Simulation for Additive Manufacturing
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Simulation of LMD repairs with a theoretically non-weldable nickel-based superalloy

Anis Doghri[1,2], Florent Fournier Dit Chabert[2], Marc Thomas[2], and Pascal Laheurte[1]

LEM3 – Université De Lorraine
4 rue Augustin Fresnel, 57078 Metz, France
{anis.doghri}@univ-lorraine.fr, {pascal.laheurte}@univ-lorraine.fr

ONERA – The French Aerospace Lab
29 avenue de la Division Leclerc, 92322 Châtillon, France
{florent.fournier_dit_chabert}@onera.fr, {marc.thomas}@onera.fr

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As a well-known nickel-based superalloy, Inconel 738 LC (IN738LC) is currently used in the hot sections of aircraft engines. However, IN738LC exhibits a high propensity to hot cracking during rapid thermal processing such as in foundry or in repairing operations. Therefore, a thermo-mechanical modelling of the laser metal deposition (LMD) process is developed here to compute the residual stresses built-up for this IN738LC. Simulations and experiments are performed to optimize the process parameters and to reduce the cracking sensitivity by finding a cracking criterion which could be related to the laser-induced metallurgical phenomena.

IN738LC exhibits enhanced mechanical properties through the precipitation of an ordered phase called γ', made of $Ni_3(Al,Ti)$ in the γ austenitic matrix. The downside of such a precipitation is to lower the weldability of the material because of HAZ cracking [1]. In the present work, a thermo-mechanical-metallurgical simulation of the process is developed using Z-set FEA software in order to have a better understanding of the repairing process. The model was used on several LMD repairs including different geometries as well as different operating conditions.

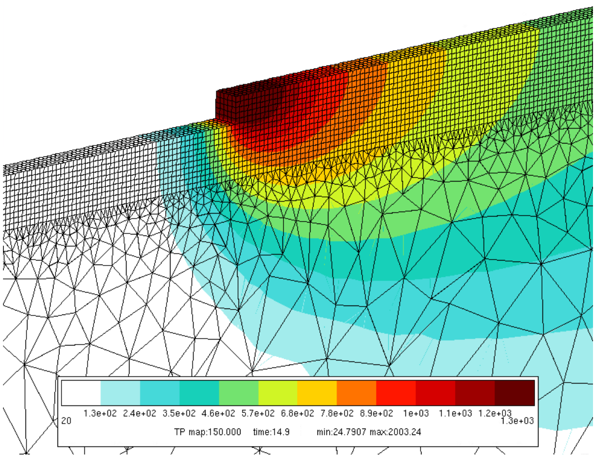

Figure 1: Thermal modelling of successive metal deposits

As the thermal modelling lies on the resolution of the heat equation, an analytical heat source is used consistently with the measured experimental power distribution. Heat exchanges are modelled through convection and radiation losses.

Experimental tests and simulation are compared using the size of the melt pools as well as temperature fields provided by K thermocouples. The successive metal deposits are taken into account using the quiet element method which consists in premeshing all the elements and adding them to the thermal modelling as soon as they are irradiated by the laser source [2]. The volume of activated elements depends on the dimensions of experimental deposits.

A weak coupling is actually used, thus meaning that the thermal modelling results are used as data entries to compute the residual stresses and γ' volume fraction.

Inactivated elements are given a low stiffness value in order to neglect their contribution in the numerical process. The thermo-mechanical simulation reveals high tensile residual stresses near and in the metal deposit. These high tensile residual stresses are therefore counterbalanced by moderate residual compressive stresses further away from the deposit [3].

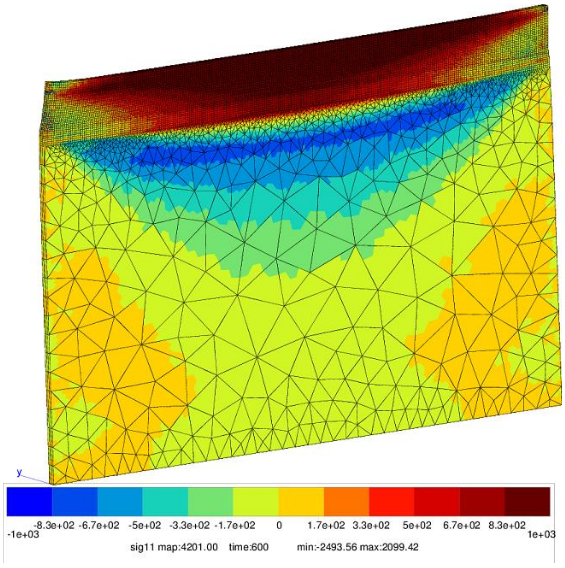

Figure 2: Longitudinal residual stresses

References

[1] O.A. Ojo, and M.C. Chaturvedi. On the role of liquated γ′ precipitates in weld heat affected zone microfissuring of a nickel-based superalloy. *Materials Science and Engineering: A*, vol. 403, 77–86, 2005.

[2] P. Michaleris. Modeling metal deposition in heat transfer analyses of additive manufacturing processes. *Finite Elements in Analysis and Design*, vol. 86, 51–60, 2014.

[3] Y. Chew, J. H. L. Pang, G. Bi, and B. Song. Thermo-mechanical model for simulating laser cladding induced residual stresses with single and multiple clad beads. *Journal of Materials Processing Technology*, vol. 224, 89–101, 2015.