Transactions of the Korean Nuclear Society Virtual Autumn Meeting
October 21-22, 2021

FRS Generation for Safety Components of Reactor Assembly for KJRR

Bong Yoo [a*], Jae-Han Lee [a], Seong-Hyeon Lee [a], Jong-Oh Sun [a], Yeong-Garp Cho [a], Jeong-Soo Ryu [a]
[a]*KAERI, 111 Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon 34057, Republic of Korea*
[*]Corresponding author: byoo3@kaeri.re.kr,KAERI

1. Introduction

This paper describes a simplified method to generate FRS for seismic qualification of safety components for Reactor Assembly for KJRR. The simplified method suggests the following two steps;

In the first the artificial time histories are generated compatible to the enveloped seismic input FRS1 at the bottom location of the Reactor Assembly which envelopes 18 cases of 3 directions (NS, EW, VT), 3 soil properties (BE, UB, LB), and 2 building conditions (uncracked, and cracked).

Secondly, the FRS2 at the supports for safety components such as Grid Plate, Out-core reflector support plate, CAR/SSR Guide Tube and UGS Flanges which are attached to the Reactor Assembly are generated using FE modeling of Reactor Assembly and the above input time histories by a transient time history analysis.

The FRS2 results are compared with the FRS3 generated using the conservative time histories linearly amplified by 20% of the given time histories provided by SSI analysis results and broadening the calculated spectra by 15-20% to cover uncertainties in modeling and material properties.

2. Simplified Method (Path-B)

Seismic Analysis procedure to compare the FRS results between two paths are shown in Fig 1.

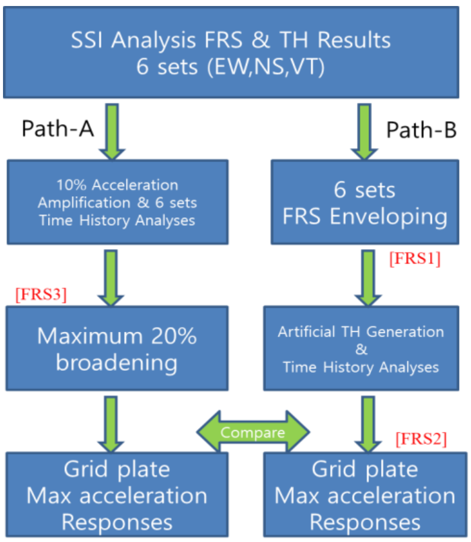
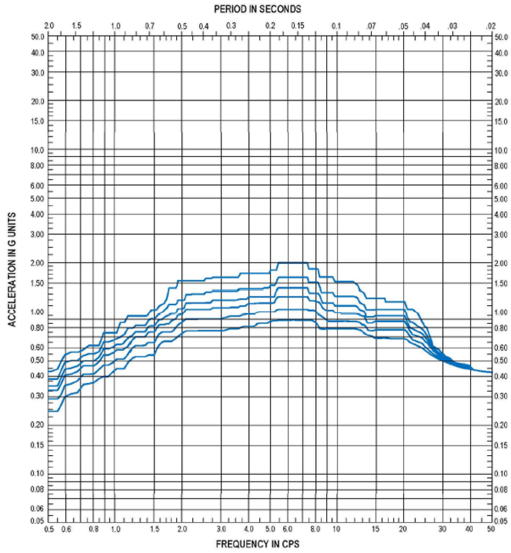


