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Development of a Reinforced Support Grid with Truss Structure to Improve the Lateral Impact Load

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1. Introduction

The purpose of this work is to develop of a reinforced support grid with truss structure to improve the lateral impact load. The functional requirement of the spacer grid as follows. They serve as impact surfaces should the assembly undergo large lateral deflections. And they are fabricated from preformed Zircaloy or Inconel strips (the bottom spacer grid material is Inconel) interlocked in an egg crate fashion and welded together. They maintain the fuel rod array by providing positive lateral restraint to the fuel rods but only frictional restraint to axial fuel rod motion [1]. As above described, the egg crate structures for the spacer grid are conventional design feature.

Like these grid designs, the all of the welding points are maintain the lateral impact load. The critical strength of the spacer grid has smaller than the rigid structure, because these welding points are caused the local buckling under the lateral load. In the design criteria, the lateral strength of the spacer grid must be sufficient to withstand a Condition Ⅱ seismic incident (OBE), Condition Ⅳ seismic incident (SSE) and the Condition Ⅳ LOCA with no channel closure greater than that which would significantly impair the coolability of the fuel rod array. In addition to these, the design criteria about the spacer grid will be required much higher than the current value [2].

To satisfy the design criteria, the newly developed support grid will be supposed, it is a reinforced grid with various truss structures. The dynamic behavior of this has some strong points. It shows the high strength comparing with the weight. And the woven structure of it enhances the cooling performance in the core.

2. Design concept

2.1 General description

The reinforced support grid with truss structure is constituted as shown in Fig. 1 [3]. The upper and the perforated plates are made up with a pair for supporting the fuel rod. These upper and the lower perforated plates are inserted into the perimeter straps, and welded from the outside surfaces of them. And the fuel rods are inserted and perpendicularly rotated on the flat-rounded circular holes of them for fixing.

The wire-woven truss structure of the mid-part is brazed among themselves. And the truss structure is second welded with the perimeter straps. The outside diameter and the aspect ratio of a wire is 0.78 and 0.2, respectively. Its material is the stainless steel. From the conventional spacer grids, the critical impact strength for the lateral direction is applied with the newly developed support grid.

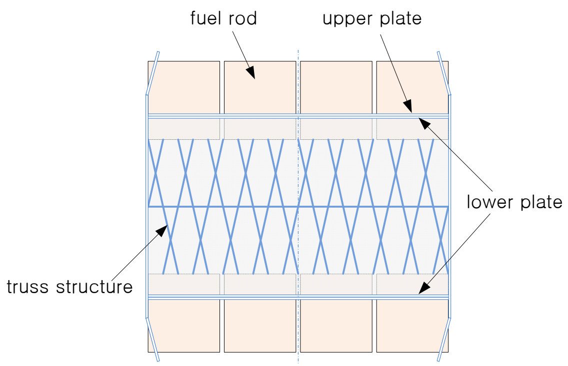


Fig.1 Schematic drawing of the reinforced support grid with truss structure

2.2 Mechanical design data

The impact surface is only considered the truss area. The self-contact points among wires are defined to prevent penetration of unit wires. In addition to this, the contact surfaces between the perimeter straps and the truss structure are assumed the one-body. Various material and geometrical data are summarized in table 1.

The target impact force for the new developed support grid is 9 kN, and the surface is 2,040 mm^2. Therefore the compact strength is about 4.5 MPa.

Table 1: Geometrical data of the support grid (unit: mm)

perimeter strap(STS304)	
outside dimension	50×30
thickness	0.5
perforated plate(STS304)	
dimension	68×68
thickness	0.5×2
truss structure(STS304)	
wire diameter	0.78
aspect ratio	0.2
layer	2,3,4

2.3 Truss support grid sample

The manufacturing procedure of the reinforced support grid with truss structure is shown in Fig. 2.

The trial specimen is made with three layers of the truss structure to execute the mechanical and the thermal/hydraulic performance test. As above mentioned, the wire diameter is 0.78 mm, and the strut length is 3.9 mm. The final test sample is shown in Fig. 3. The wire-woven structure is also shown in Fig. 3(a).

