DEVELOPMENT OF OXIDE DISPERSION STRENGTHENED FERRITIC STEELS FOR FUSION -

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OBJECTIVE

The objective of this research is to develop low activation oxide dispersion strengthened fully ferritic steels for first wall applications in a fusion power system.

SUMMARY

Uniaxial tension creep response is reported for an oxide dispersion strengthened (ODS) steel, Fe-13.5Cr-2W-0.5Ti-0.25 Y_2O_3 (in weight percent) manufactured using the mechanical alloying process. Acceptable creep response is obtained at 900°C.

PROGRESS AND STATUS

Introduction

An ODS ferritic steel has been developed in order to optimize this class of materials for first wall applications of a fusion power system.[1] This was accomplished by developing an alloy composition to be in line with low activation criteria, but with the minimum chromium content to insure fully delta-ferrite stability. The alloy composition selected was Fe-13.5Cr-2W-0.5Ti-0.25Y_2O_3. The objective of the present investigation was to determine the creep response of the ODS alloy in order to demonstrate its potential for high temperature applications.

Experimental Procedure

A SATEC creep frame, with 20:1 lever arm, was used for creep testing. A schematic of the test stand used for creep testing is shown in Figure 1. The test specimen was connected to the balance beam through the load train, a system of pull rods and couplings manufactured from alloy Inconel 718. A knife edge alignment coupling was used in the load train to facilitate self-alignment. The specimen was heated in a three zone tubular split furnace in an inert atmosphere chamber to prevent oxidation of the specimen. The inert atmosphere chamber was made of an Al_2O_3 retort which was sealed at both ends by stainless steel end caps with a metal bellows at the top cap. Strain was measured using an extensometer attached to a Linear Variable Differential Transformer (LVDT) located away from the high temperature zone. The mechanical linkages, attached to the specimen were also made of Inconel 718.

Specimens were made from two batches of rod material described previously as samples 1 and 2.[1] Specimens were 1.50 inches long, with a gauge section 1.020 inches long and 0.170 inches in diameter, with grip sections 0.250 inches in diameter. Specimen temperature was continuously monitored during heat up and throughout the test with two type-K thermocouples, one attached at the top and the other at the bottom of the specimen gauge length. The temperature gradient between the top and bottom of the specimen was minimized during the test, and did not exceed 2°C. The average specimen

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temperature was maintained to within ±20°C of the desired test temperature for the duration of the test.

The specimen was loaded in the creep frame and the extensometer was attached tightly. The Al_2O_3 retort was then inserted and sealed with the endcaps. The endcaps were then attached to the hose supplying coolant to keep the endcaps cool during creep testing. Argon gas was used to create an inert atmosphere environment inside the retort. The specimens were heated to the desired test temperature in 2-4 h and then were held for about 1 h at the test temperature to equilibrate and stabilize the specimen temperature. Predetermined loads were then applied.

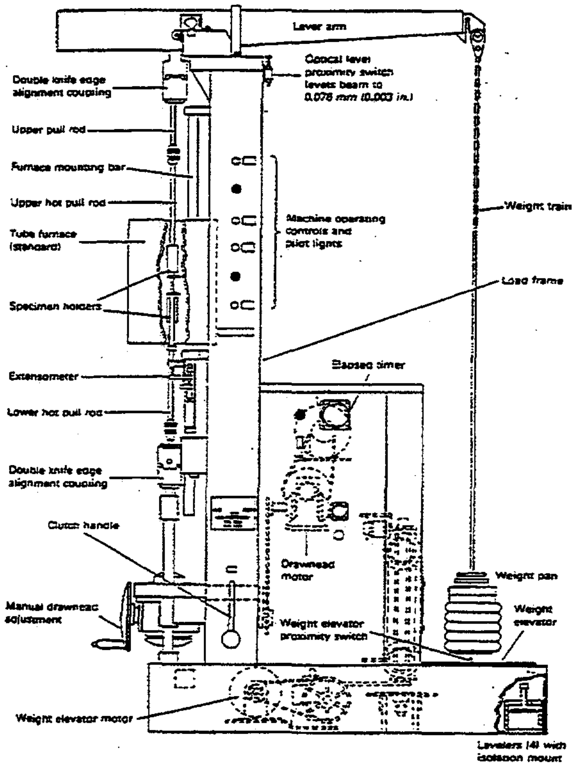

Figure 1 Schematic of the SATEC creep frame.

<u>Results</u>

Creep Test Results

Specimens were tested in argon at 650°C and 900°C at stresses ranging from 90 MPa to 350 MPa with specimens being tested to failure in all cases. Table 1 provides test parameters, elongation and rupture time for each specimen.

