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A Dynamic Behavior of the Nuclear Test Rig with Coolant using the Fluid-Structural interaction Analysis

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1. Introduction

A heat is decreased by the circulation of the coolant in the test rig. As the coolant is circulated, a hydraulic pressure is occurred in the test rig. The pressure affect to the deformation of the test rig. The pressure and deformation of the test rig is interacted. Then the pressure and deformation of the test rig is changed by time. So, a analysis method has to be applied to be able to simulate the pressure of the coolant and deformation of the test rig.

The fluid-structural interaction analysis is applied to perform the fluid and structural analysis

A fluid-structure interaction analysis is used to simulate the relationship between the deformation and hydraulic pressure.

There are two types of fluid-structural interaction analysis. One is a 1-way direction analysis in which the hydraulic pressure is calculated by a CFD and transmitted to the surface of the structure, and a structural analysis is then performed. The other is a 2-way direction analysis that is performed by changing the data between the deformation of the structural and pressure of the coolant water for every time step.

In this paper, the dynamic behavior of the test rig in the coolant flow simulator is evaluated by using the 2-way fluid-structural interaction analysis. The maximum value and location of the deformation and equivalent stress in the test rig is confirmed.

2. Analysis modeling and condition

Fig. 2 shows the three-dimensions modeling of the fluid and structure of the test rig in the coolant flow simulator.

The mass flow rate of the inlet is 1.0 kg/s. The water is applied as the fluid material of the coolant in the analysis. The material property of the water is influenced by the temperature of the water.

The bonded and frictionless contact condition is applied in the test rig to perform the structural analysis.

Table 1 Properties on the frictionless contact conditions

Contact name	Frictionless contact
Behavior	Symmetric
Algorithm	Augmented Lagrange
Detection	Gauss integration
Normal stiffness factor	1
Update stiffness	Each iteration
Pinball region factor	1

A Bonded contact condition is applied to contact between parts by bolts. MPC contact algorithm is used in the bonded contact conditions. A frictionless contact conditions is applied to be not interfere among others parts. The detailed properties on the frictionless contact condition is shown in Table 1.

A type of the element in the fluid and structure domain is tetrahedron and hexa-dominant type , respectively. The number of the element in the fluid and structure domain is shown in Table 2.

A coupling end time and coupling time step in the fluid analysis is needed by time. 0.01 and 0.0005 sec is applied as the coupling end time and time step, respectively. The end time and time step in the structural analysis is same the end time and time step in the fluid analysis.

(a) Fluid domain (b) Structure model

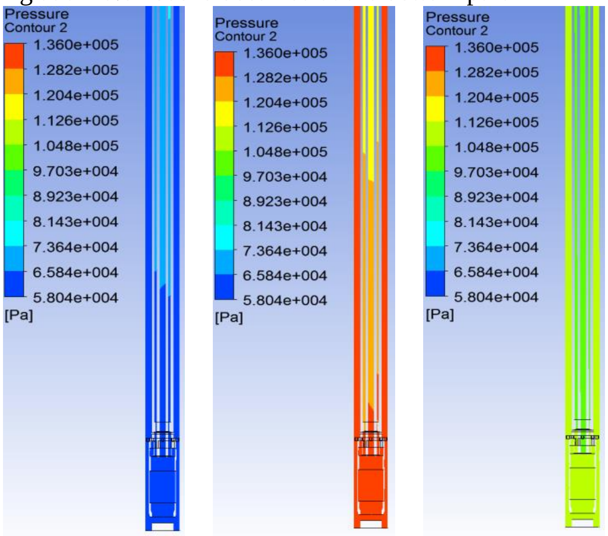
Fig. 1 Three-dimension model of the nuclear test rig in the coolant flow simulator[1]

Table 2 Numbers of elements and nodes in the structural and fluid domain

	Structure	Fluid
Element model	Tetrahedron	Hexa dorminat
Nodes	1399461	1277319
Elements	859166	359230

