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MECHANICAL PROPERTIES OF HIGH GRADIENT AND HOT ISOSTATICALLY PRESSED PWA 1480

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Single crystal superalloy (specifically, alloy 1480) turbine blades are now in development for application in the high pressure turbopump turbine sections of the SSME. The mechanical and environmental demands placed on these components are quite severe and are significantly different from the requirements of aircraft gas turbine applications for which the alloy was developed. In particular, the extreme thermal transients on start and shutdown and the very high mean stress vibratory loads lead to stronger fatigue excitations than generally encountered in gas turbine engines. In addition, the short design life, about 7.5 hours, of the SSME precludes creep and stress rupture as primary failure mechanisms.

It is recognized that the mechanical properties of single crystal superalloys, especially with respect to life under cyclic loads, are strongly dependent on microstructural defects. Fatigue cracks in single crystal superalloys have been found to initiate at such microstructural anomalies as inclusions, secondary grains and, most frequently, internal porosity. Control or elimination of these defects can be expected to significantly increase the life of single crystal components. The goal of this program is to investigate the potential benefits due to reduction or elimination of casting porosity through high thermal gradient casting and hot isostatic pressing applied to alloy 1480. Additionally, improvement in fatigue life due to alternate heat treatment is being evaluated.

Internal porosity is an inherent feature of single crystal superalloy castings. The bulk of this porosity is formed during solidification and is caused by shrinkage and restricted fluid flow into the interstices of the dendrite arms. Increased casting thermal gradient can refine the microstructure through reduced dendrite arm spacing (DAS) and an attendant decrease in the size and density of the casting porosity. Internal casting porosity can be virtually eliminated by the proper application of hot isostatic pressing (HIP) to the casting. The successful application of HIP to single crystal parts involves overcoming a unique set of obstacles. Temperature control in production HIP vessels is generally not tight enough to control within the as-cast solution heat treatment range of alloy 1480. Cooling rates from temperature are also not rapid enough to provide optimum properties. Post-HIP solution heat treatment cause pore resurgence through Kirkendall diffusion. Improper temperature and pressure application in the HIP cycle can also cause recrystallization around the closing pores. Very small amounts of free carbon in the HIP vessel cause surface carburization. With the successful removal of casting porosity, improvements in fatigue life and increased resistance to hydrogen environment embrittlement (HEE) may be obtainable through tailored heat treatments. Increased slip dispersal through optimum gamma prime distribution will provide improvements in both fatigue and HEE behavior.

This program has been designed to evaluate the potential benefits to alloy 1480 material properties due to high thermal gradient casting, hot isostatic pressing, and alternative heat treatment. Alloy 1480 castings have been obtained from vendors representing the extremes of commercial casting thermal gradients. Quantitative characterization of the DAS and pore distributions has been conducted. A HIP schedule, which avoids the many pitfalls of single crystal HIP has been devised for alloy 1480. In addition, an alternate heat treatment for alloy 1480 has been devised which provides benefits in mechanical properties. The standard gradient cast test material is being evaluated in the standard heat treated condition as a baseline and in the HIP plus alternate heat treated condition. The high gradient cast material is being evaluated in alternate heat treat and HIP plus alternate heat treated conditions. Evaluations focus on demonstration of the benefits due to the applied processes, especially in the area of cyclic life. This interim period report will present current results and procedures derived from the program.