SELECTED PROPERTIES OF

ANISOTROPIC PWA 1472

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Abstract

Previous work has shown that a high strength INCO 718 variant, PWA 1472, cast in single crystal form, may be superior to γ' strengthened single crystals in low temperature rocket turbopumps where hydrogen embrittlement is a consideration. To test this hypothesis PWA 1472 was cast in single crystal form and tested in air and hydrogen. Subsequent mechanical property testing conducted in air has shown some interesting mechanical properties suggesting potential applications in air-breathing propulsion systems. This paper presents some of those results

Introduction

Conventional PWA 1472 is a high strength variant of INCO 718 (1) with a 100F temperature advantage over PWA 1469 (cast INCO 718). Cast equiaxed PWA 1472 is the bill of material diffuser case alloy for Pratt & Whitney's PW F119, an advanced afterburning turbofan selected for the Air Force's F22 air superiority fighter. The alloy has been tested in tensile and creep up to 1500F. Single Crystal PWA 1472 was produced to confirm its anticipated value for hydrogen service (2) and was chosen over other INCO 718 forms because of its higher strength and temperature capability. SC PWA 1472 has demonstrated an inherently low hydrogen to air degradation in notched LCF and exceptional strength and ductility.

Development Status

Single Crystal PWA 1472 has been proposed for development in Pratt & Whitney's Advanced Rocket Propulsion Plan (ARPP).

Some advanced rocket turbopump designs operate at relatively low temperatures, several hundred degrees(F) below that of the SSME. SC PWA 1472 is stronger and less dense than other developmental hydrogen resistant blade alloys such as Modified PWA 1480, PWA 1482, and PWA 1484. SC PWA 1472 specific strength is 30-60% higher than these alloys.

Single Crystal PWA 1472 was also studied for use as a high pressure compressor blade alloy based on it's high strength, ductility, and low density.

The gain in strength for the anisotropic casting over the equiaxed form of PWA 1472 becomes apparent when shown as a function of temperature in ***Figure 1***. Two γ' strengthened Ni base superalloys, the single crystal alloy PWA1480 and equiaxed MAR-M-247 are included in this plot. The γ'' single crystal alloy exhibits markedly higher yield strength.

Superalloys 718, 625, 706 and Various Derivatives
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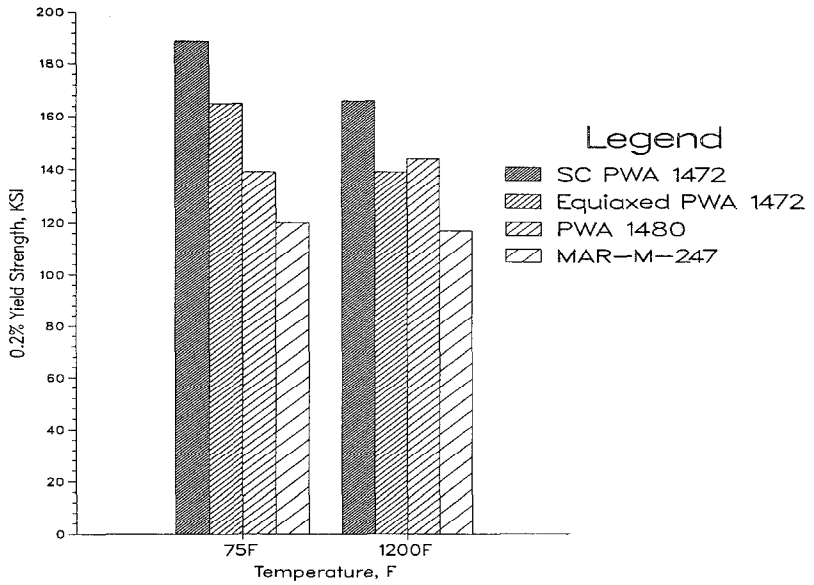

Figure 1 - The gain in strength for the anisotropic PWA1472 casting over the equiaxed form (and other hot section superalloys) is pronounced.