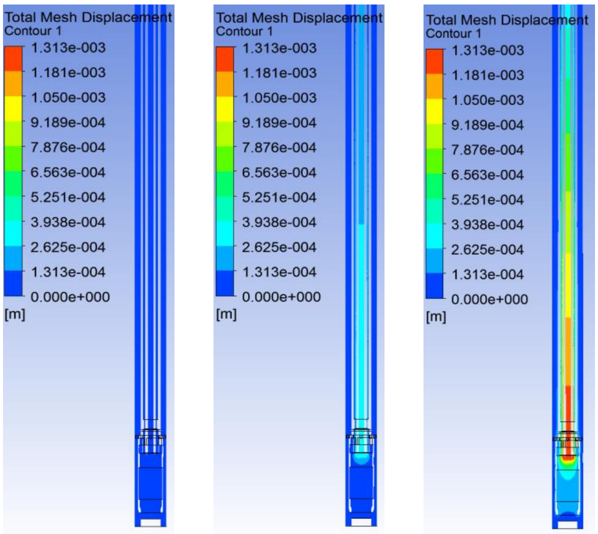
3. Analysis results

The distribution on the hydraulic pressure in the test rig by time is shown in Fig. 2. The change of the pressure affects a dynamic deformation of the test rig. The deformation of the fluid finite element model is occurred by the deformation of the structural finite element model. A mesh displacement of the fluid model is shown as Fig. 3. The deformation of the test rig isn't affected by the pressure in fluid at t = 0 sec.The test rig is deformed after t = 0.005 sec. The maximum deformation of the test rig is occurred at t = 0.01 sec. A detailed view on the maximum deformation of the test rig at t = 0.01 sec is occurred at the bottom part



t = 0 sec t = 0.005 sec t = 0.010 sec

Fig. 3 Hydraulic pressure distribution of the fluid domain at t = 0, 0.005, 0.01 sec



t = 0 sec t = 0.005 sec t = 0.010 sec

Fig. 4 Total mesh displacement distribution of the fluid domain at t = 0, 0.005, 0.01 sec

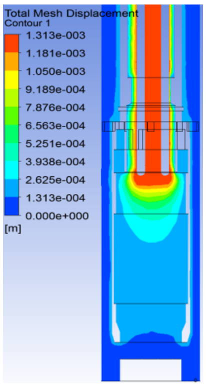
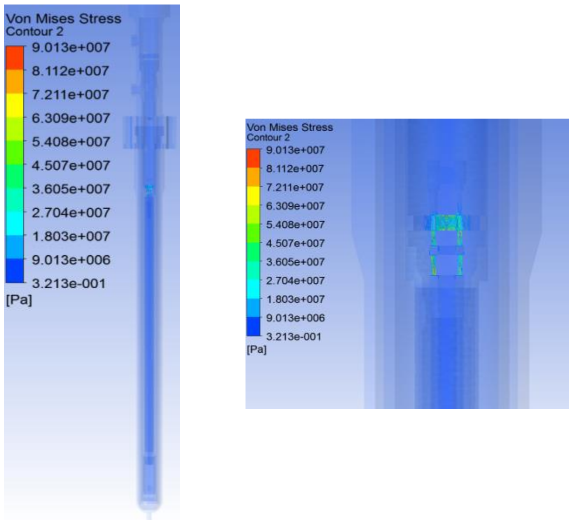


Fig. 5 Detailed view on the total mesh displacement of the fluid domain at t = 0.010 sec



(a) Total view (b) Detailed view

Fig. 6 Total and detailed view on the equivalent stress of the test rig at t = 0.01 sec

in the test rig and shown in Fig. 5.

However, the location of the maximum equivalent stress of the test rig is shown in Fig. 6.A value of the maximum equivalent is 90.1 MPa.

4. Conclusions

The dynamic behavior of the test rig under $\dot{m}_{fluid} = 1.0\ kg/s$ is performed using the 2-way fluid-structure interaction analysis.

The location of the maximum deformation of the test rig is the bottom parts of the test rig. It is expected that the equivalent stress of the test rig is occurred. The maximum equivalent stress in the test rig under the circulation of the coolant is 90.1 MPa. The location of the maximum stress in the test rig is the connect part between the fuel rod and flow divider. A safety factor on the test rig is 3, approximately.

The deformation motion of the test rig at the bottom part of the test rig is caused about the fluid-induced vibration. A test on the fluid-induced vibration of the test rig will be performed and compared with results of the analysis in further paper.

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