IoT-Based Telemetry System of Ultrasonic Measurement for Experimental Study under COVID-19 Situation

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***Abstract*— As an epidemic situation of COVID-19, social gathering and working activity have limited. The research execution and engineering activities are significantly affected, especially experimental work. This paper proposes the telemetry system concept for experimenting remotely outside the laboratory. The power source of the testing equipment is controlled remotely. The camera observes the execution of the experiment. The measuring equipment can be set remotely. Consequently, the user can operate and monitor the real-time conducting the experiment from the outside. The experiment of velocity profile measurement on the bubbly flow, which is the vital task in fluid engineering, was demonstrated to confirm the concept's applicability. Finally, the experimental result could be obtained successfully under the remoted experiment.**

Keywords—Telemetry, COVID-19, Experiment, Ultrasonic,

I. INTRODUCTION

As the high demand for electrical energy consumption in the world, the power plant is imperative to be built to respond to the requirement. One of the electrical power generations base on the utilizing of steam-power. This concept is placed on coal, gas combine cycle, and nuclear power plant. However, these power plants must be operated safely without the accident. The operation is compulsory under the safety aspect. The crucial part of the plant operation according to safety standard and sustainability is the engineering design. The thermal-hydraulic and fluid mechanic behaviors of the water-steam cycle in the steam generation's boiling unit are the main sections on the accident's occurrence. It is necessary to be predicted and optimized accurately by the numerical model [1, 2]. These characteristics precisely determine the geometry, material, and other specifications, which affect the unit's safety criteria. To confirm the reliability of the model indispensably, the model validation by the experimental data is an important task. Hence, the experimental investigation on this behavior is needed [3].

Presently, due to the COVID-19 situation [4, 5], the outbreak of COVID-19 had spread in more than 200 countries. Approximately 146,198 people had died. Several measures have been used to deal with this situation, such as complete lockdown, suspension of transportation, etc. The social gathering, education, tourism, and working activity in the workplace have been prohibited or minimized. Significantly, it influences the action on the experimental task in the facility placed on the laboratory or company.

Therefore, the completion of the experiment work is a delay. Then, the engineering design and project execution as well are belated. Hence, to solve this problem, the conducting of experimental work remotely from other places outside the workplace has been considered.

The internet of Things (IoT) [6] is a system of interrelated computing devices, mechanical and digital machines provided with unique identifiers (UIDs). It can transfer data over a network without requiring human-to-human or human-to-computer interaction. As this technology, it opens the opportunity for smart activity, automation, and so on in several sectors, as shown in figure 1 such as industrial[7, 8], medical system [9], Agrological [10, 11], education [12], transportation [13] or even in for smart home [14]. Therefore, this platform has a potential significantly to apply as a telemetry system for the execution of experimental work remotely under pandemic disease circumstance as the COVID-19.

This study presents the telemetry concept to hand on the experimental activity remotely. The experiment can be conducted anywhere on the internet is available. The demonstration is focused on the experiment of the velocity distribution measurement in the bubbly flow. It is one of the critical parameters of fluid mechanics investigation. The investigation is conducted by employing the ultrasonic velocity profiler measurement system, a powerful tool for obtaining the fluid's velocity profile.

II. Measurement Device and Telemetry System

A. *Ultrasonic velocity profiler*

The UVP measurement [15-17] is an ultrasound-reflection technique that can obtain the liquid's velocity profile. Figure 2illustrates the UVP configuration, ultrasonic pulse-echo, and velocity profile reconstruction. An ultrasonic pulse is transmitted from the transducer along the measurement line to the liquid. The same transducer derives the echo signal

