Dynamic Behavior of a Reinforced Fuel Rod Support with Wire-woven Structure

K. H. Yoon[a*], H. K. Kim[a], J. Y. Kim[a], K. H. Lee[a], Y. H. Lee[a] and H. S. Kang[a]
a Innovative Nuclear Fuel Division, KAERI, 1045 Daedeok-daero, Yuseong-gu, Daejeon, khyoon@kaeri.re.kr
** Corresponding author: khyoon@kaeri.re.kr*

1. Introduction

To enhance the side impact strength of the fuel rod support structure, a wire-woven structure was developed. This support grid was composed of a perimeter strap and a truss structure, which made up a two-layer to four-layer truss for the required strength. The wire-woven structure had the high resistant behavior even though it had a light weight. It would be used as a support grid for the segmented fuel rod or a conventional one.

Side impact analysis of the support grid structure was executed with the commercial explicit code and compared with the results of the impact test.

The developed wire-woven support satisfied the design criteria for the next generation reactor.

2. Methods and Results

In this section, the newly developed design concept of the reinforced support grid with a truss structure, the analysis model and method were described.

2.1 Wire-woven Structure

The wire-woven support may be constituted with the solid or hollow wires, and the layers of the TRUSS, made up with two to four-layer structures. As shown in Figure 1, this grid was composed of the four perimeter strap and the TRUSS structure within these outer straps.

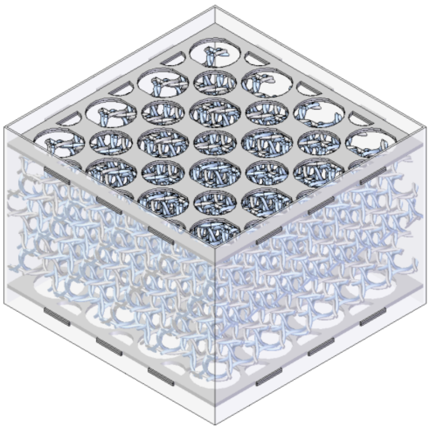

Fig. 1. Schematic drawing of the wire-woven support with four-layer TRUSS structure.

2.2 Analysis Model

A unit cell was composed of six wires in horizontal and the vertical directions. All the wires do not penetrate with each other. Therefore, the six hexahedral solid elements were modeled in the cross-sectional area. The front view of the TRUSS structure is shown in Fig. 2. And the rigid element was used an impact hammer. The materials of them were the stainless steel of 0.7 mm diameter. The basic model data are summarized in Table 1.

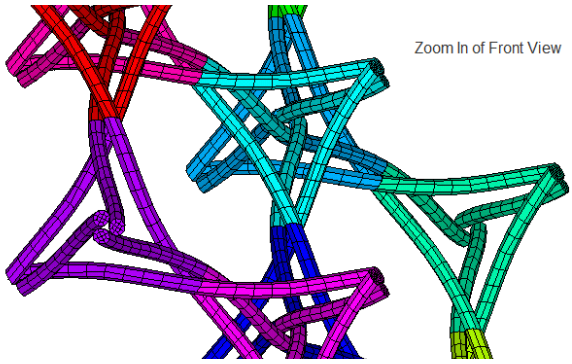

Fig. 2. Detail view of the wire-woven structure.

Table 1. Finite element analysis model data of the two and four-layer TRUSS structure.

	two-layer		*four-layer*	
	# of nodes	*# of elem.*	*# of nodes*	*# of elem.*
SOLID64	79,733	32,117	479,155	293,251
SHELL63	45,089	44,599	48,282	48,041
total	124,822	76,716	527,437	341,292

Final finite element analysis model of the four-layered structure is shown in Fig. 3.

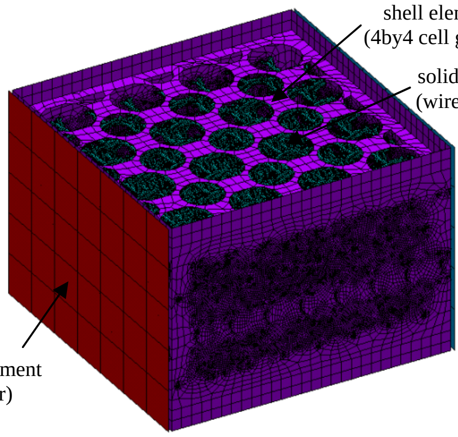

Fig. 3. FE model of the 4-layer structure for the lateral impact analysis.

