University College London

MEng Mechanical Engineering

MECH0074 Engineering in Extreme Environments

Extreme Pressure Coursework

Author:
Hasha Dar

Module coordinator:
Prof. Ian Eames

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2.1 Frequency of the water hammer pressure fluctuation in a pipe

2.1.1 Pressure fluctuation and associated frequencies analysis

The maximum magnitude of the water hammer pulse is (1). This is also known as the Joukowsky equation.

$$\Delta p = \rho a_0 \Delta v \,(\mathrm{Pa}) \tag{1}$$

where Δp is the change in pressure, ρ is the fluid density, a_0 is the sonic velocity in the pipe and Δv is the change in fluid velocity. The sonic velocity can be determined through (2)

$$\frac{1}{a^2} = \frac{1}{c^2} + \frac{\rho D}{\tau E} \tag{2}$$

where c is the speed of sound in the fluid, ρ is fluid density, D is pipe internal diameter, τ is wall thickness of pipe and E is Young's Modulus of pipe. Running the MATLAB script with the values shown in Table 1, Figure 1 was generated.

Parameter	Value
c	$1100\,\mathrm{m\,s^{-1}}$
ρ	$455\,\mathrm{kg\,m^{-3}}$
D	$793.94\,\mathrm{mm}$
τ	$19.06\,\mathrm{mm}$
E	$200\,\mathrm{GPa}$
Δv	$1.5\,\mathrm{m\,s^{-1}}$
a_0	$1041.89\,\mathrm{m\,s^{-1}}$

Table 1: Values for Joukowski Prediction.

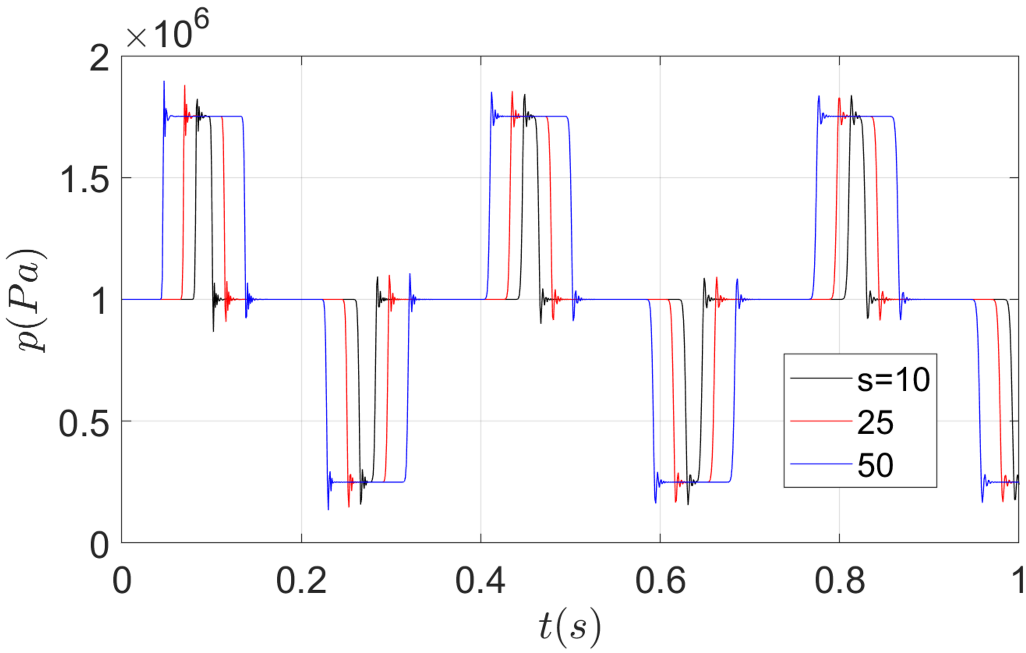

Figure 1: MATLAB script results showing pressure against time for $s = 10,\ 25,\ 50\,\mathrm{m}$.

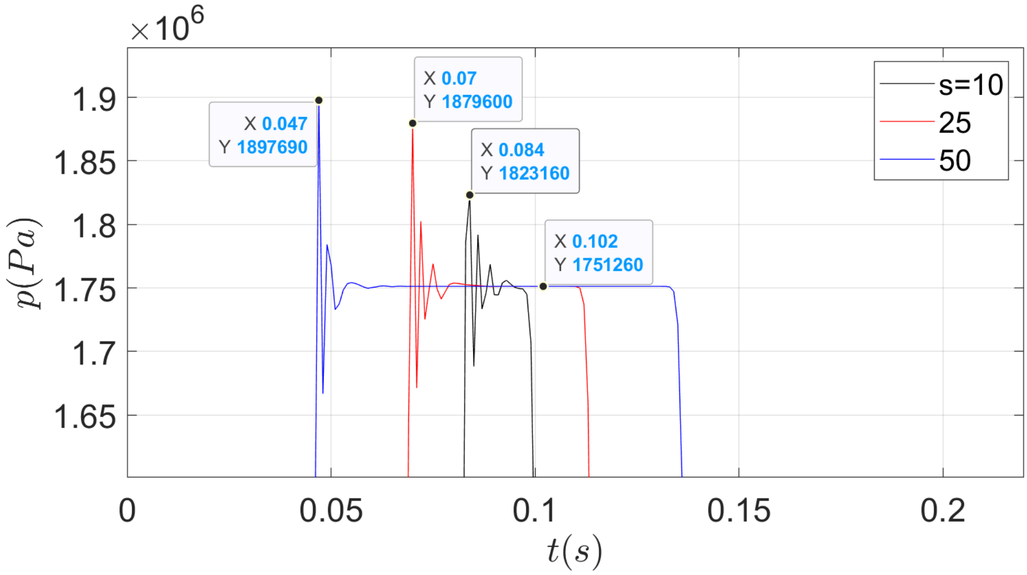

Figure 2: Index points for finding maximum pressure differential and settled pressure differential.

Using the Joukowsky equation, we attain a value for our pressure differential:

$$\Delta p_{joukowsky} = 711\,087\,\text{Pa} \tag{3}$$

Table 2 shows the maximum pressure differentials for each index point (s- value) and the pressure differential of the settled value.

s- **value**	**Maximum pressure differential**/Pa	**Percentage difference compared to analytical**
10	823160	15.76%
25	879600	23.70%
50	897690	26.24%
Settled value	751260	5.64%

Table 2: Pressure differentials for indexed s- values and settled values.

An analytical result for the frequencies of the pressure fluctuation can be found using (4).

$$T = \frac{1}{f} = \frac{2L}{c} = \frac{2 \cdot s}{1100} \tag{4}$$

Analysing the period of the pressure differentials, we can find that the frequencies of the pressure fluctuation in Table 3. The index points to find the periods of oscillation were selected as the first peak of the overshoot.

s- **value**	**Frequency**/Hz **(MATLAB)**	**Frequency**/Hz **(Analytical)**	**Percentage difference**
10	10.99	11	0.09%
25	21.74	22	1.18%
50	55.56	55	1.02%

Table 3: Frequency of pressure fluctuation.

2.1.2 Forces acting on bend and direction of total force on expansion loop

2.2 Model analysis of expansion loop

2.3 Discussion and context