High Cycle Fatigue of 2507 Super Duplex Stainless Steel: comparison between Laser Powder-Directed Energy Deposition and forge processes

Fabien Szmytka*[1], Sébastien Ballesio[1,2,3], Matthieu Dhondt , and Cédric Doudard

[1]IMSIA, UMR CNRS-EDF-CEA-ENSTA Paris – ENSTA Paris – France
[2]Institut de Recherche Dupuy de Lôme – École Nationale Supérieure de Techniques Avancées Bretagne – France
[3]Centre des Matériaux – MINES ParisTech - École nationale supérieure des mines de Paris – France

Abstract

Super-duplex 2507 stainless steel is a two-phase austeno-ferritic steel known for its good mechanical properties, particularly in fatigue, as a result of its mixed ferritic and austenitic microstructure (1). The study involves a comparison of two manufacturing processes: forging and additive manufacturing using the Laser Powder-Directed Energy Deposition (LP-DED) process, and the impact of heat treatment on the latter. The microstructures developed for each process are however very different. The forged material shows a fairly balanced microstructure (59% ferrite) with grains that are all similar (columnar along the forging axis, globular along the perpendicular one) compared with the LP-DED raw material, which is around 75% ferrite and has a very heterogeneous distribution of austenite depending on thermal history and the deposition strategy. Applying a heat treatment at 1200∘C for 3 hours to the LP-DED product brings the microstructure closer to that of forging, with a balance between the phases and a homogeneous distribution of grains in the material.

The fatigue behaviour of the various material/process combinations is then analysed in this study. Two methods for determining the fatigue limit were investigated: the processing of Staircase campaigns with reloading of unruptured specimens (3), used as a basis for fatigue limit estimation at 2 million cycles, and the empirical evaluation of self-heating tests (4). The Staircase campaigns highlighted the benefits of using the LP-DED process compared with forging, with an increased fatigue limit of more than 100 MPa. The use of heat treatment following LP-DED process, on the other hand, brings the fatigue properties closer to the forged material, while remaining very slightly higher (about 10MPa). Empirical analysis of self-heating tests is not completely satisfactory for all the tested configurations. For the forged and the LP-DED and heat-treated materials, the results are very encouraging, with differences of less than 10%. Unfortunately, the LP-DED raw material showed a larger difference. This might be expected, given the method assumptions and the impact of the material heterogeneity. The fatigue behaviour of forged alloy and heat-treated LP-DED is also investigated for loading levels above the fatigue limit, with a comparison of resistance and variability.

For the raw LP-DED material, a first modelling of the self-heating tests is also proposed

*Speaker

to enable a more detailed analysis of the results and to take into account the two-phase microstructure. A first proposition taking into account the differences in behaviour between ferrite and austenite is thus made, in order to be able to predict the self-heating of a duplex stainless steel as a function of its ferrite/austenite ratio.

Referance

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