STUDIES ON OXIDE DISPERSION STRENGTHENED NICKEL BASE ALLOYS AND IRON-ALUMINIUM INTERMETALLICS

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In this presentation I have chosen to describe some results from recent studies carried out at the Swedish Institute for Metals Research of two types of advanced high temperature materials, viz. oxide dispersion strengthened (ODS) nickel base alloys and iron-aluminium intermetallics. Both these types of materials combine impressive strength and corrosion/oxidation properties at high temperatures. A wider use of them in high temperature applications have been hampered primarily because of high production costs in the case of ODS-alloys and limited low temperature ductility for the intermetallic. However, it appears that these obstacles are and will be gradually overcome.

High Temperature Thermo-Mechanical and Low Cycle Fatigue of the ODS Alloy MA754

A common application of ODS-alloys is gas turbine components. High temperature fatigue is then often limiting the component life. At the Swedish Institute for Metals Research (SIMR) we have therefore studied both thermo-mechanical and low cycle fatigue at high temperatures in MA 754. This is an yttria (Y_2O_3)-dispersion (0.5%) strengthened nickel base alloy with about 20% Cr and small additions of Al (~ 0.3%) and Ti (~ 0.5%). Some of the results from these studies are displayed in Fig. 1.

The thermo-mechanical fatigue tests involve various cycles in the range 400-1100°C, both inphase (max. tensile stress occurs at max. temperature) and out-of-phase (max. compressive stress occurs at max. temperature). When plotting the total strain range vs. fatigue life time all test results fall in the same scatter band except the in-phase testing with cycling between 1100 and 600°C which exhibits significantly shorter life times.

Attempts have been made to rationalize both thermal fatigue, in-phase as well as out-of-phase testing, and isothermal low cycle fatigue data in one common base formula, and from that make predictions of life time. Such prediction models usually take into consideration the maximum tensile stress, the total inelastic (= plastic) strain range as well as various frequency factors accoun-

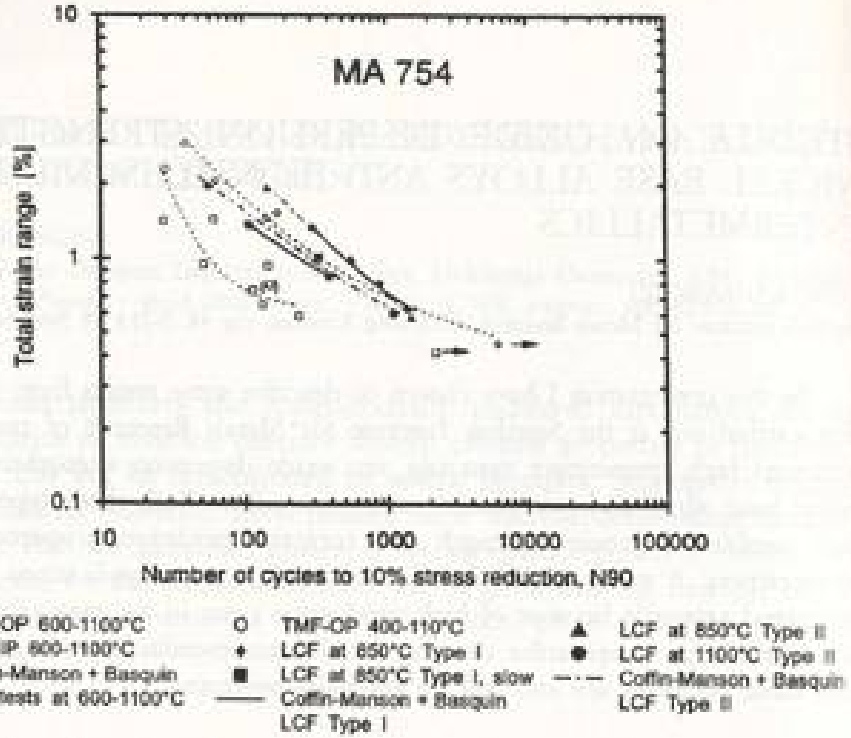

Fig. 1 - Total mechanical strain range versus number of cycles to 90% stress reduction for MA 754. The lines correspond to the summation of the Coffin-Manson and Basquin equation.

ting for the effect of the fatigue cycle time. This approach has been used with some success, but does not give satisfactory results in the present case.

