The evaluation of impact strength of IFM support grid and its experimental verification

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1. Introduction

Intermediate Flow Mixing grids (IFM) are nonstructural grids whose primary function is a flow mixing in the highest heat transfer spans between structural grids. However, its structural strength is still an important factor to endure an unexpected impact load by an earthquake causing a significant accident in a reactor. The impact strength of an IFM is evaluated using FEM and verified by experiments using a pendulum-type impact device, both of them show an excellent agreement. It is also found that the impact strength varies according to the direction of the external impact load.

2. Finite Element Modeling and Analysis

Design practice for a grid is to interpret an incipient buckling as the design failure criterion [1, 2], and this approach applies to all grid assemblies including IFM. Based on this fact, the FE (Finite Element) analysis model has been implemented to simulate the dynamic impact test environment.

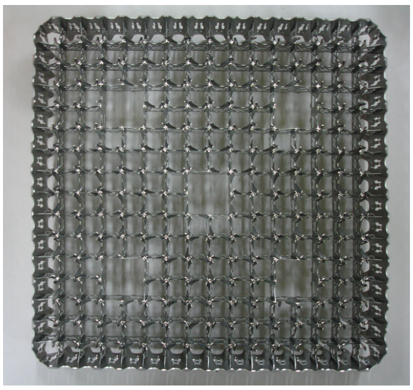
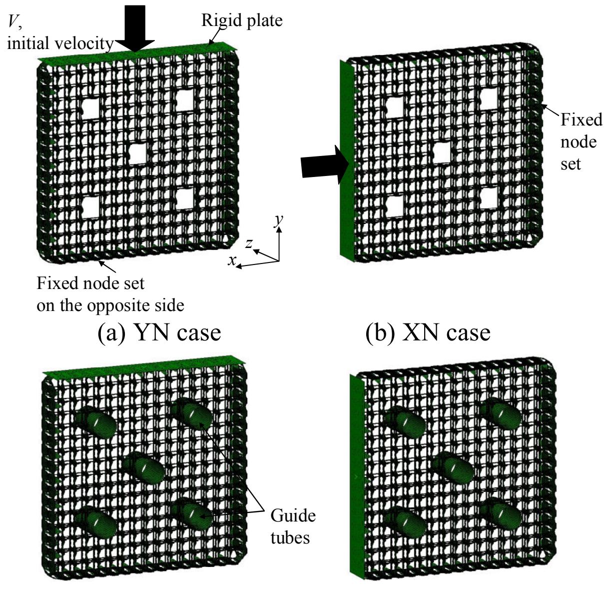


Fig. 1 Top view of IFM assembly

The geometry of an IFM assembly is shown in Fig. 1, and the FE modeling (Fig. 2) has been done using two kinds of unit straps in Fig. 3. Strap I has a gap on the "wing trapezoid" side and it is longer than the one of Strap II. The wings used for a fluid mixture are not considered in the model because they do not contribute to an impact strength (dashed lines in Fig. 3(a)). These straps do not have a spring and the fuel rods are supported only by dimples. Strap I and II stretch parallel to the *x* and *y* axis, respectively.

The IFM assembly is an interconnected array of these straps, welded at the tip of the intersections as shown in Fig. 4. The intersecting part is simplified in Fig. 4(a) where the position of a spot welding is indicated as circles at both ends. The nodes within 2 mm from the tip along the gap are connected using rigid beams as shown in Fig. 4(b), representing a spot welding condition with a 2 mm penetration depth of a welding bead. A self-contact condition is imposed on the model so that any two intersecting straps do not interfere with each other. Four node shell elements and rigid beam elements in ABAQUS/Explicit have been used, total 139,627 nodes and 117,607 elements.



