

SYNCHRONIZATION OF DATA RECORDED USING ACQUISITION STATIONS WITH DATA FROM CAMERA DURING THE BUBBLE DEPARTURE

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ABSTRACT

In this study the first part of the experimental data was recorded in a data acquisition station, and another one was recorded with a high speed camera. The data recorded using the acquisition station was recorded with higher frequency than the time between two subsequent frames of the film. During the analysis of the experimental data the problem was related to the synchronization of measurement from acquisition station and data recorded with a camera. In this paper the method of synchronization of experimental data has been shown. A laser- phototransistor system has been used. The data synchronization was required in scaling of sampling frequency in the investigated time series.

Keywords: experimental data synchronization, time series, video analysis, bubble departure.

INTRODUCTION

During the study of dynamics of bubble chain formation in liquid the data were recorded using the acquisition station and with a high-speed camera at the same time [1–4]. During the analysis of the experimental results the data synchronization was required. There are few methods of data synchronization [4, 5]. In the first method the specialized cameras which can be connected to the data acquisition station are used. Another method is based on a connection between the camera and acquisition station using PC computer. These methods allow us for the simultaneous data acquisition and the recorded video, but these methods require additional and expensive hardware. These methods need also the same sampling frequency.

In the paper the method of data synchronization, which is based on laser- phototransistor system, has been shown. This method is cheaper than the previously described methods of data synchronization. The method consisted of two stages. The first stage of data synchronization was based on the phenomenon of voltage change dur-

ing the time when the laser beam was interrupted. The second stage of synchronization was based on characteristic points inside the analysed time series. The data which were recorded using acquisition systems were sampled at frequency equal to 1 kHz. The videos were recorded with the speed of 600 fps. The time series of pressure changes in air supply system, which were recorded using acquisition systems synchronized with changes of liquid penetration into the nozzle, which were recorded with a high speed camera.

EXPERIMENTAL SETUP AND MEASUREMENT TECHNIQUE

In the experiment, bubbles were generated in the tank whose dimensions were 300×150×700 mm. The experimental setup, for which the dynamics of bubble departing was investigated, has been shown in Figure 1.

The bubbles were generated from glass nozzle with inner diameter 1 mm. The glass nozzle was placed at the bottom of the tank. The tank

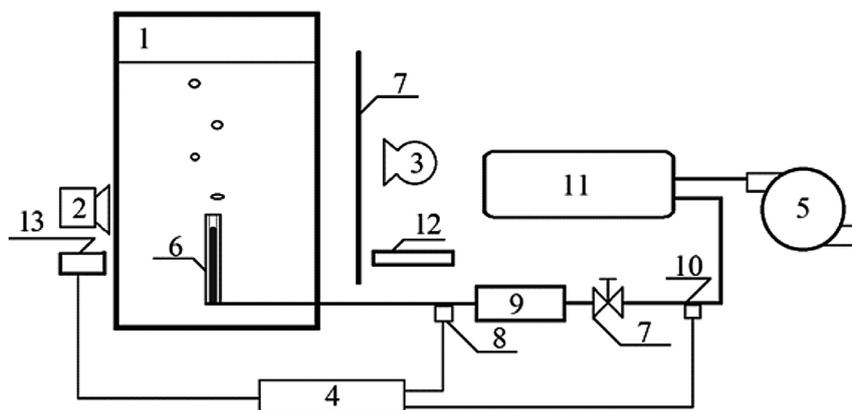


Fig. 1. Experimental setup: 1 – glass tank, 2 – camera, 3 – light source, 4 – computer acquisition system, 5 – air pumps, 6 – glass nozzle, 7 – air valve, 8 – overpressure sensor, 9 – air flow meter, 10 – pressure sensor, 11 – air tank, 12 – laser, 13 – phototransistor