Fig 1 Seismic Analysis procedure

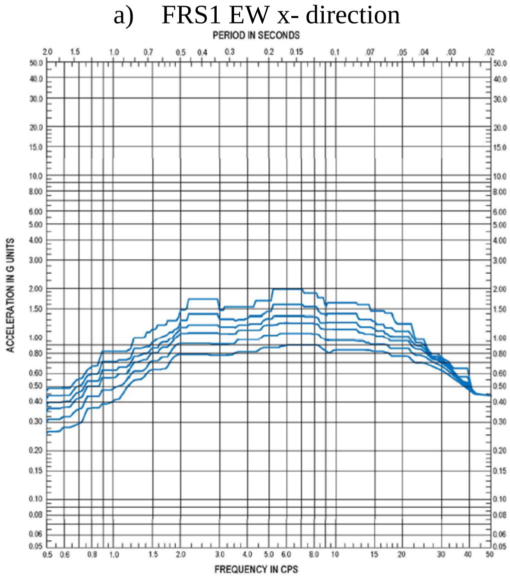
2.1. Seismic Input

The enveloped seismic input FRS1 at the bottom location of the Reactor Assembly which envelopes 18 case of 3 directions (NS, EW, VT), 3 soil properties (BE, UB, LB), and 2 building conditions (uncracked, and cracked) are shown in Fig.2. Noting that 18 case FRS1 are generated using given time histories calculated by SSI analyses of KJRR [1].

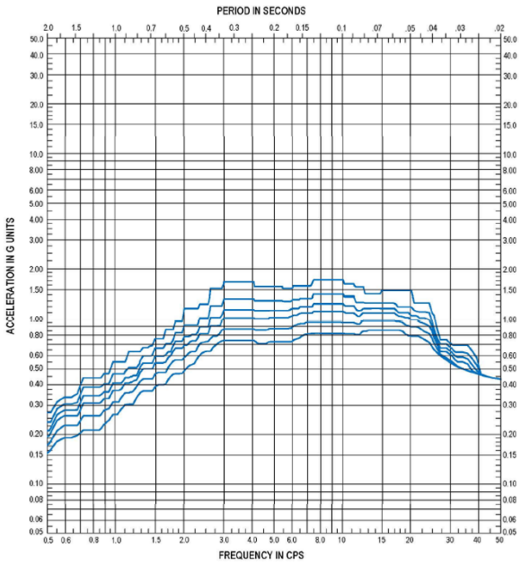
The 3 directional artificial time histories shown in Fig. 3 (EW direction only) are generated using P-CARES [2] compatible to the FRS1.



a) FRS1 EW x- direction



b) FRS1 NS y- direction



c) FRS1 VT z- direction

Fig.2. Enveloped 18 case FRS1 (EW, NS, VT, and 2,3.4,5,7,10% damping) at Reactor Assembly Bottom in Reactor Pool

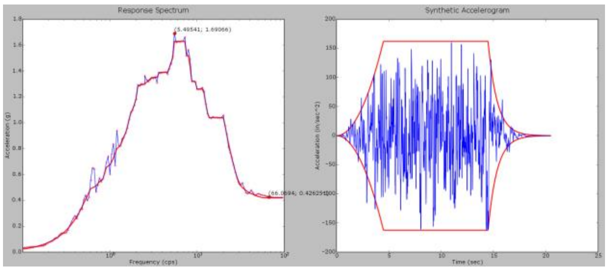


Fig. 3 Comparison of calculated Spectra (3% damping) with given FRS1 at Reactor Assembly Bottom and its Artificial Time History in EW direction

2.2. FE Modeling of Reactor Assembly

Reactor Assembly is Safety Class 3 and Seismic Category Ⅰ structure of KJRR, composed of Outlet Plenum Assembly, Grid Plate, Core Box, Upper Guide Structure Assembly (UGS), Reactor Cover Assembly, Control Absorber Rod/Second Shutdown Drive Mechanism (CAR/SSR) Guide tube, Expansion Joint, and Neutron Detector Housing Assembly (NDHA). Note that the definition of 'Reactor Assembly' in this paper does not include the components located under the pool bottom such as penetration parts and drive mechanisms of CARs and SSRs.

General FE model of Reactor Assembly (with H4.33m x W2.155m x D2.422m) is as shown in Fig. 4 using ANSYS [3].

Fluid structure interaction is considered that external added masses as 7452Kg in x direction and 6791Kg in y direction, and internal ones as 5693Kg in both x and y directions are respectively applied for the FE model of the Reactor Assembly which is submerged into the water in the Reactor Pool.

