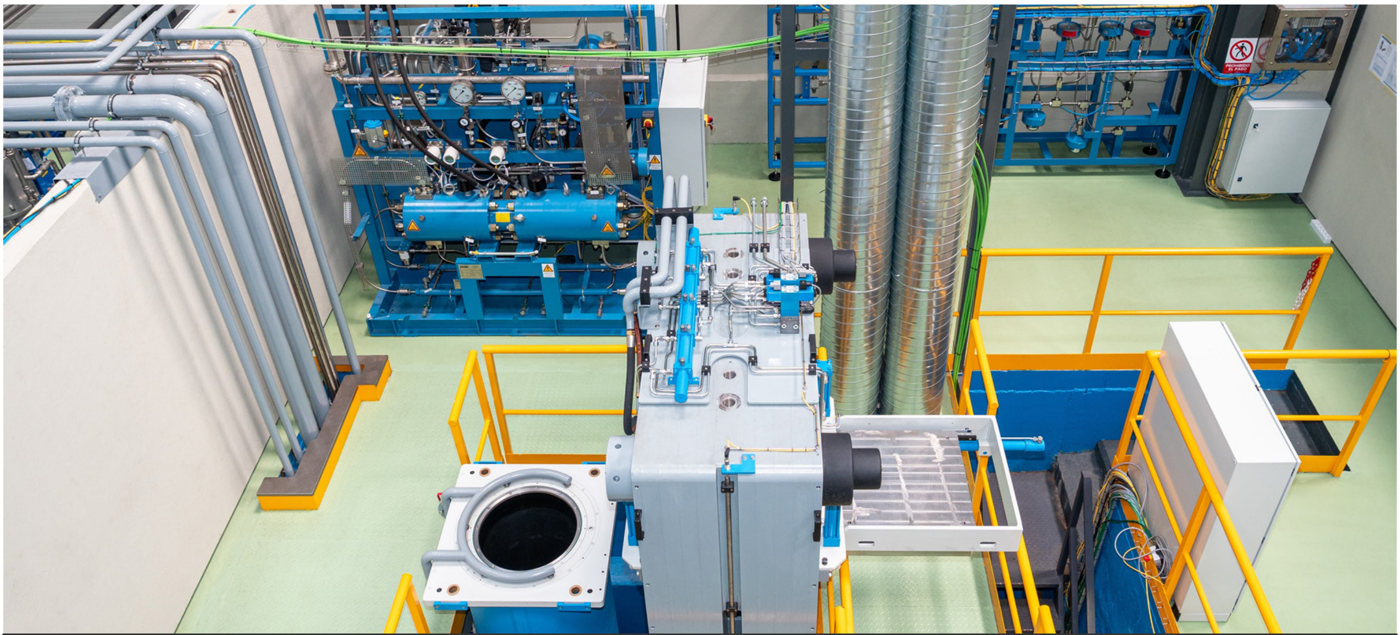
# Effect of HIP post-processing at 850ºC/200MPa on the fatigue behaviour of the Ti-6Al-4V alloy fabricated by SLM

Hiperbaric HIGH PRESSURE PROCESSING

UNIVERSIDAD DE BURGOS



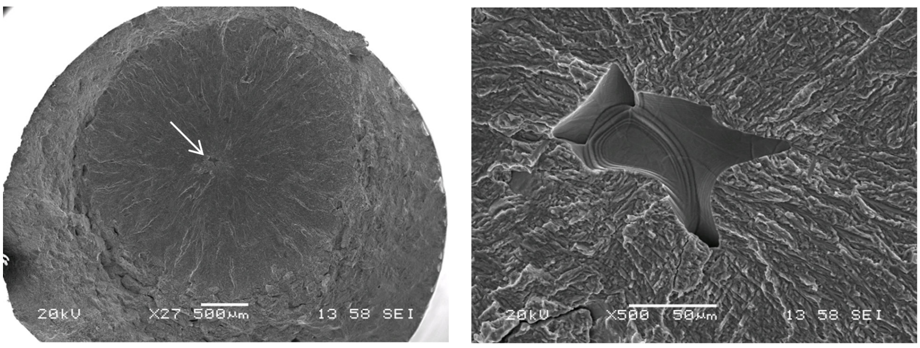
**Email:** hip@hiperbaric.com | **Telf.**: +34 947 473 874 | **Web**: www.hiperbaric.com
**Email:** info@ubu.es | **Telf.**: +34 947 258 700 | **Web**: www.ubu.es

**Sector:** Aeroespacial and biomedical
**Challenge:** The challenge of the project is to improve the fatigue life of the SLM Ti-6Al-4V alloy post-processed by HIP at 850ºC / 200 MPa and using a fast-cooling technology.

**Solution:** Through this HIP post-processing, a good densification of the material and a fatigue life similar to that of the reference material were achieved.

