Characterization of the Microstructure of SLM IN718 Under Extreme Environments

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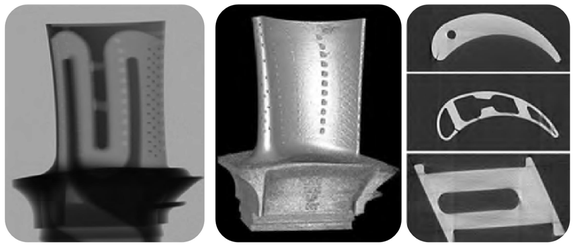
Introduction

The SLM processing of Inconel 718 holds great promise for the ease of manufacturing of turbine blades that withstand extreme temperatures, heat fluxes and high mechanical stresses associated with engine environments. The complexity of these extreme operational conditions demands precise knowledge of failure initiation within the material

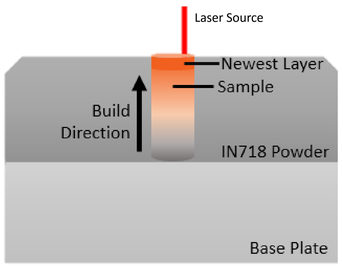


SLM IN 718 Turbine Blades (3)

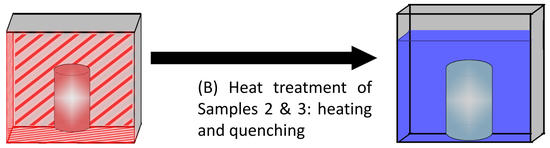
Objectives

- Investigate variation in phase composition along build direction as a result of SLM process
- Observe in-situ high temperature microstructure evolution
- Characterize role of heat treatment
- Quantify residual stress and strain in as processed and heat treated SLM IN 718

Motivation & Background



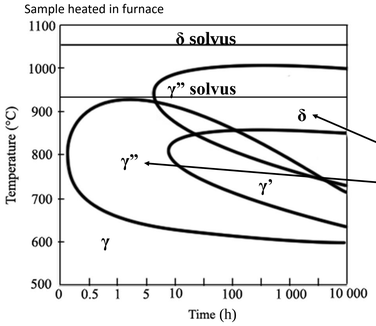
(A) Selective Laser Melting (SLM) processing of samples



(B) Heat treatment of Samples 2 & 3: heating and quenching

Sample quenched in water

Sample heated in furnace

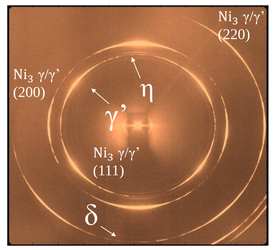


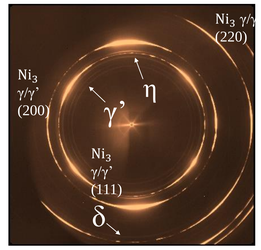
(C) T-T-T of cast IN 718:
Weakening phase
Strengthening phase

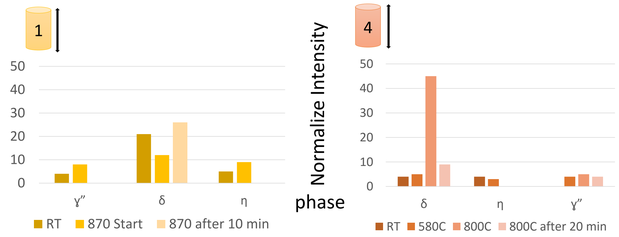
T-T-T Diagram for IN 718 (4)

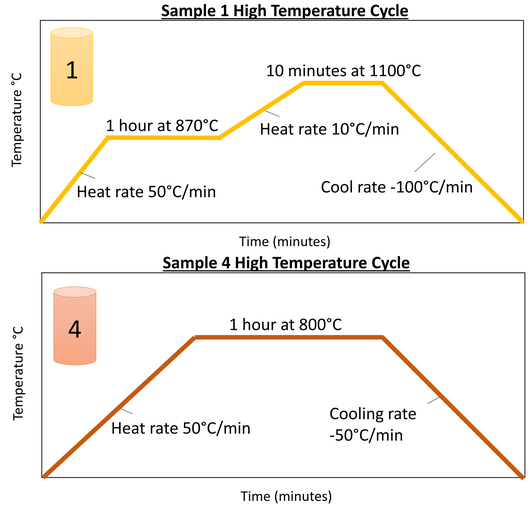
Samples were taken out of a sample manufactured by the SLM process (A). Two samples were then heat treated (B) to exhibit strengthening & weakening phases (C). The ɣ" phase increases ductility and in the material, increasing resistance to crack growth. The δ phase is considered the weakening phase, as its grains are plate-like and cause the material to become brittle and susceptible to failure (4).

