

# Numerical Simulation on Water Hammer Phenomenon for Single Feedwater Line

Meiling Sheng, Ting Hou and Jiaming Zhao

**Abstract** Since the feedwater line is susceptible to water hammer phenomenon, the effect of water hammer on single feedwater line was numerically analysed using the PIPENET software package. The main devices of the single feedwater line include a feedwater pump, a feedwater isolation valve, a feedwater control valve, and a feedwater check valve. Calculation and analysis of the water hammer were carried out based on the feedwater isolation valve which was instantaneously closed with various diameters and lengths and also different Poisson ratio and elastic modulus of the feedwater line. The results showed that the water hammer pressure and load in the lines reached the maximum at the moment of the feedwater isolation valve closing. After a long period of time, the final pressure of the lines was maintained at the initial pressure value and the final water hammer load tended to zero. The larger diameter and the shorter length of the feedwater lines would obtain the less water hammer pressure and load. The smaller the length–diameter ratio was, the lesser the water hammer pressure and load will be. When the length–diameter ratio reached a certain value, the water hammer load showed a fluctuation trend. The larger Poisson ratio and elastic modulus would obtain the higher peak values of water hammer pressure and load, but different Poisson ratios and elastic modulus of common materials had little effect on water hammer pressure and load. These calculation results in this work can provide some technical support for the diameter and material selection and length arrangement of the feedwater lines and also offer certain design basis for the stress analysis of the feedwater system.

**Keywords** Water hammer · Single feedwater line · PIPENET · Numerical simulation · Water hammer pressure · Water hammer load

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## 1 Introduction

Water hammer is a kind of pressure wave in pipe transient flow case, which is the result of the flow rate changes of one cross section. This change may be normal flow regulation or flow cutoff caused by some accident so that the pressure generates at a sudden jump or fall. This pressure wave transient is called water hammer phenomenon [1, 2].

The PIPENET software is advanced and reliable network flow calculation and analysis software, which is available for pipe network calculation and optimization, equipment selection, and water hammer analysis in accident condition. Particularly, PIPENET can calculate and generate the dynamic load versus time and then pass the load to pipe stress analysis software, when the dynamic load such as water hammer load and steam hammer load occurs in nuclear power plant or thermal power pipes [3, 4].

As the main pressure pipe, the feedwater line is susceptible to water hammer event. To better understand the impact of water hammer for the pipeline, the water hammer characteristic for single feedwater line was simulated and calculated in this paper using the PIPENET transient module.

## 2 Simulation and Calculation

The water hammer phenomenon is a very complex instantaneous process, and the water hammer pressure and load are selected to symbolize the energy of water hammer. There are a great many factors affecting the water hammer, such as the closure time of feedwater isolation valve, the diameters and lengths, and also Poisson ratio and elastic modulus of the feedwater line. In this work, the effect of water hammer on single feedwater line was analysed using the PIPENET software package, when the feedwater isolation valve was instantaneously closed with various diameters and lengths and also different Poisson ratio and elastic modulus of the feedwater line.

### 2.1 Model

The feedwater system in nuclear power plant is used to ensure cooling the steam generator and is a complex system. The main devices of the feedwater line include feedwater pump, feedwater isolation valve, feedwater control valve, feedwater check valve, and some related measuring instruments. The flowchart of single feedwater line is shown in Fig. 1.

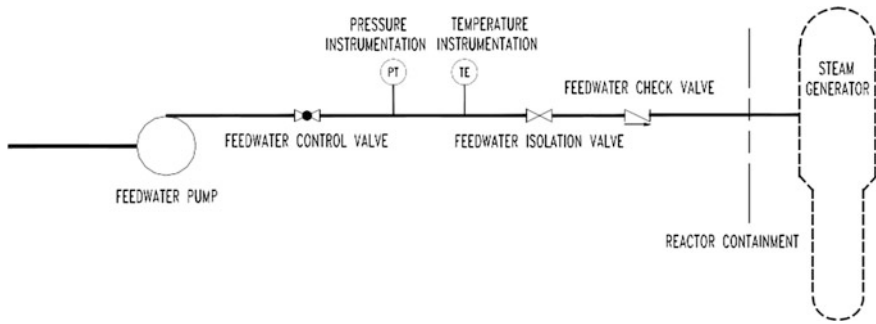


Fig. 1 Flowchart of single feedwater line



Fig. 2 Calculation model of single feedwater line: 1 feedwater pump; 2 feedwater control valve; 3 feedwater isolation valve; 4 feedwater check valve