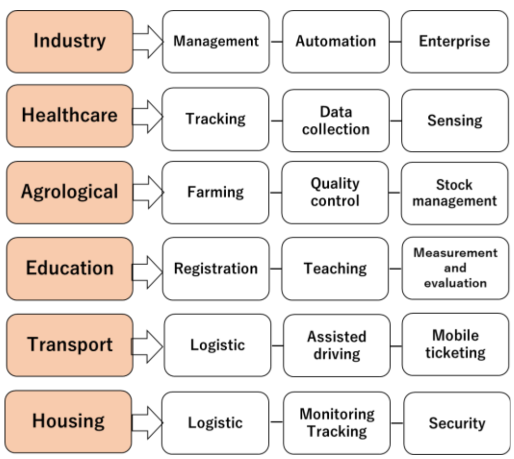

Fig. 1. Applications of IoT and relevant major scenarios.

reflected from moving reflectors such as small particles dispersed in the liquid. As the ultrasonic wave is emitted repeatedly, the echo signals are obtained sequentially. Doppler signal influenced by the velocity of a moving particle can be demodulated from the echo signals shown in figure 3. The Doppler frequency $f_D(i)$ directly relates to the velocity of the particle (i is position or channel). Hence, the velocity of the particle at that position $V(i)$ can be computed as

$$V(i) = \frac{c f_D(i)}{2 f_0 \sin\theta} \qquad (1)$$

where f_0 is the basic frequency, and θ is the incident angle. If the stokes number on the relation between small particles and liquid < 0.1, the particle will closely follow the liquidstreamline. Then, several particles dispersed in the liquid. Consequently, the velocity profile of the liquid can be obtained.

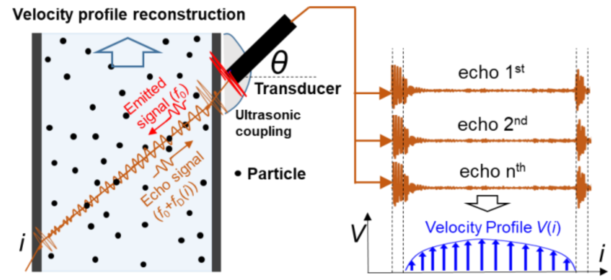

Fig. 2. The UVP measurement configuration.

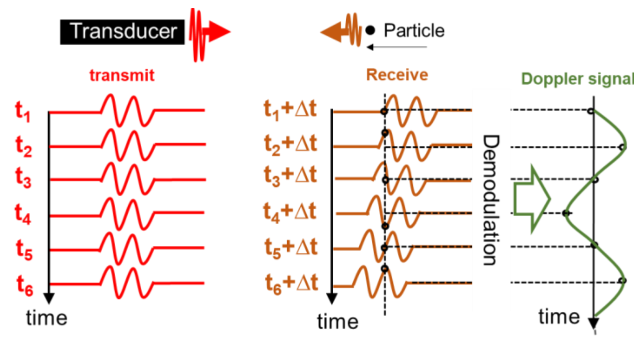

Fig. 3. Doppler signal demodulation.

In the bubbly flow, the phase separation technique for the UVP system's operation to obtain the velocity in the bubbly osed algorithm. Firstly, the Doppler signal $D(n)$ (discrete data) is extracted from the echo signals $e(t)$, as shown in equation (2) obtained from the transducer and pulser/receiver, respectively. The extraction is processed by quadrature demodulation [19].

$$D_i(n) = A_{n,i}\cos\left(\frac{2\pi n f_{D,i}}{f_{PRF}} - \varphi\right) - jA_{n,i}\sin\left(\frac{2\pi n f_{D,i}}{f_{PRF}}\varphi\right) \qquad (2)$$

where$n$ represents a sampling of Doppler signal, A is the amplitude, and φ is the initial phase. Then, the Doppler signal is sent to STFT to derive a time-frequency spectrogram of the signal. The calculation is expressed in equation (3), and the energy density of spectra at time k is denoted by Equation (4). Time-frequency resolution depends on time step S_n and window length W_n. The spectrogram is sent to the peak detector for analyzing the energy peaks of the spectrogram. Peak value in each position informs the Doppler frequency data ($\mathbf{f_D}=[f_{Da},f_{Db}...f_{Dm}]$) and time location ($\mathbf{t}=[t_a,t_b....t_m]$). Furthermore, the Doppler amplitude at each point ($\boldsymbol{a}=[a_{n=0}, a_{n=1}, ..a_{n=Nrep-1}]$) is detected by making the envelope on the Doppler signal. These data are selected by time location index obtained from peak detector ($\boldsymbol{a}_S=[a_a, a_b,...a_m]$).

