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Optoelectronic System Registering the Shape of Cavitation Cloud

Abstract

Cavitation is one of the most interesting phenomena in area of fluid flow research. It can be observed in many different hydraulic systems and its effects can be very serious. Basic problem with cavitation is its observation. The main aim of the paper is to propose and evaluate the simple method allowing registration of the cavitation cloud shape, which will be financially and computationally undemanding. Therefore, the article presents the system registering the shape of cavitation cloud. It is based on the optoelectronic devices, i.e. lasers and photoresistors, as well as on the assumption that cavitation leads to diffusion of lasers light on the vapor bubbles. The experiment was performed for three cavitation inducers and two flow velocities. Obtained results shows that the shape of cavitation cloud is dependent on the inducer, but not on flow velocity. It can be concluded that the described optoelectronic system can be regarded as an inexpensive alternative to traditional methods of cavitation observation.

Keywords: cavitation cloud, shape registration, optoelectronic system.

1. Introduction

One of the most investigated topics in area of fluid flow research is cavitation. The main reason for this interest is prevalence of this phenomenon in many hydraulic systems as well as the fact, that it can be a very significant cause of wear, especially in devices such as propellers and pumps, where cavitation causes noise, damage, vibrations and a loss of efficiency [1-5].

The cavitation itself consists in growth of vapor bubbles in a fluid under the influence of drop in pressure below the saturated liquid pressure [6-10]. Unfortunately, one of the most absorbing problems with cavitation is observation of the phenomenon itself, not only its effects. The most common method being used for that purpose is high-speed photography [11-13]. Obtained images must then be analyzed in order to obtain information concerning cavitation area or intensity. Over time, other methods were introduced, like for example holography [14, 15] or Particle Image Velocimetry (PIV) [16, 17]. Especially PIV can be useful, particularly in flow analyses, as it allows a precise monitoring of the trajectory of fluid molecules but in that case, costs are a great obstacle.

The choice of the method that will be most suitable for the specified problem depends on the laboratory stand construction, equipment availability and on the financial abilities. Measurement accuracy and usefulness of the obtained data are other important aspects. For example, in relation specifically to the registration of the shape of the cavitation cloud, the use of the sophisticated methods is not always reasonable. Therefore, the main motivation for this paper was to propose the method allowing registration of shape of the cavitation cloud using simple methods, both financially and computationally undemanding.

2. Materials and Methods

The basic idea of the measurements bases on the assumption that cavitation leads to diffusion of lasers light on the vapor bubbles. The construction of optoelectronic system designed for registering the shape of the cavitation cloud bases on lasers (Huey Jann Electronic HLDPM12-655-5) and photoresistors (GL5616D 10k/1M). These are placed in 16 rows along the length of the flow channel/cavitation chamber (i.e. Plexiglas pipe with the internal diameter of 50 mm) - symmetrically in pairs. In order to obtain information on the changes in the bubbles volume fraction of the mixture, signal from each photoresistor was measured using digital oscilloscope (EZ Digital DS1080C). In order to maintain the accuracy of measurements, signals were averaged in 0.5 s periods. The idea of the measurements is visualized in Fig. 1.

The laboratory stand is shown in Fig. 2. The detailed description of the whole equipment can be found in [18]. In the context of this study, key information are as follows:

- the cavitation inducer can be a replaceable converging-diverging nozzle,
- there is a possibility of controllable change in flow velocity.

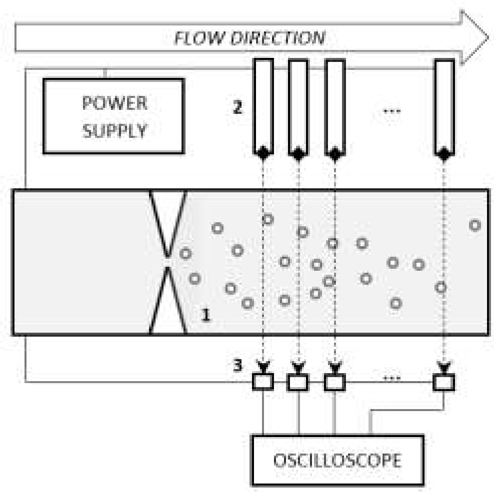


Fig. 1. The idea of the measurements: 1- cavitation chamber, 2 – lasers, 3 – photoresistors

Fig. 2. The laboratory stand [18]

The experiment was performed for three different converging-diverging nozzles, i.e. so-called Venturi tubes. Their dimensions are as follows:

- angles of converging section: 45°, 60° and 30° (for the 1st, 2nd and 3rd nozzle);
- angles of diverging sections: 45°, 30° and 60°, respectively;
- throat diameter: 3 mm;
- throat length: 6 mm.

For each nozzle, experiment was performed two times, for flow velocities (V_f) equal to 0.2 and 0.3 m·s^{-1}.

The measurement procedure was as follows:

- the cavitation chamber was filled with water;
- the whole system was switched on and calibrated - this step included inter alia adjustment of pairs of lasers and photoresistors;
- voltage signals for all photoresistors were measured without water flow (V_f = 0 m·s^{-1}) in order to obtain point of reference and avoid influence of differences in used measurement equipment – this step was repeated after each change of cavitation inducer;
- the water flow was forced and, after stabilization of flow velocity, voltage signals for all photoresistors were measured.