High Temperature Microstructure Evolution



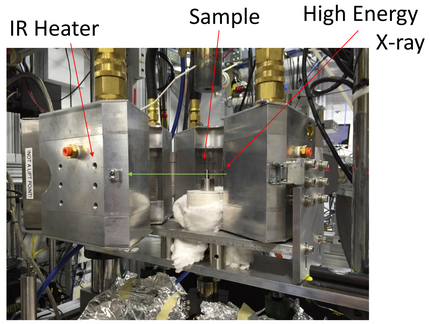






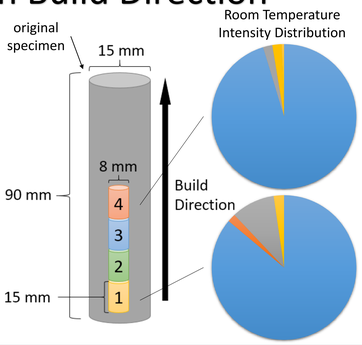
ɣ" forms and dissolves similarly to wrought IN718. η dissolves similarly in sample 1 and sample 4 with limiting conditions at 20 min of exposure and 800C. Initial high volume of η suggests high ɣ/ɣ' lattice mismatch that is corrected as grains approach preferred orientation (5).

Experimental Setup



Variation with Build Direction

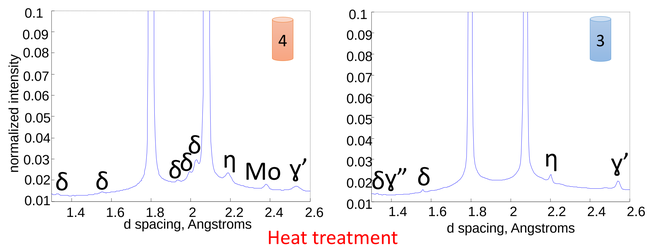
Sample 4 exhibits a microstructure closer to wrought IN718 (5). Greater volumes of precipitates in Sample 1 reflect facilitation of precipitate growth near the baseplate.



Effect of Heat Treatment

- High δ precipitation is a result of SLM process.
- Heat treatment can affect concentration of δ, but does not eradicate it completely
- Solvus temperature conventions may not apply
- As processed samples are weaker than wrought IN 718
- Extended exposure to high temperature strengthens SLM IN718

Heat Treatment: 1100°C for 1 hour, quenched and hardened at 720°C for 1 hour and 620°C for 1 hour; 1100°C for 1 hour and quenched



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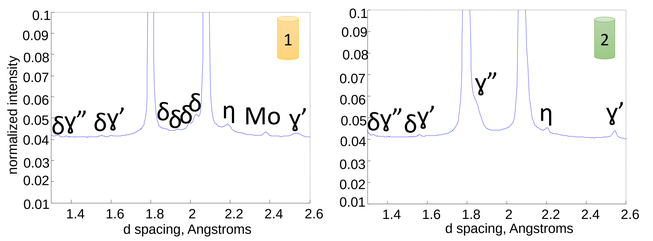
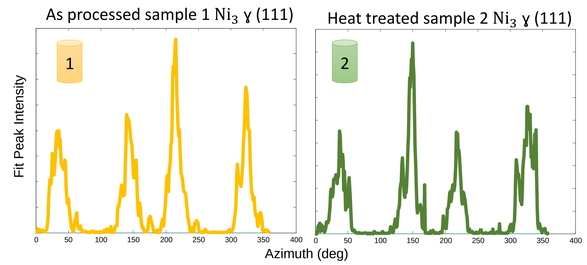
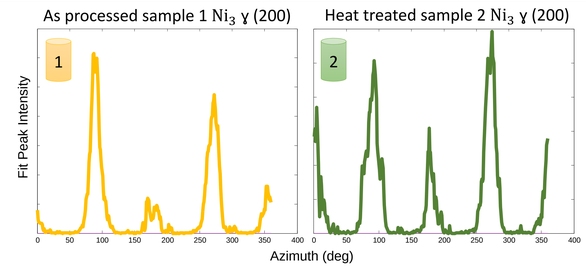


Texture and Grain Size with Heat Treatment



Samples show [111] and [200] textures along the build direction, and the degree of texture decreases with heat treatment. As processed SLM IN 718 exhibits fine grain structure and heat treatment causes grains to tend toward a preferred orientation and become coarse (6).



Future Work

- Calculate volume fraction based on intensity

$$v_\alpha = \frac{I_{(hkl)\alpha}\mu_s}{\left|F_{(hkl)\alpha}\right|^2 [LP]_{hkl}\left(\frac{e^2}{m_e c^2}\right)^2}\frac{V_\alpha^2}{M_{(hkl)}}\frac{64\pi r}{I_0\lambda^3}$$

- Find phase volume fraction for each scan and establish phase volume evolution due to exposure to high temperatures

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Stands For Opportunity