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[54] COLUMNAR-GRAINED NICKEL-BASE SUPERALLOY CASTINGS

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[52] U.S. Cl. 148/32.5, 75/171
[51] Int. Cl. C22c 19/00
[58] Field of Search 75/171, 170; 148/32, 32.5

[56] References Cited

UNITED STATES PATENTS

3,260,505	7/1966	Ver Snyder	75/171
3,005,705	10/1961	Cochardt	75/171
3,526,499	9/1970	Quigg et al.	75/171

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[57] ABSTRACT

The mechanical properties of columnar-grained nickel-base superalloy castings are improved by the addition of 1.5–3.5 weight percent hafnium to the alloy composition.

2 Claims, 3 Drawing Figures



FIG. 1

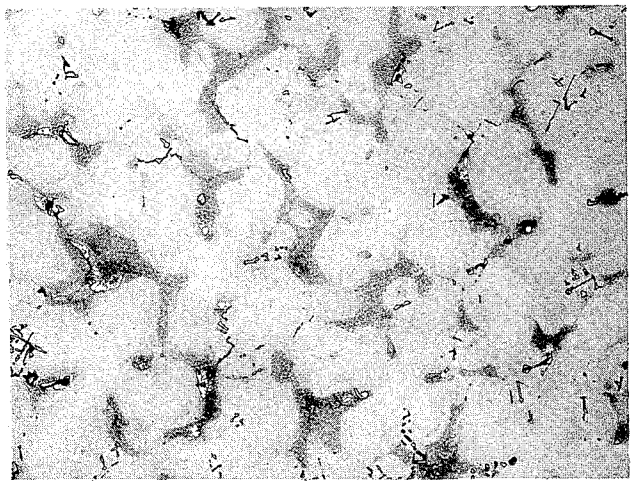


FIG. 2



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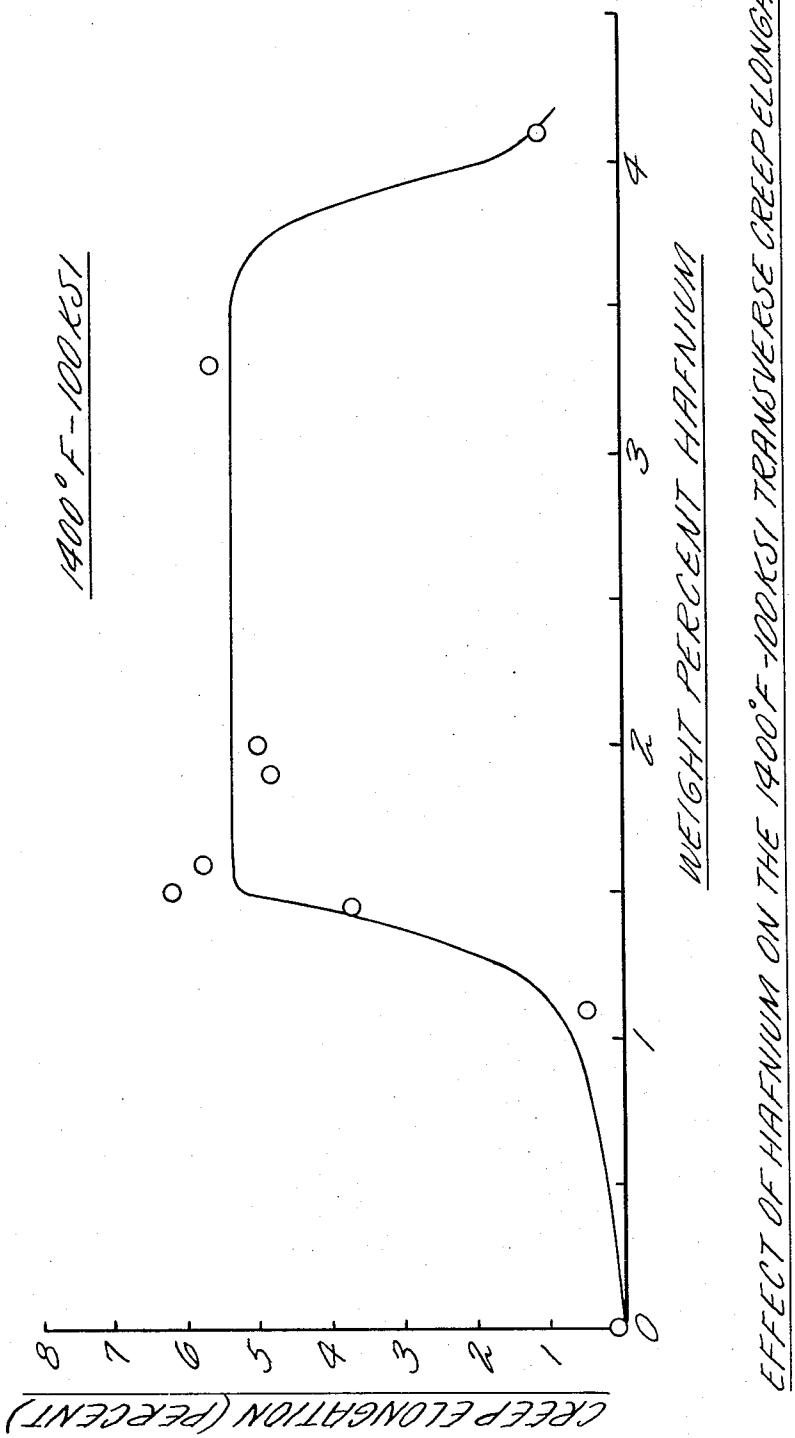


