Equivalent Thermal Conductivity of Metal Powder Beds in 3D Printing

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Abstract

The thermal behavior of metal powder beds plays a crucial role in controlling the quality of the final product in 3D printing. The discrete and particulate nature of the powders makes it computationally very challenging to model heat transfer and phase changes of metal powders during laser sintering processes in 3D printing. In the current work, a novel multiscale discrete element based modelling strategy is developed to simulate the thermal behaviour of particle beds. The main computational steps involved include:

1. Heat transfer from the laser beam to the top layer of particles is modelled by the Ray-tracing technique. As the laser beam is small and the laser rays are parallel, a small number of rays can be chosen and traced from the head of laser Galvanometer to the top layer of powder bed.
2. Heat conduction between particles in the bed is modelled by the discrete thermal element [1] and the modified pipe network approach [2]. A 3D discrete thermal element is also developed.
3. Thermal radiation between particles is modelled using the view factor based radiation thermal equation (Stefan Boltzmann's law). The view factors between particles in the powder bed will be calculated based on a highly effective numerical approach [3,4] with further modifications for un-equally sized spheres.
4. A multiscale method is applied to derive the equivalent thermal conductivity of the particle bed, which will take into considerations of both heat conduction and radiation, and thus the conductivity will be a nonlinear function of temperature.

The numerically derived equivalent thermal conductivity can thus be employed in a continuum based modelling method, such as FEM, for effectively modelling thermal heat transfer and possible phase changes of metal powders in laser sintering in 3D printing.

Keywords: Discrete element, thermal conduction, radiation, equivalent thermal conductivity, laser sintering, 3D printing.

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