HYDROGEN EMBRITTLEMENT IN SUPERALLOYS

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Volvo Aero Corporation develops turbines and the nozzle extension for the next generation of rocket within the European Space Program, the Ariane V. These components operates in high pressure hydrogen gas at various temperatures. Due to temperature and strength requirements, materials known to be sensitive to hydrogen embrittlement has to be used.

Hydrogen gas embrittlement is a complex phenomena, involving many different variables such as:

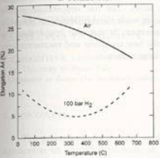
- Chemical composition of the material
- Microstructure
- Surface Structure
- Manufacturing processes, e.g. welding
- Temperature
- Hydrogen gas pressure
- Plastic deformation
- Time (frequency, strain rate)
- Impurities in the hydrogen gas

The interaction of these variables is not understood. It is thus necessary to test and characterise the material close to the operating conditions. In order to fulfil these requirements a unique test plant for mechanical testing in high pressure hydrogen gas at room and elevated temperatures has been developed. The test facility is fully automated enabling round the clock testing, thus reducing the total testing time considerably, especially for fatigue testing. Great care has been spent in order to keep the hydrogen gas as clean as possible, e.g. the oxygen content is always checked to be below 1 ppm. A test program including tensile, strain controlled low cycle fatigue, fracture toughness as well as crack propagation testing has been performed. The temperature was varied between room temperature and 1000 C.

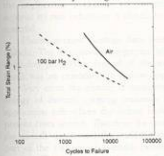
In the superalloys tested it was have found that hydrogen embrittlement is closely related to plastic deformation. This can be seen in the tensile tests in which the elongation and reduction of area is decreased, while the yield stress is unaffected. The UTS is only decreased if the hydrogen embrittlement is severe. During low cycle fatigue the deterioration in properties is most evident

Test results

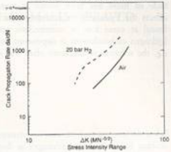
1. Tensile Test



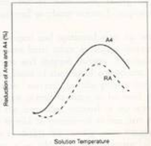
2. Low Cycle Fatigue Test



3. Crack Propagation Test



4. Effects of Solution Temperature



1. Smooth Tensile Test of Superwaspaloy in air and in hydrogen.
2. Strain controlled Low Cycle Fatigue test of Superwaspaloy at 20°C in air and in hydrogen.
3. Crack Propagation Test of Superwaspaloy at 20°C in air and in hydrogen.
4. Elongation (A4) and Reduction of Area (RA) for Inconel 718 in hydrogen gas as a function of solution temperature.

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S-461 81 Trollhättan · Sweden · Tel. +46-520 940 00 · Telefax +46-520 344 12 at large strain ranges. Also local plastic deformation, as in crack propagation, promotes hydrogen embrittlement. An increase in propagation rate of a magnitude or more has been found in many alloys. The test temperature greatly affects the hydrogen embrittlement, the most severe embrittlement is normally found at some low or intermediate temperature. It was also found that the hydrogen embrittlement is dependent on the heat treatment and microstructure, e.g. the solution temperature often has a large influence.