2.3 Analysis Results

To find a critical strength of the structure was very difficult. In the case of the single impact analysis the maximum strength of a grid became larger and larger as the initial impact velocity increased. On the other hand, as the impact analysis was repeated, that value increased a little. Therefore, a critical strength was determined as the variation point in the force-history curve. The impact force history of the two layer TRUSS structure was shown in Fig. 4. The critical impact force of the two-layer support was 13,138 N, and it was much higher than that of the egg-crate type grid.

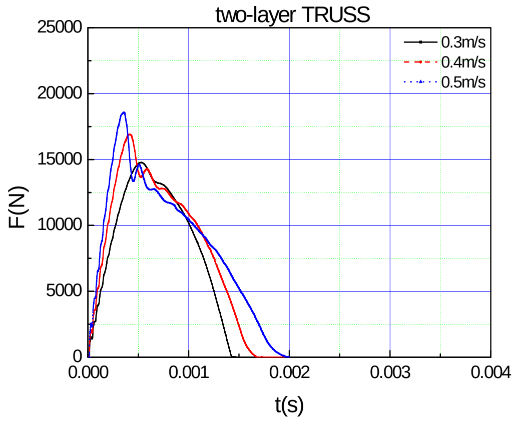

Fig. 4. Force history of the two-layer TRUSS structure by finite element impact analysis method.

The maximum stress occurred at the joint between the perimeter strap and the wire, which was 535 MPa. The von Mises stress contour of the structure was shown in the Fig. 5.

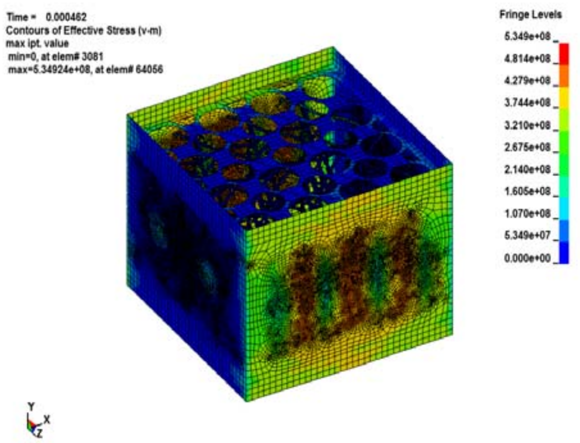

Fig. 5. Von Mises stress contour of the two-layer structure at the v_i=0.4 m/s.

2.4 Comparison Results

The analysis results were compared with those of the experimental method. The impact test was used with five samples of the two, three and four-layer structures, respectively. The maximum discrepancy between the FE and the experimental results was 28.5 % at the two-layer structure. And the comparison result of the reinforced TRUSS structure was shown in Fig. 6. In addition to this, the maximum impact force and the duration of them were summarized in Table 2.

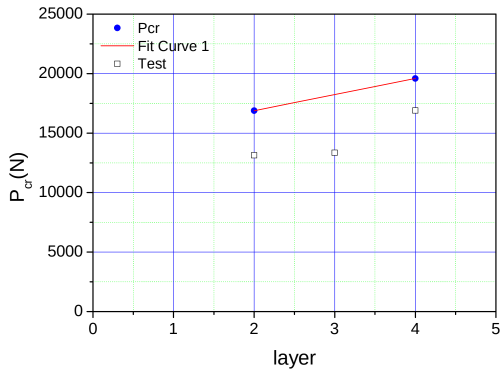

Fig. 6. Maximum impact strength as the number of the layer by two methods.

Table 2. Comparison results of the dynamic behavior of the TRUSS structure

	Critical force(N)		Duration(ms)	
	test	FEM	test	FEM
2-layer	13,138	16,888	3.0	1.7
3-layer	13,334	-	2.9	-
4-layer	16,901	19,594	2.8	1.4

2.5 Dynamic Behavior of a TRUSS Support Grid

In egg-crate spacer grid, the buckling phenomena have occurred at the cross point between the inner straps, but the TRUSS support happened at the joint part between the plate and the wire. The post-buckling behavior of the woven-wire abruptly rose after the critical point. It was very strong point of the TRUSS support.

3. Conclusions

The dynamic impact behaviors of the wore-woven support were evaluated by the finite element method. They were very similar to the experimental results. The newly developed grid will be a useful component for the next generation reactor. It is an applicable part for the single or segmented fuel rod. The reinforced support with truss structure will be an attractive component in the mechanical and thermal/hydraulic design point of view.

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