Estimation of impact pressure due to rupture in beam-tube for research reactor

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1. **Introduction**

Neutrons have been used for studies in material sciences of physics, chemistry, metals and alloys, ceramics, polymers, and biological sciences. This application leads to build up research reactor all over the world. JRTR (Jordan Research and Training Reactor) which plans to build up in Jordan is multi-purpose research reactor which is developed entirely with domestic technology to overseas. Thermal power is 5MW upgradable 10MW. JRTR have four horizontal beamtubes, 3 ST(Standard) and 1NR (Neutron radiography). The beamtube's cavities are filled with helium, purged regularly to prevent a build-up of radioactive gases and moisture. They are highly reliable because they have no moving parts. The beam tube embedded part is aligned with its corresponding beam tube in the reflector. Objective of this study is to describe water hammer phenomenon in beamtube and determine an impact pressure charged in end film of beamtube for accomplishing nuclear safety function of research reactor while beamtube is ruptured due to some accident such as earthquake. The water hammer was experimentally and analytically studied by Lai[1], Saruba[2], Ballanco[3], and Watters[4].

2. Methods and Results

2.1 Beamtube geometry and grid

The beamtube is inserted into reflector and parallelized with bottom of pool, penetrates into pool liner. In this study, calculation model is assumed that some part of beamtube submerged in pool water is ruptured due to BDBA (Beyond design basis accidents).

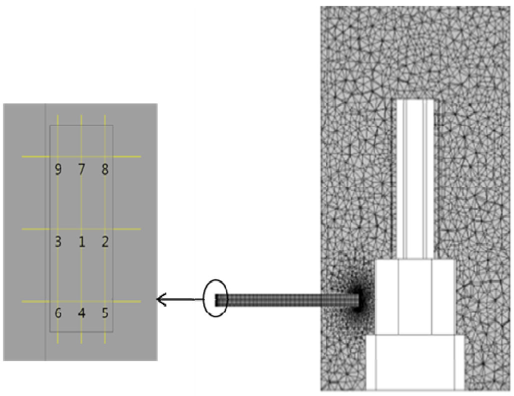

Fig. 1 Beamtube structure into pool and measurement points

Figure 1 shows the reactor and beamtube submerged in the pool and left side figure present the measurement points for pressure. In this structure, if the beamtube into pool is ruptured as shown in Fig. 1, hydraulic static pressure due to pool water is charged in a fracture.

Pool height is 11m and distance from pool bottom to beamtube is 1.475m, beamtube length from fracture to end film is 2.8m, rectangular cross-section of it is 0.08×0.21m. Beamtube get full with helium gas 120 kPa. Time step for transient calculation is 0.05s. Tetrahedral mesh 350,000 in the pool and hexagonal mesh 7,000 in the beamtube are employed for calculation. Plane facing between beamtube and pool is treated by fluid-fluid interface for conserving of mass and momentum flux. Mesh connection method for interface utilizes a general grid interface connection. Initial condition for water pool surface is ambient.

2.2 Pressure wave in the beamtube

In general, water hammer phenomenon is a pressure surge or wave resulting when a fluid in motion is forced to stop or change direction suddenly (momentum change). Water hammer commonly occurs when a valve is closed suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. It may also be known as hydraulic shock. This pressure wave can cause major problems such as pipe collapse. Water hammer can cause pipeline to break if the pressure is high enough. As the shock wave travels back and forth in the plumbing system. This like phenomenon was founded in the beamtube rupture model. Figure 2 presents in the transient pressure history obtained in the measurement points of end film of beamtube when fracture of beamtube occurs.

