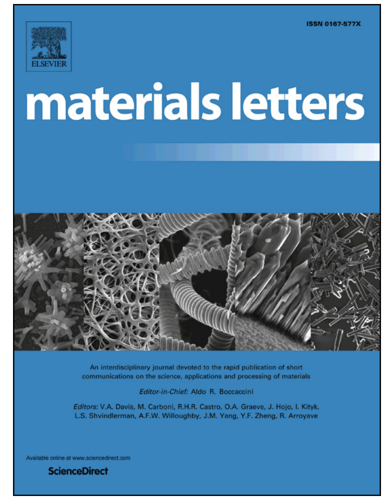

Thermal histories and microstructures in Direct Energy Deposition of a High Speed Steel thick deposit

R.T. Jardin, J. Tchoufang Tchuindjang, L. Duchêne, H.-S. Tran, N. Hashemi, R. Carrus, A. Mertens, A.M. Habraken

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Thermal histories and microstructures in Direct Energy Deposition of a High Speed Steel thick deposit

R. T. Jardin[1], J. Tchoufang Tchuindjang[1], L. Duchêne[1], H.-S. Tran[1], N. Hashemi[1], R. Carrus[2], A. Mertens[1], A.M. Habraken[1*]

[1]University of Liège, Quartier Polytech 1, Allée de la Découverte 9 (B52), B4000 Liège, Belgium

[2]Sirris Research Centre (Liège), Rue Bois St-Jean, 12, B 4102 Seraing, Belgium

Abstract

The results of 2D Finite Element thermal simulations of Direct Energy Deposition of a High Speed Steel thick deposit explain the observed microstructural heterogeneities over the whole height of a 36-layer deposit. The Finite Element model is validated by the recorded substrate temperature and the melt pool depth of the last clad layer experimentally measured. The correlation between the computed thermal fields and the microstructures of three points of interest located at different depths within the deposit is carried out. The effect of both the melt superheating temperature and the thermal cyclic history on the carbides type, shape and size is discussed.

Keywords: Finite element analysis, Laser deposition, Powder processing, Solidification microstructure, Carbide

1. Introduction

High Speed Steels (HSS) are widely used in various applications including cutting operations, high speed machining, hot stamping, moulding and hot strip mills. They withstand severe mechanical and physico-chemical stresses in service, thanks to their alloy design and to their carefully tailored microstructure. These alloys belong to the complex Fe-Cr-C-X system, where X is a strong carbide-forming element as V, Nb, Mo or W [1].

DED (Direct Energy Deposition) is an additive manufacturing technique where a powder is projected on the substrate and melted while passing through a laser beam. Very high cooling rates ranging from 10^3 to 10^7 °C/s are achieved and yield ultrafine microstructures. Advantages such as the reduction of thermal distortions, porosity, cost and machining time as well as the possibility of manufacturing material gradients through powder of different chemical compositions are the specificities of DED [2].

High temperature gradients are generated during DED leading to directional microstructures. To understand their genesis, the thermal fields predicted by Finite Element (FE) analyses often complement experiments. Yang et al. [3] studied the heat affected zone while Wang et al. [4] analyzed the melt pool. Kong et al. [5] investigated the effect of different processing parameters on the deposit height while Tran et al. [6] focused on the evolution of the microstructure in the deposit. However, works focusing on the solidification of thick HSS deposits processed by DED are innovative. Heat tends to accumulate in such thick deposits due to the laser power of 1 to 2 kW, leading to microstructural heterogeneities within the deposit height [7].

2. Materials and Method

The DED equipment of Sirris Research Centre (5-axis Irepa Laser Cladding & Nd-YAG laser operating continuously, maximum power 2kW) was used to manufacture the sample (40 x 40 x 27.5 mm^3). The raw material consisted of the commercial HSS M4 powder with a chemical composition of (in wt%) 1.35 C, 4.30 Cr, 4.64 Mo, 4.10 V, 5.60 W, 0.34 Mn, 0.9 Ni, 0.33 Si and balance Fe. The particle size ranged from 50 to 150 µm. The laser power, nozzle scanning speed, powder feed rate, and the pre-heating temperature of the 42CrMo4 substrate (40mm height, 100mm diameter) were fixed at 1100W, 6.87 mm/s, 76mg/s, 300°C, respectively. Four thermocouples were located at the four cardinal points within the substrate, 5 mm below the surface, and at 20 mm from the edge.

* Corresponding author,
E-mail address: anne.habraken@uliege.be (A.M. Habraken)