FIG. 3

EFFECT OF HAFNIUM ON THE 1400°F-100KSI TRANSVERSE CREEP ELONGATION

COLUMNAR-GRAINED NICKEL-BASE SUPERALLOY CASTINGS

BACKGROUND OF THE INVENTION

The present invention relates to columnar-grained nickel-base superalloy castings.

The common mode of failure of the high temperature nickel-base alloys in creep involves cracking along grain boundaries essentially normal to the stress axis. Previous workers have demonstrated that minor additions of elements such as born, cerium, magnesium and zirconium significantly improve the creep properties of these alloys. Thus, these additions have been widely used although the detailed mechanisms responsible for the improved properties attributable to them have not been fully resolved at this time, although it is generally believed that some form of grain boundary interaction is involved. In a similar vein, Cochardt U.S. Pat. No. 3,005,705 and Belgian patent 732,244 have reported that the addition of larger amounts of hafnium enhances creep life by increasing ductility of polycrystalline cast alloys.

A second approach to solving the problem of premature grain boundary fracture has been disclosed by Ver Snyder U.S. Pat. No. 3,260,505. In this development those grain boundaries oriented transverse to the major stress axis are essentially eliminated by directional solidification techniques which produce castings wherein the grain boundaries are aligned along the stress axis—columnar-grained castings. In the case of the very strong alloys, such as Alloy A having a nominal composition in weight percent of 0.15 C, 9.0 Cr, 10.0 Co, 5.0 Al, 2.0 Ti, 12.5 W, 1.0 Cb, 0.015 B, 0.05 Zr, balance Ni, this technique has proved superior to those relying solely upon alloy chemistry modifications to improve high temperature grain boundary properties. However, when stressed across the grain boundaries, the columnar-grained material retains its polycrystalline characteristics.

FIG. 2 is a photomicrograph of the microstructure of a columnar-grained nickel-base superalloy of the same chemistry except with the addition of 2 weight percent hafnium, after the same heat treatment.

FIG. 3 is a plot of the effect of hafnium on the 1,400°F.b$100 k.s.i. transverse creep elongation of a columnar-grained nickel-base superalloy cast material.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The most striking effect of a nominal 2 weight percent hafnium addition to columnar-grained Alloy A is the enhancement of transverse creep ductility and lifetime. These results, summarized in Tables I and II are for 0.1 inch thick flats in a fully heat treated condition (2,200°F./2 hours plus 1,975°F./4 hours plus 1,600°F./hours) and are compared to the results for the same alloy with no hafnium. It should be noted that the stress levels utilized were quite high to accelerate testing.

TABLE I

EFFECT OF HAFNIUM ON TRANSVERSE CREEP PROPERTIES OF COLUMNAR-GRAINED CASTING

temperature (°F.)	stress (ksi)	rupture life (hours)		Elongation (%)	
		2 w/o Hf	No Hf	2 w/o Hf	No Hf
1,400	85	780	0.3	4.2	0.8
1,400	100	170	f.o.l.	5.3	0.1
1,600	60	120	15	9.8	1.6
1,800	25	125	75	7.6	1.9

f.o.l. Failed on Loading

TABLE II

[Effect of hafnium on the tensile properties of columnar-grained casting]

