R&D of fuel cladding of ODS ferritic steel for maintaining fuel integrity at accidental high temperature condition (2)

(5) Order phase formation due to 8-15 wt.% Al addition in Fe-Cr-Al ferritic steels

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Abstract

The embrittlement issue associated with the formation of Fe-Al ordered intermetallic phases has been investigated in Fe-Cr-Al ODS ferritic steels. Fe-(12-17)Cr-(8-15)Al-0.5Ti-0.5Y_2O_3 (wt.%) ODS ferritic steels were produced through powder metallurgical route followed by hot rolling and their microstructural stability and mechanical property have been evaluated after ageing at 475ºC up to 1000 h.

Keywords: ODS steels, Cladding tube material, Microstructural stability, Embrittlement

1. Introduction

Fe-Cr-Al advanced ODS steels are considered to be one of the promising candidates for accident tolerant fuel cladding material for light water reactors. Besides improving corrosion and oxidation resistance, when Al is added in large quantity, it is reported to suppress the 475ºC embrittlement associated with the decomposition of ferrite phase in high Cr (>12 wt.%) ferritic steels [1]. However, addition of higher Al enhances the chances of Fe-Al ordered intermetallic precipitation. Therefore, the aim of this study was to comprehend the microstructural stability and embrittlement behaviour of high Al (>8 wt.%) containing Fe-Cr-Al steels and define a safe limit for Al so that the loss of ductility arising due to ordered intermetallic precipitation can be limited.

2. Experimental

Fe-(12-17)Cr-(8-15)Al-0.5Ti-0.5Y_2O_3 (wt%) ODS ferritic steels with varying Cr and Al content were produced through powder metallurgy route using mechanical alloying and spark plasma sintering (SPS). The SPSed materials were further hot rolled at 1150ºC and finally annealed at 1150ºC for 30 min. These annealed materials were further aged at 475ºC up to 1000 h. to precipitate out the Fe-Al ordered intermetallics. The effect of embrittlement associated the ordered phase precipitation was evaluated by Vicker's micro hardness measurement. The microstructural stability was studied using X-ray diffraction, scanning and transmission electron microscopies.

3. Results

The starting microstructure of the steels containing up to 10% Al is mainly composed of ferrite phase, within which nano-dispersed oxide particles are embedded. However, steels having >12% Al, shows the presence of Fe_3Al phase in their starting microstructure. Ageing at 475ºC resulted in formation of Fe_3Al phase even in steels containing 9% Al although the amount was very little. The hardness measurements revealed that there is very limited increase in hardness even after 1000 h ageing when the amount of Al in these steels is restricted to <12%. The maximum increase in hardness is achieved after 100 h ageing, thereafter either it decreases or saturates.

4. Conclusion

Based on the observations made in this study, the maximum amount of Al which can be safely added to Fe-Cr-Al ferritic steel may be restricted to 9 wt.%.

References

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