

Mod. 9Cr1Mo

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Effects of hardness values on the creep rupture strength in a Mod. 9Cr1Mo Steel

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Key Words : Mod.9Cr1Mo steel(Mod.9Cr1Mo), Creep Rupture Strength(), Hardness(), Microstructure(), Allowable stresses()

Abstract

The Modified 9Cr-1Mo steel identified as T91, P91 and F91 in the ASME specification has been widely used for the construction of modern power plants. The available data on the influence of process parameters during manufacturing and fabrication on its properties are not sufficient. In this study, the influence of various thermal cycles on the hardness and the creep rupture strength was analyzed in the base metal and the weldments made in tube and pipe of a Mod.9Cr-1Mo steel. The low hardness, 155Hv, showed low creep rupture strength below the allowable stresses of T91 base metal in the ASME specification. This low value was attributed to the fully recovered dislocation structure and the weakening of precipitation hardening associated with the abnormal thermal cycles.

1. Mod.9Cr1Mo Cr 9% Cr-Mo 70 ORNL CE 社가 ASME 80 9% Cr X20CrMoV12.1 12% 650°C (HRSG) Mod.9Cr1Mo (SA-213 T91), 1Mo 가 Mod.9Cr (SA-335 P91), Plate(SA-387 91 C12), Forging(SA-182 F91), Casting (Code Case 2192-1, SA-217, SA-426 WC) [1-2]. Mod.9Cr1Mo 가 Mill maker (Normalizing) + (Tempering), (, , Swaging,) X20CrMoV12.1 12Cr (,)

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*

1Mo

Mod.9Cr

ASME (max. 265Hv) Mod.9Cr1Mo 가 가 Mod.9Cr1Mo 가 가 Mod.9Cr1Mo 가 가 ASME Mod.9Cr1Mo 가 가 Kawasaki Steel Co., / (T91) Sumitomo Metal Ind., Ltd.(SMI) (P91) ASME Table1, 2

Table 1. Chemical composition of Mod.9Cr1Mo steel

Element	ASME T/P91	ASME T9	Sample 1 ¹⁾	Sample 2 ²⁾
C	0.08-0.12	< 0.15	0.09	0.09-0.11
Si	0.20-0.50	0.25-1.00	0.28	0.38-0.43
Mn	0.30-0.60	0.30-0.60	0.37	0.38-0.40
P	< 0.020	< 0.025	0.014	0.018
S	< 0.010	< 0.025	0.005	0.002
Ni	< 0.40	-	0.05	0.08-0.10
Cr	8.00-9.50	8.00-10.00	8.43	8.46-8.51
Mo	0.85-1.05	0.90-1.10	0.92	0.91-0.92
V	0.18-0.25	-	0.19	0.190-0.193
Nb	0.06-0.10	-	0.08	0.072-0.073
N	0.030-0.070	-	0.049	0.037-0.042
Ti	-	-	0.007	-
Al	< 0.04	-	0.014	0.001

1) Kawasaki Steel Co., 2) SMI

Table 2. Mechanical properties and heat treatment condition of Mod.9Cr1Mo steel

Classification	Mechanical properties				Heat treatment condition			
	T.S (Mpa)	Y.S (Mpa)	El. (%)	Hardness (Hv)	Normalizing (°C)	Tempering (°C)	PWHT ¹⁾ (°C)	PFHT ²⁾ (°C)
ASME	> 585	> 415	> 20	177-265	> 1040	> 730	> 705	-
DIN	620-850	> 450	> 19	> 190	1040-1090	730-760	720-760	650-700
BS	630-830	> 450	> 19	> 193	1040-1090	730-790	-	-
Sample 1	673-701	551-568	36-41	216-227	1050	785	-	-
Sample 2	679	538	38-39	225	1045	780	-	-

1) PWHT : Post Welding Heat Treatment, 2) PFHT : Post Forming Heat Treatment

Mod.9Cr1Mo

Ac1 850°C~1070°
 30~50°C 550°C~Ac3 900°C
 1 100

(5kg)

Vilella

(SEM)
 180Hv
 (二相)

Ac1~Ac3

Ac1 φ6.25mm 가
 600°C

180~85MPa

(TEM)

3.

