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Coarse grain C&W AD730 disk superalloy for high temperature applications

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Abstract

Coarse grain size is required for high temperature turbine disk or for the hotter zone of the disk. This work deals with the study of the effect of a supersolvus heat treatment on the microstructure, the microstructural stability and the mechanical properties of a new Ni-based superalloy disk.

Introduction

To improve the efficiency of new aircraft engines, the need of superalloys withstanding higher temperature for long duration is still constant. Studies to fulfill this requirement can focus on the development of new alloys or on the adjustment of existing materials. In the present paper, the second approach was applied to the disk superalloy AD730TM recently developed by Aubert & Duval [1].

First studies on this new cast and wrought (C&W) superalloy showed a set of promising features as:

- Good workability (below or above the γ solvus temperature) due to moderate γ phase amount [1],
- Combination of high mechanical properties for fine grain microstructures [2] compared with competing C&W superalloys,
- High microstructural stability in regard to topologically close-packed (TCP) phases for a fine grain microstructure [1].

Material

The present work was conducted on samples and specimens machined out from a sector of a ring-rolled and close die forged disk provided by Aubert & Duval after applying a γ subsolvus heat treatment (1070°C, initial mean grain size of 4 μ m). The aim of this study was to evaluate the potential of the coarse grain AD730TM alloy for high temperature disk application.

In a first step, to further complete the knowledge of this recent superalloy, several physical or metallurgical features were measured on the as-received material. These parameters include the density, the coefficient of thermal expansion and the thermal conductivity (calculated from specific heat capacity and thermal diffusivity measurements). Differential thermal analysis experiments were also carried out to determine characteristic temperatures of the AD730TM alloy to guide the heat treatment study.

Results

Microstructure

The quantification of microstructural parameters (grain and γ precipitate sizes) as a function of heat treatment conditions (solution treatments, cooling paths and ageing treatments) was realized. Based on metallurgical and practical criteria, a two-step solutioning treatment was selected. A two-step ageing treatment was also chosen on the basis of microhardness measurements. This work on heat treatment/microstructure relationships led to the following heat treatment sequence:

1120°C/1h/40°C·min⁻¹ cooling
 + 1080°C/4h/100°C·min⁻¹ cooling
 + 800°C/4h/air cooling + 760°C/16h/air cooling.

The resulting microstructure presents a mean grain size of 140 μ m and a bimodal distribution of γ precipitates with mean diameters of 372 and 106 nm. Despite the population of relatively coarse γ precipitates, this type of microstructure showed an interesting combination of mechanical properties [3,4]. Finally, a third γ precipitate population was evidenced by high resolution SEM imaging (Figure 1). These precipitates are assumed to result from the cooling following the subsolvus resolutioning treatment and are adjusted during the aging steps.

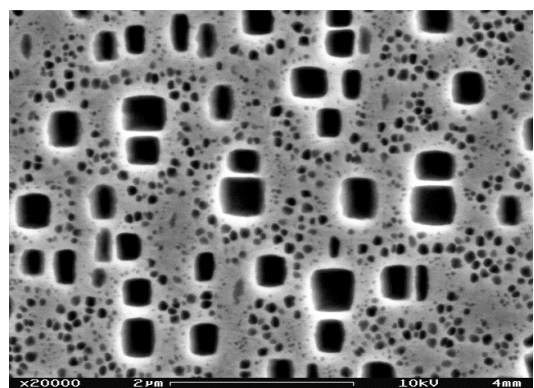


Figure 1: γ precipitation microstructure observed after the selected heat treatment sequence (SEM image).

Microstructural stability

Various long-term aging treatments (750°C/1500h, 800°C/500h, 850°C/500h and 900°C/100h) were applied on supersolvus AD730TM samples. The modification of the γ precipitates were quantified by particle size and hardness measurements. The evolutions of both first and

second generation of secondary γ' precipitates are presented in Figure 2. After these heat treatments, fine intergranular particles were more frequently observed than in the initial microstructure (BSE/SEM). EDX and EELS analyses on thin foils of AD730™ aged 500 hours at 850°C evidenced the joint presence of carbides and borides in the grain boundaries (Figure 3). No TCP phases were observed in the supersolvus AD730™, confirming the microstructural stability of this superalloy [1]. The severe aging treatment of 500 hours at 850°C was selected to evaluate the effect of long-term aging treatment on the mechanical properties.