$$X(k, f_D) = \sum_{n=0}^{N_{REP}-1} D(n)\, W_n(n - kS_n)\, exp(-jn2\pi f_D) \qquad (3)$$

$$P(k, f_D) = |X(k, f_D)|^2 \qquad (4)$$

The selected amplitude data is then compared with a threshold value. The value is defined as being higher than the maximum Doppler amplitude of the particle and lower than the Doppler amplitude obtained from the bubble. The amplitude index is classified into the index of bubble and liquid. When the amplitude value is higher than the threshold, the index is defined as a bubble index ($\mathbf{in_b}$=[in_{b1},in_{b2}..in_{bn}]). Furthermore, when the value is lower than the threshold, the index is expressed as a particle index ($\mathbf{in_p}$=[in_{p1},in_{p2}..in_{pn}]).Doppler frequency data analyzed by peak detector is classified by these amplitude indexes to be Doppler frequency of bubble group ($\mathbf{f_{Dbubble}}$=[f_{Dba},f_{Dbb}....f_{Dbm}])and particle group ($\mathbf{f_{Dparticle}}$=[f_{Dpa},f_{Dpb}....f_{Dpm}]).The Doppler frequency in each group is averaged. Hence, the Doppler frequency of bubble $f_{Dbubble}$ andparticle$f_{Dparticle}$ in the same measurement channel is decomposed apparently. Consequently, the bubble and particle (liquid) velocity can be calculated simultaneously follow the equation (1).

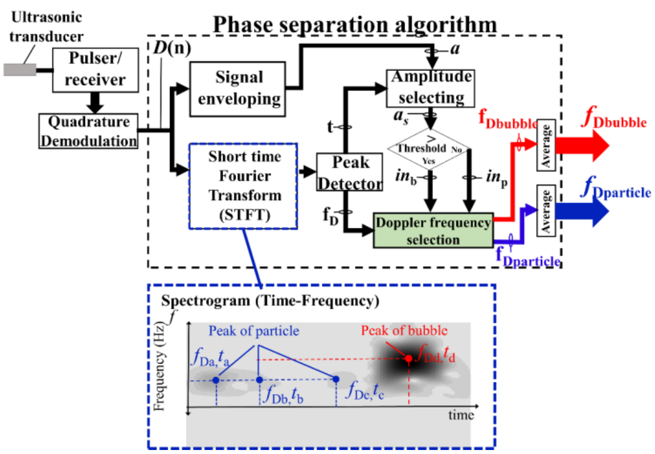

Fig. 4. The UVP with phase separation for measurement in the bubbly flow.

B. Integrated telemetry system

The internet of things (IoT) is a hot issue and plays an essential role in several sectors. For the telemetry system applied for the experimental work remotely, the client units that work and facilitate the remote work execution communicates with the outside users via Wi-Fi signal internally and with internet services provider (ISP), respectively, as shown in figure 5. The ISP provides internet service that connects data sent through router devices such as Dial, DSL, and wireless modems [20] where the latter is selected for this study. The computer, tablet, and smartphones are responsible for remote control over the internet anywhere via 3G/4G or routers that communicate with the ISP.

