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Structural Analysis of the Nuclear Test Rig Using 1-Way Fluid-Structural Coupled Analysis

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1. Introduction

To perform the experiment on the high mass flow rate of the coolant water, the coolant flow simulation is used as shown in Fig. 1. [1,2]

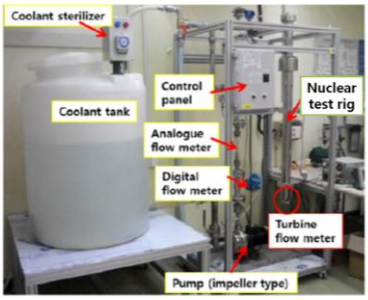


Fig. 1Experiment of coolant flow simulation[1]

The water in the coolant tank is flow into the inlet of the nuclear test rig. The mass flow rate of the water is 1.6 kg/s. The hydraulic pressure in nuclear test rig is generated by internal circulation. The fluid-induced pressure causes the vibration that affect the structural integrity of the nuclear test rig.

In this paper, the 1-way fluid-structural coupled analysis on the nuclear test rig is performed. The hydraulic pressure under the specific mass flow rate of the water is applied as load condition in the structural analysis. The location of the maximum deformation and equivalent stress is confirmed and the value of the deformation and stress is estimated to perform further experiment on the vibration characteristics.

2. Analysis modeling and condition

The three-dimension model of the nuclear test rig in the coolant flow simulator was shown as Fig. 2.

Fig. 2 Three-dimension model of the nuclear test rig in the coolant flow simulator

Twelve parts compose the nuclear test rig in analysis.

To perform the 1-way fluid-structural coupled analysis, the CFD analysis for the distribution of the hydraulic pressure is performed.

The inlet and outlet hole of coolant water into the nuclear test rig is shown as Fig. 3. The mass flow rate of the inlet is 1.6 kg/s. The water is applied as the fluid material of the coolant water in the analysis. The material property of the water is influenced by the temperature of the water. The temperature of the water is set to 25℃.

The calculated hydraulic pressure by CFD is transferred to fluid-structure interface in the nuclear test rig. The structural surface that is faced with fluid domain defined as the fluid-structure interface. The interface is applied as the load condition of the structural analysis.

SUS 304 is applied as the material of each part in nuclear test rig that the fuel mockup model is excluded.

The number of elements and nodes is 1412433, 2458040 used in structural analysis.

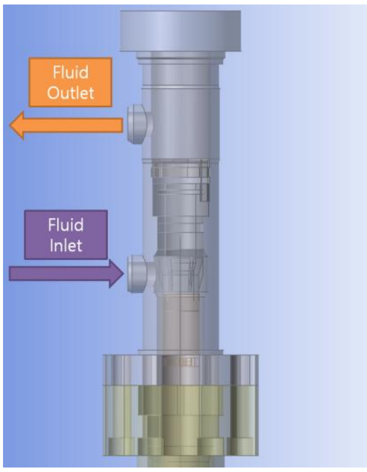


Fig. 3 Inlet and outlet hole of the fluid into the nuclear test rig

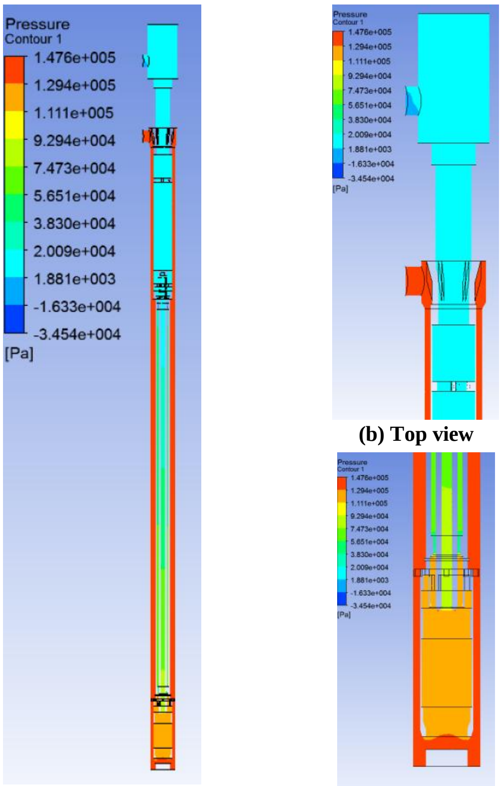
3. Analysis results

Fig. 4 shows results of the CFD analysis of the coolant water flow in nuclear test rig. The hydraulic pressure is decreased as the fluid passes by the bottom side of fuel the nuclear test rig. As shown in Fig. 5, the hydraulic pressure is differently calculated through (A) point.

