Project Title
MS-NT4: Development of Seismic Isolation Systems using Periodic Materials

PI:
Yi-Lung Mo – University of Houston

Program:
Nuclear Energy Enabling Technologies,
Advanced Methods for Manufacturing, Blue Sky

Collaborators:
Kenneth H. Stokoe, II - University of Texas, Austin
Hsiang Y. Yeh - Prairie View A&M University
Yu Tang - Argonne National Laboratory

ABSTRACT

A study of an innovative seismic base isolation system is proposed for use in advanced fast nuclear power plants (AFR) and in some of the small modular fast reactors (SMFR) recently proposed. This seismic base isolation system, in effect, uses the foundation of the nuclear island as the base isolator. The foundation is made of a new material, the so-called periodic material, which can block or reflect the damaging seismic motion being transmitted to the superstructure. Both analytical and experimental studies will be performed to demonstrate the feasibility and effectiveness of the proposed base isolation system. Developed in the field of solid state physics, the theory behind this concept predicts that by carefully engineering certain heterogeneous materials, they can be made to exhibit special characteristics useful in resisting the loads imposed on structures from earthquakes. This material, called periodic material, possesses distinct frequency band gaps. As a result this material will block or reflect the input seismic motion with the frequencies falling in between this gap. The frequency band gaps can be controlled by design and manufacture. This characteristic is exactly the characteristic needed for a base isolation system. One can properly design the frequency band gap to match the fundamental frequency of the nuclear island so that the dynamic response of the nuclear island will not be amplified, or alternatively, one can design the frequency band gap to match the strong energy frequency components of the design earthquake. Preliminary shake table tests recently conducted have shown promising and encouraging results.

Advanced fast nuclear power plants (AFR) and the small modular fast reactors (SMFR) operate at high temperature but very low pressure, usually close to atmospheric pressure. As a result, these plants use thin-walled vessels and piping that do not have adequate inherent strength to resist seismic loads. Seismic base isolation has been proposed for AFR and SMFR plants to mitigate the potential damage caused by the earthquake and to increase the safety margin of the nuclear power plants. Also, seismic base isolation can enhance the design of standard plants which can be licensed and built at lower costs.

The effort is led by a diverse team of participants from the University of Houston (UH), University of Texas at Austin (UT), Prairie View A&M University, and Argonne National Laboratory. The analytical work and experimental program will be the joint responsibility of the participating institutions. The proposed 3D periodic foundations for nuclear power plants will be tested in the free field using the mobile field shakers from the University of Texas. The test results will be used to verify and refine the design theory and design procedures of periodic foundation-based seismic isolation systems suitable for nuclear power plants.