III. Experimental Setup

Figure 6 illustrates a schematic diagram of the UVP, the experimental apparatus, and the telemetry system. The UVP system consisted of 4 MHz transducers, an ultrasonic pulser/receiver, a digitizer, and a computer with LabVIEW software. The pulser/receiver emitted ultrasonic pulses via a transducer. The echo signals received by the pulser/receiver were converted into a digital signal by the digitizer; with a sampling rate of 100MS/s. Data from the digitizer were transferred to the computer via USB port. The UVP calculation and analysis were performed by using the LabVIEW software on the experimental computer. The UVP parameter setting shown in table 1 was set to be compatible with the measurement condition. For the demonstration, the UVP was applied to measure the velocity profile of the single-phase liquid and air bubbly flow on the vertical pipe flow apparatus, respectively. The pipe with a 50 mm internal diameter was used. The tap water dispersed with nylon particles 80 µm and bubbles (diameter ≈ 2-3 mm) were used as working fluid. Its temperature is 25± 4ºC. The pump circulated the water. The electromagnetic flowmeter monitored the water flow rate. A bubble generator generated bubbles put on upstream 50D from the test section. The transducers were immersed into the water box—the transducer end located outside the pipe with the incident angle 45 degrees. In the telemetry section, the camera, smart electrical switch, and remote software were employed to control the experimental work remotely. Three cameras and two smart switches were utilized on the system.

TABLE I. PARAMETER CONFIGURATION OF UVP SYSTEMS

Parameter	Value
Basic frequency	4 MHz
Active diameter of transducer	5 mm
Emission voltage	150 Vp-p
Receiving gain	40 dB
Pulse repetition frequency	8 kHz
Number of repetition	128
Channel width	0.74 mm
Number of channel	60 channel
Sound velocity in water	1493 at 25 degree C
Incident angle	45 degree

These cameras were used foroverview observation, monitor the flow rate value on the flow meter, and observe the test section. The smart switches were employed to control the power supply of the UVP system, water pump, and air compressor separately. The camera was connected to the experimental computer via USB port, and its data was transferred via Wi-Fi, respectively. The smart switch control was executed via a Wi-Fi network. The ordering, information, and status were communicated with the user interface by utilizing the ISP. The experimental computer was proposed to operate via the remote access tool (Team viewer software was employed.

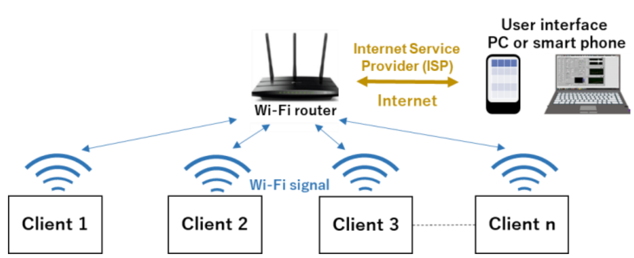

Fig. 5. Schematic of a communication network for the remoted work operation

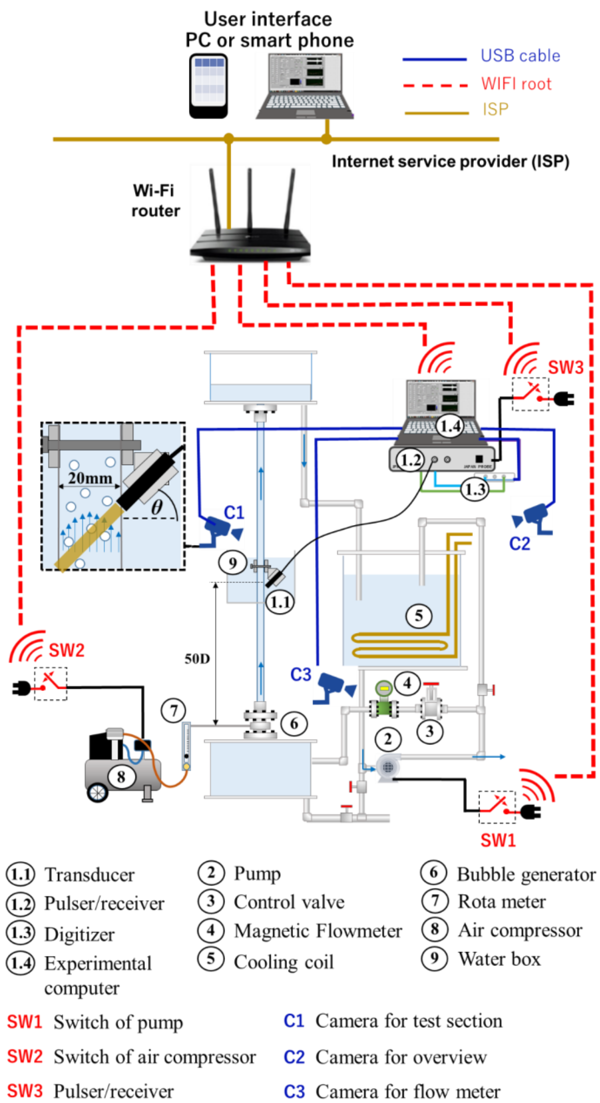

Fig. 6. Experimental setup.