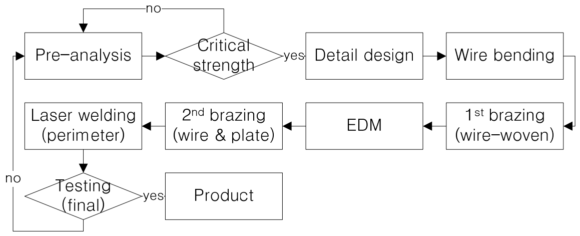
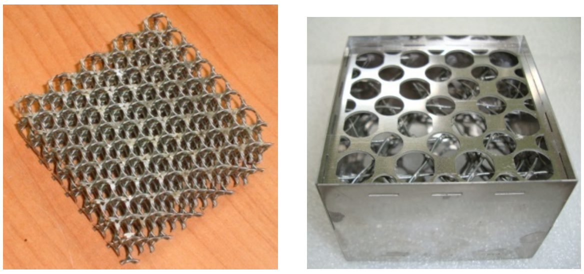


Fig.2 Manufacturing procedure of the reinforced support grid with truss structure



(a) (b)

Fig. 3 Test sample of the reinforced support grid with truss structure

3. Mechanical strength comparison

In this paragraph, the critical strength of the grid was compared with the conventional spacer grid. And the post-buckling behavior was evaluated.

3.1 Conventional spacer grid

The critical impact load for the lateral direction showed at the critical impact velocity and then decreased as the impact velocity. Because of the local buckling of the structure took place at the cross-point welding of the upper and the lower of a grid. For example, the dynamic behavior of a cylinder-inserted grid is shown in Fig. 4. The maximum impact force of it was about 10 kN at the 0.24 m/s. And then the maximum impact force was decreased as the impact velocity [4].

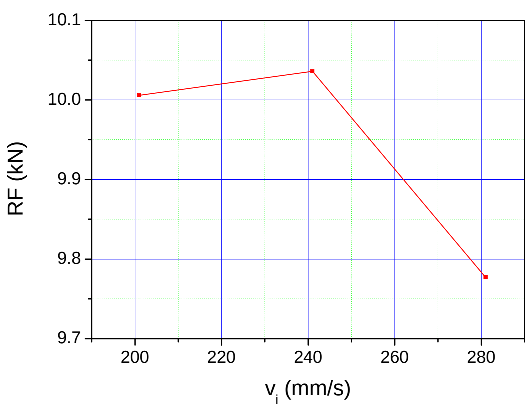


Fig. 4 Impact force vs. impact velocity of the cylinder-inserted 4×4 array spacer grid

3.2 Newly developed support grid

On the contrary, the critical impact load for the lateral direction showed at the critical impact velocity and maintained that value for a little time, and then much larger than the previous value. This dynamic behavior of the reinforced support grid was shown in Fig. 5. Of course, the maximum strength was nearly similar with the conventional grid. Nevertheless, the x-axis showed the compressive strain in this Figure, the impact behavior between two cases was quite differed.

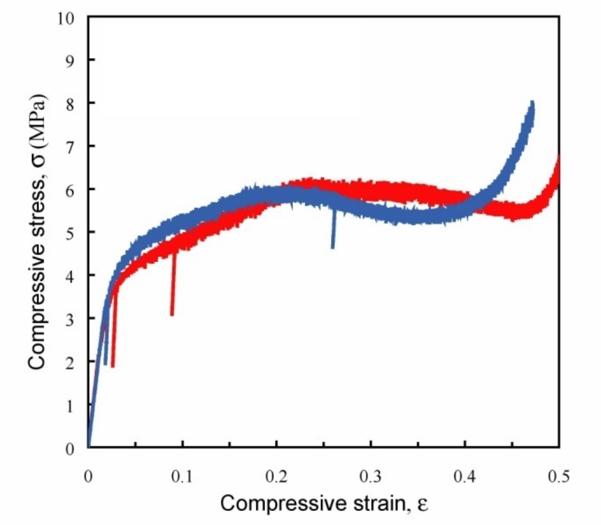


Fig.5 Compressive stress vs. compressive strain of the reinforced support grid with truss structure

4. Conclusion

The new design concept support grid for dual-cooled fuel assembly is proposed. This new grid design is satisfied the design criteria for the lateral impact load. The post-buckling behavior of the new grid will be ensured the design margin under the accident events. Also, it can be reduced the weight with the critical strength.

ACKNOWLEDGEMENTS

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