Deformed Geometry Analysis of Laser Cladding Process

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Introduction: Additive manufacturing is attracting more and more interest. Laser Cladding is one of these additive manufacturing processes. In this process a new layer of material is deposited using blown powders process . Formation of small melt pool takes place on substrate material by means of laser energy. This process involves a complex heat transfer and fluid flow multiphysics field in which melting, solidification and phase change of metal powder occurs.

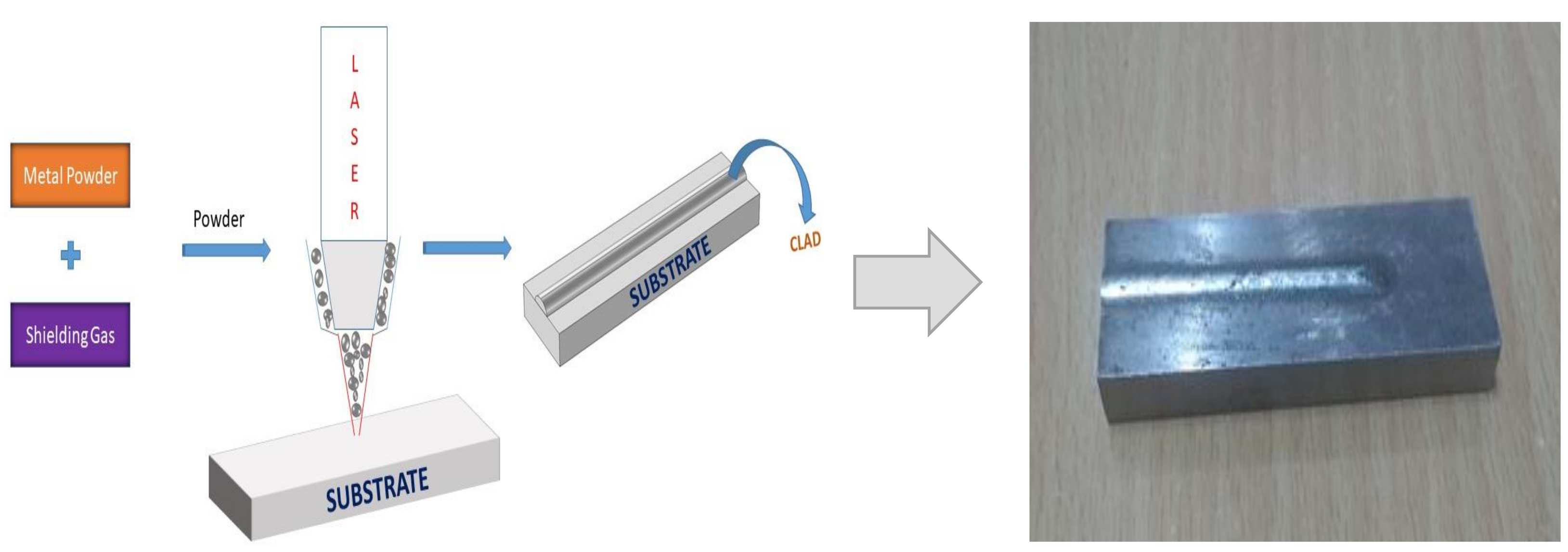

Figure 1. Laser Cladding operation and Sample after cladding

COMPUTATIONAL METHODS: 2D simulation is developed to study the process effect on the geometry of the clad and for process optimization. Thermal analysis is carried out to know the temperature history during the process, by giving laser energy input with gaussian distribution as a heat source. The Heat Transfer Module is used for this analysis. The dynamic shape of molten zone is explicitly described by a moving mesh based on deformed geometry module

$$d_z \rho C_p \frac{\partial T}{\partial t} + d_z \rho C_p \mathbf{u} \cdot \nabla T + \nabla \cdot \boldsymbol{q} = d_z Q + q_0 + d_z Q_{ted}$$

$$\mathbf{q} = -d_z K \nabla T$$

The equation for heat flux is given by:

$$q_0 = \left(\frac{2 \times P}{\pi \times rs}\right) \times \exp\left(-2 \times \left(\frac{rf}{r_s}\right)^2\right)$$