3.1

Mod.9Cr1Mo +
 100%

Mod.9Cr1Mo

가

3.1.1

Mod.9Cr1Mo

Table 2

ASME DIN
 1040°C

ASME

DIN/BS

1090°C

1120°C

Mod.9Cr1Mo

가

[3].

Mill maker

1050°C

Fig. 1

1050°C
 100%
 850°C

Nb(C,N)
 , Ac1

920°C

가 , 920°C~1070°C

(Over tempering)

400~430Hv 가 Fig. 2

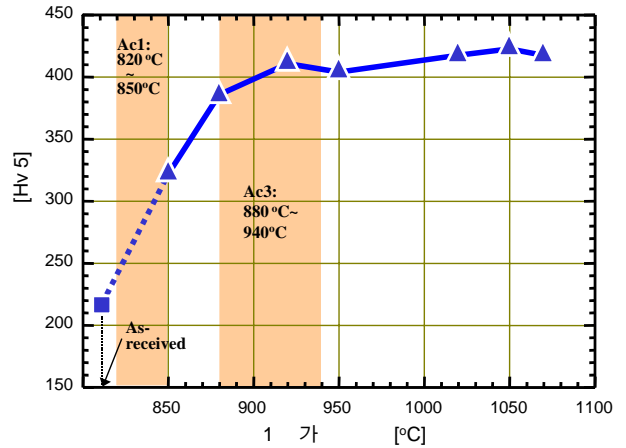


Fig. 1 Variation of hardness with normalizing temperature in a Mod.9Cr1Mo steel

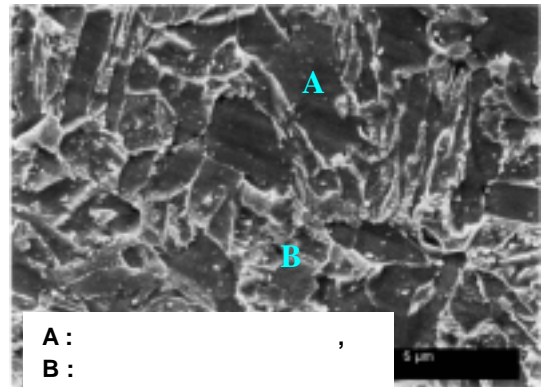
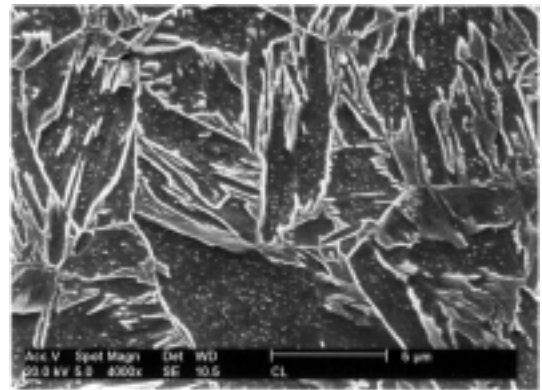


Fig. 2 Variation of SEM microstructure with normalizing temperature in a Mod.9Cr1Mo steel
 a) 1050°C Normalizing, b) 850°C Normalizing

