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Parametric Study for Deciding a Through-welding Length Using Analytical and Experimental Methods

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1. Introduction

The spacer grid(SG) has an important function of preventing a lateral impact force by a seismic and LOCA blowdown and maintaining the fuel rod space under accidental and operational loading conditions. General roles of the spacer grid assembly are providing a lateral and vertical support for the fuel rods, promoting a mixing of the coolant and keeping the guide tubes straight so as not to impede a control rod insertion under any normal or accidental conditions. To evaluate the impact characteristics of a SG such as the impact velocity, critical strength and duration time, a few types of impact tests for SGs have been conducted. The measured critical strength has to be bigger than the severe condition, i.e. 0.3g (4500lb≒20,000N) at a normal operating temperature.

In a previous study, a new welding method, a through-welding, was proposed to increase the dynamic impact characterization of a grid structure, a critical buckling load, without any design change or material change.[1] To form a SG, horizontal straps and vertical straps are crossed and usually welded at two cross points(cross spot welding method) using a laser. Through-welding is a method which welds through the four intersection lines of a horizontal strap and a vertical strap. Although this method(through-welding) takes more time than a pre-selected method(cross spot welding) because all four intersection lines are welded. It can be reduced by optimizing the through-welding length which satisfies a severe condition. FEM analysis is used to optimize the welding length which maximizes the impact characterization of SGs without any modifying shape and physical property. Then, the pendulum impact experiments with 7by7 SG specimens are conducted to verify the analysis results.

In this paper, FE model for an explicit impact analysis is established to optimize the through-welding length. And then the analysis results are carefully compared with experimental results to verify the usability of the analysis model. Finally, the optimum through-welding length is suggested by using the results of the analysis and test.

2. FEM model

The impact analysis model is made by using a preprocessor commercial program, I-DEAS NX 12[2]. The FEM model is 7by7 partial spacer grid and consists of 32,000 nodes and 25,000 elements. And ABAQUS/Explicit 6.6-3[3] is used to solve dynamic impact problem. In the spot welding case, the welding bead is modeled by rigid beam elements shown as Fig. 1. The rigid beam connects the upper node on vertical strap with the center node in horizontal strap and the lower node on vertical strap with the center node in horizontal strap. This rigid beam translates and rotates with a rigid body motion.

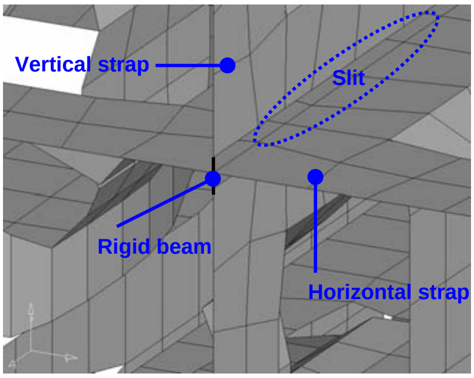

Figure 1. The rigid beam for welding bead

And the contact definition between the upper/lower nodes on slit of horizontal/vertical strap with surface of vertical/horizontal strap is specified to prevent horizontal/vertical straps from penetrating vertical/ horizontal straps. The FE model for a 7by7 partial spacer grid is shown as Fig. 2. The upper rigid plate represents an impact hammer on the pendulum impact tester which weighs 24.34 kg. The impact analysis is run with changing the initial velocity of plate from 254mm/sec until the buckling of SG happens. The impact force is obtained by summing up the reaction force of the nodes located in the bottom plate. When the impact force decreases, only a local buckling occurs. So, that only an impact force just before a decrease is the critical buckling load of the 7by7 partial SG.