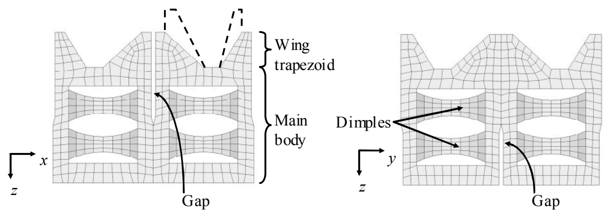
(a) YN case (b) XN case

(c) YG case (d) XG case

Fig. 2 IFM assembly with four analysis settings

The FE analysis is constructed based on the real impact experiment environment; an impact hammer is modeled as a rigid element with an equivalent mass, a contact condition is applied between the rigid plate and the support grids, and the nodes at the bottom plate are fixed as shown in Fig. 2(a). The initial impact velocity at the reference node (at the centre of the upper rigid surface) is applied, and the output accelerations for the initial impact velocity are obtained at this node. The impact force of the grid is evaluated: multiplying the maximum acceleration of the model by the mass of the impact hammer. The impact analyses are done with different velocities from

381 *mm/s* and in an increasing increment of 63.5 *mm/s*. The impact force generally increases as the initial velocity increases, but at a certain velocity case it decreases where the structure is considered to experience a buckling. The critical load is taken as the impact force from this case where the peak point is discovered.



(a) Strap I (b) Strap II

Fig. 3 Two kinds of unit straps

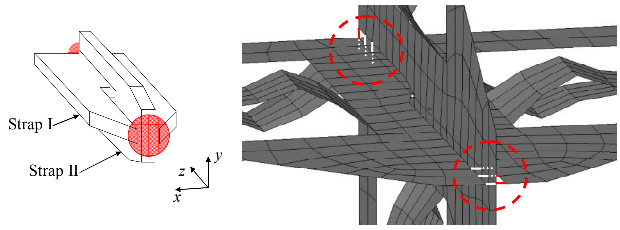
We deal with the plastic buckling phenomena, and a mechanical property of the material is imposed on the FE model to possess the elastic-plastic characteristic curve obtained from the uni-directional tensile test [3]. The elastic-plastic material properties of Zircaloy-4 [4] are used. In this paper two impacting directions (parallel to *x* and *y* axis, "Y-" and "X-" cases in Fig. 2) have been evaluated to investigate the discrepancy of the strength according to the impacting direction. Also the analyses have been done without or with guide tubes, indicated as "-N" and "-G" cases in Fig 1.

The value of the critical load from each case is indicated in Table 1. It is found that the critical load varies as the impacting direction changes: the critical loads for the "YG" and "YN" cases are about 37% larger than the "XG" and "XN" cases. As we can see the shape of Strap II in Fig. 3(b), two consecutive straps share a longer length than Strap I (the gap is shorter than that of Strap I) and this fact contributes to a greater impact strength in this direction.

3. Full Array Impact Test

The impact strength evaluated by FEM (Finite Element Method) has been verified by a real impact test, using a double parallel bar pendulum-type impact device. The weight of the impact hammer has been selected to correspond with the weight of the fuel assembly across one grid span. The dynamic impact buckling strength is interpreted as the load which induces any gird row to experience a permanent lateral deflection.

The impact test has been done for the "XG" and "XN" cases. Four specimens are repeatedly experimented and the average value is taken. According to the last column of Table 1, the crush strengths are in an excellent agreement with those from the analysis results – the values of the "*x* axis" column in Table 1 (about 13~21% larger than FE analysis).



(a) (b)

Fig. 4 Enlarged view of intersection

Table 1 Critical load for each case (*kN*)

Guide tube \ Direction	*y* axis (analysis, Y)	*x* axis (analysis, X)	*x* axis (experiment, Xe)
Without guide tube (N)	YN - 10.950	XN - 8.044	XeN - 9.104
With guide tube (G)	YG - 11.553	XG - 8.400	XeG - 10.160

4. Conclusion

A nonlinear dynamic impact analysis model for the IFM assembly using shell and beam elements is proposed in this paper. It is found that the impact strength varies according to the direction of the external impact load. To prevent this discrepancy, the gap lengths of Strap I and Strap II need to be changed to be almost the same so that the variation on the impact strength can be reduced according to the impacting direction. The critical loads evaluated by the FE analysis show excellent agreement with that measured crush strength, showing the validity of the FE model.

Acknowledgements

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REFERENCES

[1] K.H. Yoon and K.N. Song, 2000, Key Eng. Mater. 183-187, 451-456.
[2] S.H. Lee, J.Y. Kim, and K.N. Song, 2007, Journal of Mechanical Science and Technology, 21(8), 1139-1143.
[3] ASTM E8M-99: Standard Test Methods for Tension Testing of Metallic Materials (1999).
[4] K-H Yoon, W-K In, H-S Kang, and K-N Song: ICONE 12-49106 (2003).