Investigation of Lifting off Core Subassemblies under Seismic Excitations

EXECUTIVE SUMMARY

The stability of the fuel subassemblies, supported on the grid plate and held in position by self weight is demonstrated under seismic loading by shake table testing. The concern is the lifting of the subassemblies under combined effects of upward coolant flow under pressure of 0.7 MPa and upward accelerations generated by vertical seismic excitation. It is also demonstrated that with the applications of multiaxial excitations, the lifting off problem is completely ruled out even up to 1 g (g-acceleration due to gravity) peak ground accelerations in the vertical direction.

OUTLINE

In order to ensure the required core flow, the pressure of sodium in the grid plate (GP) is maintained at about 0.7 MPa, which develops an upward lift on each of the fuel subassembly (FSA), equivalent to 0.28 g, in case of pump running at 110 % design flow rate. Being less than 1 g, the net gravitational force acting on each subassembly is always downward and hence there is no fear of any uplift. The seismic analysis of reactor assembly indicates that the peak vertical acceleration of grid plate can be as high as 0.88 g under Safe Shutdown Earthquake (SSE). Hence, there is a concern of lifting off subassembly during seismic events, in particular under vertical excitation.

In this investigation, upward displacement of subassemblies is quantified under combined effect of upward fluid force and vertical seismic excitations. SSE is assumed to occur during the worst situation, viz. beginning of life where each core subassembly is freely standing on the grid plate without any resistance from the adjacent ones and the pump is running with 110 % of the design flow. The vertical displacements of subassembly are determined through shake table experiment.

The test subassembly considered here is the prototype one being manufactured for PFBR. The bundle for test assembly is fabricated using steel rods made of carbon steel with the simulated length and weight (adjusted by adding steel plates appropriately. The corresponding sleeve is also a typical prototype sleeve being manufactured for the PFBR. The sleeve is supported on a rigid structure which is bolted to the grid plate. The upward fluid pressure and seismic vertical excitations are applied simultaneously. The fluid pressure is applied at the bottom of foot by a specially designed setup as shown in Fig.1.

Vertical seismic excitations as shown in Fig.2 are applied by using triaxial shake table of 10 t capacity. A dedicated data acquisition system with 64 channels is used for capturing the structural response under seismic excitation. It is connected with the linear variable differential transformers (LVDT) and triaxial accelerometer provided at the specimen through cables. Three LVDTs are used for measuring the relative displacement of the SA with respect to GP top. The test setup is shown in Fig.3

A constant pressure of 0.7 MPa is maintained at the bottom during seismic tests. FSA is subjected to vertical excitation as per the time history depicted in Fig.2 by varying the peak acceleration values in 3 steps, viz. 0.5 g, 1.0 g and 1.5 g respectively.

