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HEAT TRANSFER MODELLING OF GRANULAR FLOW IN POROUS MEDIA

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1. ABSTRACT

This study employs discrete element modelling to investigate the heat transfer phenomena within granular flow across various porous shape scenarios. The result showed that spline with staggered shape exhibited highest maximum and average temperature with longer duration compared to other porous shape scenarios. In addition, the agglomeration of solid particles in the interstitial region of porous structure was predicted in all scenarios. This study underscores the potential for optimising porous structures to enhance the heat transfer in granular flow systems.

2. INTRODUCTION

The granular flow, which consist of fluid-solid particles or pure solid particles that are passing over porous media has been widely researched in the field of Thermal Energy Storage (TES) or packed bed systems [1,2]. The heat transfer through granular flow in those systems has been used to improve the thermal efficiency of power generation in long duration TES because of its stability at in very high temperatures [3]. However, different from the molecular fluid, the granular flow heat transfer has a challenge of modelling. To overcome this problem, Discrete Element Modelling (DEM), which uses Lagrangian framework to track the interaction between each solid particle has been implemented. Schirck et al., proposed particles TES design with hexagonal shaped heating elements, showing the effect of slope angle of the heating element and particle agglomeration, where particle flow is stagnated between the heating elements [3]. Tsory et al., analysed heat transfer through packed bed system through DEM [2]. However, there are lack of research on the mechanism of the granular flow in different shape of heated porous structures. Therefore, this study implemented four different porous shape scenarios to reveal the flow dynamics (heat transfer) of solid particles including particle average temperature, the time for achieving heated temperature, and particle agglomeration.

3. METHDOLOGY

In this section, the different scenarios for the granular flow and DEM simulation configuration will be explained. The porous geometries are configured with circle, hexagonal, spline, and spline-staggered shape. The clamps are implemented to the particle bed to lead direct particle drop into porous region. Three-dimensional simulation is conducted with 50×50×10 meshes. Fig. 1 shows the detail of each porous geometry.

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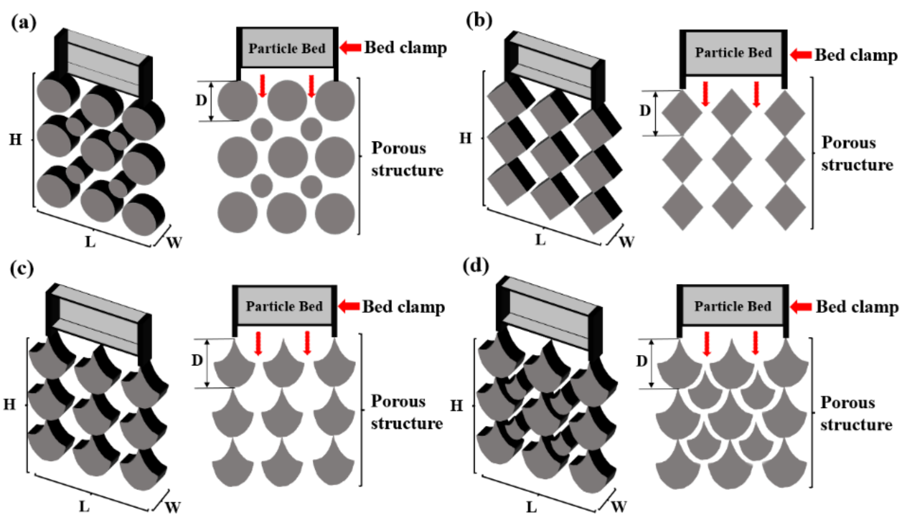

Fig. 1 Different porous shape for DEM simulation; (a) circle; (b) hexagonal; (c) spline; (d) spline-staggered; Diameter (D), Height (H), Length (L) and Width (W) of the structure are 0.1m, 0.6m, 0.35m and 0.002m respectively.

The granular flow simulation is conducted using Multiphase Flow with Interphase eXchanges (MFIX) software [4]. The modelling parameters are identical in all scenarios as shown in Table 1.

Table 1 Discrete element modelling simulation parameters

Parameters	Values	Parameters	Values
Particle diameter	0.003m	Restitution coefficients (normal)	0.9
Particle density	2600kg/m^3	Particle collision model	Linear spring-dashpot
Particle thermal conductivity	1.402W/m·K	Minimum conduction distance	1×10^{-6}m
Particle specific heat	830J/kg·K	Young's modulus for solid and wall (conduction)	70GPa
Coulomb friction coefficient	0.1	Poisson's ratio for solid and wall (conduction)	0.17
Normal spring constant (particle to particle and wall)	1000N/m	Particle volume fraction of bed	0.4
Spring tangent/normal ratio	0.285	Temperature of porous media	1273K

Based on those configurations, the heat transfer analysis of granular flow is analysed. The results of those scenarios are presented in Section 4.

4. RESULTS

Average particle temperature and the time required to reach the maximum temperature of each scenario is predicted. Moreover, the contour of agglomeration of the solid particles are drawn. Tabel 2 shows that among the porous shape scenarios, spline-staggered porous structure provides the highest maximum temperature with longer time to achieve to the maximum temperature. Since this porous structure needs more residence time to heating the solid particles, it can achieve efficient heat transfer of granular flow.

Table 2 Time for achieving maximum and corresponding average temperature of the solid particles

Parameters	Circle	Hexagonal	Spline	Spline-staggered
Time (s)	3.58	2.99	4.62	5.78
Maximum Temperature (K)	495.77	411.72	423.13	526.33
Average Temperature (K)	309.47	302.54	305.66	313.67

Fig. 2 presents that the agglomeration of each scenario is captured when the particles pass through the porous structure. The particles are accumulated at the interstitial region of different porous structures.

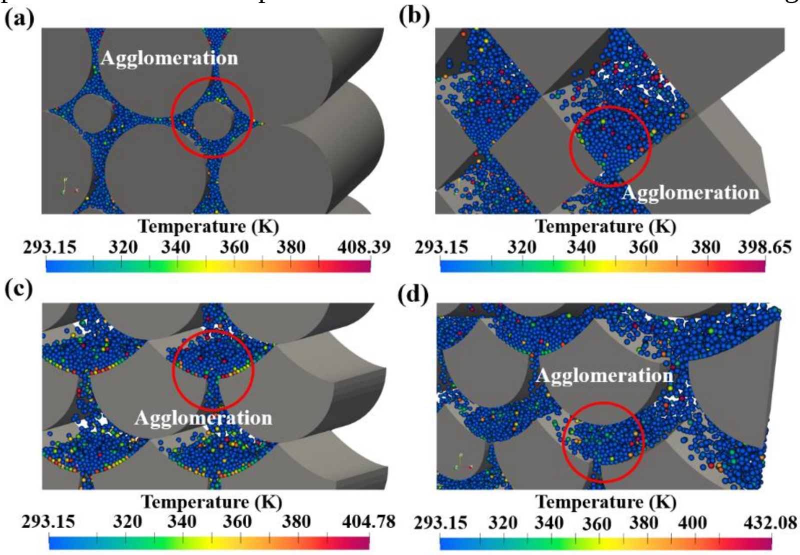

Fig. 2 Different porous shape for DEM simulation; (a) circle; (b) hexagonal; (c) spline; (d) spline-staggered.

5. CONCLUSIONS

This study investigates the heat transfer of granular flow in different porous shape. The results showed that spline-staggered shape provided the highest maximum and average temperature with longer time duration. In addition, the agglomeration of all scenarios presented that the solid particles stagnate at the interstitial region. This means that optimising the porous structure can provide efficient heat transfer of the granular flow.

ACKNOWLEDGMENT

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