

HIGH TEMPERATURE OXIDATION BEHAVIOUR OF MAR-M247 IN RELATION TO ITS INITIAL MICROSTRUCTURE

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1. Introduction

Nickel alloys used for the construction of aircraft engines are characterized by high performance properties including corrosion, heat and creep resistance [1,2]. Increasing demands by the aircraft industry have resulted in improved engine efficiency and high operating temperatures, which has resulted in increased use of nickel alloys [3]. Turbine components made from nickel alloys are exposed to extremely high temperatures, as the gas temperature upstream of the turbine may exceed 1650°C. Therefore, it is of highest importance to investigate and monitor high temperature oxidation behavior of such alloys in order to prevent catastrophic consequences related to failure of nickel-based components [4].

2. Materials and methodology

In this paper, MAR-M247 with three initial microstructures, namely coarse (GZ), fine (DZ) and column (KZ) grained, was investigated during high temperature exposure at 900°C up to 500h. The relative increase of mass as well as oxide formed on the surface were measured using Scanning Electron Microscopy.

3. Results

Fig. 1 illustrates the formation of a chromium oxide scale on the surface of the MAR-M247 alloy after prolonged exposure at 900°C for 500 hours. The micrograph reveals the development of a continuous oxide layer, which is typical for nickel-based superalloys containing significant chromium content. The oxide scale appears relatively compact and adherent to the substrate, indicating the formation of a protective Cr₂O₃ layer. Such a layer

plays a critical role in limiting further oxidation by acting as a barrier to oxygen diffusion. The morphology of the oxide suggests that the oxidation process has progressed to a steady-state regime, where the growth of the scale is controlled by diffusion through the already formed oxide. Additionally, the quality and uniformity of the oxide layer may be influenced by the initial microstructure of the material (coarse-, fine-, or columnar-grained), as grain boundaries can serve as fast diffusion paths for oxygen and alloying elements. A more homogeneous and dense oxide layer typically indicates better resistance against further degradation, while any irregularities, cracks, or spallation (if present) could suggest localized breakdown in oxidation resistance. Overall, the figure demonstrates that chromium oxide is the dominant and protective phase formed during high-temperature exposure, confirming the alloy's capability to withstand oxidizing environments.

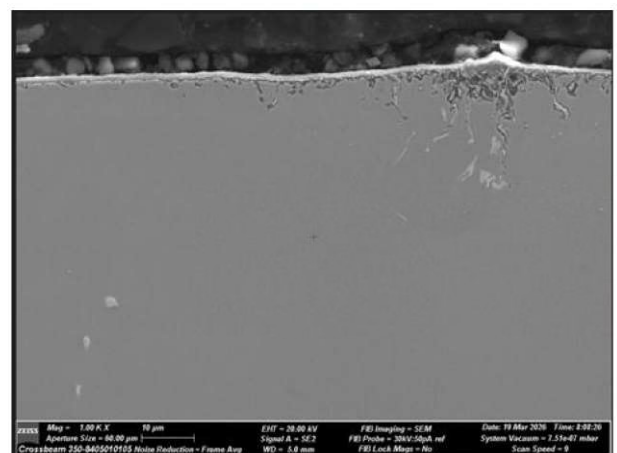


Fig. 1. Chromium oxide formation on MAR-M247 during 900°C exposure for 500h.

Fig. 2 presents the relationship between relative mass gain and annealing time for MAR-M247 alloys subjected to oxidation at 900°C. The increase in mass is directly associated with the formation and growth of oxide scales on the alloy surface. The curve typically exhibits a rapid increase in mass during the initial stages of exposure, which can be attributed to the direct interaction between the fresh alloy surface and oxygen. As the oxidation process continues, the rate of mass gain gradually decreases, indicating a transition to diffusion-controlled kinetics. This behavior is characteristic of parabolic oxidation, where the thickening oxide layer reduces the rate of further oxidation by limiting the transport of reacting species. The differences in mass gain among the investigated microstructures suggest that grain size and morphology significantly influence oxidation behavior. Fine-grained materials tend to show higher initial mass gain due to the increased number of grain boundaries that enhance diffusion, whereas coarse- or columnar-grained structures may exhibit slower oxidation rates and improved long-term stability. The figure therefore highlights not only the protective nature of the oxide layer but also the importance of microstructural control in optimizing oxidation resistance.

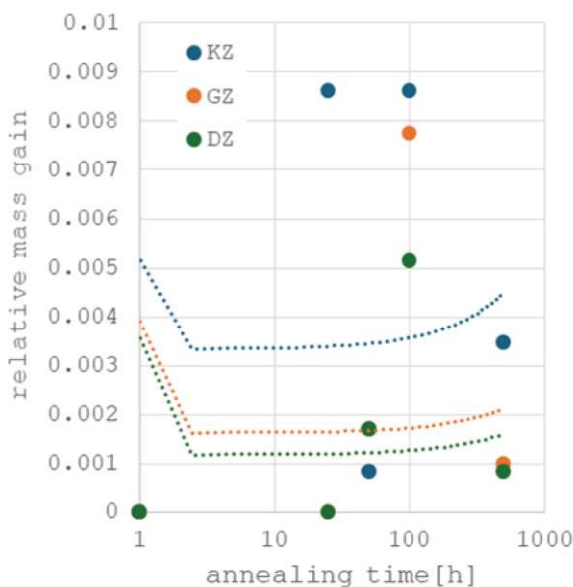


Fig. 2. Relative mass gain in relation to annealing time for MAR-M247 alloys subjected to 900°C.

4. Conclusions

The results demonstrate that MAR-M247 exhibits good oxidation resistance at 900 °C due to the formation of a protective chromium oxide scale. The oxidation process follows diffusion-controlled

kinetics, as evidenced by the decreasing rate of mass gain with increasing exposure time. The formation of a continuous and adherent Cr₂O₃ layer effectively limits further oxidation and enhances the alloy's durability in high-temperature environments. Furthermore, the initial microstructure plays a significant role in determining oxidation behavior, influencing both the kinetics of oxide growth and the quality of the protective scale. Fine-grained microstructures promote faster initial oxidation but may improve oxide layer uniformity, while coarser or columnar structures tend to provide better long-term stability. These findings confirm that, with appropriate microstructural optimization, MAR-M247 is well suited for demanding high-temperature applications such as turbine components.

5. References

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