Table 1: Creep test parameters and test results

Sample No.	Test No.	Stress (MPa)	Temperature (°C)	Elongation (%)	Rupture Time (h)
#1	1	90	900	36	520
	2	150	900	25	22
#2	3	150	900	10	2
	4	350	650	6	14

Figures 2 and 3 show creep plots of strain vs. time for two test specimens from sample # 1. About 36% strain was observed during creep test No. 1 which failed after 520 h (Figure 2). Creep test no. 2 which lasted 22 h (Figure 3), however, showed 25 % strain before failure. Figures 4 and 5 show the plots of creep strain vs. time for two test specimens from sample # 2. Creep test no. 3 which lasted for about 2 h (Figure 57) showed only 10 % elongation. Creep test no. 4 which lasted for about 14 h showed only 6 % elongation before failure.

Fractography of creep specimens after failure

Scanning electron microscopy (SEM) examination demonstrated necking during creep rupture testing of sample # 1/test # 1 at 900°C, 90 MPa. The necking clearly indicated good ductility for sample # 1. However, SEM examination of sample # 2/test # 1 showed no necking during creep rupture testing at 900°C, 150 MPa, which confirmed the reduced ductility for sample # 2.

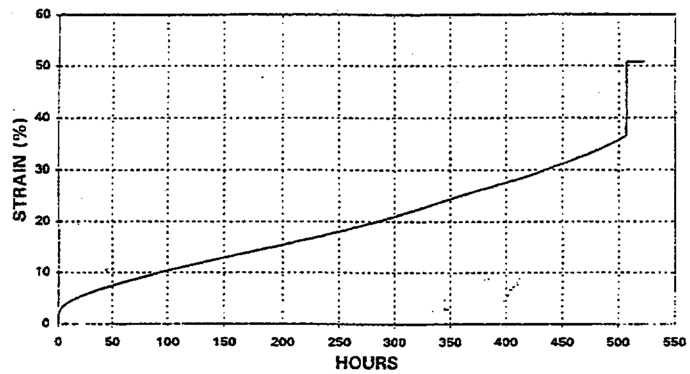

Figure 2 Creep Strain Versus Time in Sample #1 at 900°C and 90 MPa.

Discussion

The creep test performed on sample # 1 at 900°C at 90 MPa indicates a 520 h rupture life with an elongation of 36% before failure (Figure 2). Therefore, good strength and ductility can be obtained in this class of alloys at high temperature. Comparison of the creep rupture results between sample # 1 and sample # 2 indicates that the creep ductility in sample # 2 is much lower than that observed in sample # 1. This may be due to the presence of higher levels of oxygen and nitrogen in sample # 2 which may decrease the ductility of the alloy. Analyses of the powders for the sample materials are given in Table 2.[2]

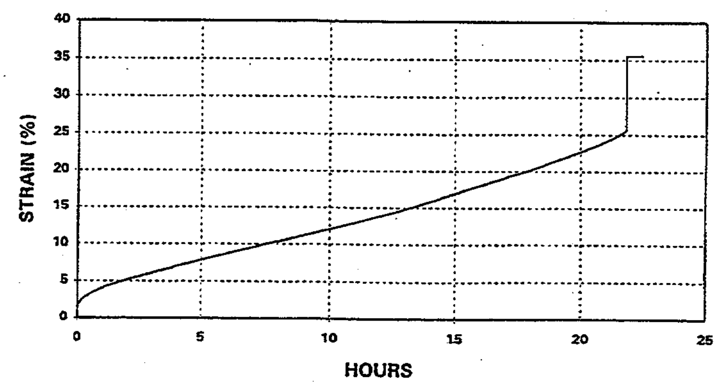

Figure 3 Creep Strain Versus Time in Sample #1 at 900°C and 150 MPa.

Nitrogen additions can cause strengthening due to nitride formation. However, nitrogen should be discouraged due to long lived radioactive isotope production. Our results indicate that nitrogen additions decrease the time to rupture and ductility. Therefore minimum levels of nitrogen are recommended.

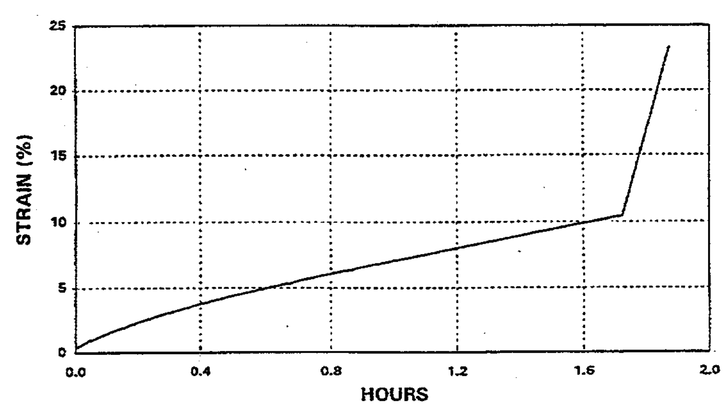

Figure 4 Creep Strain Versus Time in Sample #2 at 900°C and 150 MPa.

