§5. Development of Reduced Activation Ferritic Steels with Improved Heat Resistance and Elemental Property Characterization for High Cycle Efficiency Steel-Based Blankets

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Reduced Activation Ferritic/Martensitic steels (RAFs) are leading candidates for structural materials of D-T fusion reactors. RAFs have great interest to simplify the special waste storage of the highly radioactive blanket and first-wall structures from fusion reactors after service. One of the RAFs, JLF-1 (9Cr-2W-V, Ta), has been developed and proven to have good resistance against high-fluence neutron irradiation and good phase stability.

Recently, in order to achieve better energy conversion efficiency by using RAFs at higher temperatures in advanced blanket systems, improvement of high temperature mechanical properties is desired. For examples, modification of chemical composition and developments of oxide dispersion strengthened steels (ODS steels) are performed. Among the strengthening mechanisms precipitation hardening is the most reliable in developing RAFs and other heat resistant steels. Precipitates carbo-nitrides of MX type particles, such as TaX (X=C, N), are usually extremely fine and stable for a long time at high temperatures. However, detailed effects of MX type particles on creep property are not known sufficiently.

Based on such back grounds, effects of increasing tantalum content on creep property of RAFs were studied in this work. Used materials are JLF-1 LN+B and JLF-1 LN+BTa. These steels were prepared to improve high temperature mechanical properties by reducing nitrogen content, adding boron and increasing tantalum content. Fig. 1 shows creep rupture test results performed at 923 K. With increasing tantalum content, creep rupture time decreased and intended developments of creep property were not obtained. It is well known that such microstructures weaken creep properties. These cavity formations during creep rupture test are shown in Fig. 2. The decrease of creep rupture time was cause by the increase in mean cavity density, and the growth of the creep cavities initiate from near $M_{23}C_6$ carbides on prior austenite grain boundaries (Fig. 3). The strengthening of the matrix cannot be achieved by a dispersion of TaX particles. The increased tantalum content caused a decrease of creep rupture time as a consequence of a growth of $M_{23}C_6$ carbides. The optimizing of the heat treatments may cause the strengthening of the matrix by TaX particles.

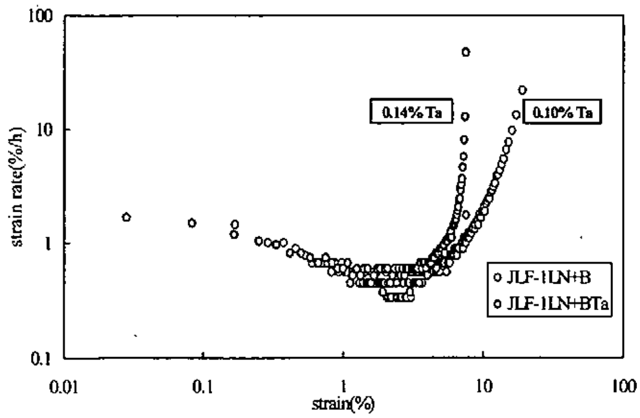
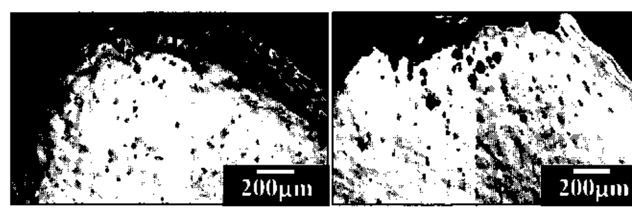
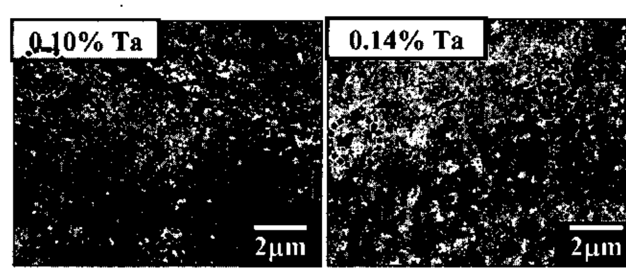


Fig. 1. Creep rupture test results (150MPa-923 K)



(*a*) JLF-1 LN+B (*b*) JLF-1 LN+BTa

Fig.2. Cavities in creep ruptured specimens.



(*a*) JLF-1 LN+B (*b*) JLF-1 LN+BTa

Fig. 3. Creep cavities near $M_{23}C_6$ carbides on prior austenite grain boundaries.

Table 1. Chemical compositions and heat treatments.

		C	N	Cr	W	V	Ta	Mn	Si	P	S	Fe
JLF-1	**IEA-HEAT**	0.0970	0.0237	9.04	1.97	0.19	**0.070**	0.460	<0.1	0.003	0.002	Bal.
	LN-B	0.0970	0.0150	8.99	2.01	0.20	**0.100**	0.500	0.049	<0.002	0.004	Bal.
	LN-BTa	0.0960	0.0151	8.97	2.01	0.20	**0.140**	0.490	0.050	<0.002	0.007	Bal.

Normalized at 1323 K x 3.6 ks followed to air-cooling
Tempered at 1053 K x 3.6 ks followed to air-cooling