Numerical simulation and experimental validation of single clad laser metal deposition

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Introduction: Laser metal deposition (LMD) is widely adopted for coating, reparation and 3D printing. The objective of present study is to develop a numerical model of LMD using Inconel 718 which can predict the dimension of the clad bead under a wide range of process parameters.

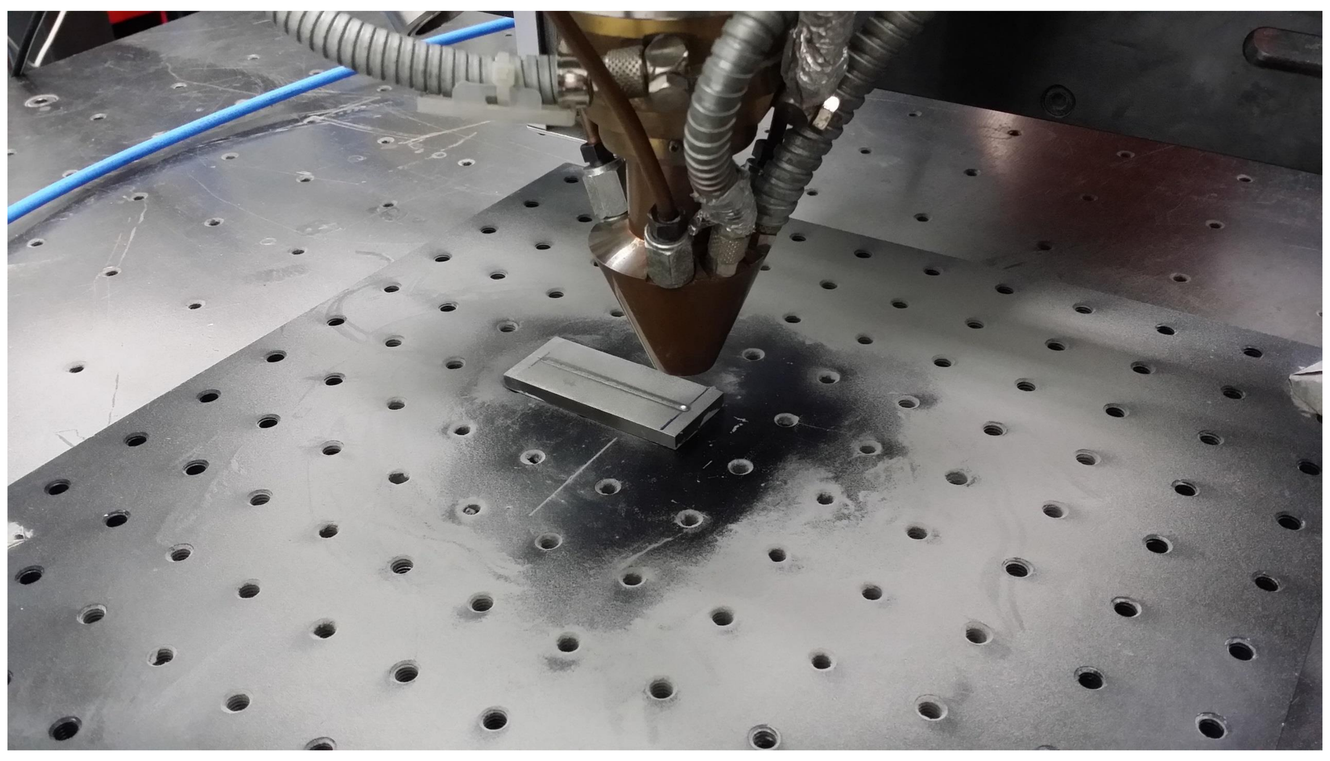

Figure 1. Clad head and substrate

Computational Methods: The LMD process is modeled with fully coupling fluid flow and heat transfer. The geometry of the clad bead is influenced significantly by the surface tension force, which comprises of the normal and tangential components

$$\mathbf{T} \cdot \mathbf{n}_{\mathrm{m}} = \sigma\kappa\mathbf{n}_{\mathrm{m}} - \gamma\nabla_{\mathrm{t}}T$$

where $\mathbf{T}$ is stress tensor, $\mathbf{n}_{\mathrm{m}}$ is normal vector of the melt pool surface. σ and γ are the surface tension coefficient and thermo-capillary gradient. T is temperature.