The safety components of the Reactor Assembly to be seismically qualified are fuel assemblies, CAR/SSR Control and Shutdown mechanisms, Reflector Assemblies and Gamma Shielding, and Penetration Assembly, and need to generate FRS (ie, either FRS2 or FRS3) at their support positions such as Grid Plate, Out-core reflector support plate, CAR/SSR Guide Tube and UGS Flanges. Typical material properties of safety components are shown in Table 1.

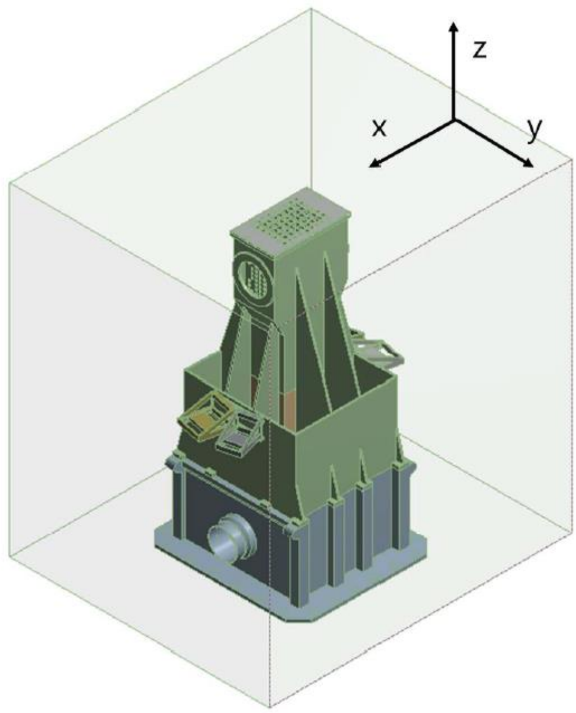


Fig. 4. General model of Reactor Assembly (EW x-direction- Nozzle, NS y- direction perpendicular to Nozzle, VT z-direction))

번호	구성품	개수 [ea]	재료	밀도 [kg/m^3]	탄성계수 [GPa]	뽀아송비	총 질량 [kg]
1	Outlet plenum assembly	1	S30403 (SA240 304L)	7900	187.8	0.300	7883.3
2	Grid plate	1	S30403 (SA240 304L)	7900	187.8	0.300	534.5
3	Core box	1	R60804 (Zircaloy-4)	6550	87.46	0.365	586.2
4	UGS	1	A96061 (AL6061)	2713	64.8	0.330	1449.5
5	RCA	1	A96061 (AL6061)	2713	64.8	0.330	122.0
6	CAR/SSR guide tubes	6	A96061 (AL6061)	2713	64.8	0.330	44.8
7	NDHAs	4	A96061 (AL6061)	2713	64.8	0.330	78.6

Table I: Material properties of safety components of Reactor Assembly

3. Results

The FRS2 are generated using FE modeling of Reactor Assembly and the above input time histories by a transient time history analysis at the support positions of the safety components such as Grid Plate, Out-core reflector support plate, CAR/SSR Guide Tube and UGS Flanges.

The FRS2 results are compared with the FRS3 generated using the conservative time histories linearly amplified by 20% of the given time histories and broadening the calculated spectra by 15-20% to cover uncertainties in modeling and material properties.

The enveloped FRS1 at the Reactor Assembly Bottom are compared with the FRS3 at the Reactor Bottom, as shown in Fig 5 resulting that

