

Cr-Al composite cladding prepared by swaging and electroplating

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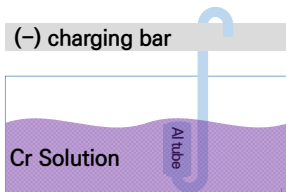
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Abstract

- Zircaloy-4 has good mechanical and chemical properties. However, they are found poor properties at **high temperature** and **pressure**.
- ATF (accident tolerant fuel) cladding development research is actively to overcome high temperature and high pressure.
- Cr plated Al is stable material at high temperature. ATF clad tube was fabricated by swaging the **Cr-plated Al tube** on the outside of Zircaloy-4.
- SEM-EDX analysis observed gap between Cr plated Al and Zircaloy-4.
- Heat treatment analysis determined the degree of oxidation due to changes in mass by temperature.

Experimental

Electroplating process



- A 30 μm -thick Cr film was formed on the outside of the Al tube by electroplating process.
- Cr plated Al tube was used outside of Zircaloy-4.

Preparation swaging process



Fig. 1. the physical role of KNO_3 filler in the swaging process.

- The inside of the Zircaloy-4 tube was completely filled with water-soluble KNO_3 powder.
- KNO_3 powder generates a force of reaction against the force acting from the outside to the center during the swaging process.

Swaging process

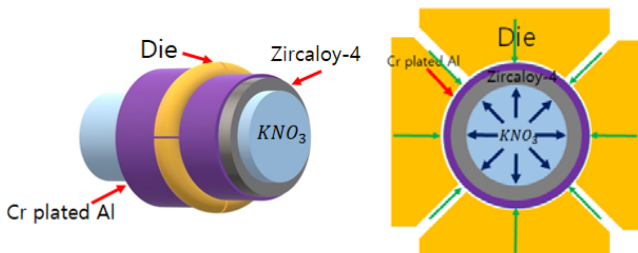


Fig. 2. Schematic diagram of the swaging process.

- The swaging process applied a pressure of 4 t/cm^2 toward the central axis of the double pipe through the swaging process.
- In addition, the thickness, inner diameter and outer diameter and length of the final tube can be adjusted according to the number of times the swaging process is performed.

PST (Pseudo Single Tube)



- PST cut into 1.5cm were prepared and a furnace was used for heat treatment.
- Heat treatment was performed at 600, 900 and 1200 $^\circ\text{C}$ and maintained for 600s.

Fig. 3. PST sample image

Results

SEM (Scanning Electron Microscope)

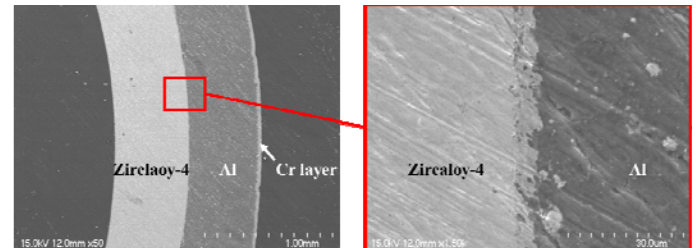


Fig. 4. SEM image of Cr plating layer after swaging Cr plated Al / Zircaloy-4.

Heat treatment

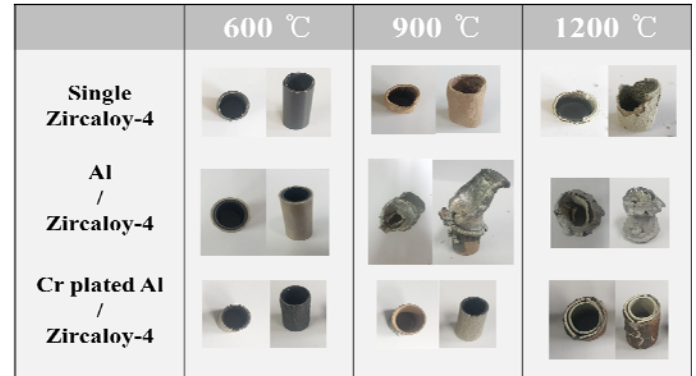


Fig. 5. Appearance of single Zircaloy-4, Al / Zircaloy-4 and Cr plated Al / Zircaloy-4 after 600, 900 and 1200 $^\circ\text{C}$ heat treatment.

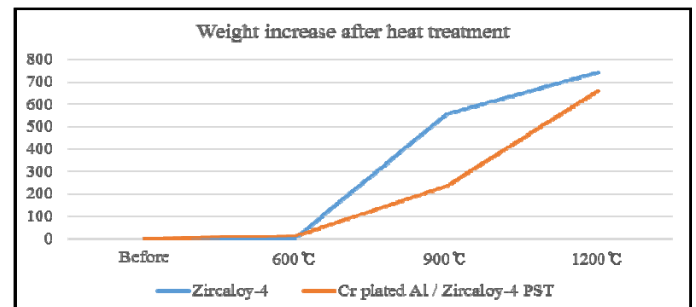


Fig. 6. Weight increase graph of single Zircaloy-4 and Cr plated Al / Zircaloy-4 after heat treatment.

Conclusions

- In this study, a double cladding tube composed of ATF exterior and Zircaloy-4 inner tube was fabricated at room temperature.
- Cr was plated on Al exterior suitable for mass production easily, and Zircaloy-4 of the size used in commercial reactor was used for inner tube.
- Post-axial ATF cladding was physically attached to the surface of Zircaloy-4 by a swaging technology, and the shape was like a single tube without peeling off at the interface between two dissimilar metals.

References

- J. Garmack, F. Goldner, Overview of the US DOE Accident Tolerant Fuel Development Program, Idaho National Laboratory: Idaho Falls, ID, USA, 2013.
- H. G. Kim, Development status of accident-tolerant fuel for light water reactors in Korea, Nuclear Engineering and Technology, 48, 1-15, 2016.
- J. H. Kim, Effects of oxide and hydrogen on the behavior of Zircaloy-4 cladding during the loss of the coolant accident (LOCA), Nucl. Eng. Desizgn, 236, 2386-2393, 2006.
- H. G. Kim, Application of Coating Technology on Zirconium-Based Alloy to Decrease High-Temperature Oxidation. Zircon, Nucl. Ind., 465, 346-369, 2015.