On the Development of Spring Supports for Rectangular Tubes

Gyeongho Kim [a*], Jong-Oh Sun [a], Yeonseok Choo [a], Yeon-Sik Yoo [a]
[a]*Korea Atomic Energy Research Institute, 111 Daedeok-daero 989 Beon-gil, Yuseong-gu, Daejeon 34057*
[*]*Corresponding author: ghokim@kaeri.re.kr*

1. Introduction

An example of a rectangular tube used as an internal structure for a research reactor is shown in Fig. 1. It channels the coolant for cooling the control rod and fuel, which travels on its inside, and provides the smooth transit of the core component through the rolling contact between the tube and the rollers prepared on the control rod.

A closely packed arrangement of the core does not allow the tube to be fastened to the grid plate, which can provide a firm support. Thus, the tube is rather supported at its both ends; the lower end is inserted in a rectangular slot prepared on the grid plat for both lateral and vertical supports, while the upper end is supported laterally by an internal structure as depicted in Fig. 1.

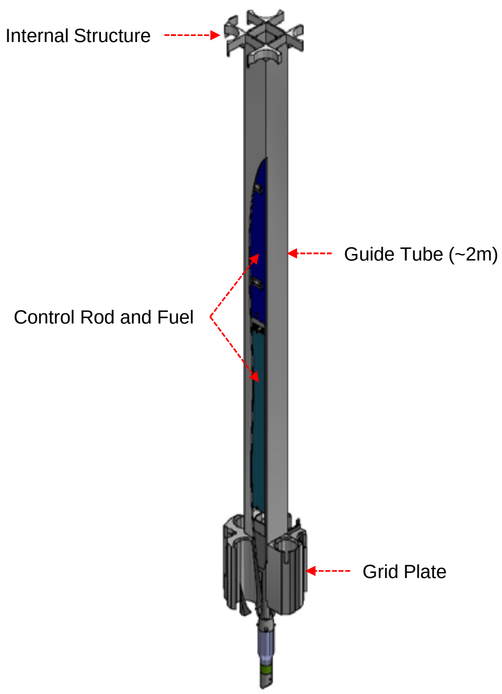

Fig. 1. Rectangular tube, an internal structure of a typical research reactor, which channels the coolant and guides the control rod and fuel on its inside.

Typically, the tube is approximately 2m long, and the mechanical clearance with its supporting structures is inevitable for an assembled structure whose components have fabrication tolerances. On the other hand, as the tube experiences differential thermal expansion or irradiation-induced growth, a moderate mechanical clearance is required, which helps prevent overfitted.

The spring support, which is the subject of the work, absorbs the mechanical clearance and mitigates compressive stress of the tube resulting from the differential expansion. Also, the spring helps prevent the tube from flow-induced vibrations and movements due to the transit of the control rod and fuel.

Various designs for the spring supports were attempted, among which two are addressed along with the design requirements in the followings.

2. Design Requirements

A spring support for the rectangular tube shall be designed to be housed in the rectangular slot of the grid plate and not to resist the coolant flows and the transit of the control rod and fuel on its inside. It shall provide firm supports for the tube to mitigate the mechanical vibrations, while allow generous deflections to accommodate the mechanical clearances and differential expansions as stated above.

According to KEPIC MNG 1122, the spring support is classified as an internal structure (IS), and required to be designed and fabricated in accordance with KEPIC MNG [1]. The performance requirements for the spring support are established as

- SSE load transmitted from the tube : 244N
- Maximum deflection : 1.5mm
- Structural integrity :
  - $P_m < S_m$ (KEPIC MNG 3221.1)
  - $P_m + P_b < 1.5\ S_m$ (KEPIC MNG 3221.2)

The Inconel X-750 (SB-637 Type 2, UNS N07750) is selected for the material for the spring support [2].

3. Design Review and Analyses Results

For two types of spring supports, the designs are briefly described, and the performance requirements outlined above are evaluated using ANSYS [3].

3.1 Leaf-type Spring Support

A leaf-type spring support is shown in Fig. 2, which consists of two wave springs pinned at the corners. The spring support is 1.5mm higher than its pins, and, thus, the load transmitted is sustained by the pins after a hard stop of 1.5mm.

A nonlinear FE analysis was performed to evaluate the performance requirements. Fig. 3 shows the stress intensity contour after 1.5mm deflection. The interior corners and the midspans exhibit relatively high stress. The stress intensity results are compared with the limits in Table 1. The reaction force exerted on the tube is calculated about 217N just before the hard stop, but higher load can be sustained by the pins.

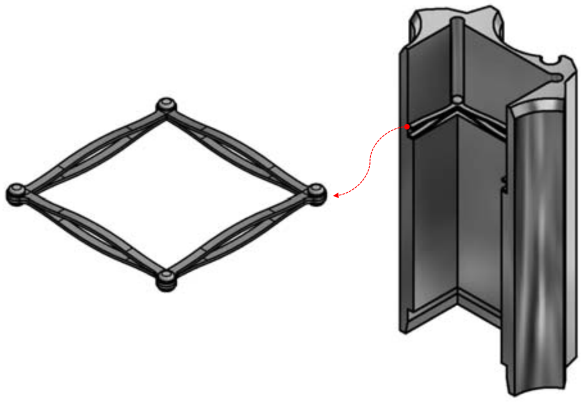

Fig. 2. Leaf-type spring support installed in the grid plate.