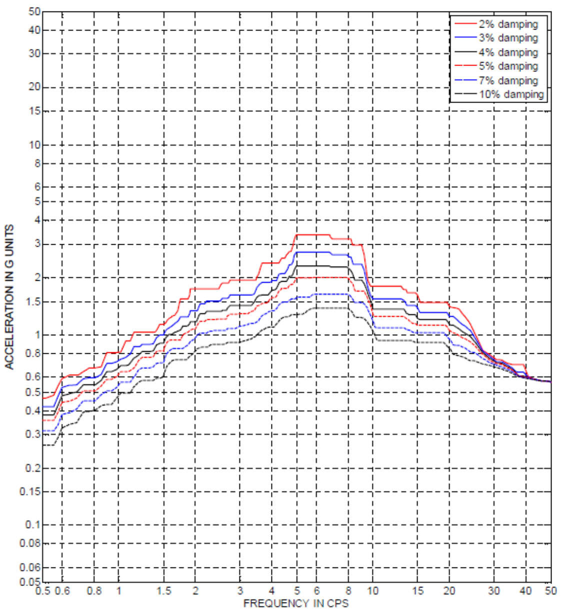
1) peak spectral acceleration, and ZPA of 2.8g in 5-8 Hz, and 0.58g of FRS3, but 1.63g in 5.4-7.3 Hz, and 0.42g of FRS1, respectively, in EW x-direction,

2) peak spectral acceleration, and ZPA of 2.8g in 4.2-7.2 Hz, and 0.61g of FRS3, but 1.6g in 5.2-7 Hz, and 0.44g of FRS1, respectively, in NS y- direction,

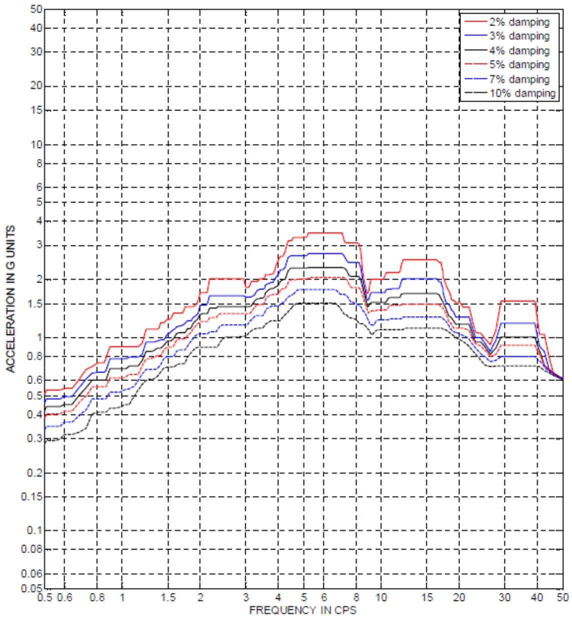
3) peak spectral acceleration, and ZPA of 1.7g in 7.2-10. Hz, and 0.55g of FRS3, but 1.42g in 7.4-10 Hz, and 0.424g of FRS1, respectively, in VT z- direction.

The FRS2 at the Grid Plate, one of support positions of safety components of Reactor Assembly are compared with the FRS3 at the Grid Plate.

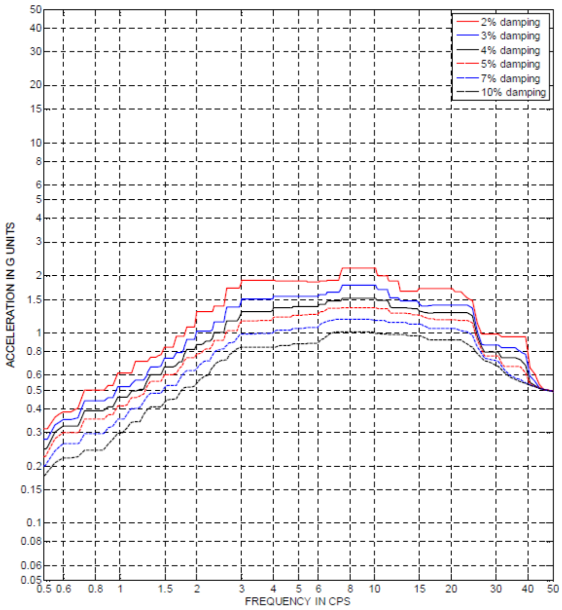
Peak spectral accelerations (3% damping) of FRS3 are much larger than enveloped FRS1 at the Reactor Assembly Bottom by 72 -75% in horizontal direction, and larger by 20% in vertical direction.



a) X direction



b) Y direction



c) Z direction

Fig. 5 FRS3 at Reactor Pool Bottom

Peak spectral accelerations of FRS3 are compared with calculated FRS2, for example, using one set of given time histories among six sets before 15-20% broadening spectral values at the Grid Plate of the Reactor Assembly as shown in Fig. 6 and 7.