In the calculation of this study, the feedwater line model was simplified as single line and shown in Fig. 2. On the single feedwater line, there are a feedwater pump, a feedwater control valve, a feedwater isolation valve, and a feedwater check valve. In the model, the inlet of feedwater pump is the input and the downstream of feedwater check valve (upstream of the steam generator) is the output. The input and output of both constant pressure are, respectively, 1.025 MPa.a and 5.9 MPa.a.

## 2.2 Closing of the Feedwater Isolation Valve

The feedwater isolation valve performs feedwater isolation, steam generator isolation and containment isolation function. To prevent water flow from either side of the break of the isolation valve in severe conditions, the feedwater isolation valve is asked to close in a certain time. This work analyzed the water hammer pressure and load changes in the feedwater line when the closure time of feedwater isolation valve is 4 s. The isolation valve closing curve is shown in Fig. 3, and the maximum water hammer pressure and load change curves are shown in Figs. 4 and 5.

The results showed that the water hammer pressure and load in the lines reached the maximum at the moment of the feedwater isolation valve closing. After a long period of time, the final pressure of the lines is maintained at the initial pressure value and the final water hammer load tends to zero.

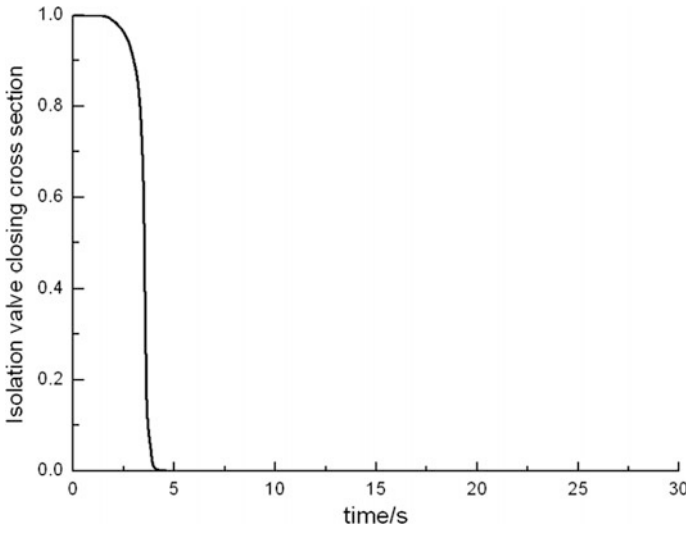


Fig. 3 The isolation valve closing curve

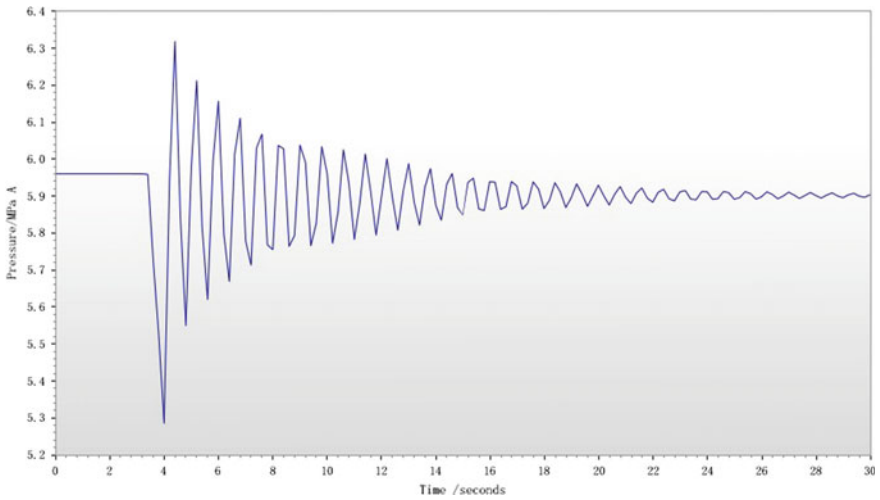


Fig. 4 Maximum water hammer pressure versus time

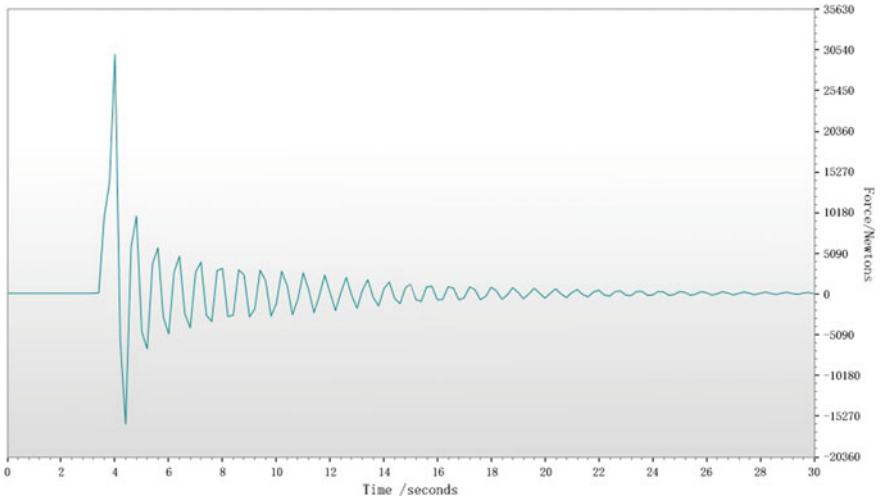


Fig. 5 Maximum water hammer load versus time

### 2.3 Relationship Between Water Hammer and Diameters of Feedwater Line

Since various diameters of feedwater lines have an impact on water hammer, this section analyzes the impact on water hammer by different pipe diameters. When the diameter varies from 300 to 650 mm, the relationship curve between water hammer and diameters was obtained and shown in Fig. 6.

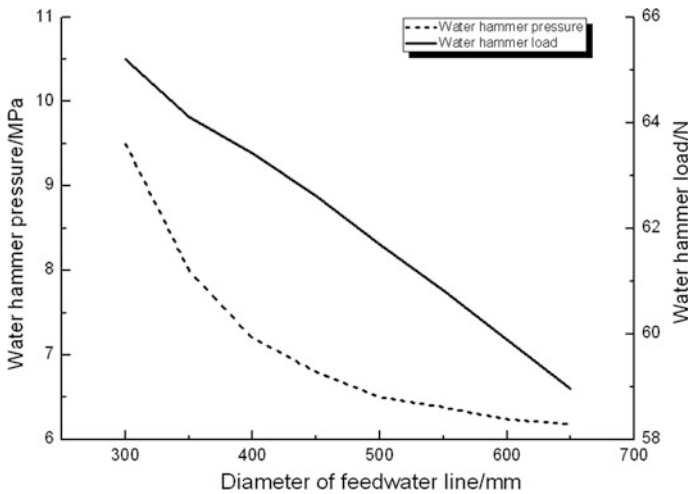


Fig. 6 Relationship between water hammer and diameters of feedwater line

According to the Fig. 6, it was clear that the larger the diameter was, the smaller the water hammer energy will be. When the diameter was 300 mm, the water hammer load reached 65 kN and the water hammer pressure reached 9.5 MPa.a so that the water hammer impact on the stress and design pressure of the feedwater line should be considered.

