THE EFFECTS OF A SULPHUR-CONTAINING ENVIRONMENT ON HIGH TEMPERATURE FATIGUE OF A NICKEL-BASED SUPERALLOY

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The effect of sulphur-containing gaseous environments on high temperature low cycle fatigue (HTLCF) failure of unidirectional solidified MAR-M200+H_f nickel-base superalloy was studied at 975°. The HTLCF mode of loading was unvaried and consisted of creep tension and plastic compression under different gas mixture environments in which the abovementioned alloy is exposed at the hot section of a jet engine. The experimental results obtained in various gas mixtures have shown a different environmental influence although a controlling effect caused by the addition of 3% SO_2 resulted in similar HTLCF life.

INTRODUCTION AND EXPERIMENTAL

Fatigue-environmental interaction resulting from the presence of sulphur in the combustion products of jet engines has a damaging effect on the life expectancy of these engines (1). One important material of turbine blades at the hot stage of jet engines is the unidirectional solidified MAR-M200+H_f superalloy. The following article aims to evaluate the effect of suphur-containing gaseous environments on the mechanism of HTLCF failure of this alloy.

The HTLCF loading was constant and comprised creep tension and plastic compression (cp mode of loading according to the strain-range partitioning life prediction method (2)) under different mixtures of gases at 975°C. The gaseous environments were mixtures of SO_2 and components of the combustion products, namely:
N_2 + 3%SO_2, Ar + 3%SO_2, Ar + 20%O_2 + 3%SO_2 and CO_2 + 3%SO_2. The crack nucleation and propagation were studied by scanning electron microscopy, X-ray diffraction and Auger electron spectroscopy.

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RESULTS AND DISCUSSION

In general, tests under the different sulphur containing atmospheres have shown a controlling effect caused by the 3%SO_2 resulting in obtaining similar HTLCF life. Tests under mixtures of Ar + 3%SO_2 and N_2 + 3%SO_2 have shown that the crack nucleates from a surface blister and propagates through a transdendritic pass. The blistering process occurred due to the combination of alternating mechanical loading and intensive hot corrosion attack. This was supported by the fact that unloaded materials which were tested under the same gas mixtures showed none of these blistering processes. In addition careful metallographical observations and microanalysis ahead of the crack tip revealed the existence of a liquid flux (eg nickel sulphide phases which melt at a lower temperature than the experimental temperature) which directly affects the crack propagation. The external layer of the crack edge was composed of a mixture of sulphide and oxide phases.

Tests under the mixture of Ar + 20%O_2 + 3%SO_2 have shown that oxygen had restrained the formation of the sulphide flux resulting in the fact that none of the blisters had appeared. Ahead of the crack tip different layers could be observed. The first and the most external layer was composed of a mixture of sulphide and oxide phases. The next layer was a wide uniphase layer consisting of coarsening of γ' phase acting simultaneously with internal oxidation (due to the presence of oxygen (3)). The last layer usually has the typical microstructure of the transdendritic zones. Under the mixture of CO_2 + 3%SO_2 carbon dioxide moderates the formation of surface blisters (eg compared to the result obtained in mixtures of SO_2 with either argon or nitrogen). The layers at the edges of the fatigue crack were similar to the layers obtained under the mixture of argon, oxygen and SO_2, differing by the fact that the uniphase layer was much more narrow probably due to the limited available oxygen. In both mixtures of SO_2 with either oxygen and carbon dioxide, the hot corrosion attack again occurs directly at the crack tip resulting in similar HTLCF life.

CONCLUSION

In conclusion, it was shown that sulphur containing gaseous environments (ie in the form of 3%SO_2) exerts a decisive influence on the mechanism of HTLCF failure of MAR + M200 + H_f superalloy. This is manifested by a blistering process at the surface (ie creating an initial crack), followed by a direct hot corrosion attack at the propagating crack tip. Due to the controlling effect caused by the SO_2 the obtained HTLCF life was similar in all the gas mixtured tested. In consequence of this, it appears that the microstructural changes at the crack tip occur due to the chemical and mechanical relaxation processes of the material system arising in reaction to the stress concentration and the presence of the gas environment.

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