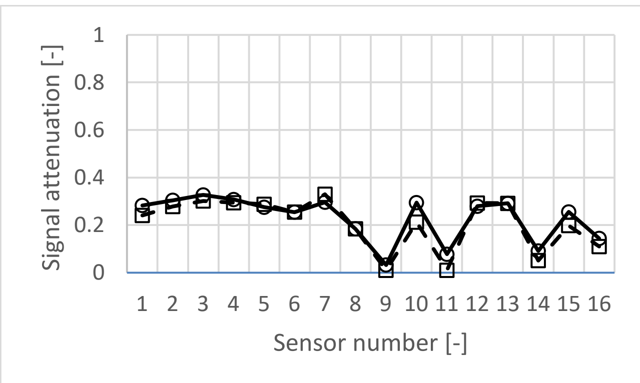
As the final step, signals were processed, i.e. normalized using reference signals and converted into an attenuation rate, which is in the range from zero to one and should be interpreted as follows:

- value of 1 means that the signal is completely attenuated, i.e. whole laser light is diffused on the vapor bubbles;
- value of 0 means that the signal is not attenuated, i.e. there is no difference between signal obtained for water flow and for stagnant water – in other words, there is no vapor bubbles in water.

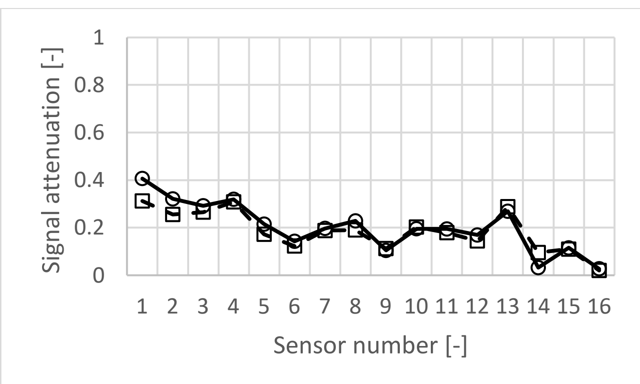
3. Results

The results of the described experiment are presented below. Diagrams shown in Fig. 3 show attenuation rate of voltage signals obtained for the first (a), the second (b), and the third (c) cavitation inducer and for two flow velocities: (V_f = 0.2 m·s^{-1} and V_f = 0.3 m·s^{-1}) Numbering of the nozzles in the figure is consistent with numbering in previous section. Numbering of sensors increases with distance from inducer, i.e. sensor number 1 is the one located next to nozzle, while the sensor number 16 is the most distant.

a)



b)



c)

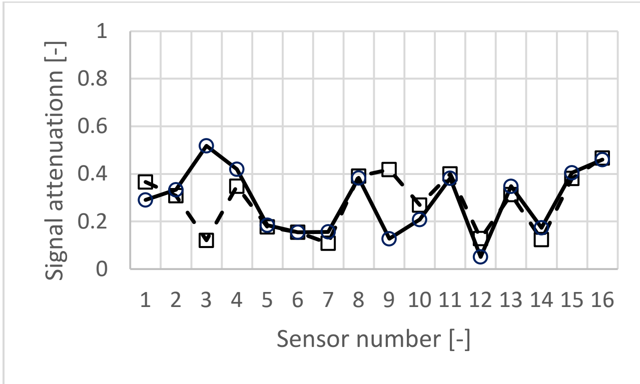


Fig. 3. Attenuation rate of signals obtained for the first (a), the second (b) and the third (c) cavitation inducer and for two flow velocities: V_f = 0.2 m·s^{-1} - dashed line, V_f = 0.3 m·s^{-1} - solid line

4. Discussion

Before we get to the point of analysis of cavitation cloud shape, it is worth to emphasize that the shape of obtained curves for each cavitation inducer is similar for both analyzed flow velocities – it is noticeable especially for the first and the second nozzle. That suggests that the obtained results are not random and the shape of the curves (which is directly related to the shape of cavitation cloud) is in fact dependent on the inducer.

The obtained results are in a way surprising, as they shows that the shape of cavitation cloud is noticeably different for each cavitation inducer:

- for the first nozzle attenuation rate is almost constant on the distance from the 1st to 7th sensor, beyond this point it subjects radical changes – these changes, however, are very similar for both flow velocities what suggests that these changes are not random;
- for the second nozzle attenuation rate noticeably decreases with distance from nozzle in a relatively regular way – the shape of passages are again very similar for both flow velocities;
- for the third nozzle it cannot be told that the shape of the passages is in a way regular – these changes are also significantly different for both flow velocities what as well suggests that shape of the cavitation cloud for this inducer is not stable.

5. Summary and Conclusions

Analysis of the results, as well as the experiment, leads to the following statements and conclusions:

- a new method of registering the shape of cavitation cloud is described;
- presented system, based on optoelectronic devices, is simple in implementation and financially undemanding;
- proposed approach appears to be useful and it can be utilized in cavitation diagnostics, especially for the fast recognition of appearing problems, when use of equipment which is sophisticated, costly or difficult of access is not reasonable;
- the shape of cavitation cloud is highly dependent on the geometry of cavitation inducer (in our case it were converging-diverging nozzles);
- the shape of cavitation cloud is not noticeably dependent on the flow velocity;
- the new method should be further investigated, particularly in the context of comparison to other methods of cavitation observation.

6. References

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