was filled with distilled water. During the experiment the temperature of water was constant at about 20°C. The air volume flow rate was changed from 0.0045 l/min to 0.125 l/min. The changes of air pressure in air supply system were measured using pressure sensor MPX12DP. The time series of pressure changes in the supply system were recorded using data acquisition station DT9800 Series USB Function Modules for Data Acquisition Systems. Sampling frequency was 1 kHz. Videos were recorded using a high speed camera (Casio EX FX 1). The films were recorded in grey scale with the speed of 600 fps. The duration of each video was 20 s. The lighting was based on LED, which gave cold white light. This kind of lighting made it possible to obtain high contrast between liquid and gas. On the videos the gas phase was a dark grey and the liquid phase was light grey. This kind of lighting allows obtaining a clear boundary between liquid and gas. The light source was powered by a DC power supply. Therefore, the light intensity could be adjusted. Between the lights and tank,

the glass plate was placed. The plate was made of translucent glass.

The recorded videos were divided into frames. Using the frames, the time series of liquid penetration were obtained. The technique of the obtained time series has been presented in the paper [1].

THE SYNCHRONIZATION OF THE EXPERIMENTAL RESULTS

In Figure 2 examples of the time series of pressure changes in the gas supply system has been shown. The exemplary time series of changes of depth of liquid penetration inside the nozzle has been shown in Figure 3.

The experimental results (liquid penetration inside the nozzle and pressure changes) were recorded with different sampling frequencies (600 Hz and 1 kHz). Adjustment of sampling frequency for the analysed time series was required. The sampling frequency of pressure changes has been

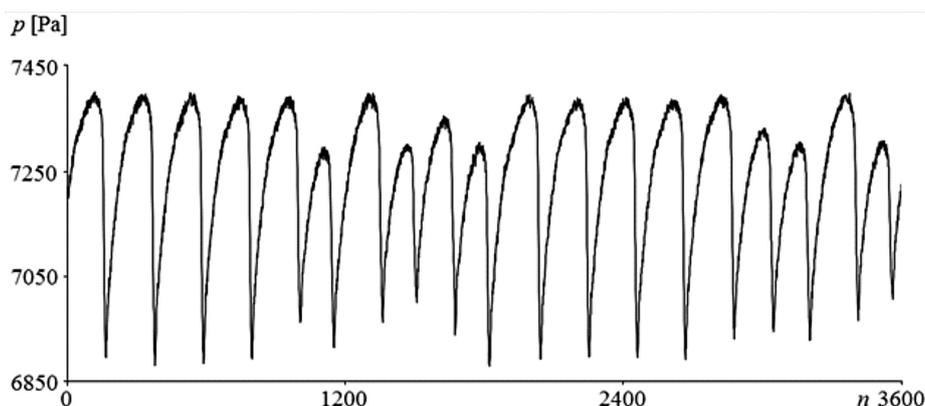


Fig. 2. Time series of pressure changes in the gas supply system

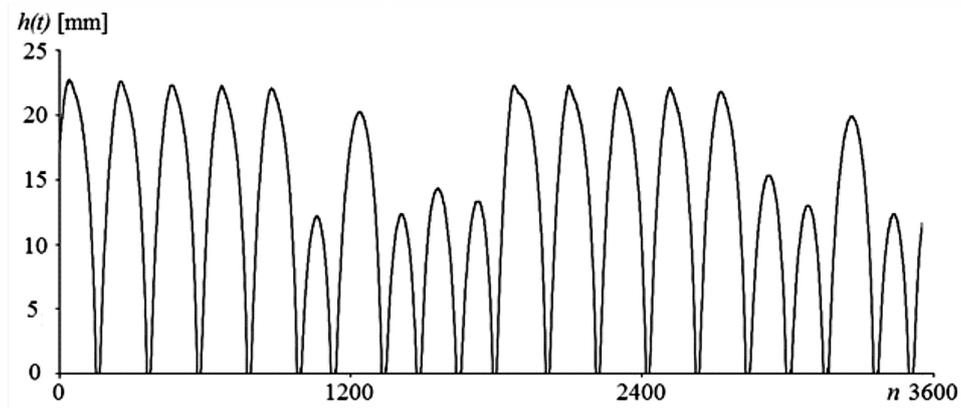


Fig. 3. Time series of changes of depth of liquid penetration inside the nozzle

modified using a computer program. The time series, which were recorded using data acquisition system, had a higher sampling frequency. In this method two samples, recorded with the data acquisition station, determined the straight line equation. The value of pressure in time between these two points was calculated using this equation. The example of the output of the algorithm is shown in Figure 4. The original points has been shown which were marked with rhombuses. The new points were plotted on a graph – marked with squares.