The present alloy MA754 is sensitive to tensile but not compressive strains. This has been demonstrated by low cycle fatigue experiments in which tensile hold times reduced life time and compressive hold times increased fatigue life. In our own experiments we found that the tensile part of the inelastic strain is proportionally larger in an in-phase test than in an out of-phase test. Accordingly, we should expect the in-phase testing to produce lower life times than out of-phase testing, and this correlates well with the experimental findings. The prediction model referred to above has therefore been modified to include only the tensile inelastic strain and not the compressive part. In this way it was found possible to describe the low cycle fatigue and thermal fatigue data for all the various experimental in one unified equation and predicting the life time with satisfactory accuracy as shown in Fig. 2.

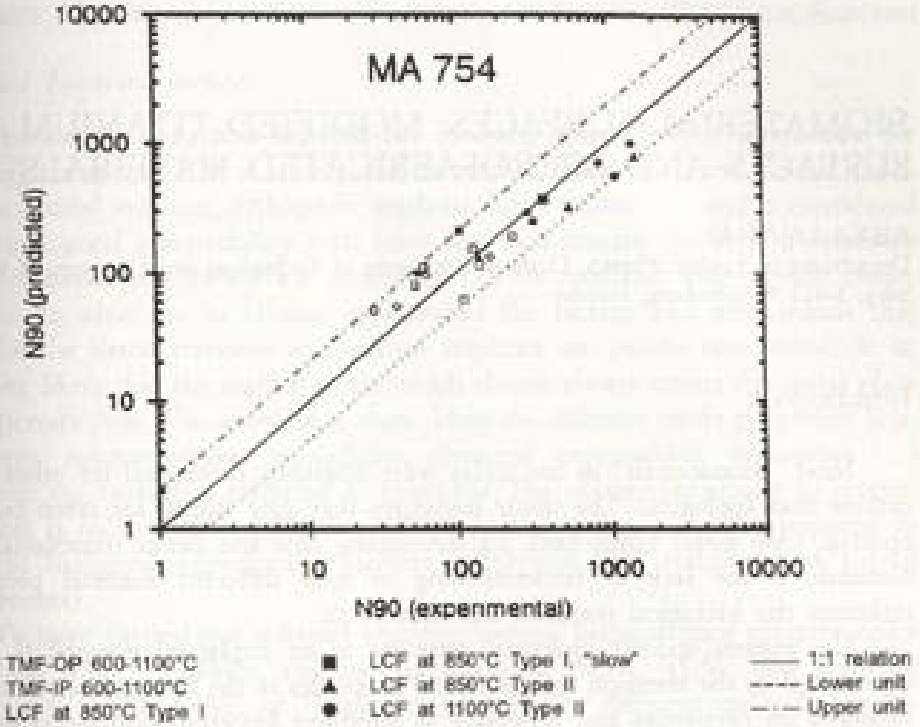

Fig. 2 - Plot of predicted life versus observed life for MA 754 using a modified Ostergren approach.

Effects of Alloying in Powder Metallurgical Fe_3Al

An investigation of the effect of various alloying elements on Fe_3Al-intermetallics is being carried out at the Swedish Institute for Metals Research. The primary objective is to reproduce the improvements achieved in previous studies with regard to room temperature ductility and high temperature strength and, of course, to examine whether improvements beyond that can be reached.

We have chosen to produce the Fe_3Al-materials in this study by the powder metallurgical route as follows

— gas atomizing of homogeneous powder
— hot extrusion of the powder in sealed capsules to fully dense material
— annealing treatment when needed

Alloying with chromium improved the ductility of Fe_3Al to levels similar to those found in previous investigations, viz. 5-8% elongation in tensile testing.

A combined alloying with chromium and zirconium seems to raise the yield strength to levels of 700-800 MPa at room temperature and to 550-600 MPa at 600°C, and at the same time produce ductilities at room temperature of 6-10%.