The simulation of granular attachment on the porous vertical surfaces

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Abstract. Granular simulations have been carried out to visualize attached to porous vertical surfaces. We simulate the optimal ratio of dry surfaces. This simulation uses the uFlex particle with three pore sizes. The movement particle using parabolic motion with the initial horizontal speed only. The simulation results show that for uniform particle velocities, the number of particles that are attached depends on the size of the particle sphere itself. These results can combine with the previous study to use in future research.

1. Introduction

The granular powder is one of the objects of research in the field of simulation with the varied application. This field allows us to use behaviors [1], dependent variables [2], multiscale [3], or combines them. Some previous studies describe research results in the form of comparisons between simulations and real experiments [4,5]. This research focuses on studying the dynamic nature of the granular material system, then analyzing both simulation and laboratory experimentation. The granular studies are not only limited to the physical system. Its characters are also used for the exploration of algae-bacteria granular consortia [6]. Its is why research on granular characteristics is so interesting and continuous.

The continuous granular research includes hydrodynamics, the study about its behavior to represent fluid characters. One of the properties of fluid is a flow, and this can be modeled computationally with the granular flow through its phase [7]. Because of its flexible character, many studies later emerged in the field of hydrodynamics; for example, individual studies on the nature of soft and hard materials to explain the granular flow [8]. With certain limitations and conditions, this granular like fluid study encourages different computational methods according to their needs. In some engineering applications, it can use discrete simulation [9]. The smoothed particle hydrodynamics is applied to study the interaction between a fluid and granular powder [10].

Besides fluid character, granular simulation with a rigid sphere character is also a popular research topic. This study can be in the analysis of hard-sphere dynamics close to the hard wall [11,12], a specific boundary condition [13], or turbulent flow [14]. Related to its nature as hard-sphere, other computational
methods can also be used, for example, Monte Carlo to increase computational speed [15] or the Boltzmann-Grad method for error analysis [16]. All of this research is interesting because the principle applied is simple, the impulse reaction.

This paper is a continuation study from previous research on two-dimensional simulation of granular particles on rigid walls [17] and studies on the interaction of rigid granular with fluid [18]. In this study, we used the uFlex simulation tool from the Unity Asset store [19]. This tool uses the unified particle physics principle in previous research [20]. This paper discusses simulations with variations of three particle sizes with constant horizontal particle velocity. The walls are made vertically with a specific diameter pore. The purpose of this paper discusses the effect of variations on particle size at a uniform speed, which strikes the porous wall.

2. Simulation methods

2.1. The granular powder

This simulation is run using the principle of impulse-based simulation [21-23]. Each granule acts as a rigid body and will not break. The particle size distribution shown in Figure 1, used is the size of diameter granules are 1 μm, 3 μm, and 5 μm.

![Figure 1. The particle size.](image)

The simulation in this paper uses the uFlex simulation package with its unified solver particle method [20]. The advantage is that it can simulate granular real-time. The coefficient of friction between particles in this simulation was identified as 0.5. The condition of the restitution coefficient is assumed on the porous surface and on each particle, equal to 0.1. The numerical samples of each grain had various diameters and contained 32768 particles shown in Figure 2. Each granule particle generated with 10 cm/s horizontal-speed. The movement using the parabolic principle by applied 9.8 m/s² gravitational acceleration.

![Figure 2. The initial condition of simulation.](image)
2.2. The porous surface

The porous surface, as shown in Figure 3, with a uniform diameter of 7.5 μm. The pore volume used is in the form of an ellipsoid split in half, as in Figure 4. In each simulated pore hole is set to a depth of 10 μm. The simulation uses a random packing sphere with packings fraction \( \varphi \approx 0.64 \) and \( n_{\text{total}} = 32768 \) granular sprinkled. The packing-ratio is then used to find the maximum amount of granular that can enter the pore \( n_{\text{max}} \) (Equation 1-2).

\[
n_{\text{max}} = \frac{V_p}{V_G} \varphi \tag{1}
\]

\[
n_{\text{max}} \leq \frac{4 \pi a^2 b}{2 \pi r^3} \varphi \tag{2}
\]

The number of granular particles is attached to the pore and the maximum granular, which is supposed to stick to cover the pore, \( n_{\text{max}} \). With this analysis, we can calculate the granular density that persists in the pore, \( \varphi_p \).

\[
\varphi_p = \frac{n}{n_{\text{max}}} \tag{3}
\]

![Figure 3](image1.png)

**Figure 3.** The vertical porous surface with 7.5 μm diameter.

![Figure 4](image2.png)

**Figure 4.** Illustration of a range of pore holes in human skin from small to largest.

3. Results and discussion

This simulation demonstrates the granular attachment to a porous system. The simulated granular attaches to a dry surface in 3 different sizes, namely 1 μm, 3 μm, and 5 μm. While the simulated Pore has a diameter of 7.5 μm with a depth of 10 μm. Figures 5-7 simulate the final conditions of granular attachment to a porous surface.
Figure 5. Attaching granules 1 μm to the 7.5 μm porous surface simulation on dry skin.

Figure 6. Attaching granules 3 μm to the 7.5 μm porous surface simulation on dry skin.

Figure 7. Attaching granules 5 μm to the 7.5 μm porous surface simulation on dry skin.

From data, Figure 5-7 shows that the amount of granular attachment is directly proportional to the size of the granule powder. Based on simulation data, it can be interpreted the continuity between the number of granular particles attached in the pores, \( n \), and the density \( \varphi \) in the pore hole of each pore, as in Table 1. The result of these simulations will combine with the previous research in horizontal porous simulation [24] in future research.
Table 1. The comparison of the number of granular in pores for 3 different granular sizes.

| Granular Diameter | Pore Diameter | $n_{max}$ | $n$ | $\phi$ (%) |
|-------------------|---------------|-----------|-----|------------|
| 1 $\mu$m          | 7.5 $\mu$m    | 360       | 112 | 31.1       |
| 3 $\mu$m          | 7.5 $\mu$m    | 13.33333  | 6   | 45.1       |
| 5 $\mu$m          | 7.5 $\mu$m    | 2.88      | 0   | 0          |

From Table 1, it can be seen that for porous surfaces with vertical conditions, granular size with a diameter of 5 $\mu$m, not attached to the pore. That is, in subsequent studies for dry pore surfaces, granular size does not need to be analyzed again. However, it still needs to be observed if the conditions are porous moisturized. It is important for analysis at the implementation level. Furthermore, granular size ranges can be chosen based on ranges between 1-3 $\mu$m.

4. Summary
A simulation of sticking granular variations has been carried out on variations in porous surface sizes. The simulation results show that for uniform particle velocities, the number of particles that are attached depends on the size of the particle sphere itself. These results can be comparative data for other character variations in subsequent studies. In simulations, in order to get better data, it needs to be equipped with other tools that support the tools that have been used in this simulation.

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