Evaluation of particle-scale radiative heat transfer in polydisperse beds

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ABSTRACT

In describing heat transfer in particulate systems at high temperature, it is essential to calculate radiative heat transfer correctly. In Eulerian (continual media) approach it is a common practice to use effective heat transfer coefficient.

Discrete elements method requires different approach, consistent with resolving heat transfer on the scale of heat fluxes between particles. In general, radiative heat flux in pair of particles is determined by both their individual properties (radius, emissivity, temperature), pairwise (relative position), and local collective parameters of particle bed (porosity, etc.). Radiative heat transfer between particle bed and external or immersed objects is also of high importance in many applications.

Several methods to account for radiative heat transfer between particles were implemented [1]. Ray tracing can be used to determine heat transfer accurately, but it turns out to be extremely computationally demanding and therefore inadequate to apply in problems with moving particles, e.g. multiphase flow. As a solution, statistical relation between heat flux and properties of particles can be proposed [2]. Each particle is considered isothermal sphere, heat fluxes *W* are described through view factors *V*: $W_{ij} = V_{ij} 4\pi {r_i}^2 \left(T_i^4 - T_j^4\right)$.

The procedure to obtain formula for view factor included generation of particle bed with specified packing characteristics. Pairwise coefficients were calculated by ray tracing method. We obtained statistics for multiple neighbour particles and several bed generations, and built statistical correlation between view factors and relative position of particles and their radii ratio. The correlation was chosen in such a way as to preserve integral flux according to Stefan-Boltzmann law, as well as preserve radiative heat flux distribution according to distance from the emitting particle. We obtained correlation for view factors between particles:

For particles in direct contact $V_{ij} = 0.23\,(\frac{r_i}{r_j} + 0.85)^{-1.82}$

For particles without direct contact $V_{ij} = e^{1.5-1.9\,L/r_i}$

View factor from a particle in bed to the nearest wall $V_{iwall} = \frac{9\,e^{-1.64\,S/r_i}}{1.9+3.1S/r_i}$,

where r_i, r_j is radius of i-th and j-th particle, *L* is distance between particle centres, *S* is distance from particle centre to the plane wall.

At the present, that relations were obtained for random dense packing of spheres with monodisperse particles or particle mixtures with dominant (~90%) and auxiliary fractions. That system models particle bed of furnaces with mixture of inert and combustible particles, including fluidized bed.

Radiative heat transfer represented by these formulas may be incorporated in DEM code seamlessly.

REFERENCES

[1] S. Amberger, S. Pirker and C. Kloss, "*Thermal Radiation Modeling using Ray Tracing in LIGGGHTS*", in: 6th International Conference on Discrete Element Methods (DEM6), (2013).

[2] M. L. Pitso, *Characterisation of long range radiation heat transfer in packed pebble beds*: Ph.D. thesis, North-West University (2011).