Transactions of the 15th International Conference on
Structural Mechanics in Reactor Technology (SMiRT-15)
Seoul, Korea, August 15-20, 1999

Dynamic Displacements of PFBR Core with Reference to Reactivity Oscillations during a Seismic Event

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ABSTRACT: Under a seismic event the subassemblies (SA) of a fast reactor core undergo a complicated dynamic movement. Two important safety requirements are ensuring scrammability and checking of reactivity oscillations. The scrammability aspect has already been demonstrated by a detailed analysis of the core SA of Prototype Fast Breeder Reactor (PFBR) and presented in SmiRT-14. The current paper discusses the possible reactivity oscillations during vertical excitation due to 1) the relative vertical movements between fuel SA and control rods within control cavity 2) the core compaction and flowering (core compaction is responsible for reactivity additions). The net reactivity oscillations during a seismic event (both OBE and SSE) are presented in this paper.

1.0 INTRODUCTION

The subassemblies of PFBR core are supported on a grid plate, which is connected to the core support structure, which in turn is welded to the main vessel. The main vessel is supported from the reactor vault, which rests on a common raft foundation. Under a seismic excitation, the seismic forces are transferred from the ground to the main vessel support, through the reactor vault. From the main vessel support, the excitation is transmitted to all other reactor assembly components. Thus the seismic displacements of the core subassemblies (SA) are caused due to the seismic excitations of the grid plate.

2.0 ANALYSIS METHODOLOGY

The seismic response of the grid plate (which forms the input for determining the seismic response of the core SA) is found from an equivalent stick model of the reactor assembly, ref[3]. Fig.1 and Fig.2 show the grid plate support response due to OBE and SSE excitations in the vertical directions respectively. The dynamic response of the core SA due to the excitation of the grid plate support in the horizontal directions for both OBE and SSE have already been computed, using code CORE-SEIS, ref [1]. The grid plate is stiff in the horizontal direction, and hence all the points of the grid plate have the same horizontal movement as the support. Thus the input excitation for all the core SA is the same. However, for finding the dynamic response of the core SA due to the excitation of the grid plate in the vertical direction, the repsonse of the grid plate has to be obtained first. This is because the grid plate itself deforms under the vertical excitation of the grid plate support. Hence dynamic response of the core SA due to the vertical excitation of the grid plate is done in two stages. In the first stage of the analysis, the dynamic repsonse of the grid plate when subjected to a vertical excitation (Fig. 2) at the support is carried out using the code ABAQUS, and the response of the grid plate at various support locations of the core SA obtained. This forms the input for the dynamic analysis of the core SA using the code CORE-SEIS.

It is of interest to note how the dynamic response (vertical and rotational directions) of the grid plate, at the support locations of the core SA affects the dynamic response (in the horizontal direction) of the core SA. The SA located at the centre of the grid plate do not undergo much rotation compared to the SA located at the periphery of the grid plate, see Fig. 4. Thus the SA at the periphery undergo more horizontal deformation along the length. The horizontal movements of the core SA are needed to compute reactivity variations during a seismic event, check for possible core compaction and insertability of control and safety rod, and diverse and safety rod, ref [1]. For getting the horizontal displacement of all the core SA, the input at the support of the SA is obtained from the rotational component at the support (obtained from the first stage of the analysis), and coverting this rotational component to an equivalent horizontal component to be applied at the foot of the SA. This process is carried out for each individual SA (because the rotational response at the location of each SA on the grid plate is different). Subsequently, all the SA are analysed using single row model concept, ref [4].

3.0 RESULTS & DISCUSSION

The displacement response of the centre of the grid plate is shown in fig.4 and fig.5 for OBE and SSE respectively. The acceleration response of the grid plate is shown in fig. 6 and fig. 7 for OBE and SSE respectively.

3.1 Lift-Off of Subassemblies

The above data is used for checking whether lift-off of SA occurs or not during a seismic event. The maximum acceleration for OBE is 5.23 m/s^2, and for SSE is 8.46 m/s^2. Hence the upward force exerted by the grid plate on the SA is 648.87 kN for SSE and 401.13 kN for OBE. The downward force due to the SA on the grid plate is 4714 kN. Since the downward force is higher than the upward forces under both OBE and SSE, the lift-off of SA does not occur.

3.2 Reactivity Changes

The reactivity changes during seismic event are a strong function of the displacements of the fuel SA, particularly the portion of the fuel SA comprising the fuel pin. The displacement worths of PFBR fuel and blanket SA are worked out in ref [5]. Based on this document, the reactivity changes of the central fuel SA during both OBE and SSE have been worked out from the displacement results obtained from CORE-SEIS. The displacements obtained from CORE-SEIS for the length of the fuel SA containing the fuel pins are known at four discrete points (this portion was discretised into three elements while doing the finite element analysis using CORE-SEIS). Since the displacement worth is to be computed at many intermediary points, the displacements at the intermediary locations have been found from the displacements of these four points (from the cubic interpolation functions used in the finite element formulation for each beam element). This is repeated for each time instant, and the displacement worth is computed for finding the reactivity of the fuel SA at that time instant. Fig. 8 and fig. 9 show the reactivity oscillations of the central fuel SA during OBE and SSE respectively.