가
Ac1~Ac3
(Lever rule)
가 가
가
3.1.2
Fig. 3 1050°C 850°C
550°C 900°C
1
1050°C

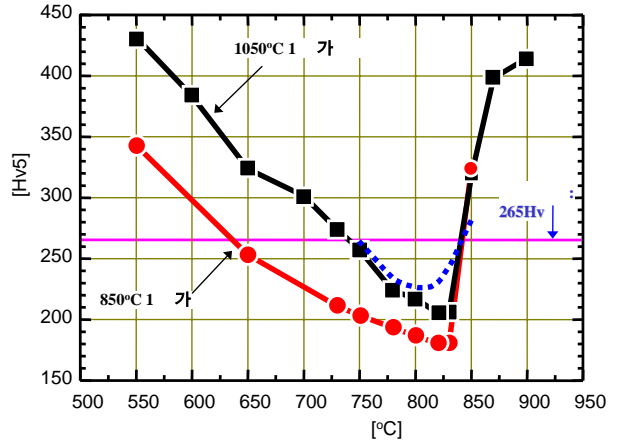
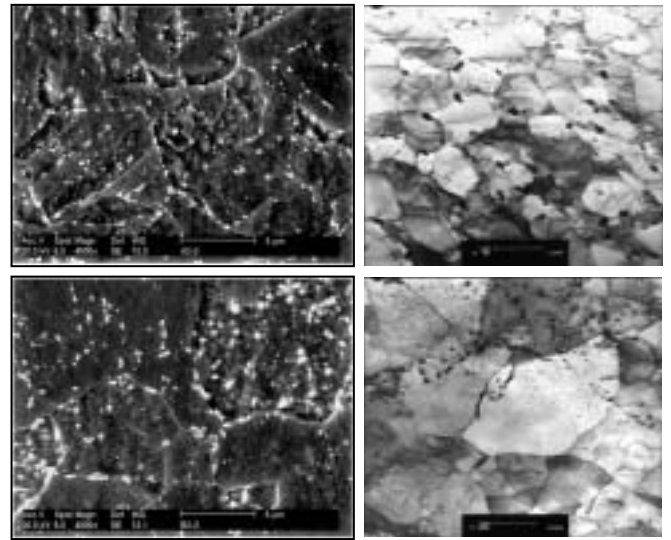


Fig. 3 Variation of hardness with tempering

550°C
2
as normaling
가 . 가 가
Ac1 830°C
가 . Ac1
가 가 . ASME
265Hv
750°C~800°C
850°C 1
가 , 1050°C 1
1050°C Ac1 830°C
200Hv
850°C 830°C
170Hv



temperature in a Mod.9Cr1Mo steel

Fig. 4(a) 1050°C + 780°C
210Hv 가 Mod.9Cr1Mo
가
가
820°C 850°C
Fig. 4(b)
가 +
170Hv
Mod.9Cr1Mo

Fig. 4 Variation of microstructure with tempering temperature in a Mod.9Cr1Mo steel
a) 1050°C (N) + 780°C (T), Hardness = 210Hv
b) 850°C (N) + 820°C (T), Hardness = 155Hv

Fig. 5
Ac1 820°C 100
. Ac1 (二相)

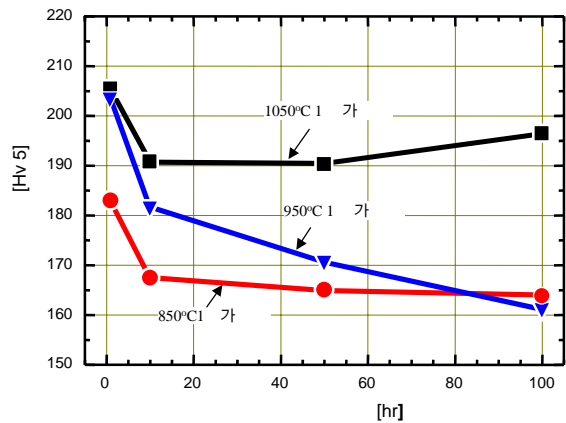


Fig. 5 Variation of hardness with hold time after tempering at 820°C in a Mod.9Cr1Mo steel

850°C 1
 170Hv , 950°C 50
 가 가 170Hv
 가 . 1050°C 1
 190Hv 가 .
 Mod. 9Cr1Mo
 (二相) Ac1~Ac3
 Ac1
 Mod.9Cr1Mo

가 , Swaging
 가 (二相)
 가 ,
 (二相) 가

3.2

Fig. 6 Mod.9Cr1Mo

ORNL [4], ASME
 [5] Standard 9Cr1Mo(T9)
 ASME
 ORNL data band
 ASME ASME
 67%
 210Hv 가 Mod.9Cr 1Mo
 ORNL data band
 ASME
 170~180Hv 가
 ORNL data band
 ASME
 170Hv 가
 ORNL data band
 ASME , V, Nb
 (V,Nb)(C,N) 가
 Standard 9Cr1Mo(T9)

