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Dynamic characteristics of a pressure measuring system

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S U M M A R Y

Some results of an experimental study on dynamic characteristics of a system measuring liquid pressure fluctuations on a rigid surface have been presented in this paper. The system consisted of pressure tapping, connecting pipe and pressure transducer. The effect of the length and diameter of the connecting tube on the dynamic response of the system has been studied. The results of the first experiments have been presented in form of transfer functions. Conclusions concerning the application of the results obtained are drawn.

R E S U M E

Des résultats des recherches experimentaux des caracteristiques dinamiques, a savoir les mesures des fluctuations de pression d'un fluide sur la paroi, ont eté presenté dans l'article suivant.

Le systéme de mesure comprend la prise de pression sur la paroi, le tube de connection, le capteur de pression, ainsi que l'enregisteur digital.

On a étudié l'influence de la longueur et du diamétre du tube sur la réponse dynamique du systéme de mesure. Les résultats des essais ont eté présentés sous forme de la fonction transmittance permettant l'application pratique des résultats obtenues.

1. INTRODUCTION

The insight into spatial distribution of static and dynamic characteristics of pressure in essential in many fields of hydraulics.

Techniques of measurement of presure fluctuations within the fluid body have been significantly improved recently, e.g. |1|.

Pressure fluctuations on rigid surfaces which are in touch with fluid have also been investigated by many researchers applying sometimes very sophisticated techniques |2|,|3| .

Pressure fluctuations are being primarly investigated in hydraulic engineering practice in order to determine fluid loads on parts of hydraulic structures. Although the load (force) can be measured directly through force balance, it is often more suitable to measure the pressure at several points and to obtain the characteristics of the force by processing the pressure signals. An example of this approach is given by Špoljarić, Maksimović and Hajdin |4|.

The most reliable pressure measurements are obtainable by a flush mounted small diameter transducer to the wall. However, this method is sometimes difficult or even impossible to apply. An alternative is to connect the pressure tapping and transducer by a small diameter connecting tube. The tube introduces changes into dynamic characteristics of the measuring system i.e the system suffers attenuation and resonance at some frequences.

To investigate these changes, an experimental study has been carried out in the Hydraulic Laboratory at the Faculty of Civil Engineering in Belgrade. The plastic flexibile pipes have been used and the length and diameter of the pipes have been varied in order to analyse the dynamic characteristics of the measuring system by comparing the relationship between its input and output. In this particular case the input to the system is pressure fluctuation at the wall (obtained by flush mounted transducer) and the output is the pressure (or corresponding voltage output) fluctuations at the end of the connecting pipe /Fig.1/. The pressure has been measured by the transducers with natural resonance frequencies much higher than those of the measuring system. Hence the changes introduced by the transducers and their electrical circuits are neglected.

The relationship between the input pressure p(t) and the output voltage v(t) of the measuring system is given by the convolution integral |5|.

$$v(t) = \int_0^{\infty} h(\tau)\, p\,(t - \tau)\,d\tau \qquad (1)$$

or by means of the frequency response function:

$$H(f) = \int_0^{\infty} h(\tau)\, e^{-j2\pi f\tau}\, d\tau \qquad \text{where} \quad j = \sqrt{-1} \qquad (2)$$