A comparison of notched LCF test results for several anisotropic γ' strengthened Ni base superalloys and SC PWA 1472, all tested in 34.5 MPa gaseous hydrogen is shown in ***Figure 2***. This environment is representative of that encountered in the NASA Space Shuttle Main Engine high pressure fuel and oxidizer turbopumps. DS MAR M 246+Hf is being phased out as the Alternate Turbopump designs("SSME Alternate Turbopump Development Program", NASA-MSFC Contract No. NAS8-36801) enter service with PWA 1480 turbine blades and vanes. The modified version of PWA 1482 (3) is an advanced γ'strengthened single crystal tailored for hydrogen service. SC PWA 1472 compares favorably with PWA 1480 and although inferior to the advanced hydrogen resistant alloy in LCF is anticipated to be superior in crack growth resistance and is less dense than either of the γ'alloys.

Advanced high pressure compressor designs require increasingly high temperature capability, specific strength and ductility. SC PWA 1472 yield strength is compared to that of a gamma TiAl alloy on a density corrected basis ***(Figure 3)***. The advantage in specific strength obtained by going to a high strength superalloy in an anisotropic casting form is clear. SC PWA 1472 tensile results show 18% elongation and 29% area reduction at room temperature. 650C test results show 36% area reduction. By comparison the TiAl alloy exhibits less than 5% elongation over this temperature range.

IN-100 is currently used in HPC applications and is shown compared to SC PWA 1472 on the basis of strength and ductility in ***Figures 4 and 5*** respectively.

Summary

Operating temperatures for high pressure compressor blades used in advanced gas turbine designs are approaching the point where single crystal Ni base superalloys may be required. A tough, ductile alloy with high specific strength and creep resistance would be attractive for this application.

PWA 1472 cast in single crystal form offers an attractive balance of properties at temperatures beyond that of conventional γ'' strengthened alloys.

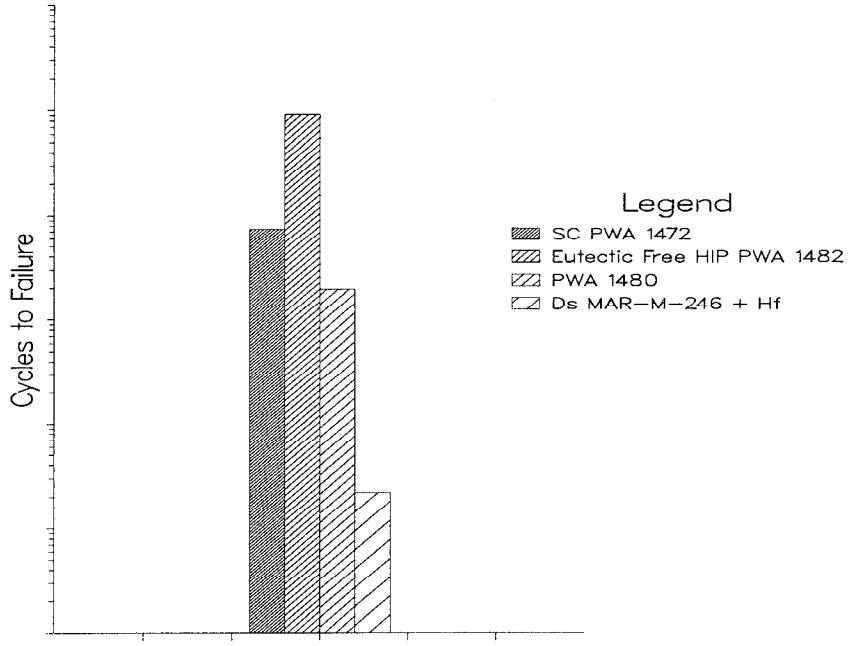

Figure 2 - A comparison of notched LCF test results for several anisotropic γ' strengthened Ni base superalloys and SC PWA 1472, all tested in 5000 psi gaseous hydrogen

