Understanding keyhole induced-porosities in laser powder bed fusion of aluminum and elimination strategy

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The parameters for mesh dependence and time-step dependence analysis are displayed in **table s1** and the corresponding melt pool profile in the cross-section perpendicular to the laser moving direction is shown in **Fig. s1**. Case1 (5 μm) and case 2 (6 μm) are used for mesh analysis. The melt pool depth is close while the calculation time of case1 is twice that of the case 2. Therefore, the mesh size of 6 μm is chosen. Cases 2 and case 3 are the time-step dependence analysis. The time step for case 2 is controlled by stability and convergence (around 0.068 μs). Similar melt pool size is obtained while the CPU time for case 3 (0.025 μs) is doubled. Therefore, the mesh size of 6 μm and time-step controlled by stability and convergence are adopted in the simulation.

Table s1 Details of the models and the melt pool dimensions for the mesh-independency and timestep-independency analysis. Laser power 500 W, scanning speed 600 mm.s-1 and laser beam diameter 50 μm.

No.	**Mesh size (μm)**	**Time step (μs)**	**Cell count**	**CPU time (h)**	**Melt pool dimension**	
					Depth (μm)	**Deviation (%)**
Case 1	5	0.068	6592320	92.5	443	5.48
Case 2	6	0.068	3988213	48	420	\
Case 3	6	0.025	3988213	95	402	4.29