The calculated hydraulic pressure by CFD analysis is applied to fluid-structure interface in the structural analysis. Results of the structural analysis are shown in Fig. 6. The maximum value of deformation and equivalent stress distribution in structural analysis is shown differently.

The maximum value of the deformation is 0.5 mm at bottom of the part in nuclear test rig as shown in Fig.6(a).

The equivalent stress contour of the nuclear test rig is shown as Fig. 6 (b). The maximum value of the equivalent stress is 41.7 MPa at top part of the nuclear test rig. SUS304[4] is used as the material on all part of the nuclear test rig. The safety factor of each part on the nuclear test rig is 5.03.



(b) Top view

(a) Full view (c) Bottom view

Fig. 4 Pressure distribution in the nuclear test rig under $\dot{m}_{fluid} = 1.6\ kg/s$

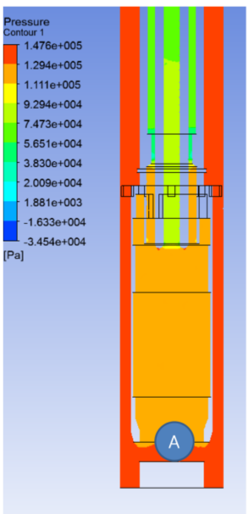
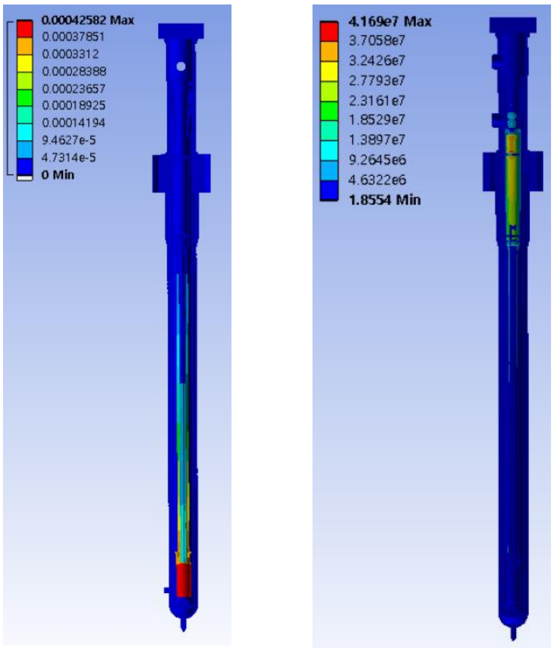


Fig. 5 Detail view of the pressure distribution in the nuclear test rig under $\dot{m}$=1.6 kg/s



(a) Deformation (Unit : m) **(b) Equivalent stress (Unit : Pa)**

Fig. 6 Deformation and equivalent stress distribution in the nuclear test rig under $\dot{m}_{fluid} = 1.6\ kg/s$

4. Conclusions

The structural integrity on each part of the nuclear test rig under $\dot{m}_{fluid} = 1.6\ kg/s$ is performed using the 1-way fluid-structure coupled analysis method. The safety factor of each part on the nuclear test rig is 5.03.

The location of the maximum deformation is the bottom parts of the nuclear test rig. It is expected that the deformation of the nuclear test rig leads to the other structural problem.

The deformation motion of the nuclear test rig on the vibration at the bottom part of the nuclear test rig will be performed using the 2-way fluid-structural coupled analysis in further paper.

REFERENCES

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[2] Hong, J.T., Kim, J.B., Joung, C.Y., Ahn, S.H. and Heo, S.H., " Measurement of Coolant Flow in a Nuclear Fuel Test Rig", International Journal of Precision Engineering and Manufacturing, Vol. 16, NO.9, pp. 1993-1998, 2015