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Corrosion monitoring and determination of aluminium fuel clad of Tehran Research Reactor (TRR)

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A B S T R A C T

Aluminium alloys are used as cladding materials for fuel plates in many research reactors. In this work, which carried out in-pool tests corrosion surveillance coupons were used.

Aluminium alloys and stainless steel had been coupons in form of circular disks were exposed to the pool water for six months.

Metallographic examinations of aluminium coupons from the corrosion rack are carried out under a reflected optical microscope equipped with camera for investigation of pits width, depth and various corrosion defects.

Pitting was the dominate form of corrosion.

1. Introduction

The TRR is a 5 MW pool type, light water cooled and reflected research reactor. Its first criticality was achieved in 1967. At present enrichment of the fuel is 20% and the fuel elements dimensions are $80.1 \times 76.9 \times 750$ (mm), respectively (Safety Analysis Report of TRR, 2007). In the reactor pool there is one rack capable to store up to 6 spent fuel elements. In order to develop a fundamental understanding of the corrosion problems with aluminium clad in the TRR reactor, a monitoring and determination program has been initiated. In this work, we carried out in-pool tests using corrosion surveillance coupons made of aluminium alloys and stainless steel. One corrosion rack was immersed in the TRR reactor pool in March 2008. It is removed after 6 months of exposure. Analyses of corroded surfaces were made to quantify the extent of surface pitting as a function of pool water parameters (IAEA-Technical Reports Series, 2003). This paper presents results obtained during analysis of corrosion effects by visual and metallographic examinations of surfaces of aluminium coupons exposed in the pool water in September 2008.

2. Experimental procedure

Corrosion coupons included 1100 and 6061 aluminium alloys and SS-304 stainless steel. They are 100 mm and 70 mm circular disks of 3 mm thickness with a central hole designed to fit over the insulated stainless steel rod rack. The nominal compositions of the aluminium alloys and AISI 304 stainless steel are shown in Table 1.

Surface preparation and treatment of the aluminium alloy coupons were identical to that given to Al-clad fuel plates. All of the coupons were machined, polished to semi-bright, identified, degreased and given the same surface treatment (pickling in hot sodium hydroxide solution, cleaning, rinsing, neutralization and drying). Two machined and polished AA-1100 and AA-6061 coupons in rack was rinsed, degreased and pre-oxidized in water at 368.15 K for 24 h. One of the surfaces of these coupons was scratched with a 0.5-mm scriber to simulate a damaged fuel element surface. Polyethylene disks separate the individual coupons and the coupled coupons, one from the other. Two 150-mm acrylic discs were added to avoid contact with the reactor walls (IAEA-Technical Reports Series, 2003). The coupons were assembled in a corrosion rack (see Fig. 1) in the order shown in Table 2.

The coupons were assembled in a corrosion rack in the order shown in Table 2.

The corrosion rack was immersed in the TRR reactor pool in March 2008 at 1.5 m above the reactor floor and at 8.5 m below the level of the water. Prior to exposure, photographs of all of the coupons (front and reverse sides) were taken. Fig. 2 shows the corrosion rack position in reactor pool. A detailed characterization of the reactor pool water during the exposure period has been made from the existing water sampling and an analysis program of TRR reactor. The species Cl^-, F^-, NO_2^-, NO_3^- and SO_4^{2-} were determined by liquid chromatography, Na, Sr, Li, Mn and Zn by Flame AAS (atomic absorption spectroscopy). The conductivity of water

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Table 1
Nominal compositions of aluminium alloys and stainless steel (wt. %) (Davis, 1999).

Element	Al	Cu	Mg	Mn	Si	Fe	Ti	Zn	Cr	Ni
AA-1100	99.0	0.05–0.2		0.05	0.95Si + Fe			0.1		
AA-6061	96.70	0.15–0.40	0.8–1.2	0.15	0.4–0.8	0.7	0.15	0.25	0.04–0.35	
AISI-304				<2	<1	<70			18–20	<8

Fig. 1. The TRR corrosion test rack.

Table 2
Description of the corrosion rack.

Order	Description of the coupon
1	Single, AA-6061
2	Single, AA-1100
3	Single, AISI-304
4	Single, AA-6061(Scratched & Pre-oxidized)
5	Single, AA-1100(Scratched & Pre-oxidized)
6	Couple, AA-6061& AA-6061
7	Couple, AA-1100& AA-6061
8	Couple, AISI-304& AA-6061
9	Couple, AA-1100& AA-1100
10	Couple, AA-6061& AA-1100
11	Couple, AISI-304& AA-1100
12	Couple, AISI-304& AISI-304

Fig. 2. Position of the corrosion rack in the reactor pool.

Table 3
TRR water conditions.

Element	Cl^-	NO_2^-	NO_3^-	SO_4^{2-}	Na	Li	Sr	Mn	Zn
Value (mg/lit)	0.09	0.092	0.2	0.23	0.02	0.015	0.01	0.018	0.015

Table 4
Measured values of electrical conductivity of pool water.

Date	July 08	Aug 08	Sep 08	Oct 08	Nov 08	Dec 08	Jan 08	Feb 08
Conductivity (μS/cm)	1.042	1.065	1.087	0.9	1.084	1.05	1.077	1.37

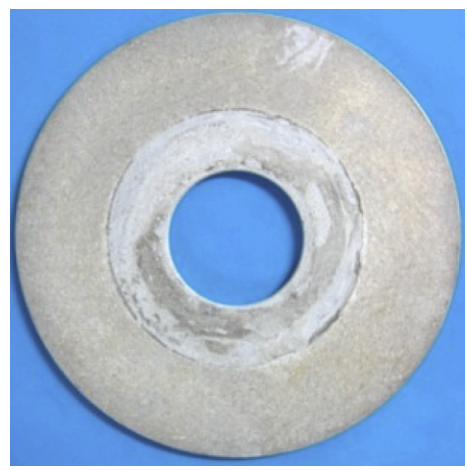

Fig. 3. Outer surface of single 6061 Al alloy coupon after 6 months of exposure in the TRR reactor.

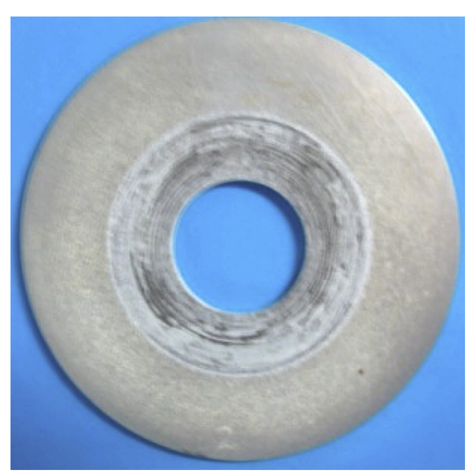

Fig. 4. Outer surface of single 1100 Al alloy coupon after 6 months of exposure in the TRR reactor.