The dimension and boundary condition of the domain is described as follows

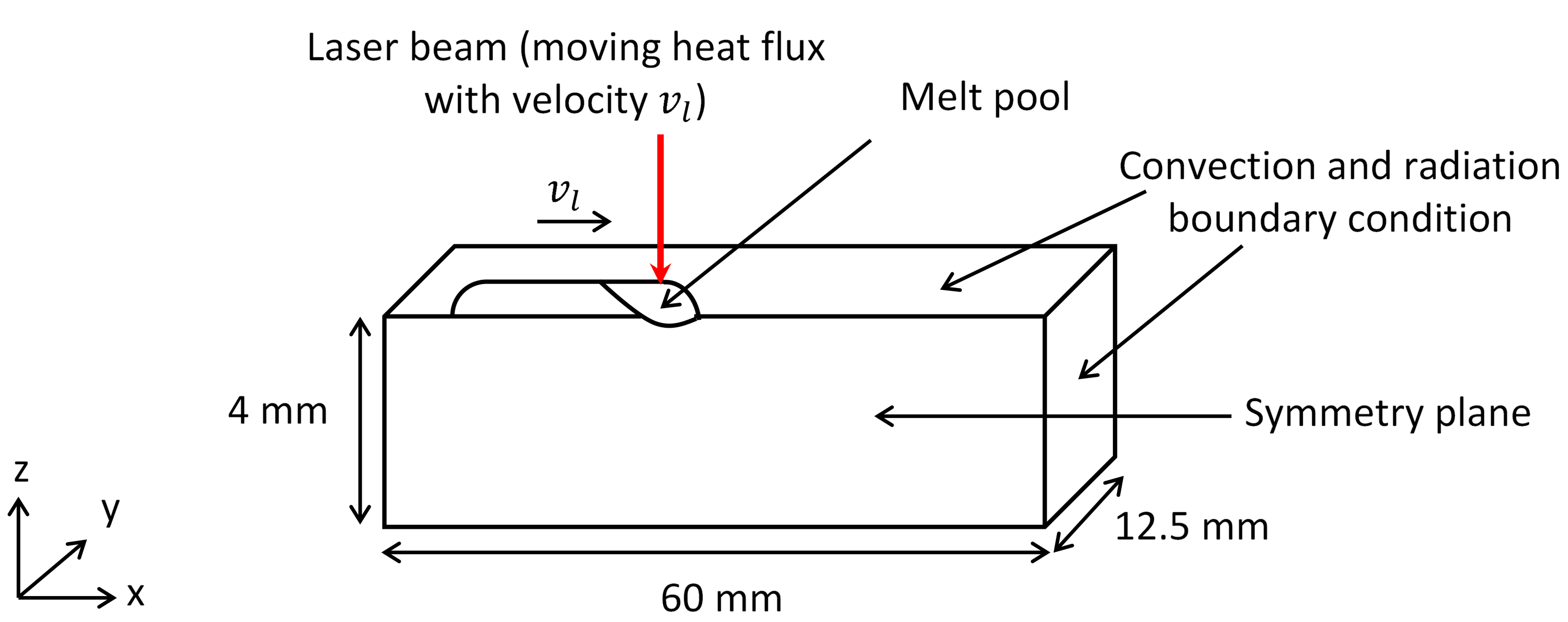

Figure 2. Schematic of the modelled LAAM process

Results: The temperature distribution and fluid flow in melt pool have been simulated. The dimension of clad bead and melt pool depth predicted by simulation match well with those in experiment.

