Motion simulation of hydraulic driven safety rod using FSI method

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1. Introduction

There are various types of reactivity control mechanisms driven independently for safety in nuclear reactors. Hydraulic driven safety rod which is one of them is being developed by Division for Reactor Mechanical Engineering, KAERI. In this paper the motion of this rod is simulated by fluid structure interaction (FSI) method before manufacturing for design verification and pump sizing.

2. System Description

The main parts of this reactivity control mechanism driven by hydraulic system consist of hydraulic cylinder, piston and shaft as shown in Fig. 1.

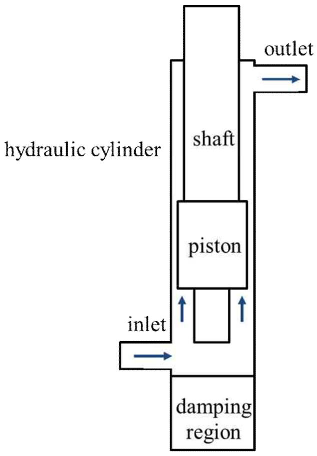

Fig. 1. Schematic of hydraulic driven safety rod

During the normal operation of the reactor, the piston is raised to the top of the cylinder by the hydraulic force induced by the pumping water of a hydraulic system. When the reactor trip is required by the reactor protection system, pumping water is by-passed and then the safety rod drops by gravity. There is a proper damping mechanism at the bottom of the hydraulic cylinder to absorb the drop impact.

3. Numerical analysis

This system has a piston which moves in the fluid region and the piston movement is determined by flow in the hydraulic cylinder. So FSI simulation method is needed to analysis this system.

3.1. FSI method setup

The deformations of piston and hydraulic cylinder by fluid induced pressure are too small to consider in this analysis. So the structures are assumed as rigid bodies.

In this case, the structural solver is not needed and the piston movement can be calculated on the computational fluid dynamics (CFD) domain using Fluent with user defined functions (UDF). The whole algorithm applied for this paper is shown in Fig. 2.

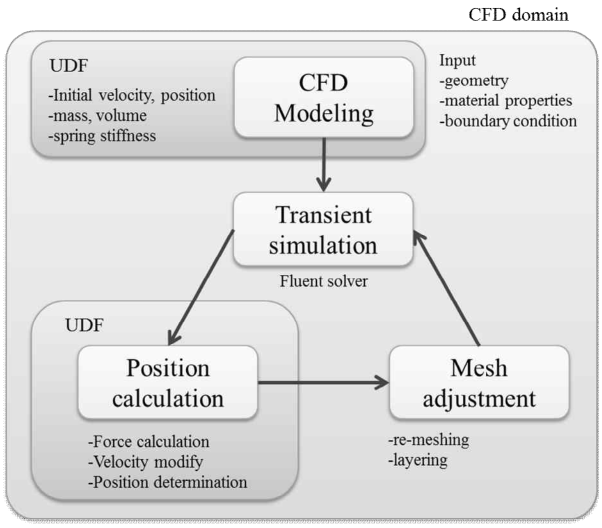

Fig. 2. FSI algorithm applied in this system

3.2. Simulation model

To minimize computation cost, the effect of inlet part is ignored and 2D axisymmetric model is applied. The simplified model is shown in Fig. 3.

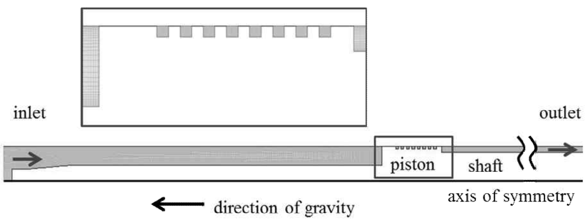

Fig. 3. FSI simulation model of safety rod

Standard k-ε model and enhanced wall function are applied to CFD model and gravitational force and buoyancy force are considered to UDF.

4. Results

Fig. 4 shows the simulated position and velocity of piston under the 5gpm flow rate. The piston reached the terminal velocity at 0.01 second. It means that the response of this system is fast as pump flow rate.

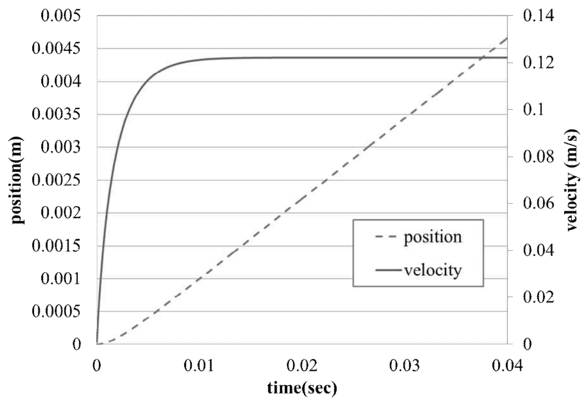

Fig. 4. Piston position and velocity under 5gpm flow rate.

Table 1 shows the terminal velocity and pressure difference between inlet and outlet at the terminal velocity depending on flow rates. The terminal velocity is linearly proportional to flow rates as shown in Fig. 5 even though the direction of flow is reversed. The pressure difference determined by head loss and weight of moving part is changed slightly according to the flow rates.

Table 1: Piston terminal velocity and pressure drop by flow rate

Flow rate (gpm)	Terminal velocity (m/s)	Pressure difference (kPa)
5	0.1212	219.66
3	0.0616	219.65
1	0.0020	219.64
-5	-0.1767	219.60

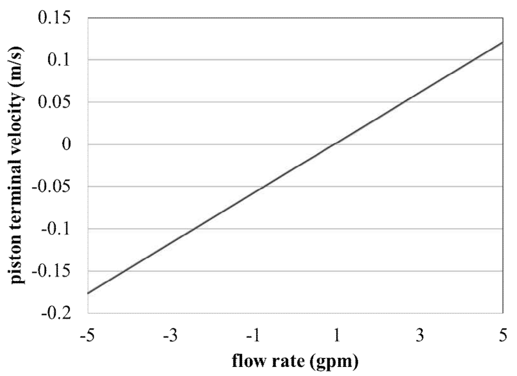

Fig. 5. Piston terminal velocity depending on flow rates

5. Conclusion

A newly designed hydraulic driven safety rod which is one of reactivity control mechanism is simulated using FSI method for design verification and pump sizing. The simulation is done in CFD domain with UDF.

The pressure drop is changed slightly by flow rates. It means that the pressure drop is mainly determined by weight of moving part.

The simulated velocity of piston is linearly proportional to flow rates so the pump can be sized easily according to the rising and drop time requirement of the safety rod using the simulation results.

REFERENCES

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