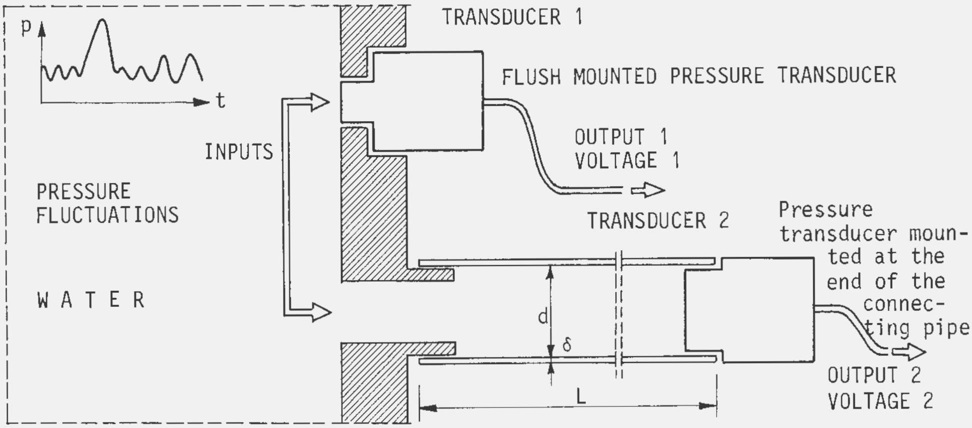


Fig. 1. Two types of pressure transducer mounting

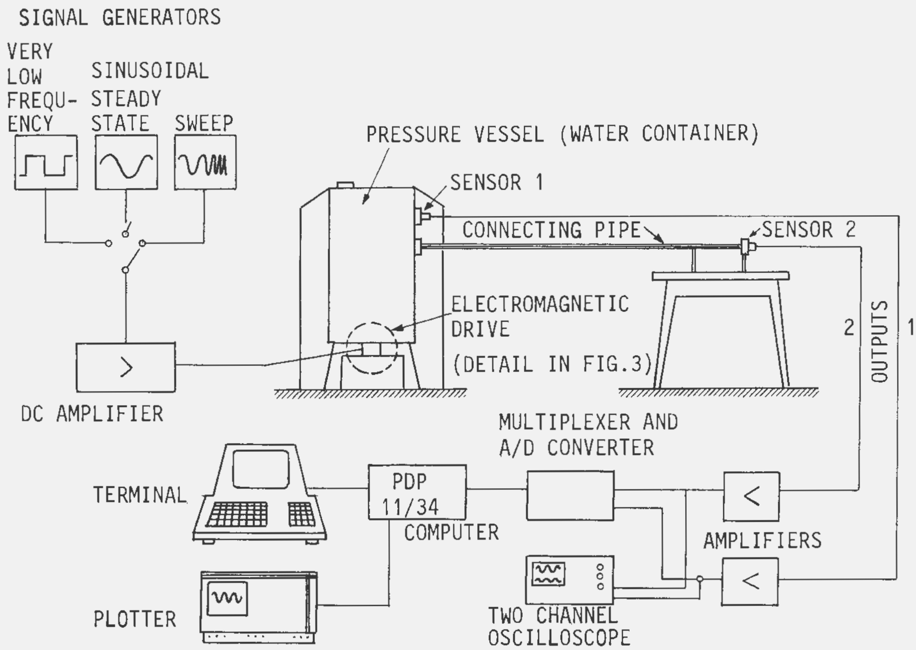


Fig. 2. The experimental rig

If P(f) is the Fourier transform of the input pressure p(t) and V(f) the Fourier transform of the resulting output voltage v(t) then

$$V(f) = H(f)\cdot P(f) \tag{3}$$

In complex polar notation it can be written as:

$$H(f) = |H(f)|\, e^{-j\,\phi(f)} \tag{4}$$

where $|H(f)|$ is the gain factor of the system.

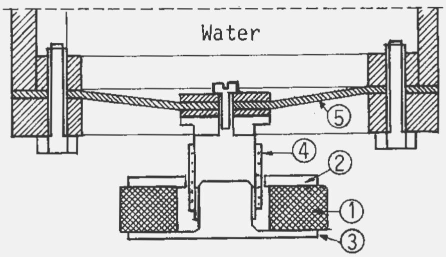
The H(f) is also called the transmissivity function. The results obtained by the experimental study in this paper will be shown in the form of gain factor.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

The experimental rig designed for investigation of the dynamic behaviour of the pressure measuring system is shown in Fig. 2.

A cylindrical container filled up with water (air released) was used for applying the defined (deterministic) pressure fluctuations.