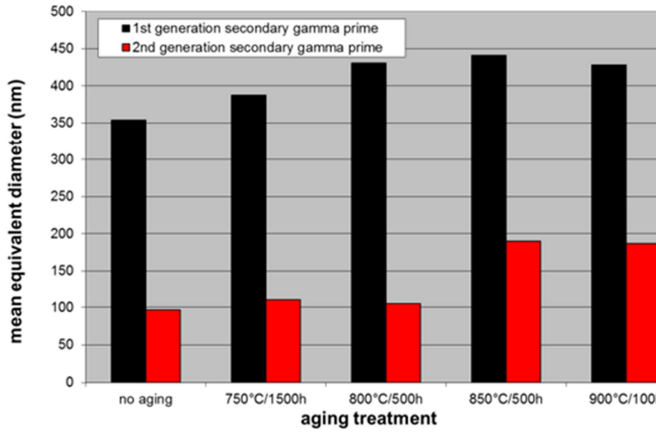


Figure 2: secondary γ' precipitate size vs aging treatment.

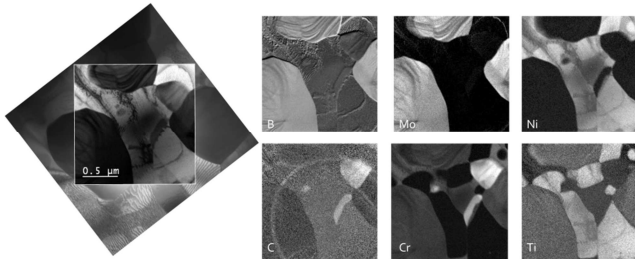


Figure 3: TEM micrograph of grain boundary precipitates and the corresponding EELS map of boron, molybdenum, nickel, carbon, chromium and titanium.

Mechanical characterization

Tensile tests were conducted between room temperature and 800°C. Tensile stress-rupture tests were performed at 750°C/500 MPa and 850°C/200 MPa. The resulting data on supersolvus AD730™ (with or without 850°C/500h aging treatment) were compared with those obtained on subsolvus AD730™ [2] and supersolvus U720 [5] (Figure 4 and Figure 5). As expected, coarse grain size AD730™ presents lower tensile properties than those of fine grain size AD730™ but much better creep properties at low and medium stresses. Moreover, supersolvus AD730™ has better tensile strength than supersolvus U720 while its creep properties are close to those of supersolvus U720, confirming previous results [2]. Finally, despite the application of a severe aging treatment to supersolvus AD730™ leads to a moderate decrease of these mechanical properties. This is assumed to be due to the excellent microstructural stability of alloy AD730™.

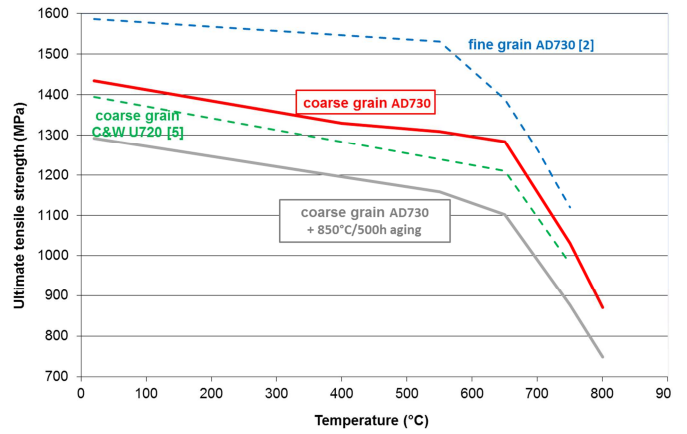


Figure 4: ultimate tensile strength of AD730™ with various microstructures compared with C&W supersolvus U720.

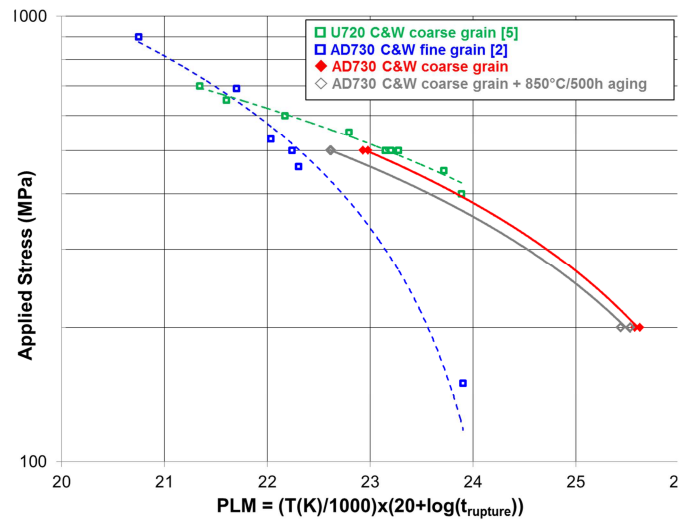


Figure 5: Larson-Miller plot of rupture creep life for AD730™ and U720 alloys

Conclusion

The new C&W superalloy AD730™ is a relevant candidate for disk manufacture because of its production cost (alloy cost and workability) combined with high mechanical properties and excellent microstructural stability. Fine or coarser grain size can be used depending on the targeted application.

Acknowledgements

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