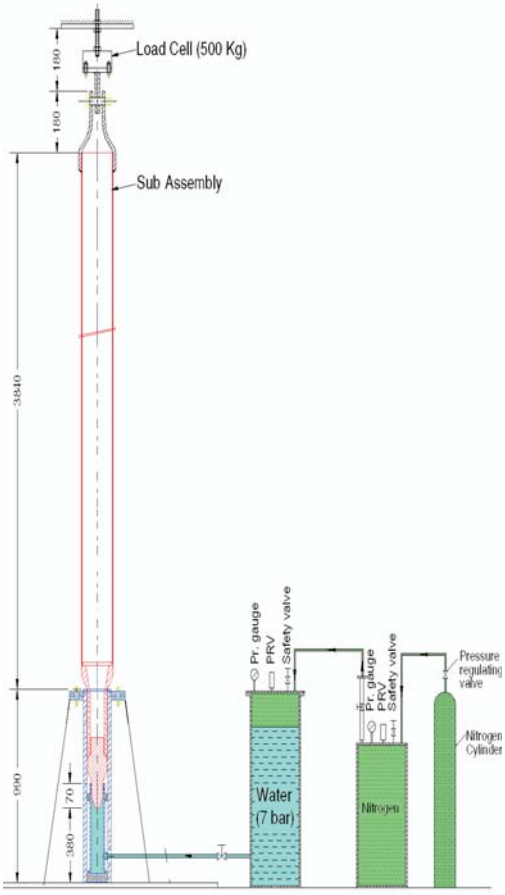

Fig. 1 : Test setup for SA lift-off study

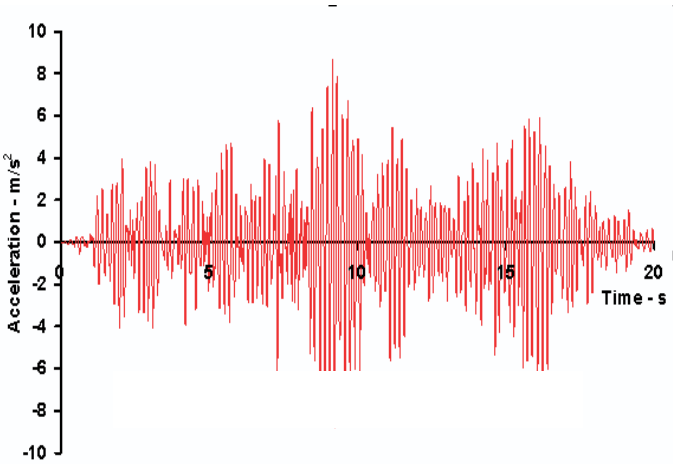

Fig. 2 : Vertical acceleration at GP support

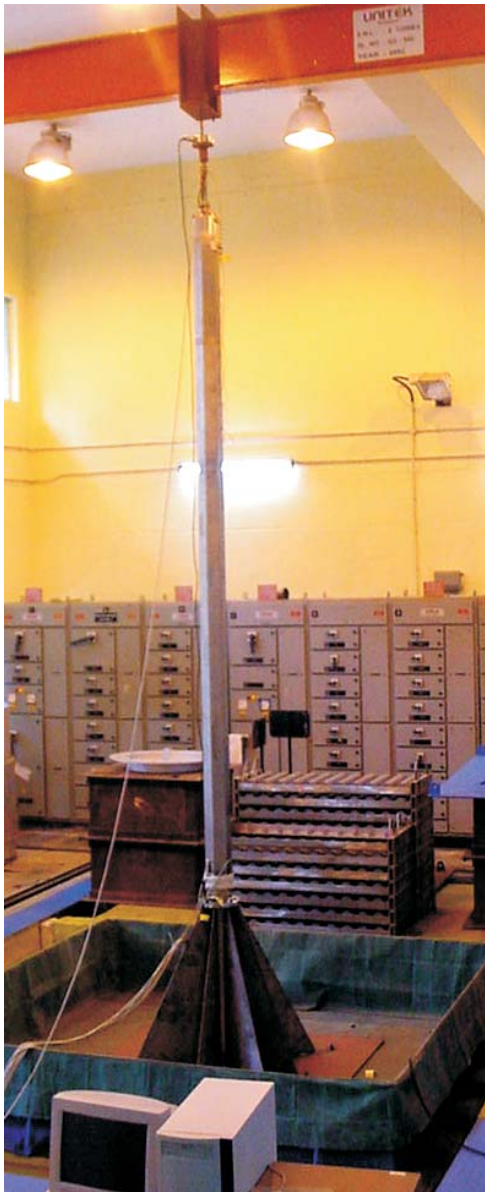

Fig. 3 : Test setup mounted on the shake table

Average values of all the three LVDT are given in Fig.4 for the maximum peak vertical acceleration of 0.5 g and 1.0 g respectively, which are insignificant. Since we have tested a single FSA, the presence of neighboring FSA will also increase further resistance towards detachment. This experiment has demonstrated the incapability of FSA detachment from the GP even under severe earthquake.

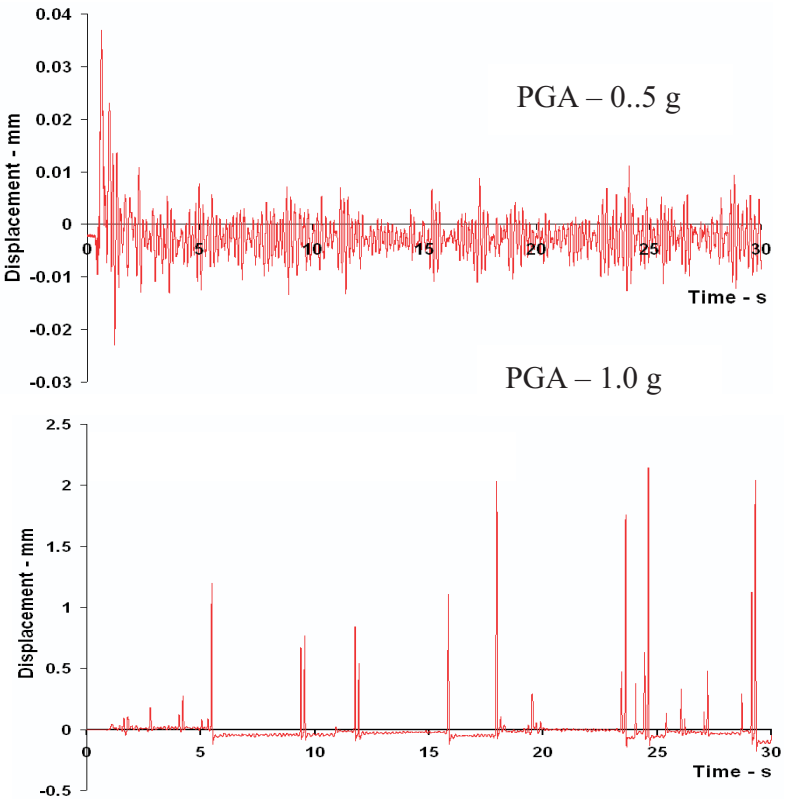

Fig. 4 : Vertical displacement of FSA

■ ACHIEVEMENT

Design and development of a novel test setup to apply simultaneously upward fluid pressure along with the seismic excitations is an innovative idea.

An important study to demonstrate to safety committee that there is no fear of lift off the core subassemblies under seismic events

■ PUBLICATIONS ARISING OUT OF THIS STUDY AND RELATED WORK

P. Chellapandi, V. Rajan Babu, P. Puthiyavinayagam, S.C. Chetal and Baldev Raj, Report No. ICONE15-10859, Proceedings of 15th International Conference on Nuclear Engineering, April 22-26, 2007, Nagoya, Japan.

Further inquiries:
Shri P. Puthiya Vinayagam, Reactor Components Division
Reactor Engineering Group, IGCAR, e-mail: vinayaga@igcar.gov.in