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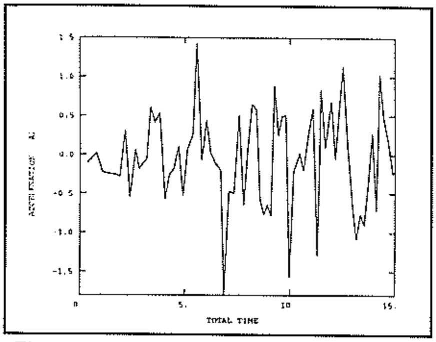

Fig.1 Input Excitation at Grid Plate for OBE

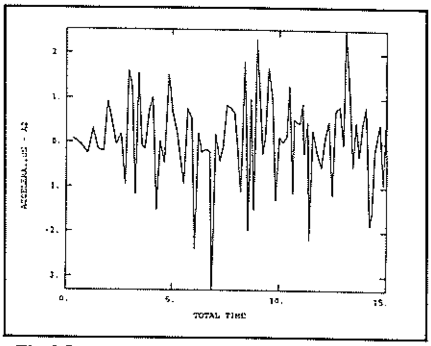

Fig.2 Input Excitation at Grid Plate for SSE

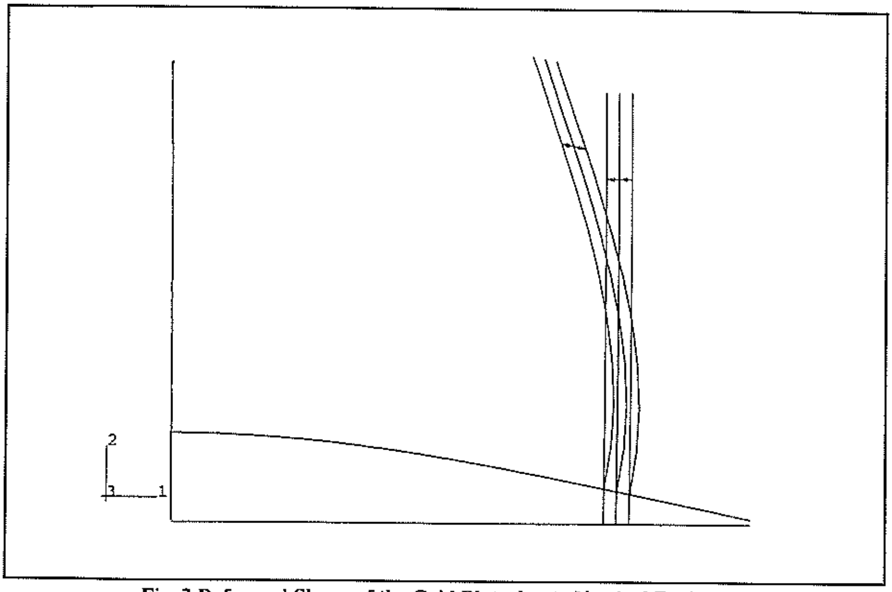

Fig. 3 Deformed Shape of the Grid Plate due to Vertical Excitation

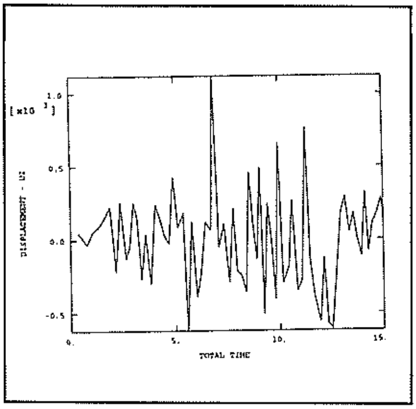

Fig. 4 Displacement Response of Centre of Grid Plate due to OBE

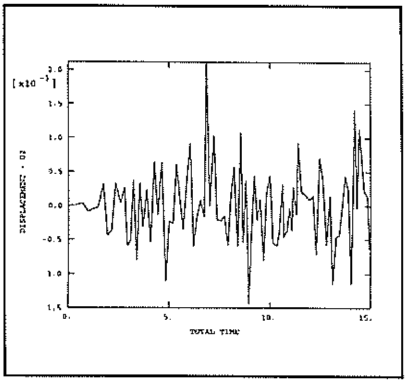

