

가 K-

**Characteristics of K-Alloys
with the Small Changes of Alloying Elements**

(Zr-0.2Nb-1.1Sn Zr-0.4Nb-0.8Sn)
 Nb, Sn, Fe, Cr, Cu Mo, Mn 가 ,
 가 . 360 water Zr-0.2Nb-1.1Sn ,
 Zr-0.4Nb-0.8Sn 가 , 400 steam 360 LiOH
 Zr-0.2Nb-1.1Sn 가 ZIRLO
 가 Mo 가 , Zr-0.4Nb-0.8Sn Cu
 가 가 , 400 Cu
 가 Mo 가 Cu 가 Fe 가 0.3 % 가
 0.4 % 가 .

Abstract

The new developed alloys (Zr-0.2Nb-1.1Sn series alloys and Zr-0.4Nb-0.8Sn series alloys) for high burn-up fuel cladding were evaluated to investigate the effect of small change of alloying elements, including the Nb, Sn, Fe, Fe, Cr, Cu, Mo, Mn, on the microstructures, corrosion resistance, tensile strength, and creep rate. The corrosion resistance of Zr-0.2Nb-1.1Sn series alloys was similar to that of Zr-0.4Nb-0.8Sn series alloys in the 360 water condition, but Zr-0.2Nb-1.1Sn series alloys had slightly higher weight gain than Zr-0.4Nb-0.8Sn series alloys in both 360 LiOH and 400 steam conditions. And the corrosion resistance of this study showed superior to that of commercial ZIRLO cladding. Under the three corrosion conditions, the corrosion resistance of Cu containing alloy in Zr-0.2Nb-1.1Sn system was improved in the comparison with Mo containing alloy, and the corrosion resistance of Cu containing alloy in Zr-0.4Nb-0.8Sn system was most excellent. The effect of tensile strength in both conditions of room temperature and 400 was not observed with the small changes of alloying elements. The creep resistance of Mo containing alloy was better than that of Cu containing alloy and the creep resistance of 0.3 % Fe containing alloy was better than that of 0.4 % Fe containing alloy.

1.

3 8 600
 ingot ¹⁾. ingot 3000
 가 , 가
 가 가
 가 가
 10 Zr-0.2Nb-1.1Sn
 Zr-0.4Nb-0.8Sn Nb, Sn, Fe, Cr, Cu Mo, Mn 가
 TEM , (creep)
 , , 가 .

2.

가. Zr
 5 가 (57) 가 .
 sponge Zr 가 VAR(vacuum arc remelting) 400g button
 chamber Ar gas 1 × 10⁴ torr
 5 ingot
 1020 30 ,
 1mm stainless , 가
 quenching . - cladding ingot 590 30
 60 % cladding
 590 3
 HF 5 %, HNO₃ 45 %, H₂O 50 % (pickling) . 70 ton
 40 % 1 2 , 60 % 3 가
 , 1 2 가 570 2
 470 3 1mm .
 . TEM
 TEM 5 (Zr-0.2Nb-1.1Sn-Fe-Cu, Zr-0.2Nb-1.1Sn-Fe-Mo,

Zr-0.4Nb-0.8Sn-Fe-Cu, Zr-0.4Nb-0.8Sn-Fe-Mn, Zr-0.4Nb-0.8Sn-Fe-Cr-Cu)

. TEM 70 μm , 90% ethanol 10% perchloric acid twin-jet polishing, twin-jet polisher 가 1.2V -40, JEOL 200 keV TEM

. 가 가 10 x 20mm 2, Mash 1200 H₂O 30 %, HNO₃ 30 %, H₂SO₂ %, HF 10 %

360 water, 400 steam, 360 LiOH(70ppm) 300 . ASTM G2-81 static autoclave 가 가 , 가 2 .

. 가 , gauge length 25mm

ASTM E8 , INSTRON-4505(10ton) 400 . ASTM B352 cross head speed 0.125 mm/min , 1.25 mm/min . 400 ASTM E21

. 가 가 gauge length 가 25mm , ASTM 139-3 , 400 , 150 MPa 240 .

