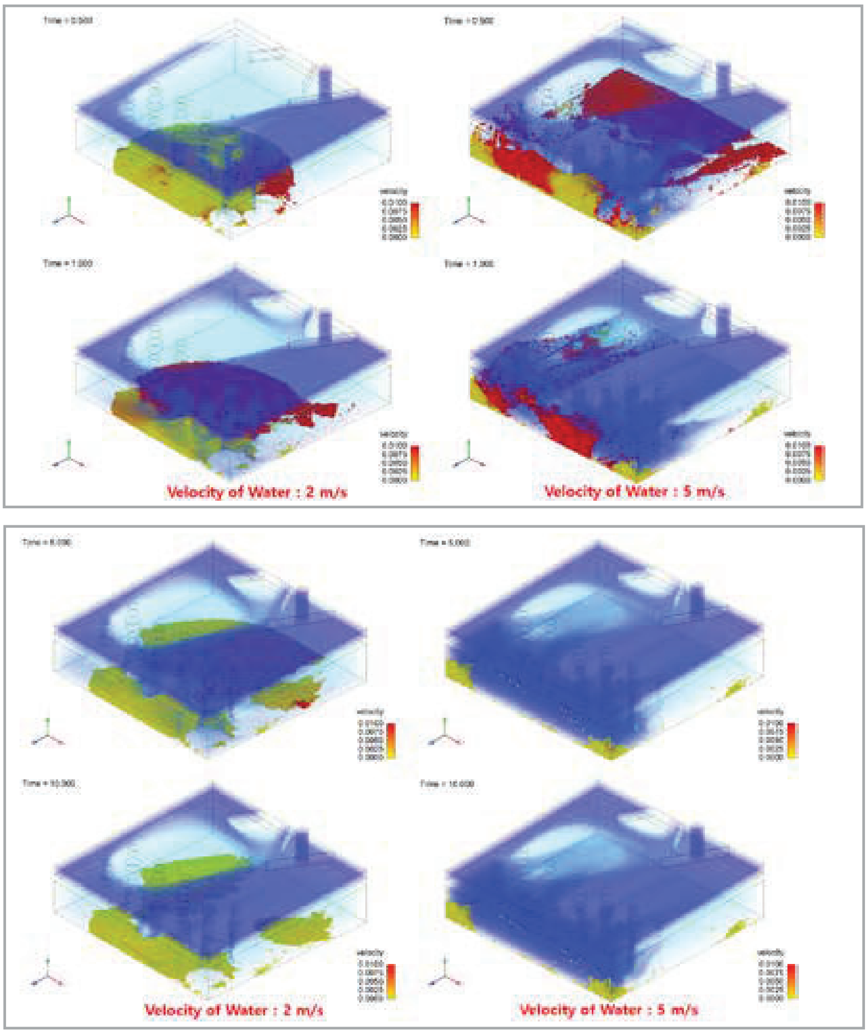

Fig. 8 – The behavior of the detergent powder according to the water flow rate

However, when the water flow rate is 5m/s, you can see that after 1 second most of the detergent is washed away and the remaining detergent particles have collected in the corner.

It can be seen that the main parameter for introducing the detergent powder into the washing machine is the flow rate. In addition, the initial position of the detergent powder is especially important.

Conclusion

Rocky-Ansys Fluent two-way coupling was used to confirm the behavior of sticky particles of detergent powder according to the flow rate of water.

In this way, Rocky enables sticky particle analysis for different particle shape, size and adhesion. Therefore, Rocky-Fluent coupling can be used to overcome the limitations of Ansys Fluent, making fluid-particle analysis available for use in various industries.

For more information
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About TSNE

Since its establishment in 1988, TSNE has specialized in CAE, providing engineering programs and services to Korean customers. Tae Sung S&E (TSNE) aims to be the “One Stop Total CAE Solution Provider” (OSTS) both in domestic and global markets.

TSNE leverages its large base of business capabilities and its team of CAE experts to provide services to customers in various industries (aerospace, automotive, civil engineering, biomedical, shipbuilding, electrical and electronics, energy, defense, chemical industries, etc.) and is expanding its business scope to research innovative technologies and apply them in the field.

The company is striving to become a global engineering company and increase its potential to become a sustainable engineering company. Tae Sung S&E is partner to all engineers who strive to solve challenges. Tae Sung S&E will work with you to achieve “NO PROBLEM, BE HAPPY”.