Impulse line characteristics

Measurement technique of process (BMEVGAG03)

1. *Aim of the measurement*

The aim of the measurement is to determine the wave velocity, the reduced elasticity modulus, and the elasticity modulus of three different examined pipe-lines.

2. *Description of the measurement*

The sketch of the experimental set-up is presented in Figure 1. There are three parallel polymer pipe-lines with different geometry and mechanical properties. During the measurements water always flows just across one pipe-line which can be controlled by valves at the pipe ends.

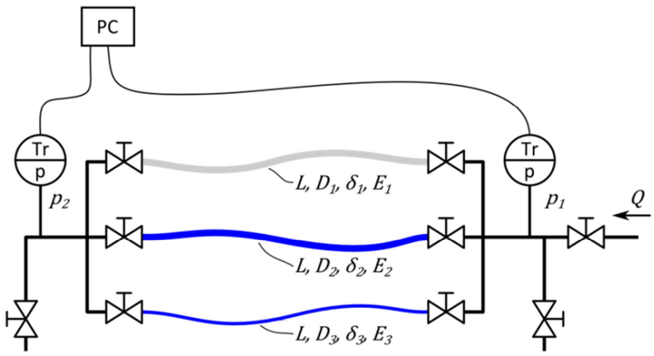

Figure 1: The sketch of the experimental set-up.

Two pressure transmitters are built in to the system, which measure the pressure in the inlet ($p_1(t)$) and in the outlet ($p_2(t)$) section of the pipe-lines. The sampling frequency is 5000 Hz. A pressure wave can be started with the help of a valve which is built near the inlet. This wave diffuses across a pipe-line; the $p_1(t)$ and $p_2(t)$ signals can be measured and saved with the help of a computer. The measurement is repeated twice in the same pipeline (to reducing the measurement errors); afterwards the other two pipe-lines (=impulse lines) can be also measured. (I.e. every group has 9 measured signals.) With the help of the cross-correlation, the time dilate t^* can be determined and the pressure wave velocity can be also calculated ($a=L/t^*$).

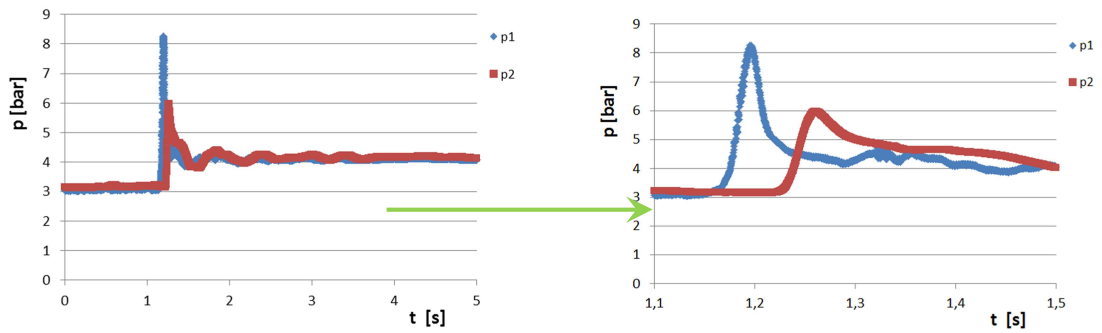

Figure 2: The choice of time interval for the cross-correlation.

3. Post-processing of the measured data

The steps of determination of the time dilate with the help of the cross-correlation (steps 1-3.) are the followings.

1. step: The measured signals are 5 seconds length; the transient event has to be found in this signal and chosen from that, see Figure 2.

2. step: The cross-correlation function is a built in command in the software (eg. MS Excel: CORREL). The signals have to be written in the argument according to the Figure 3, the column of the p_1 signal have to be fixed. Note: the lengths of the correlated signals have to be the same. (In the presented case, this implies 1000 points, which is 0.2 second, see figure 3.)