3.

가. 5 1 TEM . 5 가 1 . 5

(partially recrystallized structure)

. Zr-0.2Nb-1.1Sn series

(1)

Zr-0.2Nb-1.1Sn-Fe-Cu 360 water, 400 steam, 360 LiOH 3
가 가 2 360 water . 360 water
300 가

70 mg/dm2 가

가 . 180 가 .

400 steam 360 water

가 (3) 80 1 가

가 가가 . 1

가 가 가

240 2 . 360

LiOH 가 150 360

water 가 가 150

가 가 . 400 steam 가

가 가 . 400 steam 가

Zr-0.2Nb-1.1Sn-Fe-Mo

360 water 180 가 , Cu 가 가

가 Cu 가

400 steam Cu 가 가 Cu 가

60 . 360 LiOH 150 1 가, 270 2

가 Fe가 (0.3, 0.4 %) 가 Mo가 0.2 % 가

1

(2) 가

Zr-0.2Nb-1.1Sn-Fe-Cu Zr-0.2Nb-1.1Sn-Fe-Mo 360 , 400

360 LiOH Nb, Sn, Fe, Cu, Mo 가

. Zr-0.2Nb-1.1Sn-Fe-Cu Cu 가 Zr-0.2Nb-1.1Sn-Fe-

Mo Mo 가

● Nb 가

3 Cu 가 (a) Mo 가 (b) Nb

. 360 water Nb

360 LiOH Nb

0.05 3.0 가 . 400 steam

, 가 0.1 % Nb 가

가 가 .

- Sn 가
 Sn 가 Nb 가 가
 360 water Sn 가 , 400 steam Cu 가
 가 1.1 % , Mo 가 가 0.9 %
 . 360 LiOH 0.9 % Sn 가

- Fe 가
 360 water Cu, Mo 가 가 60 mg/dm² , Fe
 가
 Fe 가 0.3, 0.4 % 가 spalling . 1 (150
) spalling .

- Cu 가
 Cu 가 (Zr-0.2Nb-1.1Sn-Fe-Cu) Cu 가
 . 가 400 steam, 360 LiOH
 Cu 가 0.1wt.% 가 , 360 LiOH 0.2wt.%
 가

- Mo 가
 Mo 가 (Zr-0.2Nb-1.1Sn-Fe-Mo) Mo 360 water
 가 가 . 400 steam
 360 LiOH Mo 가
 , Mo 가 0.2 % 가 .
 400 steam Mo Cu 가 가 .

. Zr-0.4Nb-0.8Sn series

Zr-0.4Nb-0.8Sn-Fe-Cu 11 Zr-0.4Nb-0.8Sn-Fe-Mn 11 , Zr-
 0.4Nb-0.8Sn-Fe-Cr-Cu 13 360 , 400 360 LiOH
 300 . Zr-0.4Nb-0.8Sn-Fe-Cu Cu
 가 Zr-0.4Nb-0.8Sn-Fe-Mn Mn 가 , Zr-0.4Nb-0.8Sn-Fe-
 Cr-Cu Cr/Cu 가 .

(1)

Zr-0.4Nb-0.8Sn-Fe-Cu 360 water , Cu 가 0.05, 0.1 %
 가 가 150 Cu
 가 가 . 400 steam 가
 60 mg/dm² , 60 1 가
 가가 가 . 360 LiOH

가 40 mg/dm² 150 가 가

가

Zr-0.4Nb-0.8Sn-Fe-Mn 360 water Cu 가

. Cu 가 Cu

Mn 가 150 가 . 가

Mn 가 70 mg/dm² Cu 가 10 mg/dm²

. 400 steam 45 가

. Cu 가 , Cu 가

. 360 LiOH Cu 가

가 150 가 Cu 가 .

