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Qualification of Ni-Base Superalloys for Hot Gas Duct of VHTR

Dae Whan Kim, Chang Hee Han, Woo-Seog Ryu
Nuclear Materials Technology and Development Div., Korea Atomic Energy Research Institute,
P.O. Box 105, Yuseong, Daejeon, 305-600,
dwkim1@kaeri.re.kr

1. Introduction

Hot gad duct of VHTR is operated at 950℃. Ni based superalloys for hot gas duct have been candidate in other country such as Hastelloy X for Japan, Alloy 617 for USA, and Haynes 230 for France because of good strength and corrosion properties at high temperature. Mechanical properties of these alloys are tested and compared with ASME design Code to apply to hot gas duct of VHTR.

2. Experimental procedure

Superalloys for test are commercial Hastelloy-X, Alloy 617, Haynes 230. Chemical compositions of alloys are satisfactory to ASME range. Tensile tests were conducted at RT-1000℃ and strain rate was $2x10^{-3}$/s. Tensile test specimen was 2mm thick, 6.25 mm width, 25 mm gauge length.

LCF tests were conducted at 900℃ and strain rate was $2x10^{-3}$/s under strain control. Fatigue specimens was 7 mm diameter and 8mm gauge length. Waveform was triangular and fully reversed. Fatigue life was defined as 25% reduction of tensile peak stress.

All tests was conducted at air environment. Test temperature was maintained constant within ±2℃ during the period of the test.

3. Results

3.1. Tensile properties

Tensile strength and elongation are show in Fig. 1. Yield stresses of Hastelloy X and Alloy 617 are not greatly different but that of Haynes 230 is higher than other alloys. Elongations of all alloys are almost same up to 800℃ but that of Haynes 230 is the worst above 900℃. Yield stresses of all alloys are decreased slowly up to 700℃, almost same to 900℃, and drastically decreased above 900℃. Elongations of all alloys are almost same up to 700℃ and increased greatly above 700℃. Yield stresses of alloys are higher than ASME draft Code Alloy 617 at all temperature range.

Serrations were shown in 300-800℃ temperature range. Serration is a evidence for DSA. Elongation was not increased in the temperature range which DSA was occurred but increased at above 900℃ which DSA did not occur. Temperature range of Hastelloy-X for DSA is lower than those of Alloy 617 and Haynes 230.

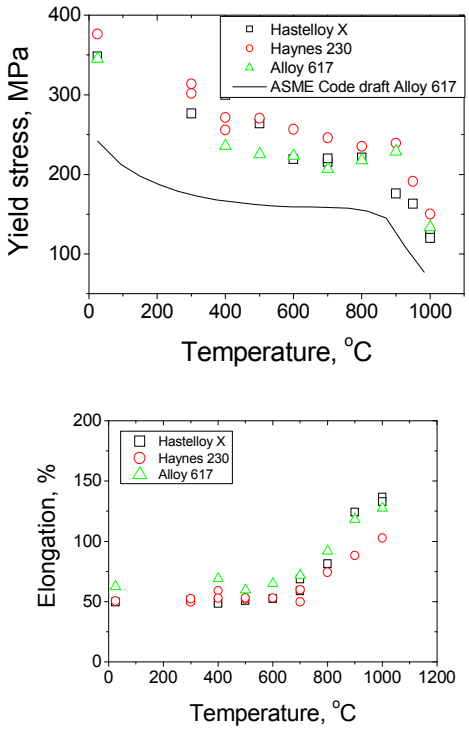

Fig. 1. Tensile properties of alloys with temperature.

3.2. Stress relaxation at 950℃

Stress relaxation behaviors of alloys are shown in Fig. 2. Stress relaxation of Alloy 617 was higher than other alloys. Stress relaxation of Hastelloy X and Haynes 230 was almost same. Stress relaxation was decreased with the increase of displacement, which is different from stainless steel.

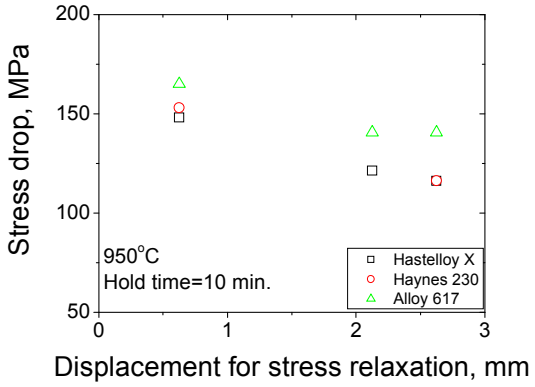

Fig. 2. Stress relaxation of alloys at 950℃

3.3. LCF properties at 900℃

LCF life was shown in Fig. 3. LCF life of Hastelloy X was higher than other alloys. LCF lives of Alloy 617 and Hayens 230 were almost same. All alloys are safer than ASME draft Code Alloy 617 design curve.

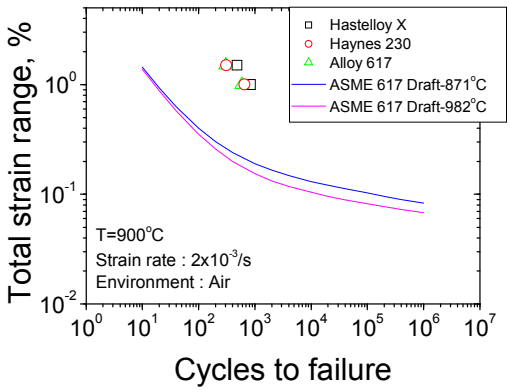

Fig. 3. LCF life of alloys at 900℃

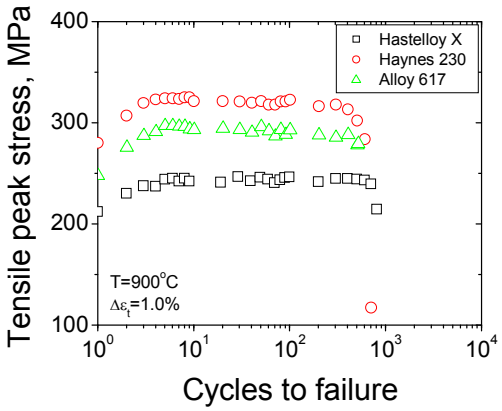

Fig. 4. Tensile peak stress of each alloy

LCF tensile peak stress was shown in Fig. 4. Tensile peak stress of Haynes stress is the highest. And Alloy 617 is higher than Hastelloy X, Hastelloy X is the lowest. Hardening at an early stage was shown in all alloys although DSA was not detected at 900℃, saturated, and failed.

From observation of fracture surface, striation was not clearly observed at each alloy. Failure was started at surface and propagated to inner direction.

4. Conclusion

Yield stress of Haynes 230 is the highest and those of Hastelloy-X and Alloy 617 are almost same. Elongation of Haynes 230 was the worst above 900℃. The temperature range for serration was 300-800℃.

LCF life of Hastelloy X is the best but tensile peak stress is the lowest.

Acknowledgement

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