Additive manufacturing of parts in Inconel 738 processed by laser beam melting

Addressing the problem of cracking
for superalloys with a high fraction of γ' -Ni_3 (Al, Ti) precipitates

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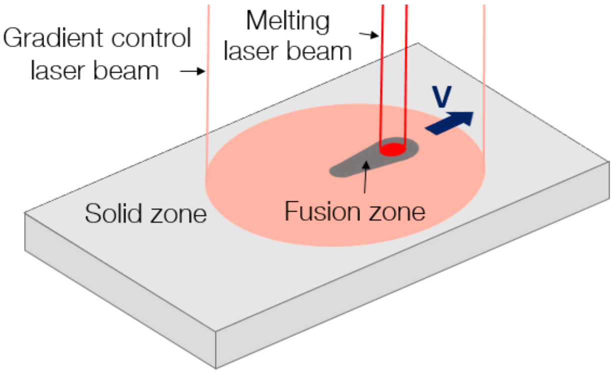

Control of thermal gradient during fabrication

- Selective laser melting of a hardly weldable superalloy
- Prevention of cracking during fabrication and heat treatments
- Control of thermal gradient during fabrication

Abstract:

The subject of this PhD concerns additive manufacturing of parts made out of nickel-base superalloys for the aeronautical sector. These materials are relevant for the parts of plane and helicopter engines that reach very high temperatures in operating conditions. For next-generation engines, Safran Group is considering using the Laser Beam Melting (LBM) process to manufacture pieces in Inconel 738. This alloy is made of an austenitic γ matrix reinforced by a high fraction of γ' - Ni_3 (Al,Ti) precipitates, that confer interesting mechanical properties at high temperatures but that also complicate its shaping by the LBM process. The alloy endures high thermal gradients during its melting by a laser source and often cracks during fabrication or during further heat treatments. Similarly to the Inconel 738, some high performance materials (materials with low weldability) are currently not eligible to Laser Beam Melting fabrication.

The goal of this work is to better understand the cracking mechanisms of the Inconel 738 and to propose a fabrication method suitable for these cracking-sensitive materials. Several complementary approaches will permit to reach that objective. First, different fabrication conditions with the LBM process and different heat treatment conditions will be explored. A novel multi-laser machine (patented and developed by the Centre des Matériaux) will allow new fabrication strategies, with a higher control of the cooling rate and of the thermal gradient. It is equipped with an in-situ monitoring system that will be an asset to understand the formation of cracks and to propose relevant fabrication strategies with one or two lasers. Secondly, microstructural characterizations will permit to understand the link between precipitation of hard phases (like carbides and borides), stress relaxation and cracking mechanisms. This understanding will be enriched with the study of alloys with close compositions, as René77. Last, numerical simulation of the process – in partnership with the CEMEF – will enable to access some data which are not directly measurable with the instrumentation, as the thermal gradient at the bottom of the melt pool. As cracking is known to strongly depend on the design of the parts, a particular attention will be given to using geometries that are representative of industrial pieces, with a high stress concentration factor.

As a conclusion, this work will participate in making more high performance materials eligible for an additive manufacturing.