An electromagnetically driven coil (details in Fig. 3.) was mounted to the rubber bottom of the container.



1 permanent magnet
2, 3 soft iron
4 coil
5 rubber bottom of the water container

Fig. 3. Detail of the pressure fluctuations drive

TABLE 1 Characteristics of the investigated connecting tubes

CODE OF THE EXPERIMENT	LENGTH OF THE TUBE (m)	DIAMETER (mm)	WALL THICKNESS (mm)	RESONANT FREQUENCY (Hz)
EXP 1	0.85	9.6	1.60	10.6
EXP 2 A	1.80	7.00	1.00	14
2 B	0.90			33
2 C	0.45			66
EXP 3 A	0.90	4.5	0.75	32
3 B	0.45			64
EXP 4 A	0.96	7.5	1.60	14
4 B	0.85			20
4 C	0.48			28

A presure transducer (Transducer Nº 1 - Fig. 2.) was mounted flush to the wall of the container, whereas the other was installed at the end of the plastic pipe. The length and diameter of the pipe were varied as shown in TABLE 1.

The electromagnetically driven coil was supplied by alternating current in such a way that it enabled the pressure to fluctuate in either of the following ways:

sinusoidal 

square wave 

sinusoidal sweep 

The output signals from the piezoresistive transducers were fed to the computer via an A/D convertar for fourther digital proceesing.

An example of the output signal from the flush mounted transducer is shown in Fig. 4. The sinusoidal sweep input was applied in this case.

The natural frequency of the water container is 118 Hz which is observed as a "burst" in Figure 4. The same value has been determined by applying the step signal as an input and allowing the peessure in the container to fluctuate at its natural frequency.

In figure 5 an example of pressure fluctuations at the flush mounted transducer (1) and at the transducer (2) the end of the connecting tube are shown.

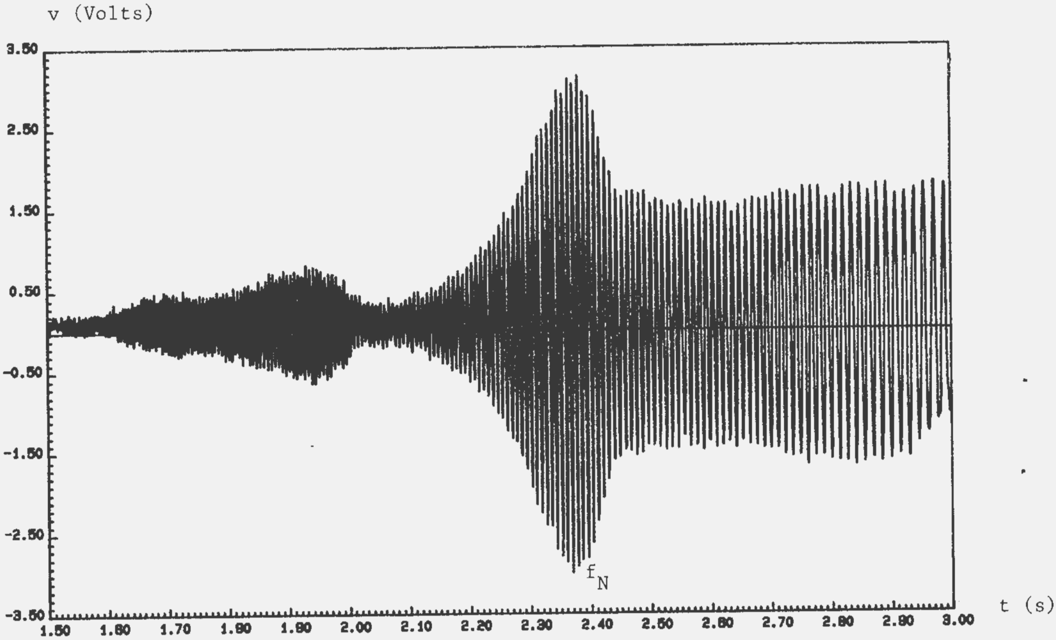
A single pulse of the step function was applied as an input. It can be seen that the pressure at transducer 1 starts to fluctuate at the frequency equal to the natural frequency of the container, whereas the pressure at point 2 (transducer 2) is subject to damping of the connecting pipe.