Fig. 5 Displacement Response of Centre of Grid Plate due to SSE

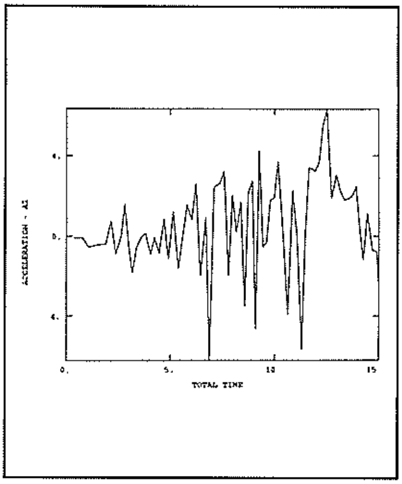

Fig. 6 Acceleration Response of Centre of Grid Plate due to OBE

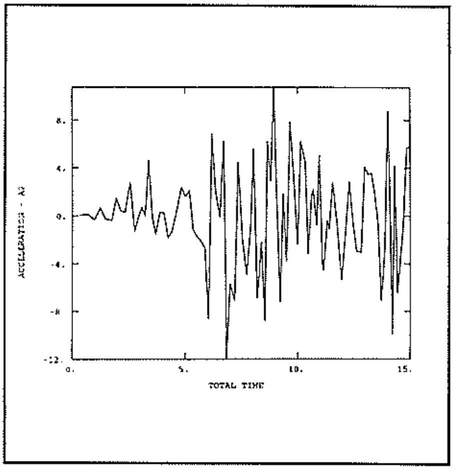

Fig. 7 Acceleration Response of Centre of Grid Plate due to SSE

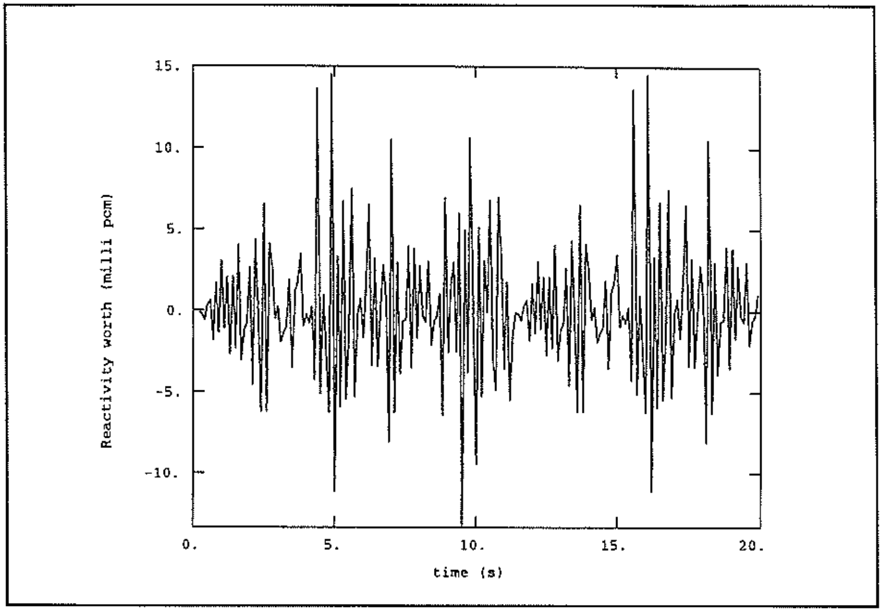

Fig. 9 Reactivity Oscillations of Central Fuel SA due to OBE

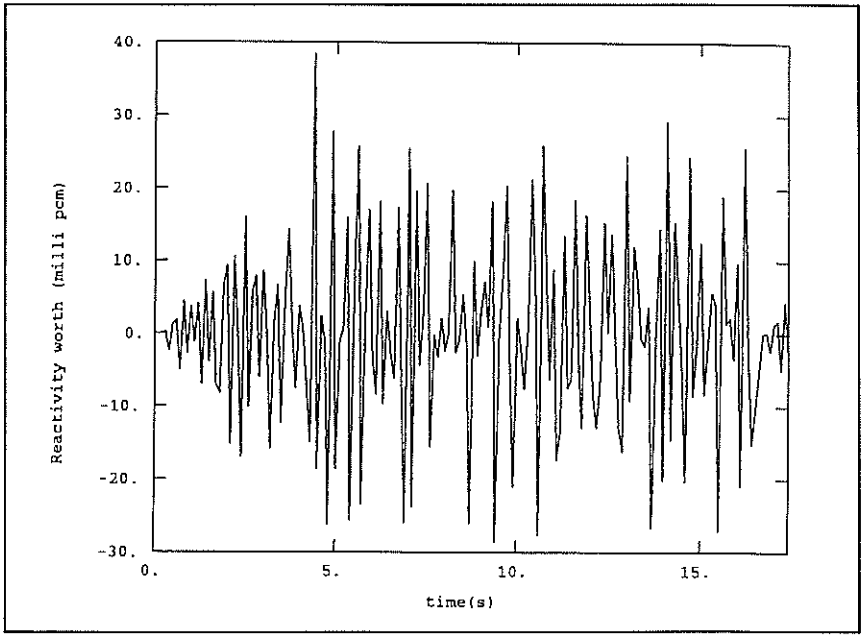

Fig. 10 Reactivity Oscillations of Central Fuel SA due to SSE