IV. Result and Disscussion

A. Telemetry system testing

Figure 7 shows the web browser of smart switch control. These switches were used to control the power source to energize the UVP system, fluid circulating pump, and bubble generator's air compressor. The power of equipment can be controlled remotely on the web browser. Besides, the remoted observation during the experiment was operated via cameras, as illustrated in figure 8. The flow meter display unit was monitored continuously for an accurate experiment. The test section and an overall view of the apparatus were observed due to the safety aspect. Figure 9 shows the operating panel of the UVP program. The program was developed in the LabVIEW version 2011.

Figure 10 illustrates the remote access screen of the telemetry system. Every browser was arranged to fit the monitor.

B. The experiment in single-phase liquid flow measurement

UVP parameters such as basic frequency, pulse repetition frequency, measurement channel, number of the profile, and others could be set via the remote access software. The UVP system and liquid pump were started remotely. Figure 11represents the results ofthe instantaneous of the velocity profile of single-phase liquid flow. Figure 12 illustrates the averaging profile of 5,000 instantaneous data in single-phase liquid flow. The superficial liquid velocity U_L was set at 300 mm/s. The horizontal axis is the distance from the wall (r) nominalized by the pipe radius (*R*). However, the velocity value of UVP near the wall's vicinity showed small fluctuations due to some parts of the ultrasonic measurement volume located within the wall, which overlapped the ultrasonic wave on the fluid and pipe wall. The echo signal in

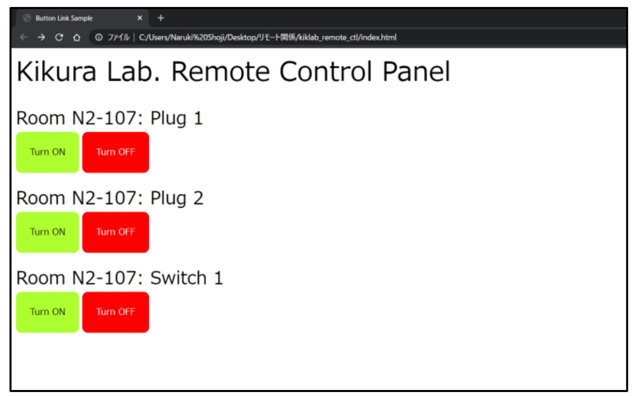

Fig. 7. Smart switch control browser.

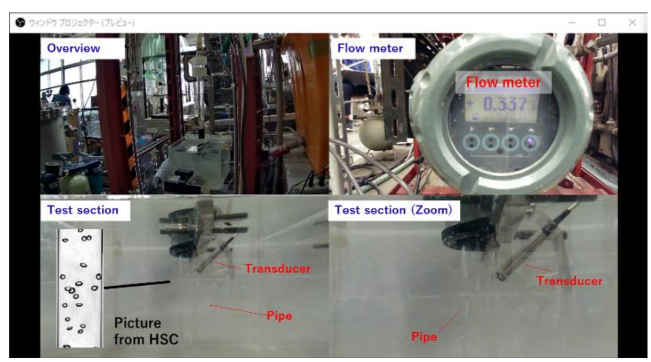

Fig. 8. Camera viewing browser.

that zone is not only affected by the particle. Moving particles and the pipe wall influence the measurement result. Hence, it can be concluded that the UVP efficiently measured the velocity profile on a single-phase flow even executed via the telemetry system. Moreover, the measurement result could be transferred to the user interface device promptly for post-processing.

