FUNDAMENTAL STUDY OF THE LATER STAGES OF LIQUID PHASE SINTERING OF A Ni BASE P/M SUPERALLOY - METALLOGRAPHIC OBSERVATIONS ON QUENCHED SUPERSOLIDUS - SINTERED MATERIALS

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ABSTRACT

Mechanisms governing the later stages of liquid phase sintering of prealloyed Astroloy powder (a high performance P/M nickel base superalloy) were studied using liquid phase sintered compacts quenched from temperatures within the dual phase solid-liquid interval (1210 °C - 1340 °C).

The study was centered on the distribution of both solid and liquid phases and on their relative composition with the help of quantitative image analysis (QIA) and microstructural observations (optical and scanning electron microscopy coupled with microanalysis by an energy dispersive system).

From these observations it was, in particular, inferred that the distribution of the liquid phase was rather different from that usually reported for the sintering of mixtures of elemental powders (in the presence of a liquid phase). The presence of some liquid inside the particles (along interdendritic spacings) is thought be quite specific to prealloyed dendritic powders. The temperature at which both interparticular and intra-particular liquid interconnect appears to be quite critical and correlate well with the optimum temperature for liquid phase sintering and supersolidus hot pressing determined in previous studies.

Three types of argon atomized Astroloy powders were used, differing mainly in grain size and carbon content.

Conclusions were discussed in relation with densification by liquid phase sintering and supersolidus hot pressing (under moderate uniaxial pressure, \( \leq 50 \) MPa): these two processes being proper to obtain closed porosity sintered materials and net shape materials, respectively, due to a satisfactory rheological behaviour of liquid-solid P/M Astroloy.

1. INTRODUCTION

Certain superalloy powders can be sintered in the presence of a liquid phase in order to achieve for example forging or HIP (Hot Isostatic Pressing) preforms or net shape small parts.¹
However, the mechanisms governing supersolidus sintering of such pre-alloyed powders are somewhat different from those occurring in the sintering of elemental powders and there is only scant information on the subject.

This work highlights the influence of the presence of liquid on densification by focusing on the distribution of both solid and liquid phases and on their respective compositions determined by quantitative image analysis (QIA) and microstructural observations (optical and scanning electron microscopy, SEM) coupled with microanalysis by energy dispersive spectrometry (EDS).

The experimental procedure was based on the study of compacts quenched from temperatures within the solidus-liquidus range. A similar technique has already been used to characterize "Rheocast" materials. Such experiments seem to be better adapted to the study of the later stages of densification (with slow kinetics) than in situ SEM observations suited to the study of rapid phenomena in the first stage of rearrangement of the particles and which need, for experimental reasons, a rather low liquid fraction.

2. MATERIALS AND APPARATUS

Astroloy, one of the highest P/M nickel base superalloy, was chosen. Loose prealloyed powder as well as closed porosity sintered material* from two different batches designated "AA1" and "AA2" were used. They were produced by argon atomization and mainly differed by the carbon and sulphur contents (chemical composition in Table I) and by the particle size (< 250 μm for AA1; < 150 μm for AA2). In order to study the influence of the particle size, even finer AA1 (φ< 100 μm) was obtained by sieving from the original supply.

Samples of about 50 mm in length and 5 mm in diameter were heated in a gradient furnace and the rapidly transferred (using an hydraulic jack) to a water cooled chill chamber. The maximum temperature was attained in about 5 min and held not less than 60 min before quenching. The main apparatus, conventionally designed for directional solidification, has already been described elsewhere.

Fairly moderate thermal gradients such as 20 K/cm were applied in order to use the whole length of the sample within the proper temperature interval corresponding to a volume fraction of liquid ranging from 0% to about 50% (solidus and liquidus temperatures of Astroloy being about 1210 °C and 1340 °C, respectively). The temperature profile was measured by the displacement of a 1 mm dia. alumina-sheathed thermocouple: (a) in a groove machined along the Astroloy rod sample, in the case of pre-sintered Astroloy, or (b) directly inside the powder when using loose Astroloy powder.

3. RESULTS AND DISCUSSION

3.1. Experimental

Quenched specimens were achieved following the experimental conditions given in Table II. Similar conditions were set for each material except for (a) holding time at temperature, which was longer (100 min against 60 min) when loose powder was used in order to promote sintering than that

* Material obtained by vacuum supersolidus sintering: 10⁻⁵ torr - 1 h - 1290/1300 °C.