### 2.4 Relationship Between Water Hammer and Lengths of Feedwater Line

Since various lengths of feedwater lines also have an impact on water hammer, this section analyzes the impact on water hammer by different pipe lengths. When the length varies from 50 to 90 m, the relationship curve between water hammer and lengths was obtained and shown in Fig. 7.

According to the Fig. 7, it was clear that the shorter the length was, the smaller the water hammer energy will be. When the length was about 85 m, the water hammer load reached 103 kN and the water hammer pressure reached 8.6 MPa.a.

### 2.5 Relationship Between Water Hammer and Length–Diameter Ratio of Feedwater Line

After independently analyzing the impact of diameters and lengths of feedwater lines on water hammer, the synthesis influence was taken into account namely

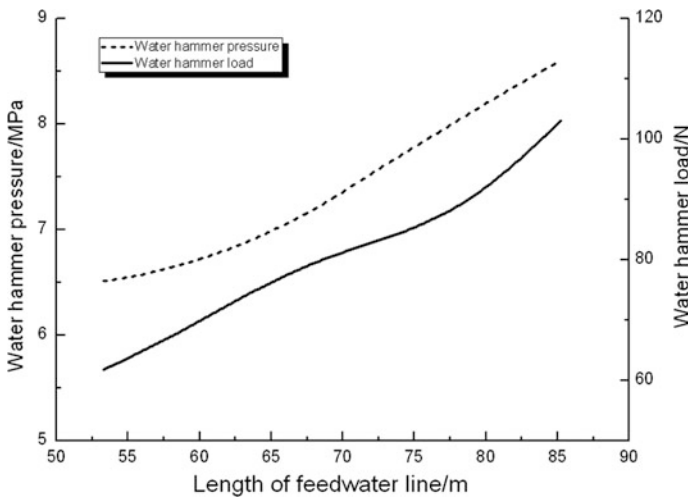
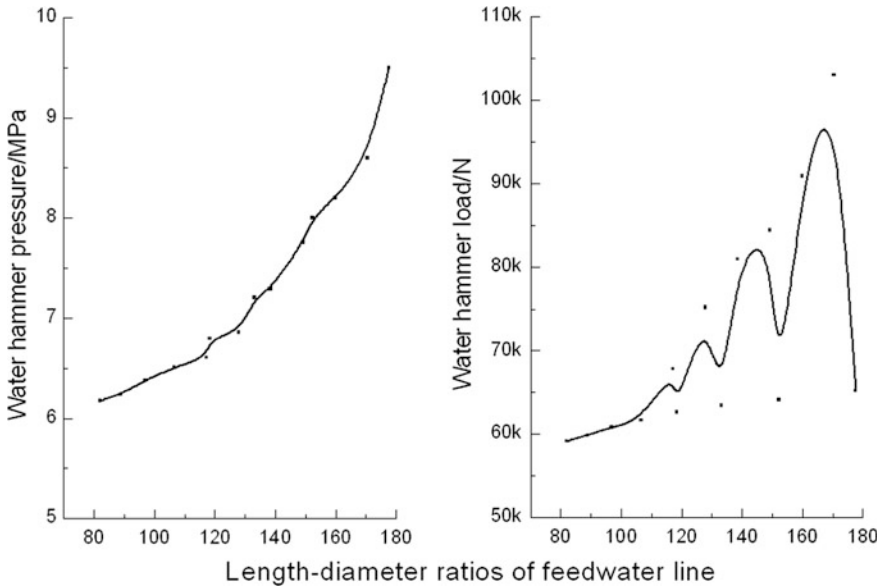


Fig. 7 Relationship between water hammer and lengths of feedwater line



**Fig. 8** Relationship between water hammer and length–diameter ratios of feedwater line

various length–diameter ratios. The relationship curve between water hammer and length–diameter ratios was obtained and shown in Fig. 8.