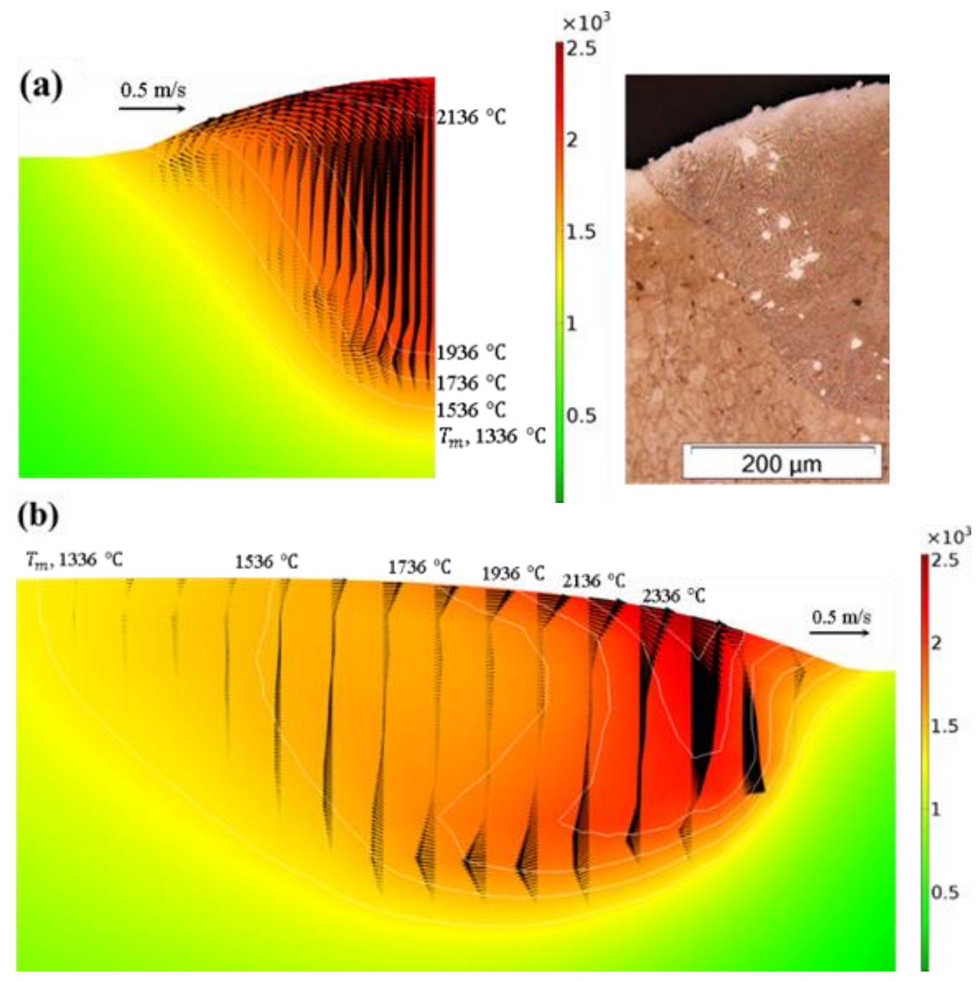

Figure 3. (a) Melt-pool thermal and fluid fields for exp. No. 4 in the clad bead transverse cross-sectional view and; (b) in the clad bead longitudinal cross-sectional view along the cladding direction

Expt. No.	Power (W)	Scan speed (mm/min)	Powder feeding rate (g/min)	Clad height (mm) Expt. / predicted	Clad wdith (mm) Expt. / predicted	Melt pool depth (mm) Expt. / predicted
1	640	600	4.35	0.516 / 0.554	2.000 / 1.876	0.571 / 0.630
2	840	600	4.35	0.511 / 0.561	2.175 / 2.015	0.981 / 0.891
3	1010	600	4.35	0.548 / 0.544	2.227 / 2.230	1.210 / 1.137
4	840	600	2.90	0.361 / 0.363	2.193 / 2.158	1.105 / 1.011
5	840	600	5.80	0.701 / 0.721	2.188 / 2.006	0.960 / 0.889
6	840	900	6.52	0.509 / 0.512	2.082 / 1.882	0.721 / 0.668
7	840	1200	8.70	0.511 / 0.558	1.951 / 1.784	0.459 / 0.436

Table 1. Experimental parameters with experimental and predicted clad bead dimensions and melt-pool depths

Conclusions: LMD process has be simulated using COMSOL's laminar fluid and heat transfer modules. The model has been validated by experiment under 7 different sets of process parameters. Both fluid flow and temperature distribution of melt pool can be obtained.

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