The merit of the new low activation ODS alloy can be demonstrated using a Larson-Miller plot. Figure 6, a Larson-Miller plot of stress rupture data plotting rupture stress as a function of temperature and time to rupture shows a summary of creep rupture values of the present ODS alloy (sample # 1 and sample # 2), MA 957,[3] MA 956,[4] two similar ODS steels developed in Japan by Asabe[5] and Ukai,[6] a Belgian ODS steel,[7] and HT-9

Table 2. Interstitial element analysis (in wt%) of the powders before consolidation.

Sample No.	Condition	Carbon	Oxygen	Nitrogen
#1	10h SPEX milled	0.055	0.84	0.281
#2	50h attritor + 10h SPEX milled	0.070	1.24	0.404
#3	25h attritor milled	0.084	1.33	0.078

martensitic steel.[8] From this it can be seen that despite limited data, the new low activation alloy compares favorably with similar ODS ferritic alloys MA956 and MA957, which are far superior to martensitic steels.

The plot indicates a higher stress rupture value of sample # 1 than that of sample # 2 and that may be due to the higher interstitial content in sample # 2. The creep resistance of both MA956 and MA957 were lower than that of sample # 1 and sample # 2. The Larson-Miller plot also indicates that the creep resistance of martensitic steel is much lower than that of sample # 1 and sample # 2. The very fine and uniform dispersion is mainly responsible for the superior creep resistance of the present ODS alloy.

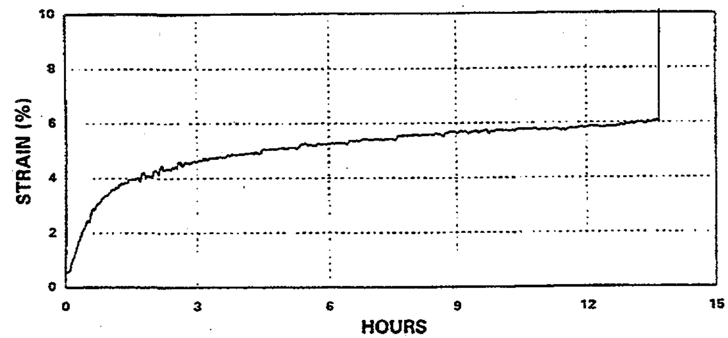

Figure 5 Creep Strain Versus Time in Sample #2 at 650°C and 350 MPa.

CONCLUSIONS

An optimized low activation grade ODS ferritic steel of composition (Fe-13.5Cr-2W-0.5Ti-0.25Y_2O_3) has been tested in uniaxial creep in order to provide comparison with similar composition. Results of tests at 900°C demonstrate that this alloy has creep properties similar other alloys of similar design and can be considered for use in high temperature fusion power system designs.

FUTURE WORK

This work is completed.

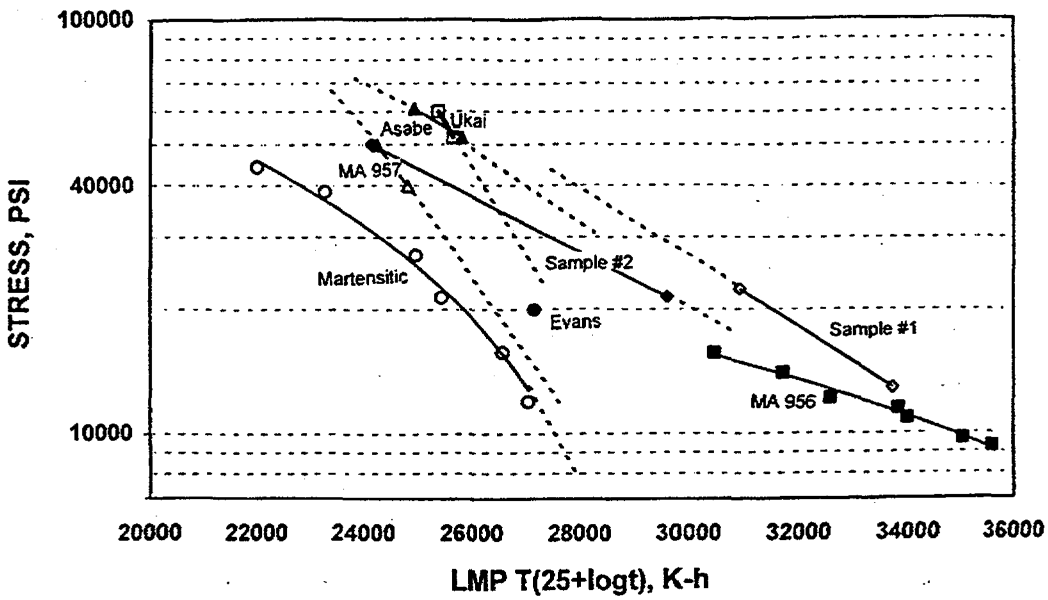

Figure 6 Larson-Miller Plot Comparing the Creep Strength of the new ODS Ferritic Steel with those of Similar Steels.

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