According to the left cure between water hammer pressure and length–diameter ratios of Fig. 8, it was clear that the smaller the length–diameter ratio was, the less the water hammer pressure will be. According to the right cure between water hammer load and length–diameter ratios of Fig. 8, it was clear that the smaller the length–diameter ratio was, the less the water hammer load will be, and when the length–diameter ratio reached a certain value, the water hammer load showed a fluctuation trend. Therefore, when the diameter selection and length arrangement of the feedwater lines is carried out, the water hammer should be calculated particularly.

### ***2.6 Relationship Between Water Hammer and Poisson Ratio of Feedwater Line***

The Poisson ratio is an inherent elasticity parameter of material, and the Poisson ratios of some common materials vary from 0.23 to 0.42. The water hammer pressure and load were calculated with the Poisson ratio, respectively, being 0.23, 0.33, and 0.42. The maximum water hammer pressure and load curves with different Poisson ratios of feedwater line were, respectively, shown in Figs. 9 and 10.

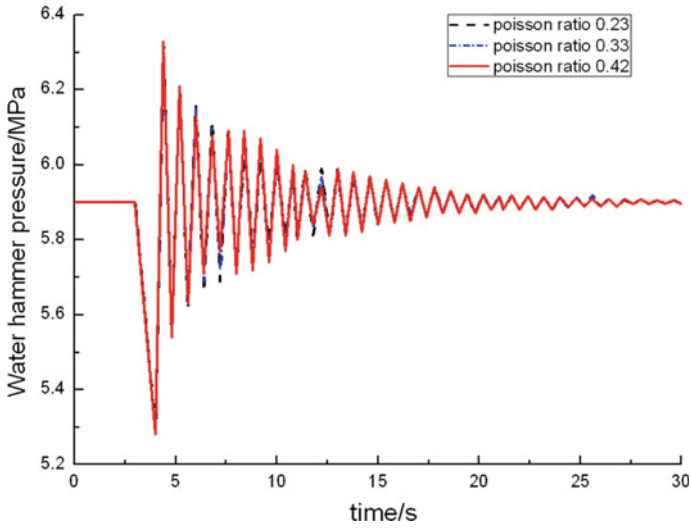


Fig. 9 Maximum water hammer pressure curves with different Poisson ratios of feedwater line

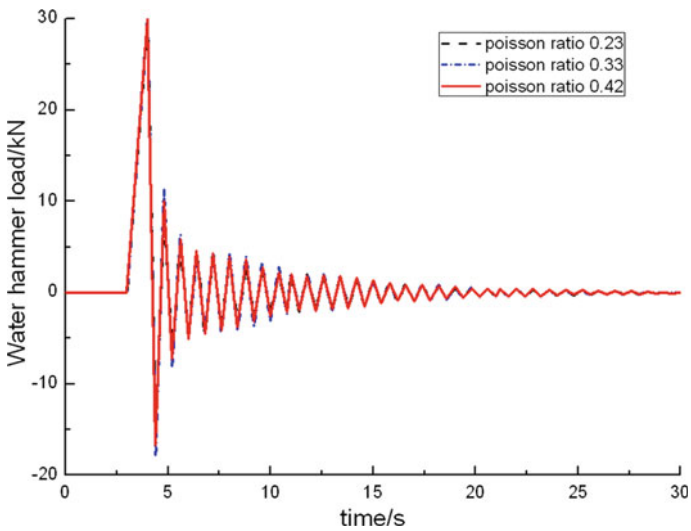


Fig. 10 Maximum water hammer load curves with different Poisson ratios of feedwater line

According to Figs. 9 and 10, the change trend of the maximum water hammer pressure and load was almost same. However, the larger the Poisson ratio was, the higher the peak values of water hammer pressure and load will be.



Since the Poisson ratio was elected from some common materials, the change range of Poisson ratio was small and the difference of water hammer pressure and load was little.

### 2.7 Relationship Between Water Hammer and Elastic Modulus of Feedwater Line

The elastic modulus is also an inherent elasticity parameter of material, and the elastic modulus of some common materials may vary from 70 to 216 GPa. The water hammer pressure and load were calculated with the elastic modulus, respectively, being 70, 143, and 216 GPa. The maximum water hammer pressure and load curves with different elastic modulus of feedwater line are, respectively, shown in Figs. 11 and 12.