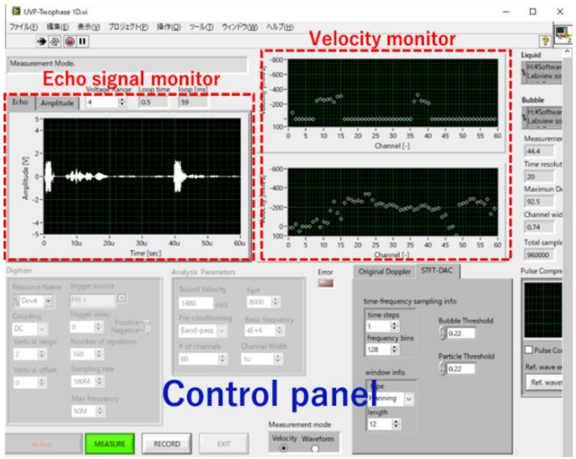

Fig. 9. The UVP program operation panel

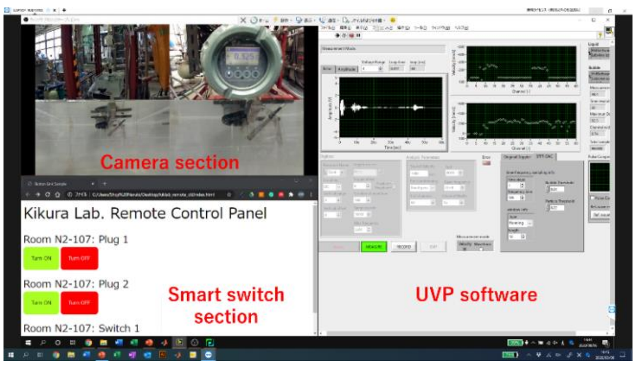

Fig. 10. The screen of the remote access to experimental computer.

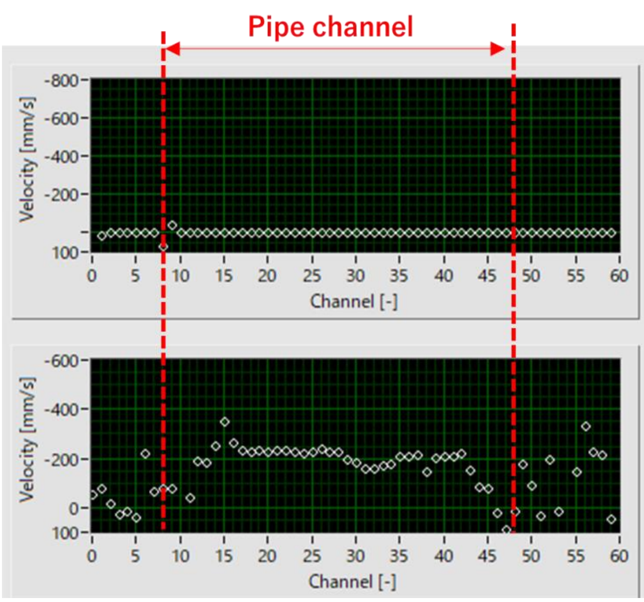

Fig. 11. The result of instantanous velocity profile in single-phase liquid flow.

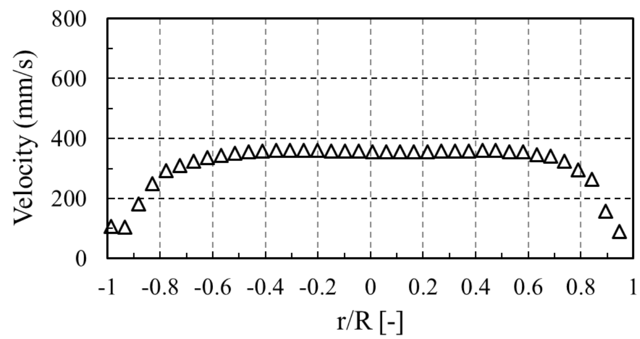

Fig. 12. The result of average velocity in single-phase liquid flow.