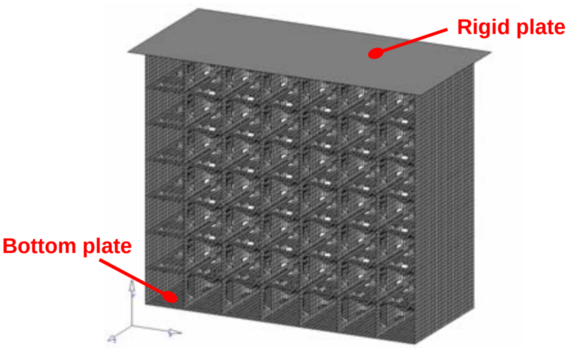

Figure 2. FE model of 7by7 SG

In the through-welding case, the upper/lower nodes on the slit are merged with the nodes of a strap inside from an intersection point. In this paper, the analysis results of 7.275, 13.28 and 17.2mm through-welding lengths are explained. The contact definition and rigid plate are the same as the spot welding case.

3. The results of analysis

The dynamic impact analysis is performed by changing the initial velocity of the rigid plate until a buckling happens. The analysis results of four cases, spot welding, 7.275mm, 13.28mm and 17.2mm through-welding, are compared and Fig. 3 shows the analysis results.

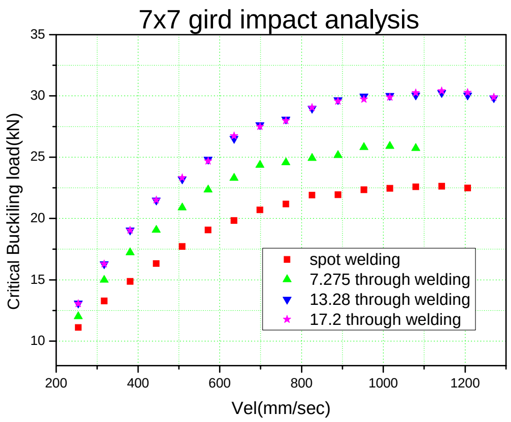

Figure 3. The results of impact analysis

These results suggest that the buckling load of a through-welded SG is increased by about 34% more so than the spot-welded SG. And the result of the 13.28mm through-welded SG is merely the same as those of the 17.2mm through-welded SG.

4. The Pendulum impact test of partial spacer grid

A pendulum type shock machine is used to perform the impact test for the 7by7 spacer grid structure. The impact hammer is made of mild steel. In the case of a 7by7 SG, the mass of the hammer is 24.39kg and the length of one span is 540mm. The impact test of the grid structure is carried out for 5 specimens by each welding method i.e. total 20ea. It is made of Zircaloy-4 with a 0.457mm thick inner strap, and a 0.664mm (horizontal)/0.457mm (vertical) thick outer strap. The pendulum impact test has been conducted with an initial velocity of 281mm/sec. If some grid cells experience a local buckling, the duration time is longer than that before the buckling state. This means that the stiffness of the grid structure after a buckling is much smaller than that before the buckling phenomena[4].

5. Results of experiment

The results of the 7by7 grid pendulum impact test are summarized in Table 1. The results of the impact tests are merely the same as the analysis results, that is, the through-welded 7by7 spacer grids have more resistant to a local buckling than the spot-welded SG by about 33%.

Table 1. 7by7 impact test resluts

Num	Spot welding (kN)	Through-welding		
		7.275mm (kN)	13.28mm (kN)	17.2mm (kN)
1	5.88	6.21	7.65	8.49
2	5.72	6.04	7.12	7.09
3	5.65	6.65	8.91	6.67
4	5.34	6.44	6.65	7.07
5	5.65	6.37	7.37	8.21
Aver.	5.65	6.34	7.54	7.51
Dev.(%)	basis	12	33	33

6. Conclusion

Parametric study about a through-welding length is performed by using an analysis and verified with test results. The conclusions of this study are

1. The optimum welding length for increasing the critical buckling load of SGs without any design change is 13.28mm.
2. Although the impact analysis method couldn't predict the critical buckling load exactly, it estimated the tendency for changing a critical buckling load for each case.
3. The dynamic impact analysis model will be modified to predict the buckling load accurately.

ACKNOWLEDGEMENTS

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