According to Figs. 11 and 12, the change trend of the maximum water hammer pressure and load was almost same. However, the larger the elastic modulus was, the higher the peak values of water hammer pressure and load will be. Besides, the larger the elastic modulus was, the greater the attenuation speed of water hammer pressure and load will be.

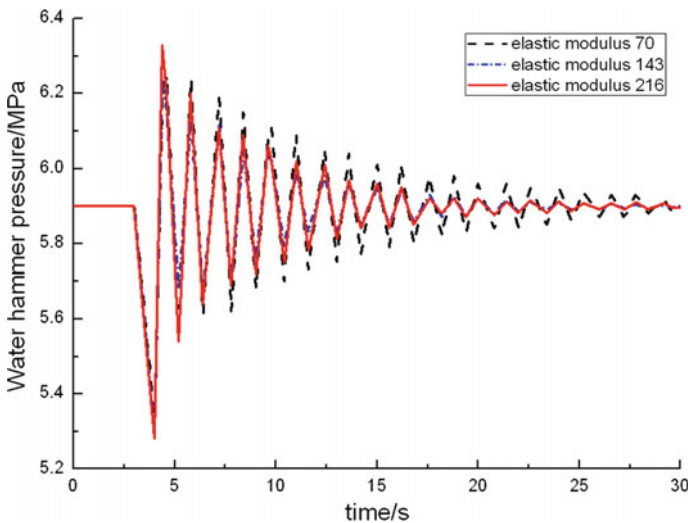
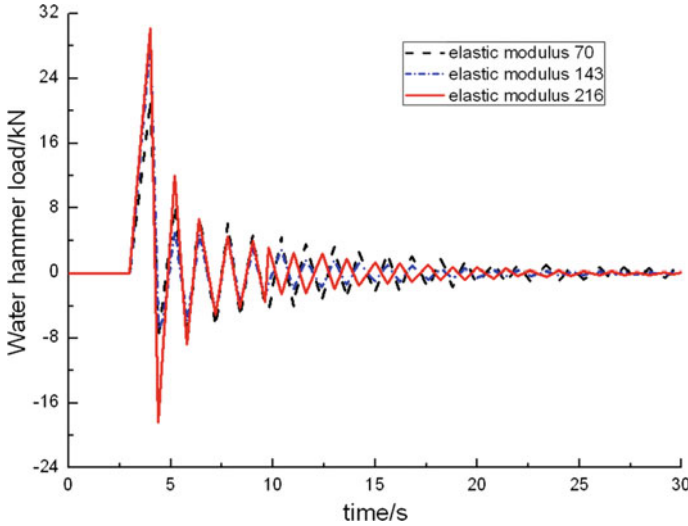


Fig. 11 Maximum water hammer pressure curves with different elastic modulus of feedwater line



**Fig. 12** Maximum water hammer load curves with different elastic modulus of feedwater line

Since the elastic modulus was elected from some common materials, the change range of elastic modulus was small and the difference of water hammer pressure and load was little.

### 3 Conclusions

The effect of water hammer on single feedwater line was numerically analysed using the PIPENET software package. The water hammer pressure and load in the lines reached the maximum at the moment of the feedwater isolation valve closing. After a long period of time, the final pressure was maintained at the initial pressure value and the final water hammer load tended to zero. The larger diameter and the shorter length of the feedwater lines would obtain the less water hammer pressure and load. The smaller the length–diameter ratio was, the less the water hammer pressure and load will be. When the length–diameter ratio reached a certain value, the water hammer load showed a fluctuation trend. The larger Poisson ratio and elastic modulus would obtain the higher peak values of water hammer pressure and load, but different Poisson ratios and elastic modulus of common materials had little effect on water hammer pressure and load.

Through the brief calculation in this work, the water hammer effect should be considered when carrying out the diameter selection and length arrangement of the feedwater lines and also the stress analysis of the feedwater system.

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