Similar plots have been taken from other experiments and used for analysis of the dynamic characteristics of the measuring system.

3. RESULTS FROM THE FIRST EXPERIMENTS

The experiments have been carried out with each of three excitation functions.

The sinusoidal signals provide the most reliable results but they require most time consuming analysis, since the analisis of one block of data is required for obtaining only one point at the transmissivity function.



Natural frequency of
the container
f_N = 115 Hz

Fig. 4. Plot of the output signal from the flush mounted tranducer

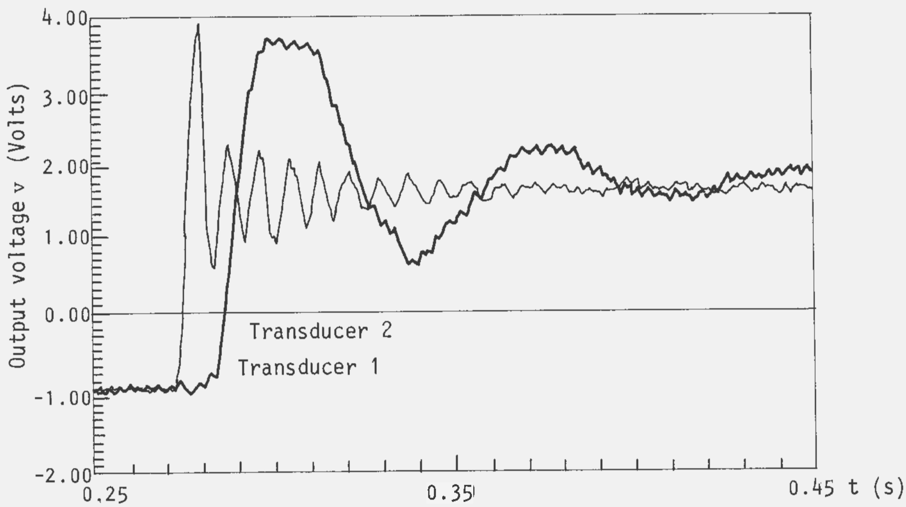


Fig. 5. Pressure fluctiations at transducers 1 and 2

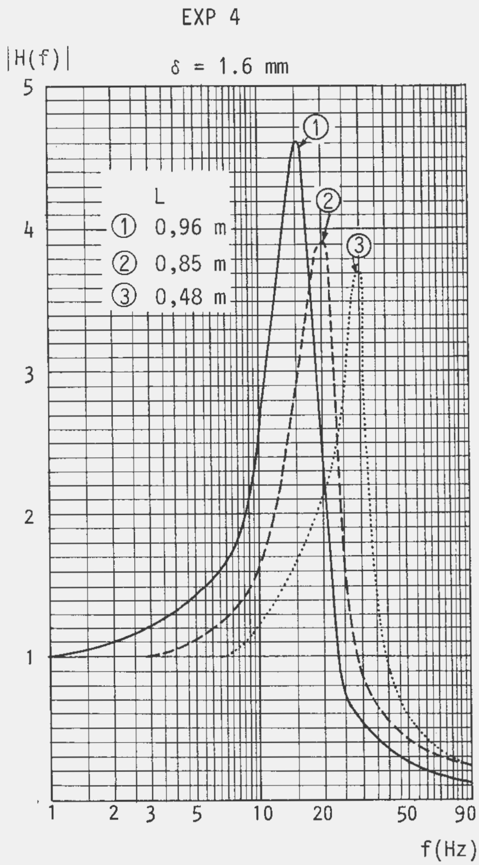


Fig. 6. Transmissivity function for the connecting tube in EXP 4. (Tube diameter d=7,5mm)