Fig. 7

600°C, 140Mpa

210Hv 5000

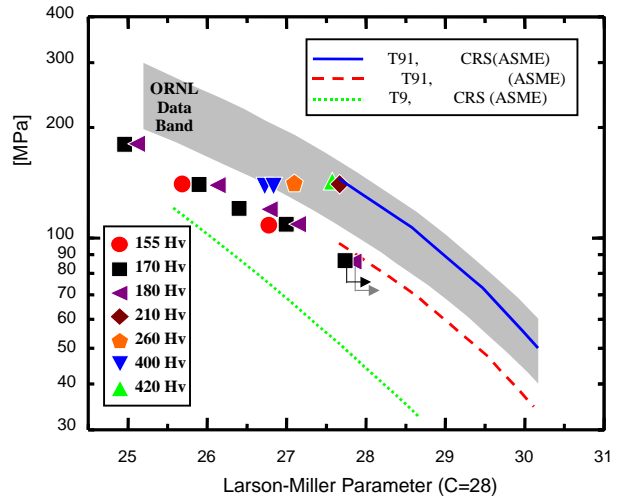


Fig. 6 Comparison of creep rupture strength at 600°C measured with Mod.9Cr1Mo steel

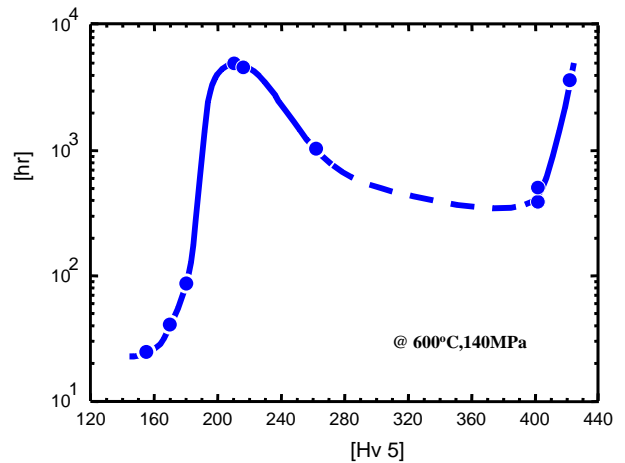


Fig. 7 Variation of creep rupture strength with hardness at 600°C and 140MPa in Mod.9Cr1Mo steel

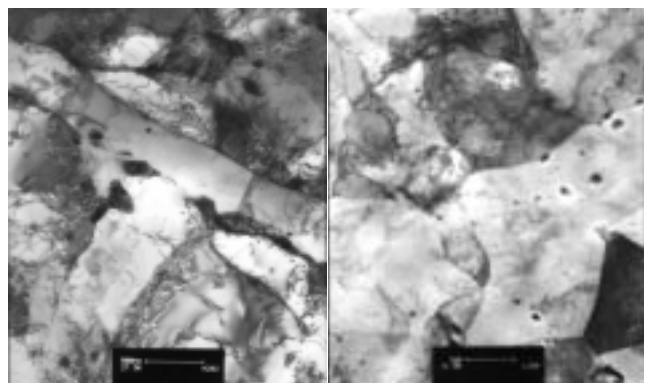


Fig. 8 Variation of microstructure after creep rupture at 600°C and 140Mpa in Mod.9Cr1Mo steel
 a) Normal hardness 210Hv, $t_r=5,002$ hrs
 b) Abnormal hardness 155Hv, $t_r=26$ hrs

100 , 180Hv
2%

Fig. 8 600°C 140Mpa

(TEM)
Mod.9Cr1Mo

가

1Mo 170Hv
가

4.

Mod.9Cr1Mo

4.1 Mod.9Cr1Mo (二相)
Ac1~Ac3 Ac1
180Hv

4.2

4.3 Mod.9Cr1Mo
가

4.4 170~180Hv Mod.9Cr1Mo
ASME

4.5 170Hv ASME
Standard 9Cr1Mo (T9)
가

4.6

4.7 180Hv Mod.9Cr1Mo

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