Zr-0.4Nb-0.8Sn-Fe-Cr-Cu 360 water Sn Cr

300

. Fe Cu

가 180

가 . Nb 180

가 Nb . 400 steam 가

80 가 . 360 water 가 Sn, Cr 가

Nb, Fe, Cu 가

가 . 360 LiOH (Cu, Mo

가) 가 150 가 .

(Sn). Sn 가 , Sn

가 가(0.9%) .

(2) 가

- Nb 가

360 water Cu, Mn 가 400 Mn 가 가 Nb

가 , 360 LiOH

Nb 가 .

Cr/Cu Nb 0.3 0.6wt.% 가

- Sn 가
- Sn 가 가 Sn
- 가

- Fe 가

Cu 가 Cr/Cu 가 3 가 Fe 가 0.2
 0.4% 가 가 , Cr/Cu 가 가 Cu
 가 Fe 가
 Mn 가 Fe 가
 400 steam Fe 가 가 가(0.4 %) Fe 가 가

● Cu 가
 Cu 가 (Zr-0.4Nb-0.8Sn-Fe-Cu) Cu
 . 360 water 400 steam Cu
 가 . 360 LiOH
 Cu 가 Zr-0.4Nb-0.8Sn-
 Fe-Cr-Cu 3 가 Cu

● Mn 가
 Zr-0.4Nb-0.8Sn-Fe-Mn Mn 360 water
 360 LiOH Mn . 400 steam
 Mn 0.05 0.2 % 가 가 0.3 %
 가

● Cr 가
 Zr-0.4Nb-0.8Sn-Fe-Cr-Cu Cr ,
 가 Cr . 360 water 가
 가

(1) Zr-0.2Nb-1.1Sn series

Zr-0.4Nb-0.8Sn 400 , Cu Mo
 가 (4). Sn

(2) Zr-0.4Nb-0.8Sn series

Zr , 가 ,
 . Zr-0.4Nb-0.8Sn 가
 가

(3)

가 가 가 Mo
 Cu 가 (5).
 Zr Cu Fe 가 가 Zr

Cu 가 Zr
 0.4Fe 가 0.3Fe 가
 Cu 가 Mn 가
 Fe 가 Cu 가 Zr

4.

- 1) Zr-0.2Nb-1.1Sn Zr-0.4Nb-0.8Sn 360 water
 가 , 400 steam Zr-0.4Nb-0.8Sn
 가 360 LiOH Zr-0.2Nb-1.1Sn
 가 ZIRLO
- 2) Zr-0.2Nb-1.1Sn-Fe-Cu Zr-0.2Nb-1.1Sn-Fe-Mo ,
 Cu 가 Mo 가
- 3) Zr-0.4Nb-0.8Sn-Fe-Cu Zr-0.4Nb-0.8Sn-Fe-Mn , Zr-0.4Nb-0.8Sn-Fe-Cr-Cu
 360 water Mn 가 가 가
 Cu 가 가 . 400 steam
 Cu 가 Cr/Cu 가 가 ,
 Mn 가 가 가 . 360 LiOH
 Cu 가 Mn 가 Cr/Cu 가
- 4) 400 가
- 5) Mo 가 Cu 가 , 0.4Fe 가
 0.3Fe 가 Cu 가 Mn 가

5.

- 1) / , KAERI/RR-2020/99,
 , (2000).