## CHALLENGE

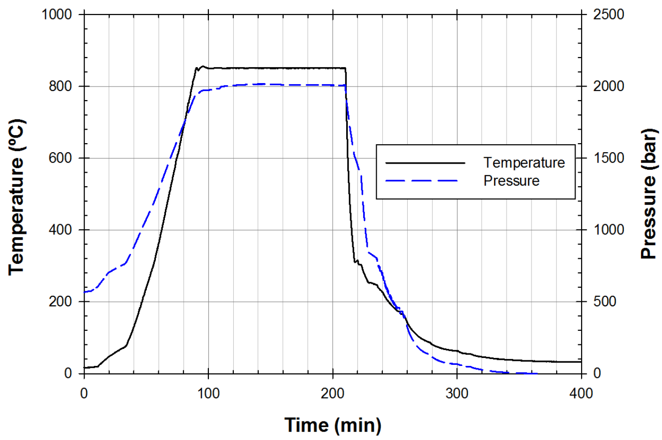
Hot Isostatic Pressing (HIP) is a thermomechanical post-processing technique widely used in Additive Manufacturing parts to reduce internal defects, such as entrapped-gas-pores or lack-of-fusion, which have a great influence on the mechanical and fatigue properties of the material. In this case study, the effect of a HIP-cycle carried out at a pressure of 200 MPa and a temperature of 850ºC for 2 hours, on the microstructure and fatigue properties of a Ti-6Al-4V alloy manufactured by SLM is studied. Moreover, the HIP equipment developed by HIPERBARIC allows a fast-cooling stage faster than that obtained from conventional furnace cooling rates. The present HIP-process allows for very good material densification, a microstructure that shows minimal coarsening effects, and good fatigue properties comparable to the conventional wrought processed material.




*Typical fatigue failure from an internal lack-of-fusion defect type. Ti-6Al-4V fabricated by SLM. As-built conditions.*

## SOLUTION

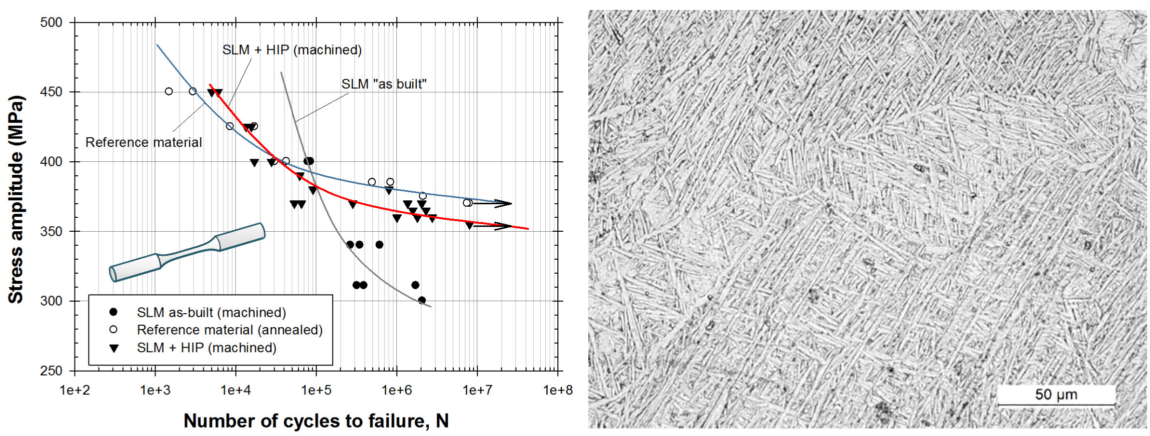
The standard HIP-cycle for Ti-6Al-4V alloys manufactured by SLM consists of heating to a temperature of 900-920°C and a pressure of around 100-120 MPa, in an Argon atmosphere, and usually followed by furnace cooling. Typical heating and cooling rates of about 10°C/min are reported. Some authors have observed as certain material properties decrease with an increased heat treatment temperature as a consequence of microstructural coarsening effects. This has motivated the study of HIP treatments at higher pressures and lower temperatures combined with rapid cooling to limit these microstructural coarsening effects. The HIP cycle applied in this case study consist on a temperature of 850ºC (above the Ms=800ºC and below the b-transus temperature of 980ºC, as the convectional HIP cycle) and a pressure of 200 MPa for 2 hours. The fast-cooling process achieves an average cooling rate of -138°C/min for the initial range of temperatures between 850°C-600°C (between typical conditions for air cooling and oil quenching), and subsequently an average cooling rate of approximately -67ºC/min (similar to air cooling) for the temperature range between 600ºC-400ºC.




*HIP-cycle carried out in this case study at the HIP Innovation Center of HIPERBARIC.*

## ADVANTAGES

Fatigue tests and metallographic analyses have been carried out at the Laboratory of the Structural Integrity Group of the University of Burgos. The HIP cycle applied has achieved a good densification of the material and a minimum coarsening of the microstructure. None of the failures observed for the specimens treated by this HIP-cycle initiated from lack-of-fusion defects, which indicates that the post-treatment is effective for eliminating these internal defects. The fatigue results have been compared with those corresponding to a reference alloy of Ti-6Al-4V Grade 23, obtaining very similar fatigue life values. Furthermore, the microstructure achieved has not experienced significant coarsening of the alpha phase, typically observed in HIP processes at higher temperatures and with conventional furnace cooling.




*Fatigue life results of the three situations studied: SLM, SLM+HIP and reference material. Microstructure of the SLM+HIP condition.*