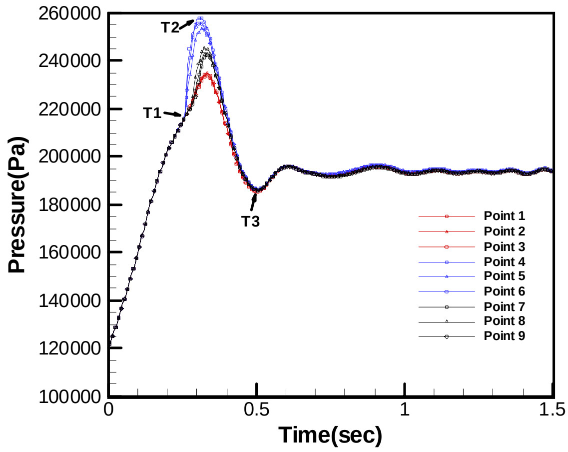

Fig. 2 Time history of pressure in end of beamtube

Pressure increases dramatically from beginning of fracture of beamtube to T1(0.255s). Peak of pressure shows at the T2(=0.31s) and this indicates impact force charged in the end film. This high peak pressure is distributed in bottom of end film and makes the end film break. However, the impulse pressure is disappeared within estimate 0.2s after high peak. At T3(=0.505), pressure is sharply decreased because momentum of water is reduced. Pressure wave travels the length of beamtube after T3. The pressure behavior of gas and water through beamtube will describe in next section related with volume fraction.

2.3 Volume fraction in the beamtube

Figure 3 shows behavior of gas and water in beamtube as time goes on. White and blue present the helium gas and water, respectively. Helium gas does not leak out from the beamtube before T1(=0.255). The gas begins to leak out T1 and water travel into beamtube. Gas is compressed and absorbs the momentum of water. In high peak pressure of T2(=0.31) phase, water impinges in bottom of end film as shown in figure, the water downstream of the fracture will attempt to continue flowing. The gas flows out due to the water charged in beamtube.

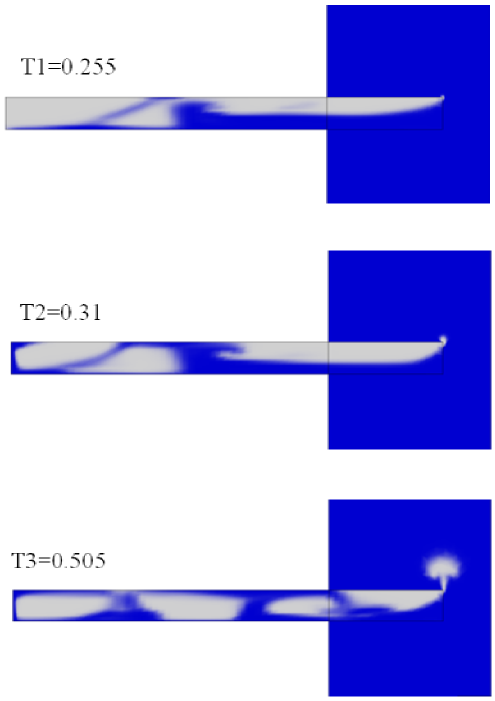

Fig. 3 Volume fraction with time variation in beamtube

2.4 Helium and Water velocity in beamtube

In this section, gas and water velocity in the fracture inlet will show when beamtube rupture accident occurs. Minus velocity indicates flooding into the beamtube. The measurement position for velocity of gas and water is at top and bottom of beamtube fracture plane. The gas is sucked into beamtube to T1=0.255 because of viscous force of water and hydraulic head of pool water. The pool water flows into beamtube and high momentum at fracture initiation transforms into pressure traveling in beamtube. Water velocity dramatically decreases from initiation of fracture to 0.31s. After 0.31s, helium gas begins to leak out into pool.

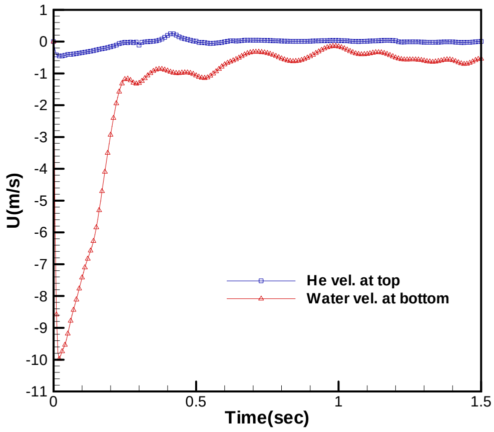

Fig. 4 Helium & water velocity with time variation in beamtube

3. Conclusions

In this study, water hammer due to beamtube rupture in reactor pool was simulated. Although beamtube rupture is beyond design basis accident, pool water may be lost when the accident occurs. Therefore, this impact pressure should be reflected in beamtube design of research reactor. Calculation of impact pressure can determine design parameter such as film thickness for mechanical durability of end film of beamtube. In case of pool height 11m and beamtube filled with helium gas 120kPa, impact pressure 260kPa was pressurized in the end film of beamtube and water hammer phenomenon appeared in the beamtube.

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