Temperature (° F.)	U.T.S. (K s.i.)		0.2% Y.S. (K s.i.)		Elongation (percent)		R. of A. (percent)	
	2 w/o Hf	No Hf	2 w/o Hf	No Hf	2 w/o Hf	No Hf	2 w/o Hf	No Hf
A. Transverse:*								
R.T.	133	118	117	116	9.0	3.0	14.5	6.2
1,400	141	123	115	117	7.2	1.7	13.5	1.9
1,800	85	76	67	57	17.4	4.2	15.3	2.4
B. Longitudinal:								
R.T.	161	153	136	137	6.1	7.7	8.3	8.5
1,400	172	172	140	150	9.0	7.5	14.0	8.6
1,800	89	85	69	65	21.8	18.0	28.0	25.6

*The columnar grains in the transverse specimens are perpendicular to the tensile axis, whereas they are parallel to the tensile axes in the longitudinal specimens. This results in a higher resolved shear stress on the slip planes (Schmid factor) for the transverse specimens, thereby lowering the measured yield strength.

SUMMARY OF THE INVENTION

The present invention contemplates the addition of 1.5–3.5 weight percent hafnium to the columnar-grained nickel-base superalloys.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a photomicrograph of the microstructure of a columnar-grained nickel-base superalloy casting without hafnium after 2,200°F./2 hours plus 1,975°F./4 hours plus 1,600°F./32 hours.

Improvements in the transverse rupture life and ductility incident to the hafnium addition occur at all testing temperatures, 1,400°, 1,600° and 1,800°F. with the effect being the greatest at the lower temperatures. Furthermore, the longitudinal stress-rupture properties, taken in alignment with the columnar grains, are equivalent to those of the hafnium-free alloy. Thus, the hafnium addition appears to have no significant adverse effect on the mechanical properties.

The improvement in transverse properties of the columnar-grained castings is formed over a range of

hafnium contents. However, there appears to be a critical range of hafnium outside of which no beneficial effects are observed, as seen in FIG. 3. Below about 1.5 weight percent and above about 3.5 weight percent hafnium, the creep ductilities fall to the low values found in the hafnium-free material.

In addition to imparting additional ductility to the transverse properties of the casting at 1,400°F., hafnium alters the fracture characteristics. When hafnium is absent both creep and tensile fractures are entirely intergranular. The addition of hafnium results in a fracture with extensive areas of crystallographic cracking. The crystallographic mode of crack propagation indicates enhanced cracking resistance of the grain boundaries. This transgranular fracture made at 1,400°F. appears to be a characteristic of the hafnium effect in columnar-grained castings.

The addition of hafnium alters the microstructure of columnar-grained Alloy A as seen in FIGS. 1 and 2. Additions of hafnium increase the amount of the eutectic (γ/γ') constituent normally present in this alloy. The carbides are also affected. Instead of the single (Ti, Cb, W) C carbide normally found, two MC carbides of different lattice parameter are formed. A carbide of the larger lattice parameter (a_o= 4.59 A) suggests that it is hafnium-rich, with some dilution by elements of smaller atomic size tending to decrease a_o below the value for HfC (a_o =4.64 A). The other MC carbide has a lattice parameter slightly larger than the MC type usually found in this alloy (4.40 vs. 4.36 A) which suggests that some hafnium is present in this carbide causing a lattice parameter increase. X-ray diffraction phase identification of electrolytically extracted residues has indicated that $M_{23}C_6$ carbides are only present after heat treatment. This is in contrast to the hafnium-free alloy where some of these carbides are present in the as-cast condition. Contrary to the results of others working with the polycrystalline castings, the results indicate that hafnium produces no obvious refinement in MC carbide size.

In summary, the addition of a critical amount of hafnium to the columnar-grained nickel-base superalloy castings results in a significant improvement in the transverse creep properties while maintaining the excellent longitudinal mechanical properties associated with the columnar-grained structure. Although the invention has been described in detail in connection with certain preferred embodiments, these are illustrative only for obvious modifications will occur to those skilled in the art within the true spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A casting consisting essentially of an alloy of the nominal chemistry, by weight, 0.15 percent carbon, 9 percent chromium, 10 percent cobalt, 5 percent aluminum, 2 percent titanium, 12.5 percent tungsten, 1 percent columbium, 0.015 percent boron, 0.05 percent zirconium, 1.5–3.5 percent hafnium, balance nickel, having a columnar-grained structure.

2. A casting according to claim 1 wherein the hafnium content is about 2 percent by weight.

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