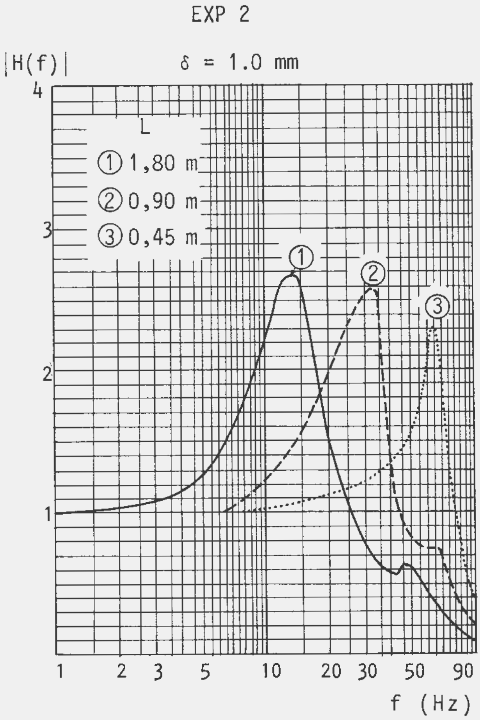


Fig. 7. Transmissivity function for the connecting tube in EXP 2 (Tube diameter d= 7,0 mm)

The sinusoidal sweep signal is the most effective for the analysis. One can obtain the transmissivity function over the whole frequency range with only one experimental which lasts several seconds.

By applying the fast Fourier Transform (FFT) procedure on the block of sampled data the power spectrum functions are obtained for sweep inputs.

In the Figures 6 and 7 the final results are shown for the experiments coded EXP 2 and EXP 4 (see Table 1 for details). The natural frequencies of all connecting tubes are shown in Table 1 as well.

The effect of the tube length is obvious in Figures 6 and 7.

The dynamic characteristics can be determined from the plots shown in the figures.

If the length of the connecting tube is such that its natural frequency is close to the natural frequency of the phenomenon investigated, significant errors can occur. To obtain reliable results the length of the tube has to be short enough in order to access its natural frequency well beyond the natural frequency of the hydraulic quantify to be measured.

The results presented in this paper are only the first steps. The investigation of the phenomenon is to be continued.

Some results presented in this paper are obtained in the work of Prodanović 6 .

4. CONCLUSIONS

The experimental rig which was designed for the present study enables the dynamic characteristics of the connecting tube between the pressure tapping and transducer to be determined by a single experiment of short duration.

Although some improvements of the rig are to be done, the results obtained by the present rig are reliable enough for practical application.

It is essential for reliable measurements of pressure fluctuations by this method that the connecting tube should be short enough in order to avoid an amplification and damping of the expected fluctuations.

5. NOMENCLATURE

d	Connecting pipe diameter
f	Frequency
$h(\tau)$	weighting function of measuring system
$H(f)$	Transfer function (transmissivity function)
$\lvert H(f)\rvert$	Gain factor
L	Length of the connecting pipe
$p(t)$	Pressure (input to the measuring system)
$P(f)$	Fourier transform of the p(t)
t	time
$v(t)$	Output voltage
$V(f)$	Fourier transform of the output voltage
δ	thickness of the wall of the connecting pipe
τ	time interval
$\phi(f)$	phase factor

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The practical application of measuring techniques in hydraulic research is treated in this volume. The emphasis is on experimental methods applied to a variety of hydraulic phenomena. However, for computational methods observation of the actual phenomena, either in the field or in the laboratory is necessary. Measuring techniques are also of great importance for the verification in the field of these mathematical models. This requires more accurate instruments and instrumentation systems which enable a greater number of measurements to be recorded simultaneously. The contributions in this work give a good impression of the efforts and the achievements made in both these fields.

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