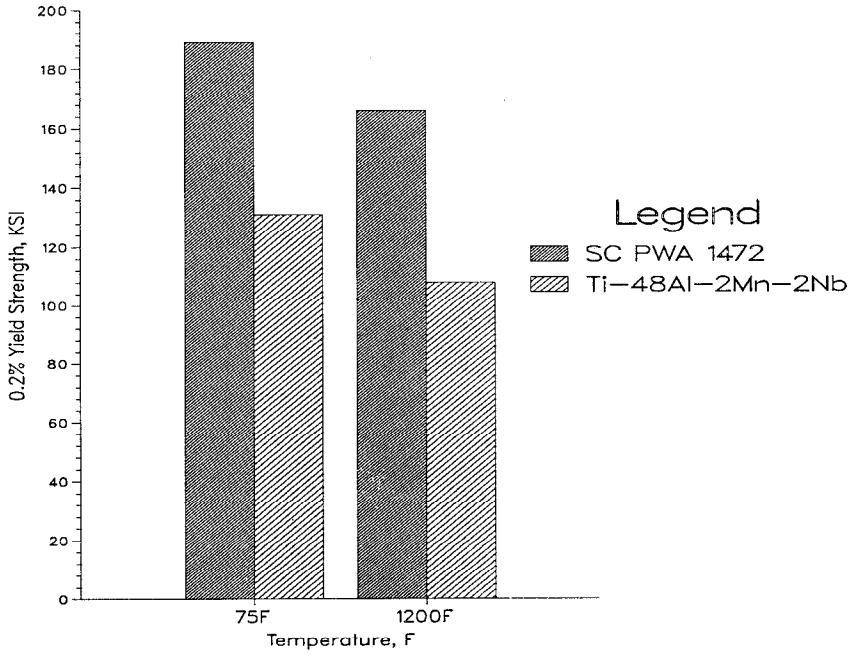

Figure 3 - SC PWA 1472 yield strength compared to that of a gamma TiAl alloy **on a density corrected basis**

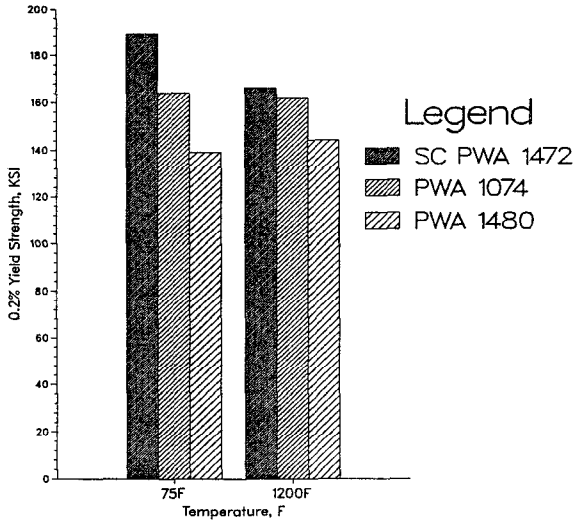

Figure 4 - IN-100 compared to SC PWA 1472 on the basis of strength

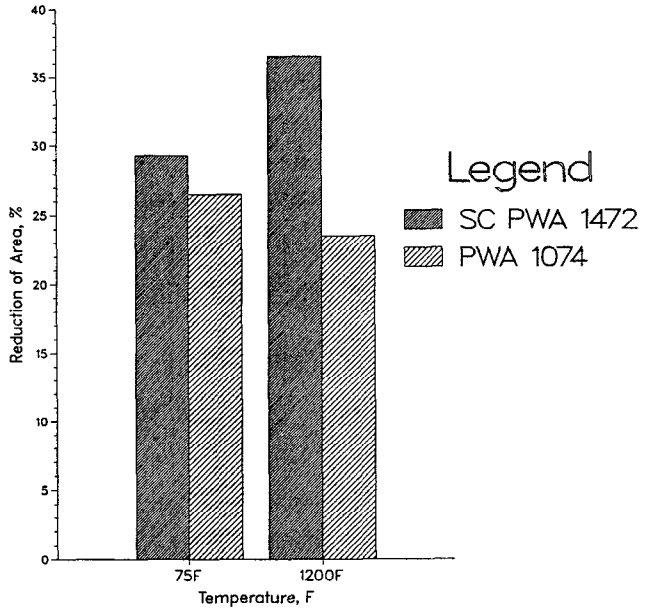

Figure 5 - IN-100 compared to SC PWA 1472 on the basis of ductility

References

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3. C. M. Biondo et. al. , "The Influence of Thermal Processing and Microstructure on the Mechanical Properties of Single Crystals in Hydrogen" (Paper presented at the Third Workshop on Hydrogen Effects on Materials in Propulsion Systems, NASA Marshal Space Flight Center, 1994), Vol. 1, 10.