The mesh velocity due to powder addition:

$$V_p = N_p \times \frac{\eta_p D_m}{\rho_0 \pi rp^2} \exp\left(-Np \frac{(x - Vst)^2}{r_p^2}\right) . j$$

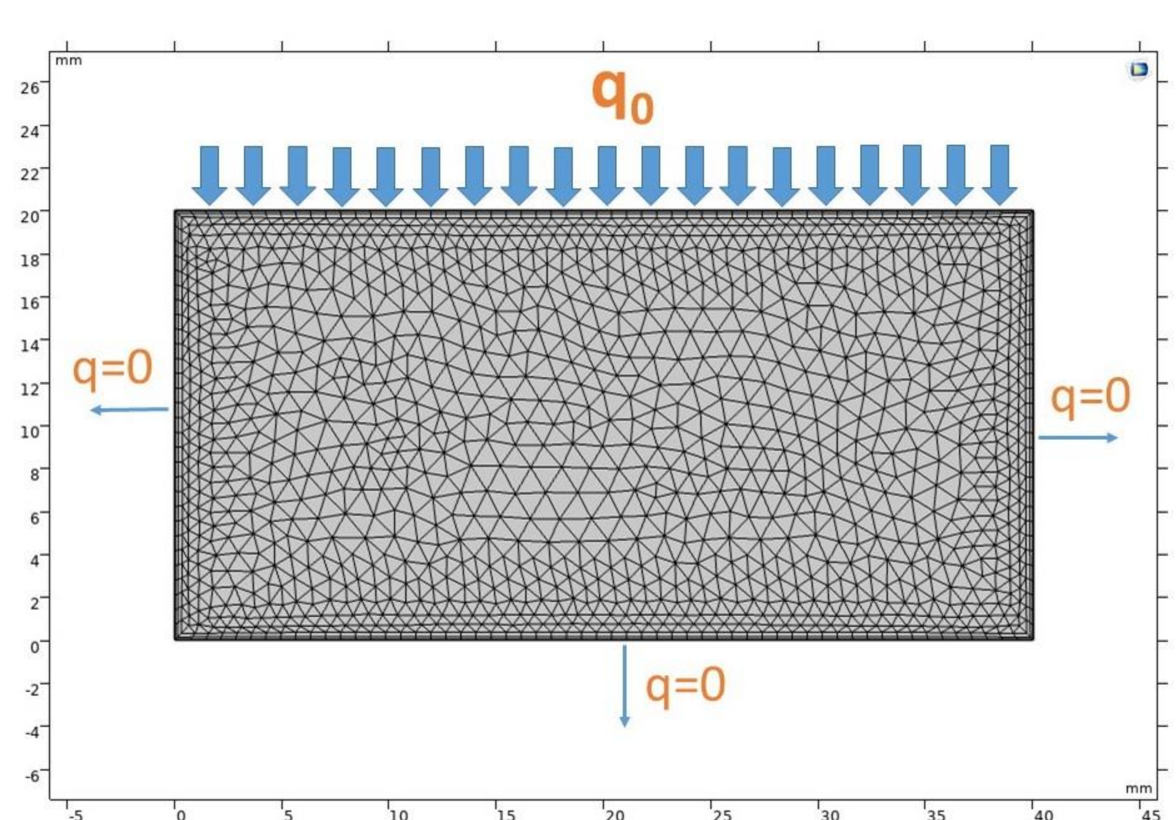

Figure 2. 2-Dimensional Physics Controlled Meshing

Results: The thermal profile and deformed geometry results in laser cladding process obtained by COMSOL Multiphysics® analysis, is shown in Figure 3. b. The simulated profile shows a good agreement with the experimental results.

