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Stress Analysis of Single Spacer Grid Support considering Fuel Rod

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1. Introduction

Pressurized water reactor (PWR) nuclear fuel assembly is mainly composed of a top-end piece, a bottom-end piece, lots of fuel rods, and several spacer grids. Among them, the main function of spacer grid is protecting fuel rods from Fluid Induced Vibration (FIV). The cross section of spacer grid assembled by laser welding in upper and lower point. When the fuel rod inserted in spacer gird, spring and dimple and around of welded area got a stresses.

The main hypothesis of this analysis is the boundary area of HAZ and base metal can get a lot of damage than other area by FIV. So, design factors of spacer grid mainly considered to preventing the fatigue failure in HAZ and spring and dimple of spacer grid.

From previous researching, the environment in reactor verified. Pressure and temperature of light water observed 15MPa and 320℃, and vibration of the fuel rod observed within 0 ~ 50Hz [1,2].

In this study, mechanical properties of zirconium alloy that extracted from the test and the spacer grid model which used in the PWR were applied in stress analyzing. General-purpose finite element analysis program was used ANSYS Workbench 12.0.1 version. 3-D CAD program CATIA was used to create spacer grid model.

2. Experimental procedures

2.1 Material and specimen

Material used in this study is zirconium alloy for spacer grid. Tensile and high cycle fatigue specimens with having width of 12.5 mm and thickness of 0.46 mm were cut from the thin plate such that was in the longitudinal and transverse directions as shown in Fig. 1.

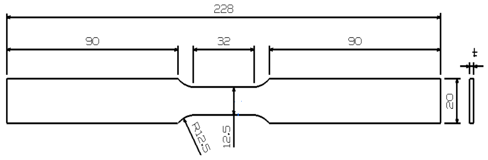

Fig. 1. Configuration and dimensions of specimen for tensile and fatigue tests

2.2 Test method

Tensile and high cycle fatigue tests were conducted on a MTS 810 servo-hydraulic test machine, according to ASTM standard E8, E21. And strength was observed both in longitudinal and transverse directions of the sheet-type specimen.

Tensile tests were conducted in displacement control mode at a constant of 2mm/min. An extensometer with a total gauge length of 25 mm was used. Test temperatures are chosen at R.T., 300℃, 350℃, and 400 ℃.

2.3 Tensile properties

Tensile tests were performed at the temperatures of R.T., 300℃, 350℃, 400℃ in order to evaluated tensile strength. The ultimate strength of L and T specimens at 350℃ showed about 50% and 55% lower than at room temperature, respectively. While the Yield strength of L and R specimens at 350℃ showed about 59% and 65% lower than at room temperature, respectively. Thus Yield strength and Ultimate strength significantly decreased with increasing temperature.

Also depending on the direction of specimen showed a different behavior. For the Ultimate strength, L specimen showed higher strength T specimen. Material properties based from the experiment and MATWEB [3]. Engineering data that used in finite element analysis show as Table 1.

3. Finite Element Analysis

3.1 Modeling

Fig. 3 is the simplified model of spacer gird that used in PWR. The unnecessary parts removed from the model used in stress analysis. In the model, mixing vane and melted area by welding were removed. The spacer grid model meshed by using thin small strain elements, 10-node 3-D Tetrahedral Solid (SOLID 92) [4]. Model was composed by 2132 nodes and 4976 elements.

3.2 Boundary condition

Situation and environment of inside the reactor were considered in simulation. The simulated factors chosen as high temperature and pressure and vibration from the fuel rod to spring and dimple. By supporting the fuel rods of the spring and dimples of spacer grid receive the load. Both sides of the spacer grid is fixed by welded area. So, both side of spacer grid selected as a fixed condition. From previous research, 5N was imposed to spring and dimples. Finally, 5N and 0 ~ 50Hz imposed to spring and dimples in this analysis.

Table 1. Engineering data of Zirconium alloy

Poisson's ratio	**0.294**	
Density	**6.56 g/cm^3**	
Coefficient of thermal expansion	**6 mm/mm·℃**	
Thermal conductivity	**21.5W/m·k**	
Tensile yield strength	**426.65 MPa**	
Tensile ultimate strength	**533.23 MPa**	
Transverse direction		
Young's modulus (GPa)	**R.T**	**90.85**
	300℃	**74.71**
	350℃	**69.22**
	400℃	**65.96**
Longitudinal direction		
Young's modulus (GPa)	**R.T**	**94.46**
	300℃	**75.75**
	350℃	**72.83**
	400℃	**70.31**

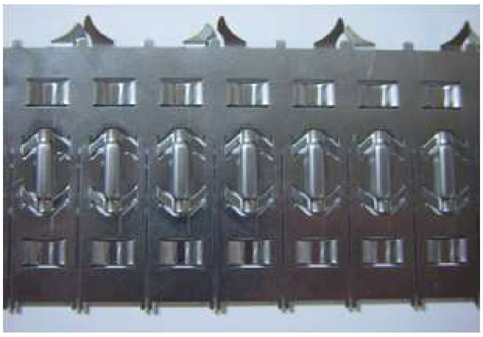

Fig.2. Zirconium alloy spacer grid

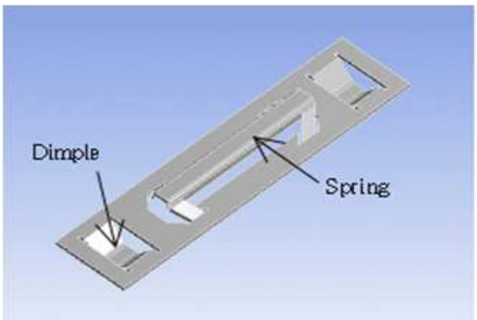

Fig.3. Simplified model of spacer grid

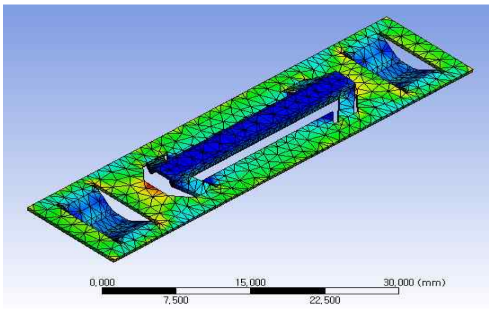

Fig. 4. Stress distribution of unit cell spacer grid

Fig. 5. Stress distribution on both edges

3.3 Results

Fig.4. Showed stress distribution on the unit cell. Maximum stress value of T-direction and L-direction were 276.24 MPa and 284.12 MPa. These values behave within elastic region. A high stress values observed in each corner of the spacer grid. This section refers to the welded area. Thus, the stress values of welded area were key-point in this analysis.

4. Conclusions

In this study, stress analysis of spacer grid performed under unit cell. Maximum stress value behave within elastic region. Furthermore, high stress values observed in welded area. So, this areas are very important aspect in design of body cell. After the experiment for welded area will finished, more specific analysis for welded area can performed.

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