Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2026

Mechanical, Physical and Thermal Properties of Titanium-Based Neutron Absorbing Structural Material Produced on a Large Scale

Young-Bum Chun [a*], Ji-Hoon Kang [a], Sun-Young Park [a], Seungmun Jung [a], Younguk Lee [b]
[a]*Materials Safety Technology Research Division, Korea Atomic Energy Research Institute, Daejeon, South Korea*
[b]*Nuclear Physics Application Research Division, Korea Atomic Energy Research Institute, Daejeon, South Korea*
[*]*Corresponding author: youngbumchun@kaeri.re.kr*

Keywords : neutron absorber, mechanical properties, thermal conductivity, criticality, spent nuclear fuel

1. Introduction

Neutron absorbers are used in spent nuclear fuel (SNF) storage systems such as dry cask and racks to control reactivity of SNF. The utilization of neutron absorber allows storage of SNF at maximum packing density, which provides certain economies of the SNF management. The basket structurally supporting SNF bundles plays important roles in maintaining structural integrity and sub-criticality, and dissipating heat coming from SNF, which are accordingly influenced greatly by the design of basket and performance of neutron absorber. Due to its excellent neutron absorbing capability, an Al-B_4C metal-matrix composite (MMC) has been widely used as neutron absorber in SNF storage system, being inserted in the pockets made by structural materials on the four sides of the square tube shaped basket. Such a triple-walled basket structure is simply due to lack of structural performance of the conventional Al-B_4C MMC, which leads to undesirable basket design. This causes the problems of thicker basket wall, and thus larger and heavier storage system, increased manufacturing cost, and lower efficiency of heat dissipation due to two planar gaps formed in the triple-wall structure. For this reason, designers of SNF storage system have longed for neutron absorbing structural materials that combine both neutron absorbing capability and structural performance. This work evaluates the characteristics of a titanium-based neutron absorbing structural material developed by KAERI, and explores the future R&D directions and practical applications of the material.

2. Methods

An 900 kg ingot of titanium-based neutron absorbing structural material was prepared by plasma arc melting under argon atmosphere. The ingot was hot-forged and then hot-rolled at 1100 °C, followed by stress-relief annealing 700 °C (Fig. 1). A 20-mm-thick plate was used for mechanical testing and analyses of thermal and physical properties: an uniaxial tensile test and a Charpy impact test were performed at various temperatures below 400 °C, and the specific heat, thermal diffusivity, and thermal conductivity were measured according to the standard procedure as a function of temperature.

Fig. 1. Fabrication routes for industrial scale titanium-based neutron absorbing structural material

3. Results and Discussion

The annealed plate exhibits a microstructure in which the Gd-rich phases, i.e., pure gadolinium and gadolinium oxides [1,2], are embedded in the alpha titanium matrix (Fig. 2). The Gd-rich phases are elongated along the rolling direction of the plate, suggesting that the phases exhibit considerable formability.

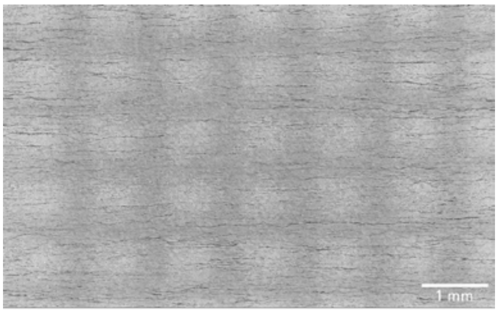

Fig. 2. Optical micrograph of the as-hot-rolled plate produced on an industrial scale

The yield strength of the plate decreases with increasing temperature, being 353 MPa and 135 MPa, at room temperature and 400 ℃, respectively. Similar trends are observed for the ultimate tensile strength and the maximum amount of work-hardening. The ductility of the plate is 25 % at room temperature, increases with temperature, peaking at 200 ℃, and then decreases again with temperatures up to 400 ℃.

The Young's modulus of the plate is about 97 GPa at room temperature and decreases with temperature, showing a value of 72 GPa. The Poisson's ratio also decreases from 0.244 at room temperature to 0.181 at 400 ℃. Such lower values of the Poisson's ratio, when compared with ordinary metals showing values around 0.3, are attributed to the anisotropies in crystallographic and morphological textures of the plate [3,4].

The coefficient of thermal expansion of the plate increases gradually with temperature, being 8.96×10^{-6} /K and 9.49×10^{-6} /K at room temperature and 400 ℃, respectively. The specific heat also increases from 478 J/kg·K at room temperature to 478 J/kg·K at 400 ℃, whereas the thermal diffusivity decreases with temperature, being 6.7 mm^2/s at room temperature and 5.8 mm^2/s at 400 ℃. The thermal conductivity determined from the experimental data above is found to be insensitive to temperature, showing values around 15.3 W/m·K.

4. Conclusions

The mechanical and thermal properties described above for the titanium-based alloy are found to be superior to those of conventional, triple-walled basket structures, suggesting that the application of neutron absorbing structural material developed in this work could improve the design and manufacturing efficiency of the SNF storage facilities.

REFERENCES

[1] D. H. Hur, Y. B. Chun, S. Y. Park, Corrosion behavior of neutron absorbing Ti-Gd alloys in simulated spent nuclear fuel pool water, Corrosion Science, Vol. 209, p. 110776, 2022.
[2] D. H. Hur, S. H. Jeon, J. Han, S. Y. Park, Y. B. Chun, Effect of gadolinium addition on the corrosion behavior and oxide properties of titanium in boric acid solution at 50 C, Journal of Materials Research and Technology, Vol. 21, p. 3051, 2022.
[3] M. Kikuch, M. Takahashi, S. Okuno, Elastic moduli of cast Ti-Au, Ti-Ag, and Ti-Cu alloys, Dental Materials, Vol. 22, p. 641-646, 2006.
[4] W. Koster, H. Franz, Poisson's ratio for metals and alloys, Metallurgical Reviews, Vol. 6, p. 1-56.