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Dynamic Impact Characteristic of an Additively Manufactured Debris Filtering Bottom Grid

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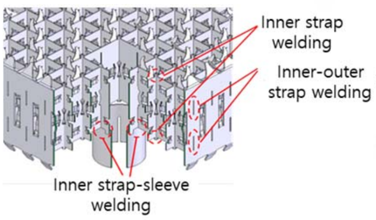
1. Introduction

Additive manufacturing is a technology that build objects by adding many layers of material, whether the material is usually plastic and metal. KEPCO NF has been putting efforts to seek feasibility of adopting this technology for the manufacturing of nuclear fuel components especially spacer grids.

Advantages of additive manufacturing of spacer grid are as follows.

- Enable design freedom to the designer
- Provide robust products by breaking away from the conventional sheet metal working
- Achieve integral design by removing assembling and welding process. The spacer grid design is required to withstand the lateral impact load and maintain high strength.



< Conventional manufacturing>

< Additive manufacturing >

In case a spacer grid is subjected to an excessive load during shipping, handling, manufacturing and operating, the spacer grid carries out crucial roles such as protecting the fuel from impact and maintaining mechanical integrity. For this reason, the spacer grid design requires to have superior capabilities.

A prototype of debris filtering bottom grid (DFBG) was designed and manufactured using additive manufacturing technology, and dynamic impact test was performed to investigate the dynamic impact characteristics. Finally, the result was compared with the test result of conventional spacer grid..

2. Test Specimens

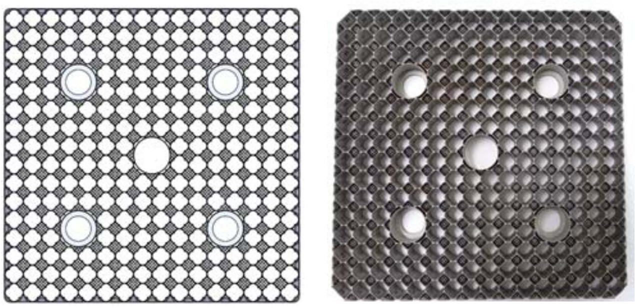
2.1 Conventional Spacer Grid

KEPCO NF's HIPER16 top grid was selected in order to perform a comparison test. Conventional top grid is fabricated using Inconel 718 inner and outer straps which has spring, dimple and slot by sheet metal work. After fixing the straps as assembled in the jig, each cross section is connected by brazing filler metal. The welding strength is strong but the constrained area does not cover entire cross-sectional line of the straps.

2.2 AM Spacer Grid

KEPCO NF has introduced a new design concept of DFBG which has not only advanced debris filtering features but integrated design and diamond shaped cells to reinforce the mechanical strength along with increased elasticity. Unlike the conventional spacer grids, all cross-sectional lines are connected and there are no windows behind the spring or dimples, therefore the load-bearing area increases drastically even though the overall height is decreased.

- 3D Printer: SLM280HL
- Feedstock: Inconel 718
- Post Processing: Stress relief thermal treatment, bead blasted



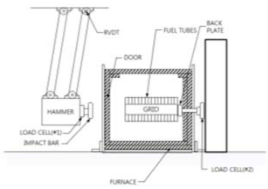
< 3D model (left) and actual printed (right) DFBG prototype>

3. Dynamic Impact Test

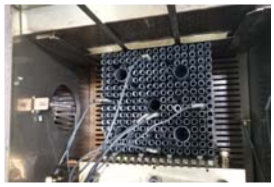
3.1 Test Outline

KEPCO NF's dynamic impact test equipment was used to apply impact to the spacer grid specimen. The equipment consists of hammer, load cell and high temperature furnace. The hammer connected to the pendulum applies an impact to one side of the specimen which is fixed in the opposite side. The weight of the hammer is equivalent to the weight of the fuel rods within one span supported by the spacer grid. The impact velocity of the hammer can be calculated using the energy conservation law and the initial test angle of the pendulum. Through the impact test, the impact load on the spacer grid was measured according to the impact velocity of the hammer.

- Test specimen
  - HIPER16 Top Grid (conventionally manufactured)
  - Debris Filtering Bottom Grid (3D printed)
- Test condition
  - Furnace Temperature: 600°F
  - Hammer Weight and Test Angle: 100 lbs, 5° to 34° (1° increment per each test sequence)



< Dynamic impact test equipment >



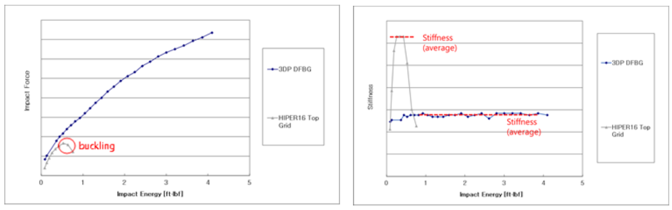
< Installation of specimen >

3.2 Test Result

The test result shows that dynamic crush strength of additively manufactured DFBG is approximately 5 times bigger than HIPER16 top grid, and stiffness of the DFBG is approximately 40% smaller than HIPER16 top grid.

Although detail design is different to each other, DFBG can be considered to be weak in terms of impact because the strap height is about 0.7 times smaller than the HIPER16 top grid. But from the test, it can be concluded that increased load-bearing area due to integrated design actually dominates the crush strength.

Moreover, additively manufactured grid can be superior compared with the current grid in terms of seismic integrity. This is because the impact strength, stiffness and seismic factor of the dynamic crush test data are main inputs regarding fuel seismic performance calculation of the nuclear fuel.



< Dynamic crush test result (crush strength (left) and stiffness (right)) >

Items	HIPER16 TG	3DP DFBG
Rel. Crush strength	0.22	1.0*
Rel. Stiffness	1.76	1.0

* *No buckling occurred: Maximum impact during test*

< Comparison of dynamic crush test result >

4. Conclusion

Dynamic impact test was conducted on additively manufactured DFBG and conventionally manufactured HIPER16 top grid of Inconel 718, with simulated fuel rods and guide tubes inserted in the high temperature furnace.

Frim the test result, it can be concluded that;

- DFBG designed and manufactured in consideration of additive manufacturing has significantly higher strength and lower stiffness
- This leads to an improvement in seismic performance, consequently suggests direction as an ideal approach for a new concept grid design