E2 fx =CORREL(C$5700:C$6699;D5700:D6699)

	B	C	D	E
1	t [s]	P1 [bar]	p2 [bar]	Koreláció
2	0,0000	3,053	3,136	-0,22349
3	0,0002	3,053	3,144	-0,2235
4	0,0004	3,053	3,140	-0,22352
5	0,0006	3,046	3,138	-0,22353
6	0,0008	3,054	3,135	-0,22354
7	0,0010	3,056	3,139	-0,22354
8	0,0012	3,056	3,139	-0,22354

Figure 3: The cross-correlation in the MS Excel.

3. step: The cross-correlation function is presented on Figure 4. This function has a local maximal value (0.7 – 0.9) which determines the t^* time dilate. (In this case the time step is practically equal with the original time step.) The actual value of t^* is $t^* = 0{,}0822$ in the presented case. From this time dilate knowing the length of the pipes, and the pressure wave velocity can be also calculated ($a = \frac{L}{t^*} = \frac{10\ m}{0{,}0822\ s} = 121{,}6\ \frac{m}{s}$).

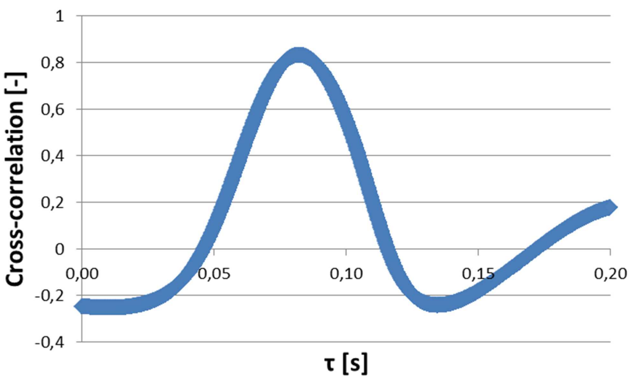

Figure 4: The cross-correlation function.

4. The results

The geometrical properties of the examined pipe-lines are presented in Table 1. (*D*: inner diameter of the pipes, δ: width of the pipewalls, *L*: length of the pipes) The elasticity modulus of the water is $E_{water}=2,2$ GPa, and density of the water is $\rho_{water}=1000$ kg/m^3.

	1. pipe (transparent)	2. pipe (thick – pneumatic)	3. pipe (thin – pneumatic)
D [mm]	5	5	3
δ [mm]	1,5	1,5	1
L [m]	10	10	10

Table 1:The geometrical properties of the examined pipe-lines.

With the help of the Allievi-theory, the pressure wave velocity (*a*) can be calculated from the reduced elasticity modulus of the system (E_r), and from the density of the fluid (ρ):

$$a^2 = \frac{E_r}{\rho}.$$

The reduced elasticity modulus can be estimated from the following equation:

$$\frac{1}{E_r} = \frac{1}{E_{water}} + \frac{1}{\frac{\delta}{D} E_{pipe}},$$

where the E_{pipe}) is the elasticity modulus of the pipe.

From the two former presented formulas, the values of Table 2 can be determined.

	1. pipe (transparent)	2. pipe (thick – pneumatic)	3. pipe (thin – pneumatic)
a [m/s^2]			
E_r [MPa]			
E_{pipe} [MPa]			

Table 2: The calculated properties of the examined pipes.

The report has to contain the compulsory requirements (see on the website) and also the following:

- A brief introduction of the applied mathematical methods.
- In this description presented figures (with own measured data).
- The calculated data according to Table 2.

5. The pressure transmitters

- Product: Keller Druckmesstechnik
- Type (pressure transmitter 1) : PA-21SR/16 bar/80520.35
- Product number (1 pressure transmitter) : 222140.0574/02/08
- Type (pressure transmitter 2) : PA-21SR/16 bar/80520.3
- Product number (pressure transmitter 2) : 222140.0006/07/07

6. Questions

- Presents the sketch of the experimental set-up!

- Describe the process of the measurement (3-5 sentences)!
- Describe briefly the post-processing methods (3 steps: 3-5 sentences)!
- Define the pressure wave velocity if the density of the fluid and the reduced elasticity modulus is known!
- Define the reduced elasticity modulus!