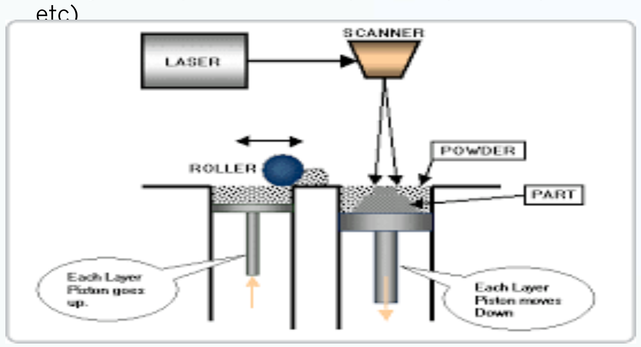
Cyber Enabled Manufacturing Systems (CeMs) for Small Lot Manufacture

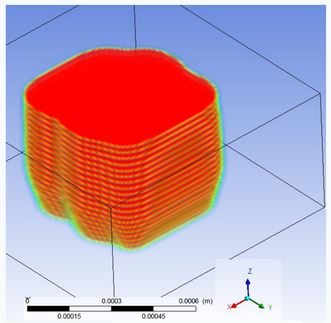
Selective Laser Sintering

- Method for creating solid parts directly from CAD model
- Builds up a solid 3-D object by selectively fusing successive layers of powder
- Successful build requires proper control of subsystems (ie. Laser scan pattern, power, speed, etc)

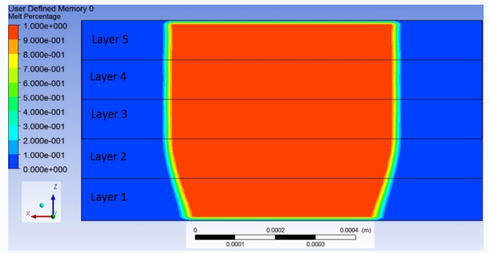


Continuum SLS Modeling

- Approximates powdered materials as continuum to make the problem tractable
- Predicts temperature history and melt fraction of an SLS part produced with a given set of processing parameters
- Requires bulk material properties for the powder



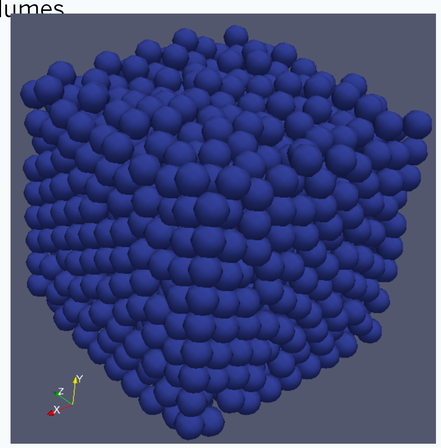
3D View: Predicted Part Shape



Cross Section: Predicted Part Shape

Multi-Scale Modeling

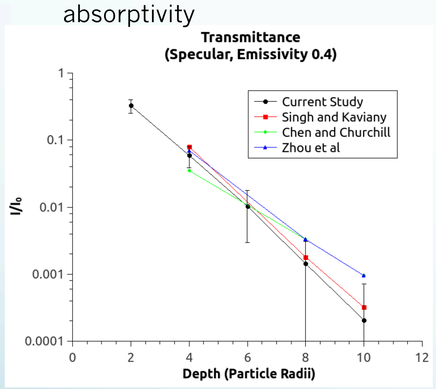
- Calculate bulk properties using a particle-level model to reduce uncertainties
- Discrete element modeling represents particles as spherical control volumes

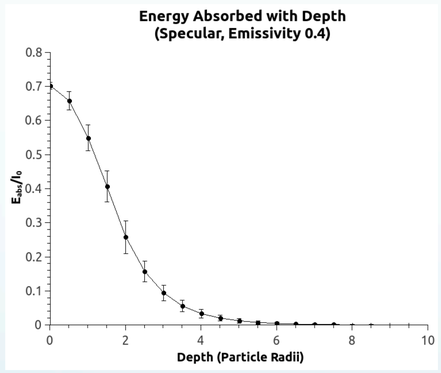


Example Packing Structure

Optical Modeling

- Ray tracing used to predict how laser energy is absorbed in the particle bed
- Used to calculate effective extinction coefficient and absorptivity



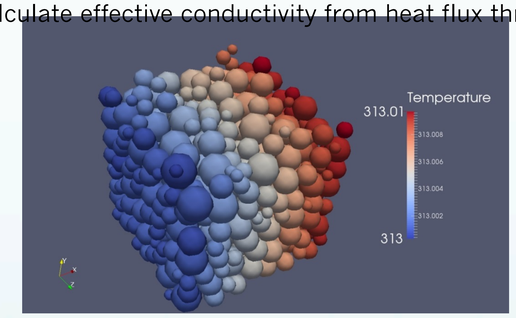


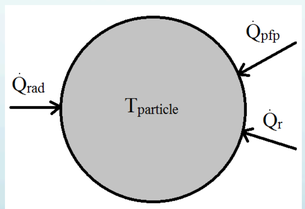
Study	βR (B-L)	Dev (B-L)	βR (Abs)	Dev (Abs)
Singh & Kaviany	0.7	0.1	N/a	N/a
Chen & Churchill	0.75	0.08	N/a	N/a
Zhou et al	0.7	0.02	N/a	N/a
Current	0.7	0.1	0.58	0.02

Comparison with previous results

Conductivity Modeling

- Each particle treated as a control volume with a single temperature
- Impose small temperature gradient
- Use constitutive heat transfer models
- Determine steady state temperature distribution
- Calculate effective conductivity from heat flux through bed



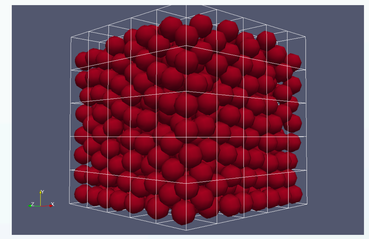


Material	D_p (mm)	k_{model} (W/m.K)	σ_{model} (W/m.K)	k_{exp} (W/m.K)
Copper	0.25	0.627	0.051	0.652 [1]
Copper	0.15	0.576	0.061	0.546 [1]
Lead	1.6	0.457	0.022	0.418 [3]
Steel	1.0	0.333	0.022	0.34 [23]
Steel	3.2	0.397	0.022	0.4-0.6 [3]

Table 1: Comparison of Model Predictions with Experimental Data

Melting Modeling

- Hybrid Continuum-DEM Model
- Solid particles represented in DEM
- Melt represented in continuum mesh
- As DEM particles melt and shrink, add the mass to the background mesh



Continuum-Discrete Representation