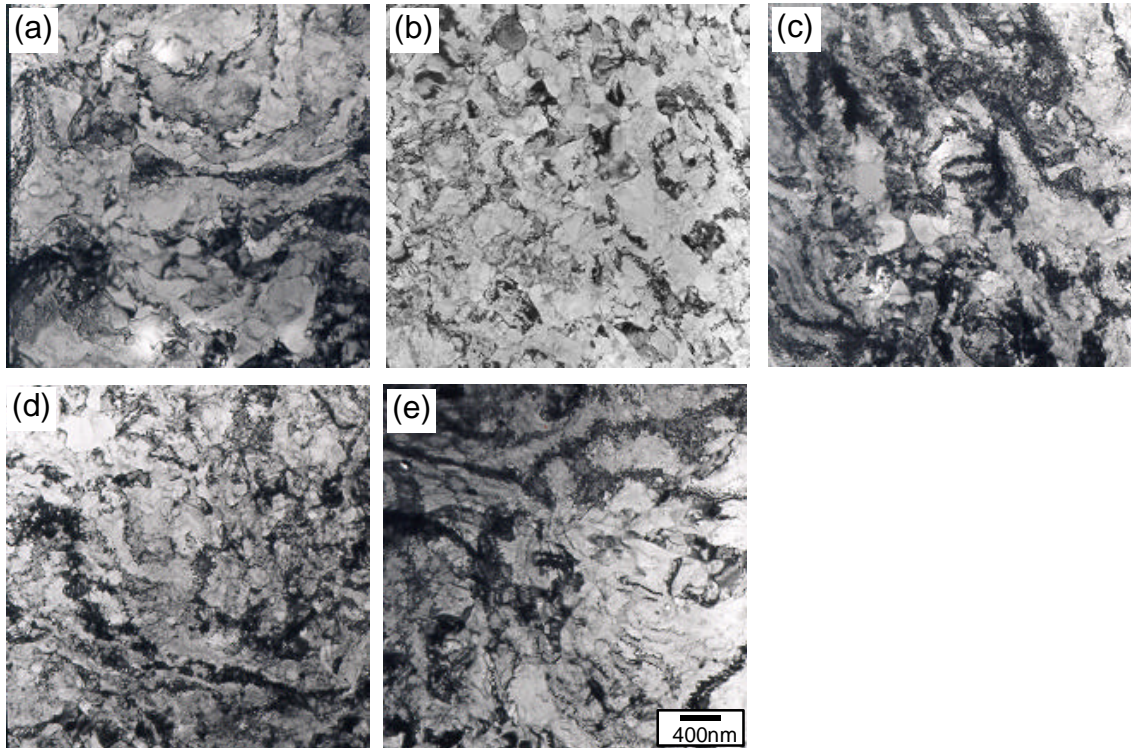


Fig. 1 TEM micrographs of new Zr alloys annealed at 470 °C for 3hr
(a) Zr-0.2Nb-1.1Sn-Fe-Cu, (b) Zr-0.2Nb-1.1Sn-Fe-Mo
(c) Zr-0.4Nb-0.8Sn-Fe-Cu, (d) Zr-0.4Nb-0.8Sn-Fe-Mn
(e) Zr-0.4Nb-0.8Sn-Fe-Cr-Cu