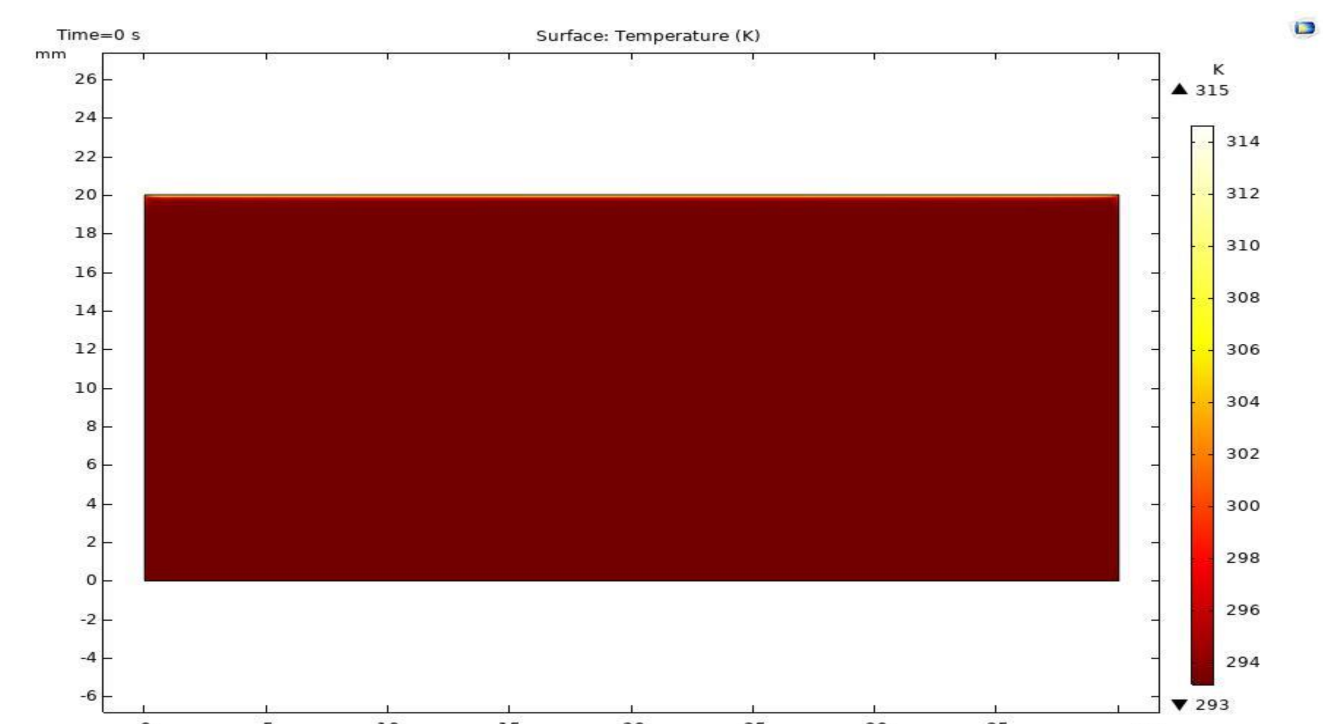

Figure 3. a SS410 Substrate Geometry

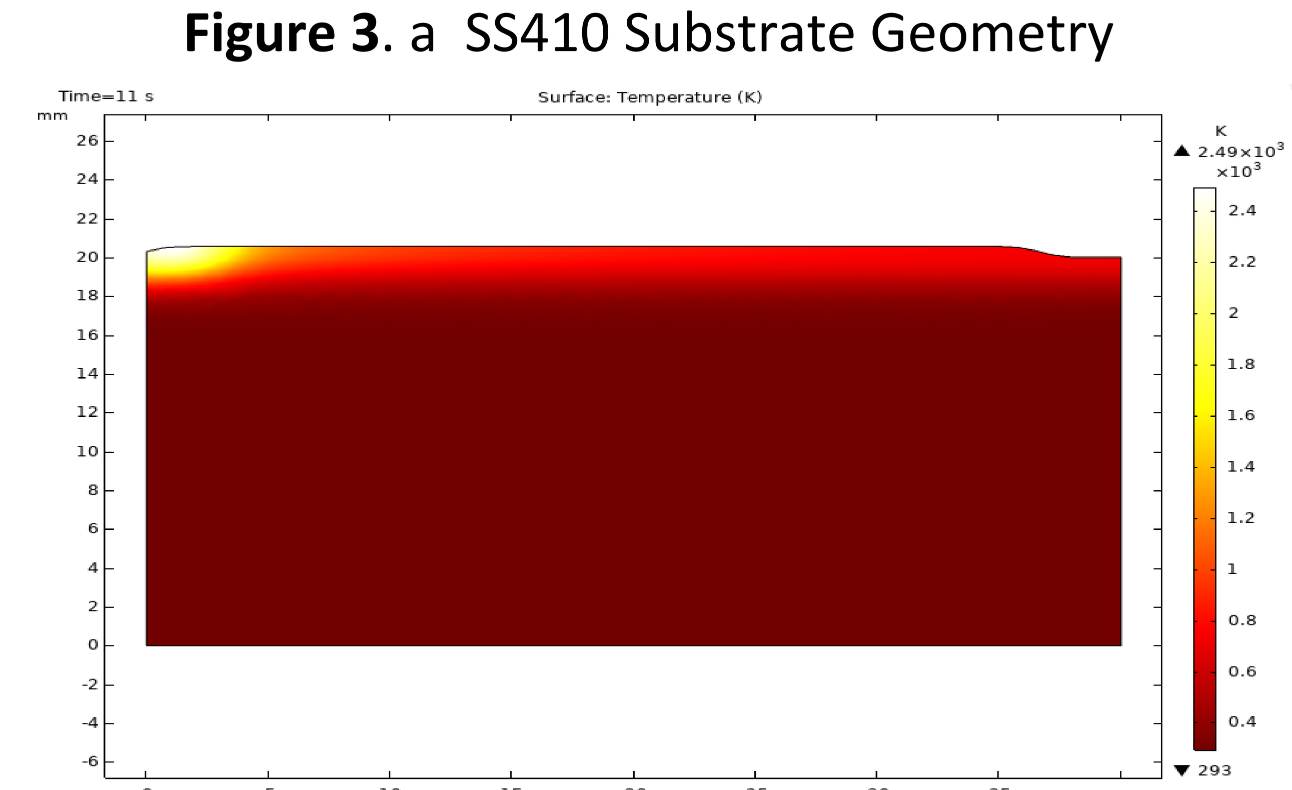

Figure 3. b Deposition of Sterlite Layer on Substrate Material by Laser Cladding process

Variable	symbol	Value	Units
Laser power	P	2000	W
Powder catchment efficiency	η_p	0.5	-
Mass powder rate	D_m	1.5	gm/min.
Liquid density	ρ_0	3800	Kg/m^3
Powder stream radius	r_p	2.2	mm
Constriction Coefficient	N_p	5	-
Scanning speed	V_s	0.1-0.4	m/min

Table 1. Important Parameters In Laser Cladding Process

Conclusions: A self-consistent 2-D longitudinal transient heat transfer model has been developed by simulating a direct metal laser deposition process. The dynamic shape of the free surface is explicitly tracked by using deformed geometry moving mesh. Simulated value of clad height is 0.565mm, and experimental value is 0.576mm. The comparison between experimental and numerical results has indicated that the layer thickness is well predicted by this simulation model.

Refrences:

1. A. Gowtham et. al, Experimental Investigations on laser cladding of NiCrBSi+WC Coating on SS410,Material Proceedings Today(2019)
2. S. Morville et. al, 2D Longitudnal Modeling of Heat Transfer and Fluid Flow During Multilayered, HAL archives-overtes, (2013)

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