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Nickel-based superalloys for advanced turbine engines

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Abstract – Nickel base superalloys are widely used for high temperature applications, such as aerospace engines and industrial gas turbines. While the operating conditions and structural requirements are different, in both cases increasing the operating temperature will increase efficiency and lower costs. Therefore, in order to develop and optimize application-appropriate superalloys, an understanding of how their structure, properties, and performance relate is necessary. This talk will discuss the different operating requirements and present current research on aerospace turbine blades. The effect of temperature and microstructure on crack initiation and propagation during cyclic testing will be discussed.

Ni-based superalloys are used in the aircraft engine industry because of their excellent high temperature properties, which include good ductility, oxidation and hot corrosion resistance, and microstructural stability [1] . They are used in the hottest sections of the turbine engines for both disk and blade applications. Most Ni-based superalloys are comprised of two phases: the matrix phase, γ, and the ordered $L1_2$ phase, γ', which forms as precipitates. The γ' strengthening causes Ni-based superalloys to have high strength even at high temperatures, making them favorable for turbine components.

Previous research on Ni-based superalloys is a useful starting point for superalloys that are to be used in industrial systems. Main differences to consider are the variations in size, operating temperature, and lifetime of the components. For aerospace turbines, a main concern is increasingly higher operating temperatures in an effort to improve efficiency and reduce fuel consumption. In the case of industrial turbines, a more corrosive operating environment results in a smaller selection of acceptable superalloys. In both cases, the correct design will address these differences and boost the performance and efficiency of the advanced turbine system [2].

In current work, we characterize Ni-based superalloys under various cyclic loading conditions in order to gain a comprehensive understanding of their fatigue and creep-fatigue behavior. Creep-fatigue studies in a second generation monocrystalline Ni-base superalloy, as well as low cycle fatigue studies in a third generation polycrystalline powder metallurgy Ni-base superalloy were used to investigate the variation in crack initiation with temperature and load. SEM and TEM analysis indicates that the addition of cyclic loading at high temperatures inhibits the reorganization of γ' in comparison with the "rafted" structure observed under monotonic creep conditions. Fatigue crack growth studies in the monocrystalline superalloy have focused on the effect of temperature on crack propagation. Higher temperatures result in a significantly smoother crack path (Figure 1), and a concomitant increase in crack growth rates (Figure 2).

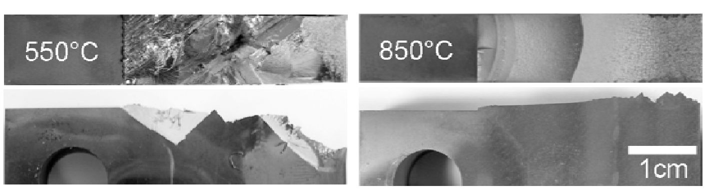

Figure 1: Fractography of fatigue crack growth specimens tested 550˚C (left) and 850˚C (right). Top- view parallel to loading direction. Bottom- profile of crack path.

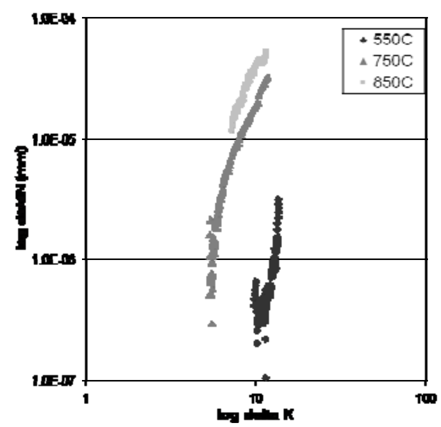

Figure 2: Fatigue crack growth test results with varying temperature. Tests conducted at 10Hz, R=0.1, and in vacuum.

References

[1] R. W. Fawley. Superalloy Progress: in The Superalloys, C. T. Sims, W. C. Hagel (Eds.). John Wiley & Sons: New York, 1972. p.20.
[2] Brij B. Seth. Superalloys- the Utility Gas Turbine Perspective in Superalloys 2000, Pollock, Kissinger, Bowman, Green, McLean, Olson, Schirra (Eds.) The Minerals, Metals & Materials Society: New York, 2000. p.3.