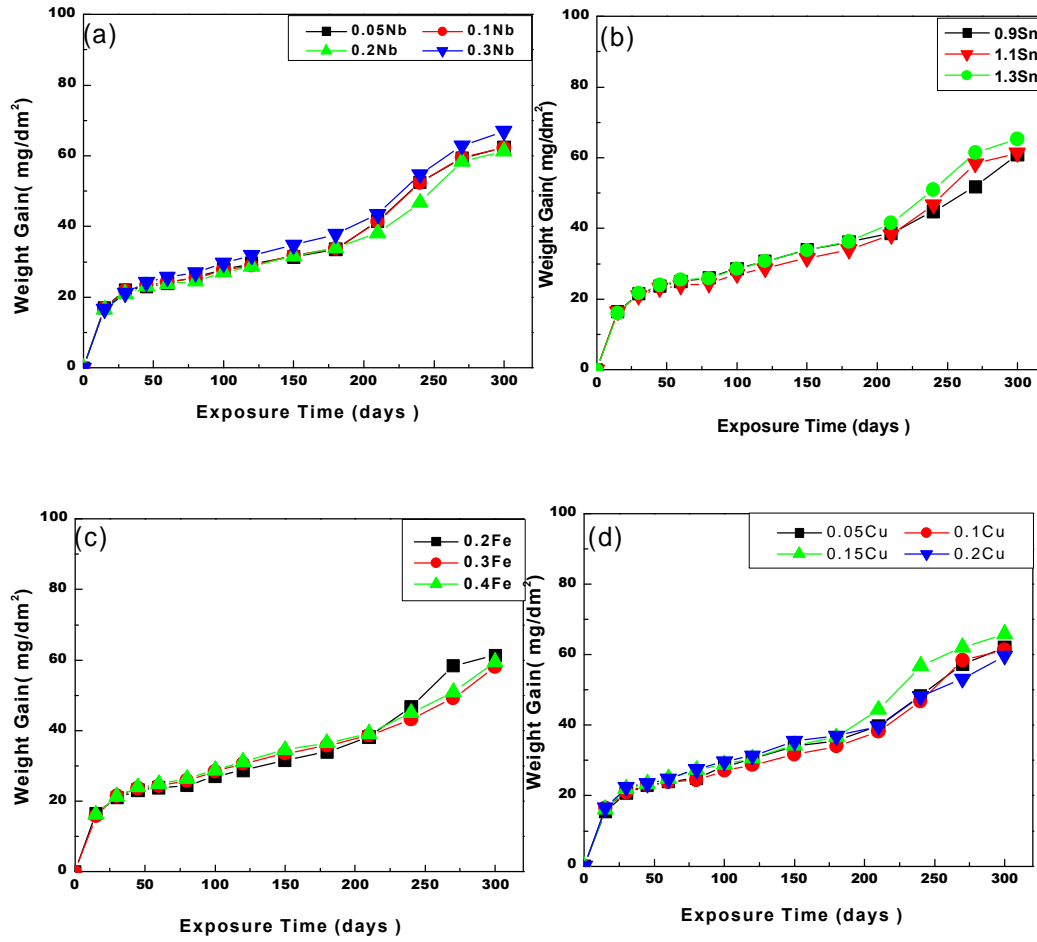


Fig. 2 Corrosion behaviors of new alloys in 360 water with variation of alloying elements ; (a) Nb, (b) Sn, (c) Fe, (d) Cu

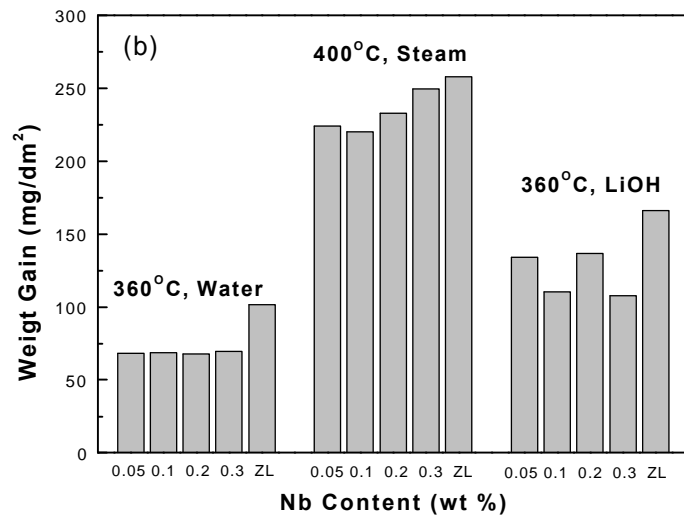
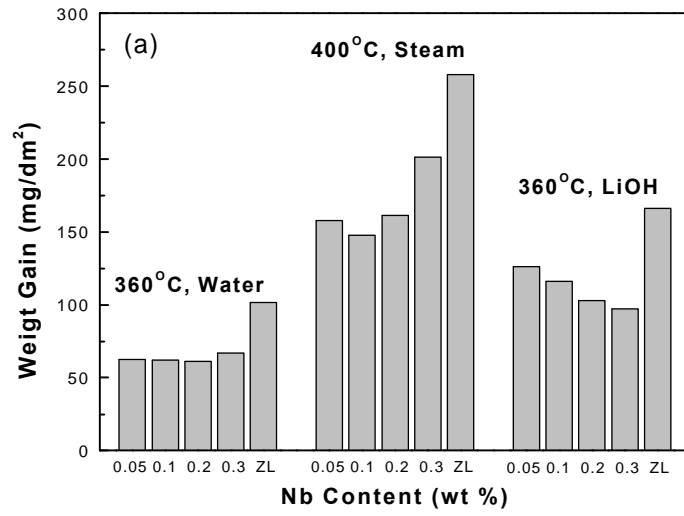


