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A Study on the Dynamic Analysis of the Nuclear Fuel Test Rig Using 1-Way Fluid-Structure Coupled Analysis

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1. Introduction

To remove the heat generated by a burn-up test of nuclear fuels, the cooling water was used. The cooling water with specific flow rate was flowed in the nuclear fuel test rig. When the cooling water was flowed in the test rig, the hydraulic pressure was generated by fluid flow. The pressure was loaded to the test rig, the fluid-induced vibration was generated. The structural integrity of the test rig was affected by the vibration. The fluid-induced vibration test had to be performed to obtain the amplitude of the vibration on the structure.

Various test systems was developed. Flow-induced vibration and pressure drop experimental tester was developed in Korea Atomic Energy Research Institute. The vibration test with high fluid flow rate was difficult by the tester. [1,2] To generate the nuclear fuel test environment, coolant flow simulation system was developed. [3] The scaled nuclear fuel test was able to be performed by the simulation system. The mock-up model of the test rig was used in the simulation system. The mock-up model in the simulation system was manufactured with scaled down full model.

In this paper, the fluid induced vibration characteristic of the full model in the nuclear fuel test is studied. The hydraulic pressure on the velocity of the fluid was calculated. The static structure analysis was performed by using the pressure. The structural integrity was assessed using the results of the analysis.

2. Analysis modeling and condition

The 3-dimension modeling of the nuclear fuel test rig was shown as Fig. 1

Fig. 1 three-dimension of the test rig

The bonded contact condition is applied to surfaces of parts that is bonded by bolt and weld method. The frictionless contact condition is applied to the other surfaces of parts. An option of the frictionless contact condition is shown as Table 1.

The inlet and outlet surface in fluid domain is shown as Fig. 2. The velocity of the inlet is 3.24 m/s. The mass flow rate by calculating velocity of the inlet is 1.6 kg/s

Full fluid domain is composed with three fluid domains. The conservative interface flux model is applied in the interface surface between each fluid domain

The water is used as the material of the fluid. The laminar fluid model is applied.

Table 1 Properties of the frictionless contact condition

Name	Option
Behavior	Auto Asymmetric
Formulation	Augumented Largrange
Detection method	On Gauss point
Normal stiffeness	1
Stabilization damping factor	0.1

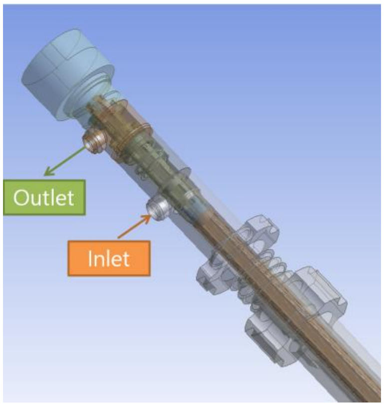
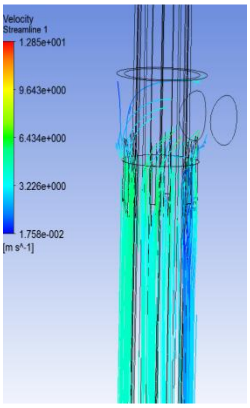


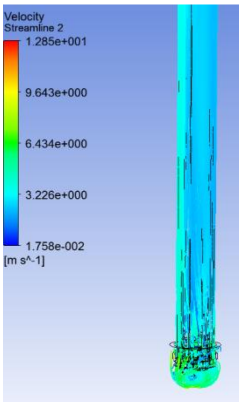
Fig. 2 Inlet and outlet of the fluid

3. Analysis results

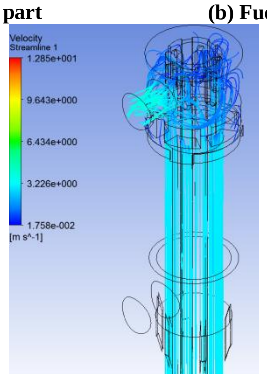
Results of the fluid anaysis was shown as Fig. 3 . The velocity streamline of the fluid on inlet face, outlet face and fases that fuel rod is mounted. the whirlpool occurs at bottom in test rig. Due to the fluid flow from the inlet, the fluid is bottom of the test rig is moved to outlet face through fuel rods. the hydraulic pressure of the fluid flow is obtained by fluid analysis shown as Fig. 4. It is observed the difference between the inlet pressure and outlet pressure.



(a) **Inlet part**



(b) Fuel rod part



(c) Outlet part

Fig. 3. Velocity of the fluid in the fuel test rig

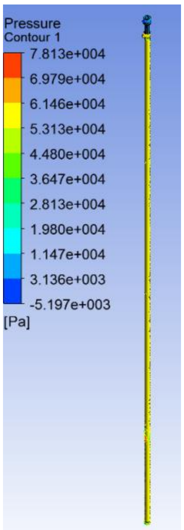
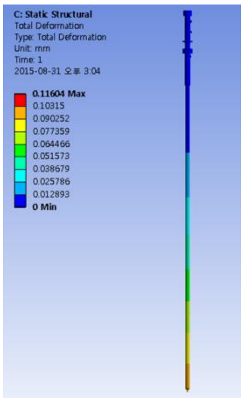
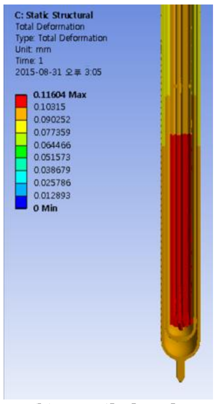


Fig. 4. Hydarulic pressure counter in the test rig

Using the hydraulic pressure by fluid analysis, the static structure analysis is performed. The deformation and stress contour of the test rig is obtained. The deformation contour of the test rig is shown as Fig. 5. The maximum value of the deformation is 0.11 mm at bottom of the part that the fuel rod is mounted. The Von-mises stress contour of the test rig is shown as Fig. 6. The maximum value of the Von-mises stress is 140 MPa at upper part of the test rig. SUS 304[4] is used as the material on all part of the test rig. It is evaluated that the maximum stress value of the test rig is lower than the yield stress of the SUS304.



(a) Full scale



(b) **Detailed scale**

Fig. 5 Deformation of the fuel test rig under V_{fluid} = 3.24 m/s

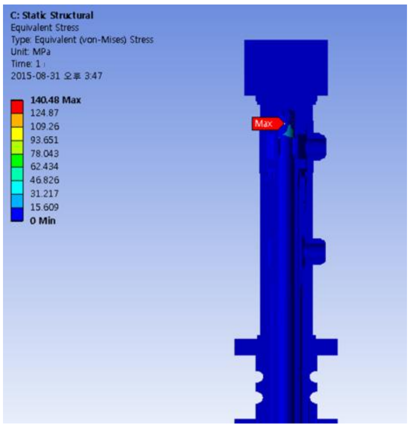


Fig. 6 Von-misess stress contour of the fuel test rig under V_{fluid} = 3.24 m/s

4. Conclusions

1-way fluid-structure coupled analysis is used to estimate the dynamic characteristic of the fuel test rig. the motion at the bottom of the test rig is confirmed. The maximum deformation of the test rig is 0.11 mm. The structural integrity of the test rig is perforemd by using the comparison with the Von-mises stress of the analysis and yield stress of the material. It is evaluated that the motion at the bottom of the test rig is able to cause other structural problem. Using the 2-way fluid-structural coupled analysis, the structural integrity of the test rig will be performed in futher paper.

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