In the first stage of the synchronization a laser-phototransistor system has been used. The schema of electronic circuit of the laser-phototransistor system has been shown in Figure 5. The integrated circuit LM317 was used to power the laser which allowed us to achieve the stable op-

eration of the laser. Laser module was equipped with aperture. The laser beam diameter was approximately 0.1 mm. The phototransistor that was used (BPYP22) allowed the registration of the signal with a frequency above 75 kHz. The phototransistor was equipped with a cover whose length was equal to 30 mm and was made of a tube with inner diameter of 4 mm.

The laser beam was directed to the translucent plate of glass. On the other side of the glass plate the phototransistor was set. The part of the laser beam was passed through the translucent plate of glass and the next part was reflected, which gave the effect of a spots on the videos (Figure 6a). A signal from phototransistor as a time series of changing of voltage, which was generated in phototransistor, was recorded by the data acquisition station.

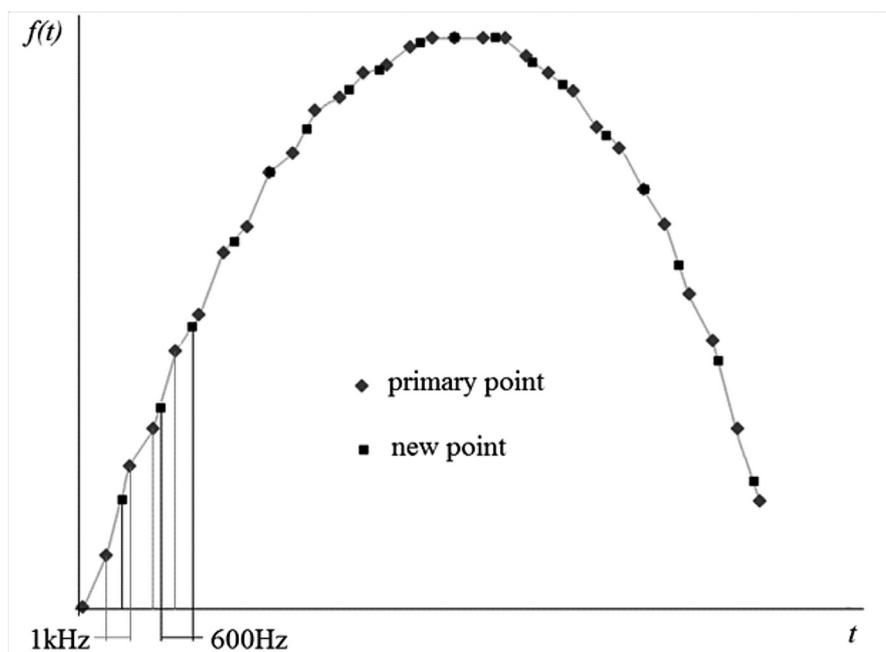


Fig. 4. The example of the result of the algorithm of changing the sampling frequency