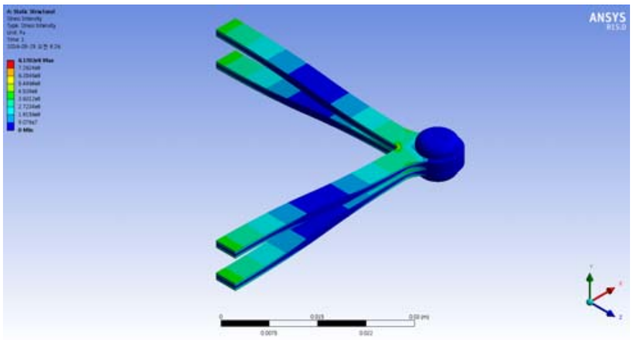

Fig. 3. Stress intensity contour for the leaf-type spring support after 1.5mm deflection.

Table 1: Structural integrity evaluations

	Max. Results, MPa		Stress Limits, MPa	
Leaf-type Spring Support	P_m	57.2	S_m	254
	$P_m + P_b$	380	1.5 S_m	381
Box-type Spring Support	P_m	43.2	S_m	254
	$P_m + P_b$	337.8	1.5 S_m	381

3.2 Tube-type Spring Support

The other design, which is a tube-type spring support, is shown Fig. 4. It can be fabricated from a rectangular tube by slitting along its height.

A nonlinear FE analysis was conducted, and Fig. 5 shows the stress intensity contour after 1.5mm deflection. The stress intensity results are compared with the limits in Table 1. The reaction force exerted on the tube is calculated about 309N after 1.5mm deflection, which is higher than the SSE load.

4. Conclusions

Two types of spring supports are developed for supporting an internal structure shaped of a rectangular tube. The spring supports are designed not to obstruct the coolant flows and transit of the control rod and fuel inside the tube. Design requirements are established considering the mechanical clearance and operational loads including SSE load. Nonlinear FE analyses were conducted, and both spring supports were evaluated to meet the requirements.

To further improve the deflection limit, the spring supports such as shown in Fig. 6 are under study.

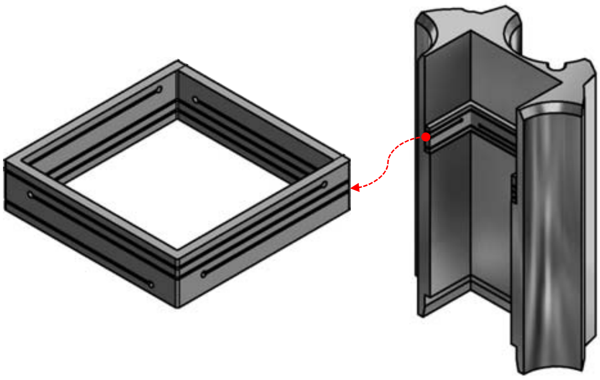

Fig. 4. Tube-type spring support installed in the grid plate.

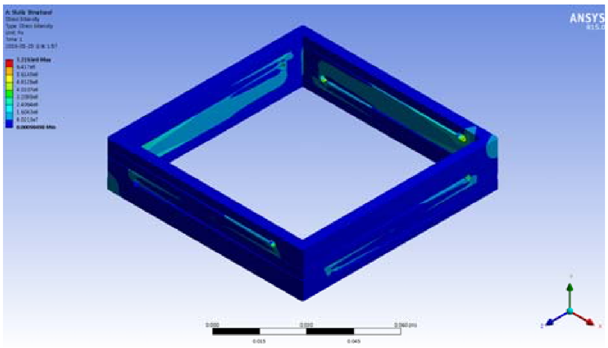

Fig. 5. Stress intensity contour for the tube-type spring support after 1.5mm deflection.

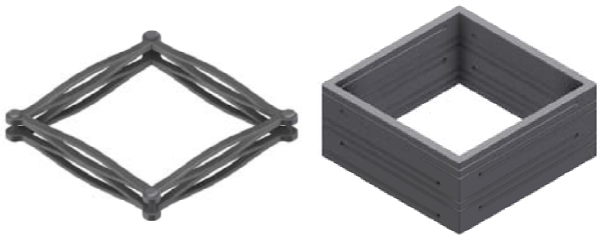

Fig. 6. Spring supports for larger deflection limit.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (2012M2C1A1026910).

REFERENCES

[1] Korea Electric Power Industry Code, MNG, "Core Support Structure", 2005 through 2006 addenda, Korea Electric Association.
[2] Korea Electric Power Industry Code, MD, "Materials", 2005 through 2006 addenda, Korea Electric Association.
[3] ANSYS Release 15.0, "ANSYS Mechanical and Workbench".