Peak spectral accelerations for FRS3 (2% damping) are 3.65g in EW, 3.78g in NS, and 2.19g in VT, but those for FRS2 (2% damping) are 2.13g in EW, 2.22g in NS, and 1.99g in VT direction, respectively.

ZPAs of FRS3 at Grid plate are 0,517g in EW, 0.649g in NS, and 0.476g in VT direction, and those of FRS2 at the Grid plate are 0.47g in EW, 0.478g in NS, and 0.442g in VT direction, respectively.

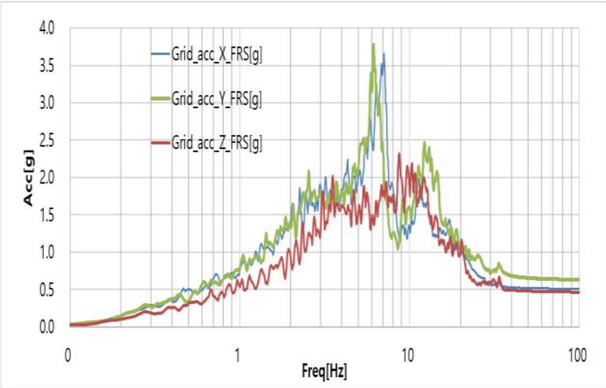


Fig. 6 FRS3 at Grid Plate of Reactor Assembly

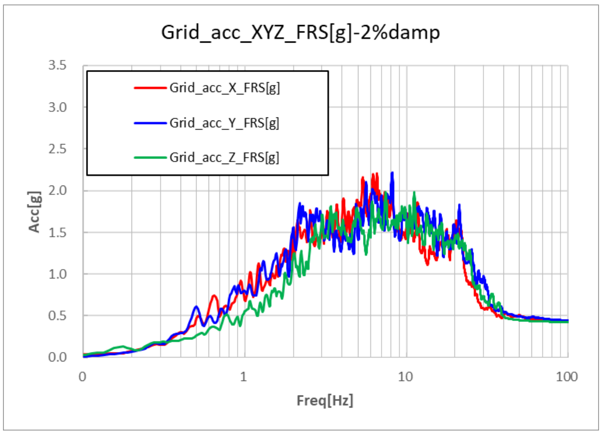


Fig. 7 FRS2 at Grid Plate of Reactor Assembly

4. Conclusion

The simplified method is proposed to generate FRS2 to be used for the seismic qualification for the safety components attached to the Reactor Assembly.

The artificial time histories generated at the Reactor Assembly Bottom are less conservative than the 20% amplified time histories.

As seismic input motions at the Reactor Assembly Bottom, Peak spectral accelerations of enveloped FRS1, 1.63g in EW and 1.6g in NS are much smaller than those of FRS3, 2.8g in both EW and NS by 72-75% in horizontal direction, and 1.42g of FRS1 smaller than 1.7g of FRS3 by 20% in vertical direction.

The FRS2 are much less conservative than the FRS 3 generated from the linearly amplified time histories in most frequency ranges by 70% in horizontal directions, and less conservative by 10% in vertical direction.

The simplified method proposed can reduce remarkably computing and post processing times, and provide with reasonable seismic responses for the seismic qualification for the safety components in the Reactor Assembly.

Acknowledgement

This research was supported by Brain Pool program (2020H1D3A2A02110911) funded by the Ministry of Science and ICT through the National Research Foundation of Korea.

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[1] Chapter 4, PSAR of KJRR, 2017
[2] Jinsuo Nie, Jim Xu, P-CARES, 2.0, 2007
[3] ANSYS, v.17