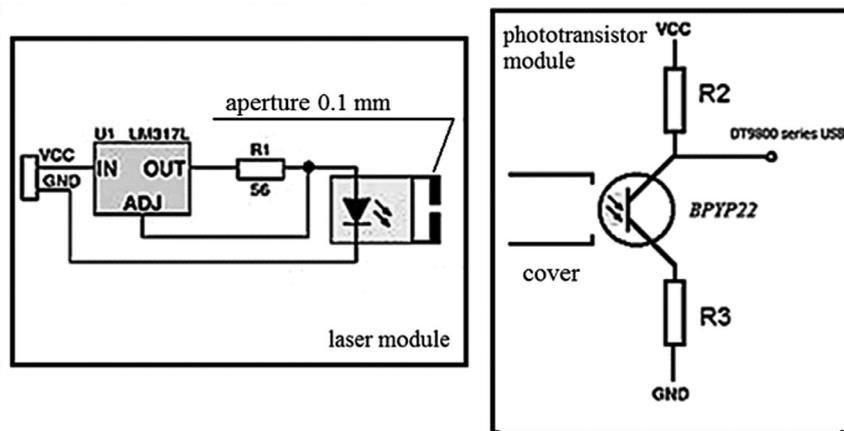


Fig. 5. The schema of electronic circuit of the laser-phototransistor system

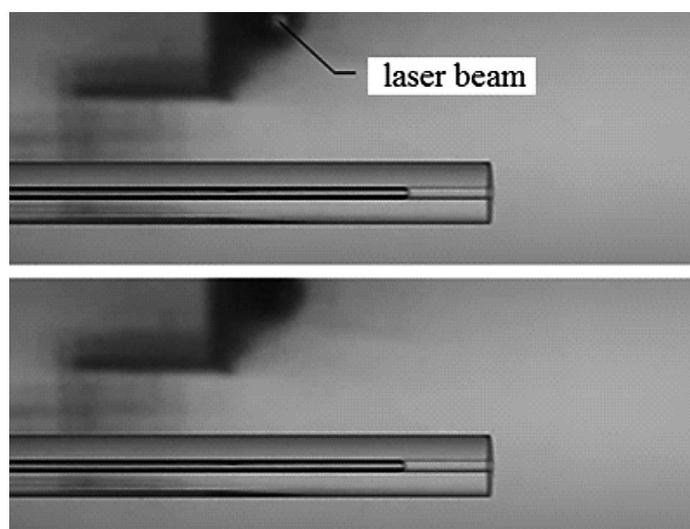


Fig. 6. The frames of the video a) visible laser beam, b) the block the laser light

Before the start of the measurement the laser was on and the voltage generated by phototransistor was equal to 2.5V. During the measurement the laser beam was temporarily blocked by a shutter. The shutter was made from a rod with an outside diameter of 5 mm. The time when the laser beam was invisible was about 0.3 s – about 180 frames. The frame in which there was no light of laser is shown in Figure 6.b. The moment when the laser beam was blocked was also observed in the signal recorded by the data acquisition station as a voltage change (Figure 7). The moment in which the voltage was re-stabilized on phototransistor (2.5 V) and the re-emergence of light on the video frame was treated as the starting of the synchronized time series.

The data obtained from the high-speed camera was analysed from the frame where the re-emergence of laser beam was noticed. In this way, the changes of liquid penetration into the nozzle

and the time of bubble growth connected with the pressure changes in the supply system.

The time of voltage rise of the signal from the laser was about 0.05 s, therefore, the accuracy of the first phase of synchronization was about 30 frames. As a result, the time series of pressure changes have been shifted to the time series of liquid penetration into the nozzle. In the second phase of synchronization the beginning of those time series have been corrected using characteristic points in those time series.

Second phase of synchronization of changes of pressure in the supply system and the time series of changes of liquid penetration into the nozzle is shown in Figure 8. Point A and point B in Figure 8 were the characteristic points of the two time series - changes in pressure in the supply system and change of the depth of liquid penetration in to the nozzle, so those points were used in second part of synchronization. In the time se-