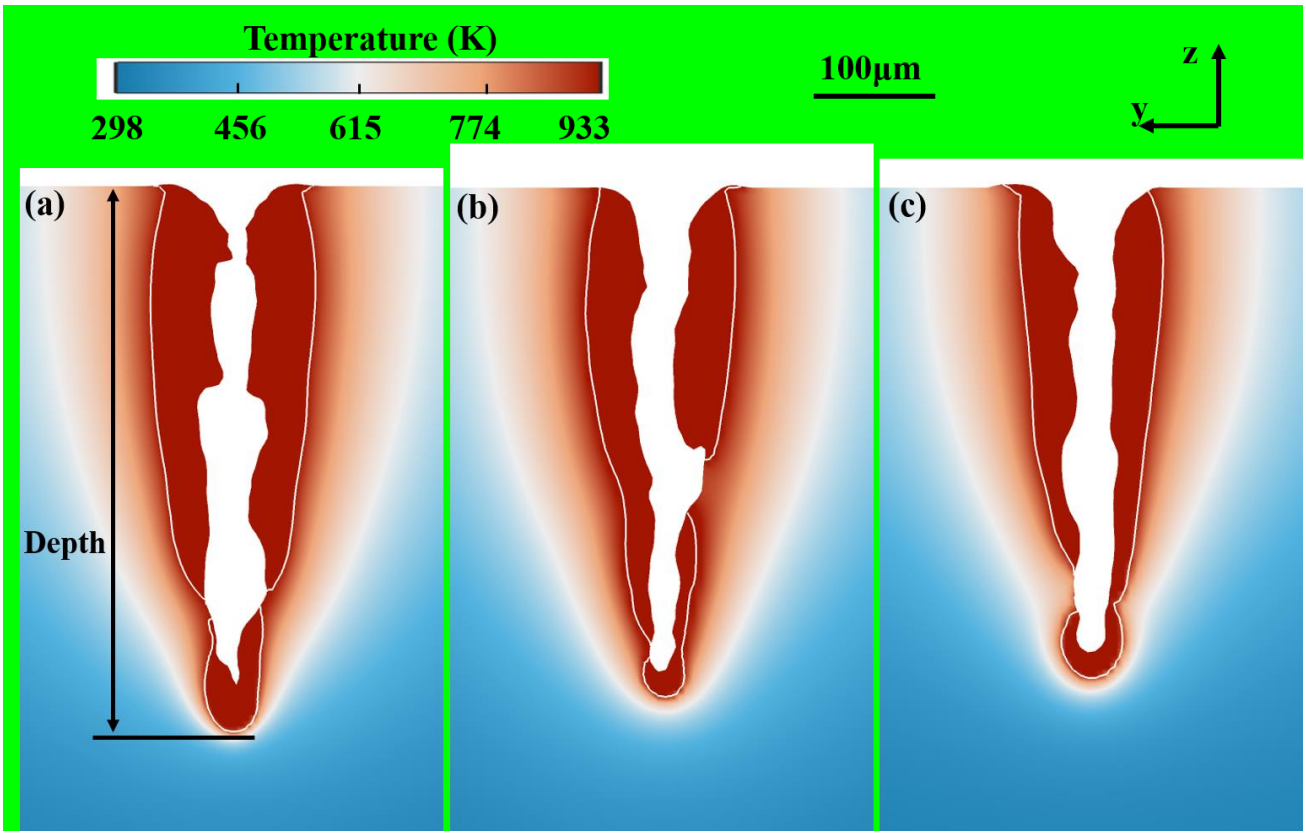

Fig. s1 Melt pool profile for sensitivity analysis: (a) case 1, (b) case 2, (c) case 3. Laser power 500 W, scanning speed 600 mm·s^{-1} and laser beam diameter 50 µm.

Table s2 Laser parameters used in the simulation

Number	Power, P(W)	Scanning speed, V(mm/s)	Laser diameter spot, d (μm)	Powder bed
1	500	600	40	without
2			50	
3			80	
4			140	
5		1000	50	
6			80	
7			140	
8		1400	50	
9			80	
10	400	600	50	
11			80	
12			140	
13		1000	50	
14			80	
15		1400	50	
16			80	
17	300	600	80	
18		1000	80	
19	500	600	50	with

Video1

Dynamics of keyhole and keyhole pore formation during laser melting with bare aluminum plate. Laser power is 500W, scanning speed is 600mm/s, and laser spot diameter is 50μm.

Video2

Dynamics of keyhole and keyhole pore formation during laser power bed fusion with 30μm thick pure aluminum powder layer. Laser power is 500W, scanning speed is 600mm/s, and laser spot diameter is 50μm.

Video3

Dynamics of keyhole and keyhole pore formation during laser melting with bare aluminum plate. Laser power is 500W, scanning speed is 1400mm/s, and laser spot diameter is 50μm.

Video4

Dynamics of keyhole and keyhole pore formation during laser melting with bare aluminum plate. Laser power is 500W, scanning speed is 1400mm/s, and laser spot diameter is 80μm.

Video5

Dynamics of keyhole and keyhole pore formation during laser melting with bare aluminum plate. Laser power is 500W, scanning speed is 600mm/s, and laser spot diameter is 140μm.

Video6

Dynamics of keyhole and keyhole pore formation during laser melting with bare aluminum plate. Laser power is 500W, scanning speed is 1000mm/s, and laser spot diameter is 140μm.

Video7

Dynamics of keyhole and keyhole pore formation during laser melting with bare aluminum plate. Laser power is 400W, scanning speed is 1400mm/s, and laser spot diameter is 50μm.

Video8

Dynamics of keyhole and keyhole pore formation during laser melting with bare aluminum plate. Laser power is 400W, scanning speed is 600mm/s, and laser spot diameter is 80μm.

Video9

Dynamics of keyhole and keyhole pore formation during laser melting with bare aluminum plate. Laser power is 400W, scanning speed is 1000mm/s, and laser spot diameter is 80μm.

Video10

Dynamics of keyhole and keyhole pore formation during laser melting with bare aluminum plate. Laser power 400is W, scanning speed is 600mm/s, and laser spot diameter is 140μm.

Video11

Dynamics of keyhole and keyhole pore formation during laser melting with bare aluminum plate. Laser power is 300W, scanning speed is 600mm/s, and laser spot diameter is 80μm.