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A STUDY OF HYDROGEN ENVIRONMENT EFFECTS ON MICROSTRUCTURE PROPERTY BEHAVIOR OF NASA-23 ALLOY AND RELATED ALLOY SYSTEMS

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ABSTRACT

The present research work is a study into the behavior of hydrogen environment effects on microstructure property behavior of NASA-23 alloy and related alloy systems Incoloy 909, Inconel 718 and JBK-75, a modified A 286. This work is part of the overall advanced main combustion chamber (AMCC) casting characterization program of the Materials & Processes Laboratory of the Marshall Space Flight Center. The influence of hydrogen on the tensile properties and ductility behavior of NASA-23 alloy has been analyzed. NASA-23 and other referenced alloys in cast and hipped conditions have been solution treated and aged under selected conditions and characterized using optical metallography, scanning electron microscopy and electron microprobe analysis techniques. The yield strength of NASA-23 is not affected much by hydrogen under tensile tests carried at 5,000 psig conditions, however, the ultimate strength and ductility properties are degraded. This implies that the physical mechanisms operating would be related to the plastic deformation processes.

The fracture surfaces characteristics of NASA-23 specimens tensile tested in hydrogen, helium and air were also analyzed. These revealed surface cracks around specimen periphery with the fracture surface showing a combination of intergranular and transgranular modes of fracture. It is seen that the specimens charged in hydrogen seem to favor a more brittle fracture mode in comparison to air and helium charged specimens. The AMCC casting characterization program is to be continued, under which the referenced alloys have yet to be analyzed for their hydrogen behavior. As a result of this summer faculty research program, the basic microstructural factors and fracture characteristics in some cases have been analyzed.

INTRODUCTION

Development of NASA-23 alloy with a 180 ksi ultimate tensile strength and a 160 ksi yield strength and with no appreciable loss in ductility in hydrogen environments is the goal of the current advanced main combustion chamber (AMCC) program being pursued at the Materials and Processes

Laboratory of the Marshall Space Flight Center. As a part of the casting characterization plan, during the 1990 NASA/ASEE summer faculty research program , a study has been carried out of the NASA-23 and other related alloys Incoloy 909, Inconel 718 and JBK-75 alloys. Though some information related to the phase stability and effects of alloying elements in the referenced alloys is available in some references (1-7), very little is known related to the hydrogen environment embrittlement (HEE) behavior of these alloys.

The several objectives of the research that has been carried out are:

1. Evaluation of Gaseous Hydrogen environment effects and relate these to metallurgical behavior of selected basic alloy systems NASA-23, 909, 718 and JBK 75 alloys.
2. Heat Treatment and characterization of referenced alloys.
3. Test and evaluation of hydrogen environment effect.
4. Recommend future directions for research to establish fracture mode and effects of hydrogen to help development of hydrogen resistance alloys.

EXPERIMENTAL PROCEDURES

Hipped and as cast condition materials of NASA-23, Incoloy 909, Inconel 718 and JBK-75 were solution treated and aged : solution treatment times were 1 hour - at 1700 F for NASA-23 , at 1800 F for Incoloy 909 , at 1900 F for Inconel 718, and 1800 F for JBK-75 and aging treatments involved a dual aging (1325F/8hr,2hr,1150 F/8hr) for NASA-23 and 909 alloys a dual aging (1400 F/10 hr, 2hr, 1200 F/8hr) for Inconel 718 and (1325 F/16 hr) aging for JBK-75 alloy. Compositions, heat treating conditions , hardness values for all alloys are included in data presented at the Marshall Space Flight Center (8).

All solution treated and aged specimens were characterized using techniques of optical microscopy and analyzed for their microconstituents with the SEM and electron microprobe analysis techniques. In an evaluation of NASA-23 alloy , specimens were tested for smooth tensile properties and their ductility behavior under ambient air and 5,000 psig helium and 5,000 psig hydrogen environment test conditions. Test results of NASA-23 are analyzed and related to microstructural behavior and fractographic characteristics of this alloy.

Determination of total hydrogen contents using LECO analyzer on specimens charged with hydrogen under 5,000 psig at 150 F with a 10,000 sec exposure has been carried out for all alloys. An attempt was made to determine the values of hydrogen on a local microstructural level using technique of Schober and Dieker (9) . This was not completely successful , though a local high concentration of silver was seen which can be , according to the technique related to the local hydrogen level of the specimens.

RESULTS AND DISCUSSION

NASA-23 tested in air , helium and hydrogen revealed a loss of ductility in hydrogen in comparison to air and helium tested samples. The optical and SEM microstructural characterizations carried and the fractographic analyses have revealed presence of surface cracks on the periphery of the specimens. The fractures are seen to be of mixed transgranular and brittle intergranular fracture mode. A characterization of fracture surfaces using technique developed by Underwood (9)to measure the fracture surface roughness will be highly useful in discriminating the fracture modes and to understand better the fracture behavior of the alloys.

The results of the several microstructural characterizations and the fractographic analyses carried out are detailed in the data presented (8). It is seen that the Incoloy 909 had a higher total hydrogen about 16.9-25.5 ppm on a 5,000 psig , 150 F exposure compared to values of 2-9.9 ppm in other alloys.

The metallurgy of the basic alloy systems studied has been analyzed and correlated where possible with the potential hydrogen environment behavior of the referenced alloys. The overall AMCC casting characterization program is a three year program and some of the results of this work and recommendations are expected to be beneficial in modeling and continuing research in this important area of hydrogen environment behavior and hydrogen resistant alloy development. Details of all research findings are in reference 8.

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