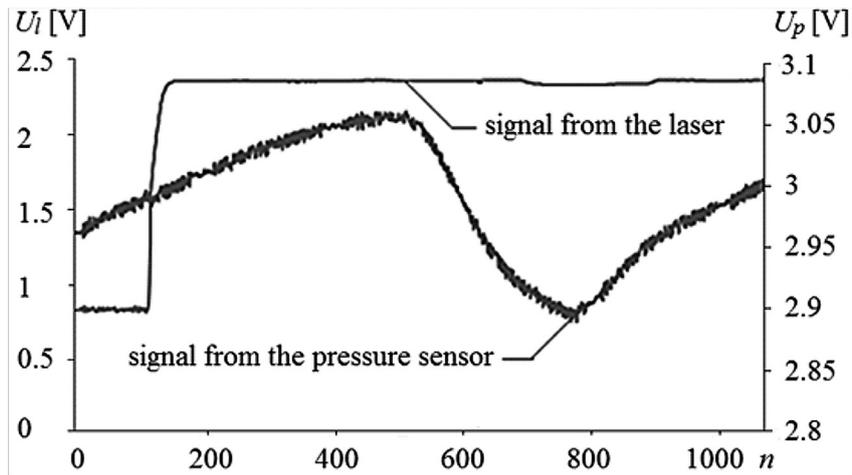


Fig. 7. Voltage change observed in the time series recorded by the data acquisition station

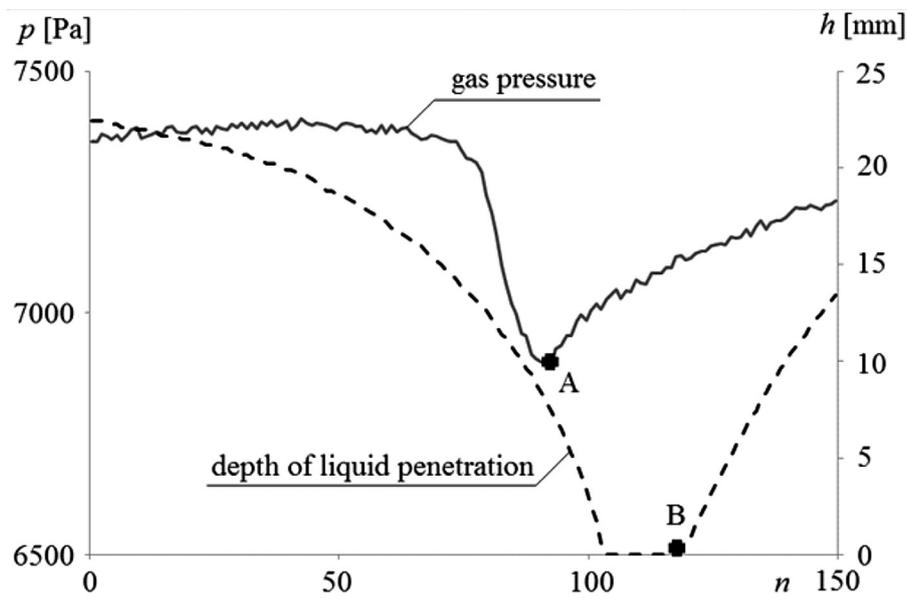


Fig. 8. Second phase of synchronization of changes of pressure in the supply system and the time series of changes of liquid penetration into the nozzle

ries of gas pressure changes in the supply system the lowest pressure value determines the time of bubble departure (A). During the bubble growth, the value of liquid penetration into the nozzle was zero. The moment when the liquid penetration increased, the time of gas bubble departing (B) is Determined. The number of samples with the lowest pressure value and the number of frames where the process of liquid penetration was starting become new onset points of time series. Using these points in the time series the experimental data was synchronized. Points A and B in those time series were set on the same values of the samples (x-axis). The samples corresponding to the presented values, at points A and B, was beginning of the analysed time series.

CONCLUSIONS

The presented method of data synchronization allowed us to fit the pressure time series recorded using the data acquisition station and the time series of changes of liquid penetration into the nozzle, recorded by the high-speed camera.

The method described in this paper can be applied only to the time series, which contain characteristic points. In this case, these points were the characteristic pressure conditions in which the bubble departed and characteristic depth of liquid penetration into the nozzle before bubble departure. Synchronization accuracy was about 0.0017 s, which is the duration of one frame.

A great advantage of the presented method of data synchronization is that additional specialized equipment is unnecessary. This reduces the costs required to perform the studies. This method enables the analysis of the time series recorded at different intervals.

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