Field Assisted Sintering Technology applied to a modern Nickel superalloy powder

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Highlights

- Consolidated Material was produced using a modern Nickel superalloy powder feedstock
- Dwell time and load were found to have marginal effect on final density and hardness
- Grain size inhomogeneity was seen in post sintered material in contrast to HIP material
- EBSD results showed no dominant crystallographic texture

1. Introduction

Nickel Superalloys are materials with complex chemistries designed to excel at high temperatures, typically produced using powder metallurgy routes to limit segregation. For the first time, field assisted sintering technology (FAST) has been used to produce highly dense samples of a multifaceted material, whose alloy chemistry represents a modern high performance Nickel superalloy. Previous work, for example [1] has showed that FAST (SPS) can be used to produce consolidated elemental Nickel material using bimodal powders which can retain grain morphologies related to the powder feedstock. More complex nickel alloys produced via FAST however, have received little attention. It is thought that FAST can be used to increase usability of these alloys in less safety critical components within a modern aerospace gas turbines.

2. Methods

Table 1 - Alloy 131072 Chemistry

Element	Ni	Co	Cr	Mo	Ti	Al	Ta	Hf	C	Trace elements
Wt. %	51.87	18.11	14.78	4.91	3.59	3.10	2.00	0.64	0.023	0.977

Alloy 131072, a modern Nickel Superalloy, based on the commercial alloy RR1000, was produced under collaborative research agreement with Carpenter Technology Corporation and Rolls Royce ltd. The chemistry of which is shown in Table 1. Alloy 131072 was used a basis to produce gas atomized powder, which was consolidated using FAST (SPS) to produce 20mm diameter billets. Variations in sintering loads (13kN and 16kN), dwell times (10 to 240 minutes) and temperatures (1100°C and 1150°C) were used to examine the effect on the resultant microstructure post sintering. Micro-hardness measurement were collected along with Archimedes density to draw conclusions regarding optimum sintering parameters. Microstructural examination was conducted using a combination of light, backscattered and scanning electron microscopy using multiple etching techniques, to reveal different phases in the material and examine the effect of sintering conditions on the grain and precipitate morphologies. EBSD techniques were used to reveal crystallographic orientations to identify any textures present for a chosen sintering condition. The material produced via FAST was compared to material produced via hot isostatic pressing (HIP) using feedstock from the same powder batch. Identical characterization techniques were performed to allow direct comparisons between the two materials.

3. Results and discussion

For a fixed sintering load of 13kN it was found that marginal improvements in density could be observed when increasing the sintering dwell time from 10 to 120 minutes however further dwell time during sintering led to reduction in density when comparing sintering times of 240 minutes. Using HIP material produced using relatively long dwell times (350 minutes using a dwell temperature of 1125°C) as a benchmark, the highest relative density produced using FAST was

measured to be 99.4% which was produced using a dwell time of 60 minutes, a dwell temperature of 1100°C and an axial sintering load of 13kN (41MPa pressure). The reduction in post sintered density for increasing dwell times beyond 120 minutes is thought to be related to the expansion of gas pores originally present in the powder feedstock due to the gas atomization process. The observed remaining porosity is shown to be discrete and sparsely distributed which suggests a retainment of porosity from the powder feedstock. Micro-hardness measurements revealed that hardness was reduced with sintering dwell times beyond 10 minutes (up to 240 minutes), this is related to change in precipitate morphologies over the extended dwell times as visualized in the captured micrographs. Increasing the dwell temperature during sintering from 1100°C to 1150°C was found to result in large grain growth, this is due to the partial or fully dissolution of the strengthening gamma prime precipitates which removes the grain pinning effect they provide allowing significant grain growth to occur. This is further corroborated by micro-hardness measurements, which suggest a significant drop in micro-hardness for the increased sintering dwell temperature. Light micrographs showed a region of carbon ingress due to the graphite die set used for sintering, however the depth of the layer is sufficiently shallow to not inhibit consolidated material to be used for component production.

EBSD crystallographic orientation mapping shown in Figure 1 reveals clustered regions with differential grain sizes, this has been noted in a previous work using a bimodal size Ni Powder [1]. Supplementary texture analysis revealed near isotropic textures, comparable with HIP derived material.

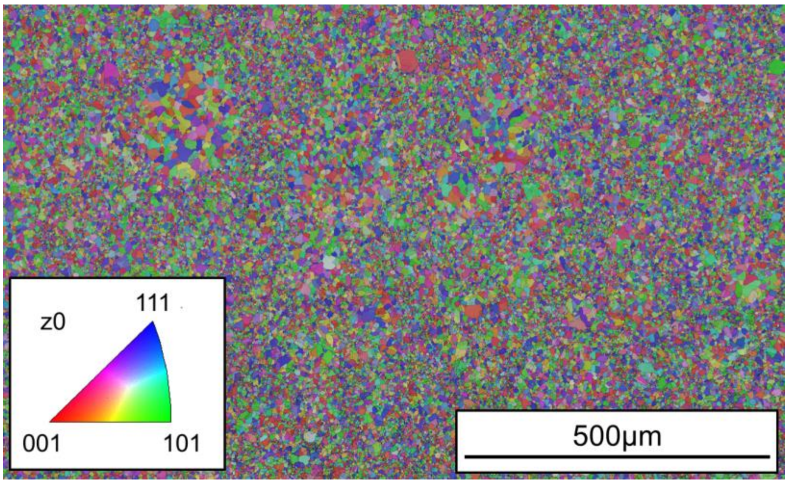

Figure 1 - EBSD map for alloy 131072 sintering using a dwell time of 60 minutes, a dwell temperature of 1100°C and a sintering load of 16kN, captured parallel to the direction of applied load and current flow in the radial center of the produced billet.

4. Conclusions

Alloy 13072 has been, for the first time, consolidated using FAST (SPS), it has been demonstrated that the microstructure, hardness and density of the final material can be affected by the chosen parameters and the optimum parameters for maximizing material strength and density have yet to be determined. However, a processing window can be proposed. Comparisons with HIP material reveal FAST is capable of producing unique features such as inhomogeneous grain size, the benefits and drawbacks of which are unknown. EBSD characterization further reveals inhomogeneity in grain size and also reveals that the produced material is near isotropic (akin to the material produced using HIP) in spite of the uniaxial nature of the applied load during FAST processing.

References

[1] D. Tingaud, P. Jenei, A. Krawczynska, F. Mompiou, J. Gubicza, and G. Dirras, Investigationof deformation micro-mechanisms in nickel consolidated from a bimodal powder by spark plasma sintering," Materials Characterization, vol. 99, pp. 118{127,2015}

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