C. *The experiment in bubbly flow measurement*

In the bubbly flow, the experiment was conducted at U_L = 300 mm/s and U_G = 5.3 mm/s. The bubble diameter in this experiment was about 2-3 mm. The UVP system and liquid pump were started. Also, the air compressor was powered up by the telemetry system to inject bubbles. Figure 13 represents that the instantaneous velocity profile of the bubble and liquid can be obtained remotely. Figure 14 shows the average measurement results of two-phase bubbly flows. Bubbles rised mainly near the wall region. The graph shows the mean velocity profile data. Liquid velocity distribution is the averaging of 5,000 profiles, and bubble velocity is averaged by the amount of data obtained. The measurement result of the bubble velocity profile after separation by the developed technique was derived. The velocity level was higher than the liquid velocity due to the buoyancy force effect. Besides, the liquid velocity profile was obtained and separated from the bubble phase. The velocity of both phases could be measured separately. Then, the slip ratio also was derived.

It can be summarized that the bubble velocity, liquid velocity, and slip ratio of the bubbly flow can be derived, although the experiment was conducted on the telemetry system.

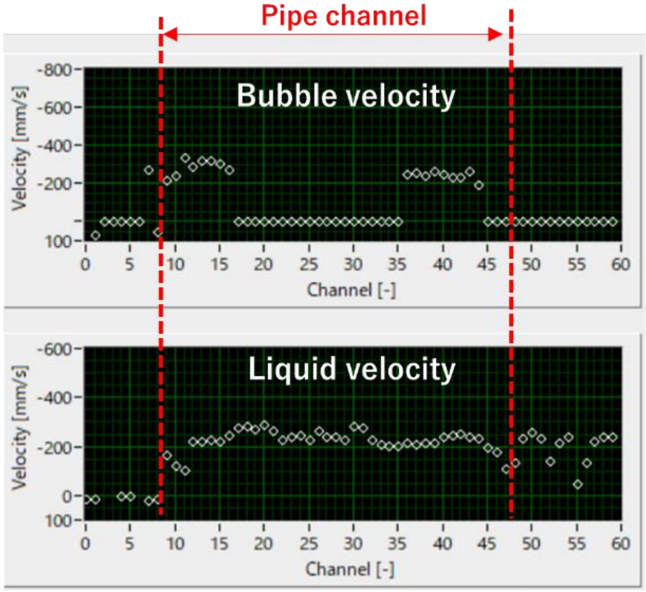

Fig. 13. The result of instantanous velocity profile on bubbly flow.

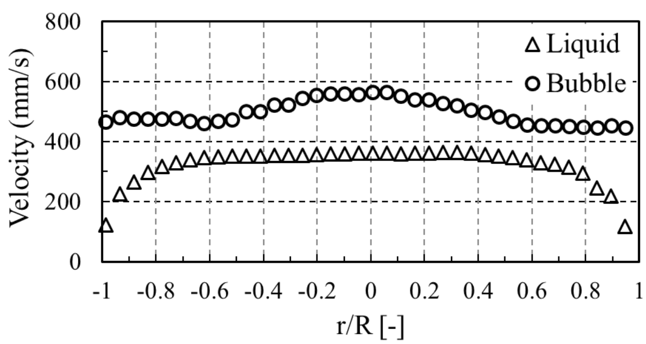

Fig. 14. The result of average velocity profile on bubbly flow.

V. CONCLUSION

The IoT based telemetry concept to execute the experimental activity remotely was proposed. The experimental investigation on the facility can be conducted anywhere outside on the internet is provided. The limitation of the experimental task in crisis or pandemic disease situation is removed. The experimental study on the velocity distribution measurement in the bubbly flow using ultrasonic measurement, which is vital in fluid engineering, was demonstrated to confirm the telemetry system's ability. The power supply of the UVP system, liquid pump, and bubble generator was controlled via the web browser interface. The UVP program operation and cameras were executed with the remote access tool. The remoted experiment's velocity profile results, whether single-phase liquid or bubbly flow, were obtained apparently.

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