CFD Analysis of the Anti-Surge Effects by Water Hammering

Tae-oh Kim¹, Hyo-min Jeong², Han-shik Chung³, Sin-il Lee⁴, Kwang-sung Lee⁵
Department of Energy Mechanical Engineering, Institute of Marine Industry,
Gyeongsang University, Tongyeong, Republic of Korea

Email: Taeo_k@naver.com¹, hmjeong@gnu.ac.kr², hschung@gnu.ac.kr³,
lsi4493@naver.com⁴, Lks815@naver.com⁵

Abstract. Water hammering occurs due to the surge effect that comes from operating the pump, sudden stop during the operating due to a blackout and rapid open and close of the valve. By the water hammering of the pipeline and the pump, the valve are damaged. In this paper, transient analysis is conducted by CFD (Computational Fluid Dynamics). The purpose of this paper is to provide the research data about the change of the pressure and flow in the pipe that caused by the water hammering.

1. Introduction
Pressure rise and down occur due to the surge effect that comes from operating the pump, sudden stop during the operating due to a blackout and rapid open and close of the valve. Water hammering is a pressure surge or wave caused when a fluid in motion is forced to stop or change direction suddenly. A water hammer commonly occurs when a valve closes suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. This pressure wave can cause major problems, Vapor Cavity and Column Separation that draw pipe collapse. It is possible to reduce the effects of the water hammer pulses with Air Chamber, Surge Tanks, Surge Relief Valve, and other features. Among them, Surge Relief Valve is more useful than others to reduce the water hammering.

In this study, we did numerical analysis of water hammering in the pipeline to improve the surge relief valve by using CFD.

2. Methods and numerical analysis
2.1 Analysis model
Fig. 1 is the basic 2D pipe model with length and height that were used in the CFD analysis. In addition, the given area of the pipe is X * Y = 30m * 0.3m. Fig. 2 the boundary conditions were the valve inlet minus the remaining three equal parts at regular intervals which showed that the inlet and the outlet valve serves.

Numerical methods
We used unsteady flow calculation for water hammering analysis. And we make the water hammering by locking the valve of the pipe that instantly obstructs the steady flow in the pipe.
3. numerical value analysis result

Fig. 3-5 and Fig. 6-7 were analyzed in respective inlet pressure 6bar and 30bar. Time step for the transient state analysis was conducted 0.0001 seconds. Interprets the pipe valve to 0.0006 seconds is opened, analyzing while the valve is closed is 0.0007 seconds, and the maximum pressure. Pressure drops more and more from 0.0009 seconds, the pressure of 6bar pressure of 30bar can be seen to become constant at the initial pressure of 0.0015 sec 0.0022 seconds.
Fig. 4 Pressure changes in the pipe for water hammer (0.0007(sec))

Fig. 5 Pressure changes in the pipe for water hammer (0.0022(sec))

Fig. 6 Pressure changes in the pipe for water hammer (0.0007(sec))

Fig. 7 Pressure changes in the pipe for water hammer (0.0014(sec))
Fig. 8 has represented the pressure curve for the 10 meter long pipe where pressure range is 1-5bar.

Fig. 9 has represented the pressure curve for the 20 meter long pipe where pressure range is 1-5bar.

Fig. 10 has represented the pressure curve for the 30 meter long pipe where pressure range is 1-5bar.

| Table. 1 Measured and Results total Pressure |
|--------------------------------------------|
| 10m | 20m | 30m   |
|-----|-----|-------|
| 1bar| 5.82693E+14 | 1.08143E+15 | 1.93275E+15 |
| 2bar| 7.11921E+14 | 1.32231E+15 | 2.34669E+15 |
| 3bar| 8.20482E+14 | 1.51627E+15 | 2.70599E+15 |
| 4bar| 9.18226E+14 | 1.71175E+15 | 3.03296E+15 |
| 5bar| 1.00848E+15 | 1.87913E+15 | 3.32602E+15 |
Fig. 8, Fig. 9 and Fig. 10 have represented the pressure profiles of outlets for the three different sizes of pipes where applied pressure range is 1-5bar. Table. 1 has shown that when same pressure is applied to the three different sizes of pipes (10m, 20m and 30m), high pressure has developed in the smaller pipe i.e. more pressure in 10 m long pipe and this value of pressure has decreased with the increase the length of pipe.

Fig. 11 Calculating the measured pressure curve using three valves (10m)

Fig. 12 Calculating the measured pressure curve using three valves (20m)

Fig. 13 Calculating the measured pressure curve using three valves (30m)
Fig. 11-Fig. 13 The interpretation of the three valves in the single pipe. Moment comes the pressure is higher in the three valves near the inlet. Even if the same pressure at the inlet to the pipe 10m, the 20m, 30m and interpreted as 1-5bar pressure, high pressure valves hitting the short piping. Moment comes the pressure is higher in the three valves near the inlet. The higher the pressure is coming out will force greater the damage will be greater in water hammer.

4. Conclusion

In this paper, the pressure condition and the variation of it inside the pipe caused by the water hammering (surge) was analyzed with the help of CFD (computational fluid dynamics). The study was conducted for the improvement of the surge relief valve. The respective pressures were given for each pipe and the values of pressure and force were obtained at every 0.0001 seconds.

- High pressure appears in the smaller pipe and this value of pressure decreases when the length of pipe is increased.
- There is an existence of high pressure near the inlet and the value of the pressure decreases with the increase the distance from the inlet.
- The maximum pressure of 6bar and 30bar are 3.59E +14 and 7.56E +15 respectively and the maximum power of 6bar and 30bar are 1.08E +14 and 2.269E +15 respectively.

5. Reference

1. 2013. Performance Evaluation of 3D CFD Code for Water Hammer Phenomenon in Pipeline. The Korean Society of Mechanical Engineers. Vol 12. No 1. pp 4098-4102. Republic of Korea.