Fig. 3 Weight gain of new alloys for 300 days (ZL : Zirlo)
 (a) Zr-xNb-1.1Sn-Fe-Cu,
 (b) Zr-xNb-1.1Sn-Fe-Mo

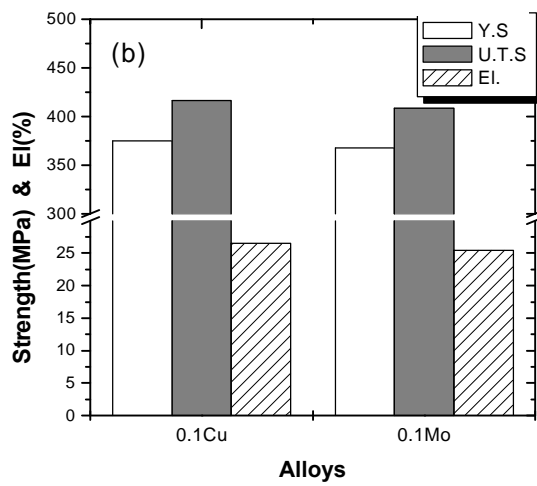
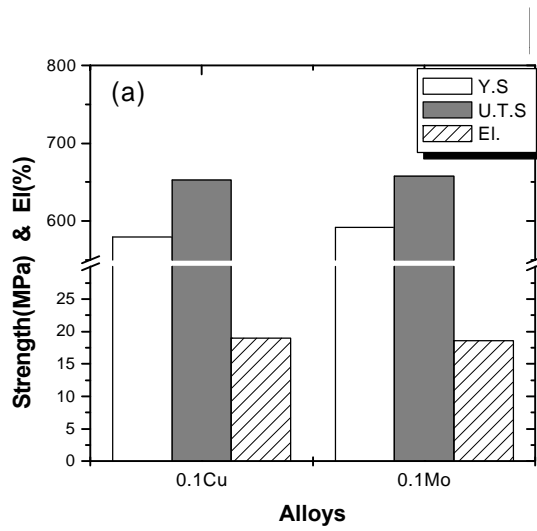
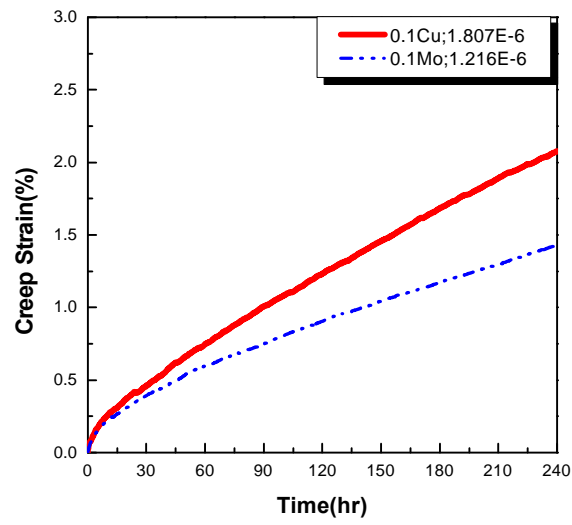


Fig. 4 Effect of alloying elements (Mo, Cu) of Zr-xNb-1.1Sn series alloys on the mechanical properties; (a) room temperature, (b) elevated temperature



(b) Fig. 5 Creep curves of Zr-0.2Nb-1.1Sn series alloys at 400°C under applied stress of 150 MPa