UNCERTAINTY EVALUATION OF ADCP MOORING BOAT STRUCTURE ON OBSERVED FLOW VELOCITY VALUES

SHOJUN ARAI
Toyama Prefectural University, Toyama, Japan, p.changsun4@gmail.com

TAICHI TEBAKARI
Toyama Prefectural University, Toyama, Japan, tebakari@pu-toyama.ac.jp

TAKASHI KITSUDA
Hydro Systems Development, Inc., Osaka, Japan, t-kitsuda@hydro-sys.com

YORIKO YOSHIKAWA
Hydro Systems Development, Inc., Osaka, Japan, y-yoshikawa@hydro-sys.com

YUKIHIRO SASAKAWA
Hydro Systems Development, Inc., Osaka, Japan, y-sasakawa@hydro-sys.com

ABSTRACT

In recent years, ADCP (Acoustic Doppler Current Profiler) has been used in various ways along with the advancement of river flow observation. However, the uncertainty in ADCP observations is not completely clear. The purpose of this study is to evaluate the influence of moored boats used in ADCP on the flow velocity, and to clarify the uncertainty of moored boats give to observed flow velocity values. The observation point of this research is Shinano River, a first-class river in Nigata Prefecture, Japan. The Shinano River has the characteristics of large discharge and high flow velocity. We investigated the flow velocity distribution in the Shinano River using ADCP. We used and compared three moored boats: Riverboat (RB), Highspeed Riverboat (HSRB), and 3m Riverboat (3m RB). RB is the cheapest and the usage rate is high. However, when observing high flow velocities, it is recommended to use HSRB or 3m RB. The ADCP's observed flow velocity values include ADCP specs such as Pitching and Rolling, reflection intensity and correlation, and %Good. The relationship between these elements and the flow velocity value was compared. It was found that the observation accuracy of HSRB and 3m RB is higher than that of RB. In the case of high flow rate, half of the observed flow velocity value were missing for RB. However, the observed flow velocity values of RB are not completely unusable. Analyzes using Relative Frequency and Probability Density Function (PDF) can improve the accuracy observed flow velocity value of RB. From the above, we were able to clarify the uncertainties of mooring boats in observations using RB. By using the analysis method of this study, it was found that even with RB, it is possible to observe with the same accuracy as HSRB and 3m RB.

Keywords: *ADCP*, Uncertainty, mooring boat, Pitching, Rolling

1. INTRODUCTION

Recently, instruments that replace floats and rotary anemometers have been used to measure flow rates. Typical examples include radio wave current meters, as well as particle and space-time image velocimeters. The most widely used device is an acoustic doppler current profiler (ADCP), which measures river flows both vertically and horizontally, as well as riverbed depth. The revised Survey on River Sabo Technical Standards of June 2012 stated that ADCPs should be used for discharge measurements. Various studies have been published, but none have explored whether the type of boat to which the ADCP is moored affects the resulting measurements. Thus, we performed this study to explore the influence of mooring boat type on ADCP measurements.

2. OBSERVATION EXPERIMENT SITE, EQUIPMENT USED, DATA USED

The river studied was the Class 1 Shinano River flowing through Asahibashi in Ojiya City of Niigata Prefecture; the river flows through both Niigata and Nagano Prefectures. The riverbed slope ranges from 1/300 to 1/4,000, and was 1/600 at our observation point. The ADCP was manufactured by Teledyne R&D Instruments (TRDI). This company's products enjoy an 80% market share worldwide and exhibit relatively good reliability; moreover, TRDI products are popular in Japan. Table 1 describes the moored boats. A riverboat (RB) is an inexpensive workhorse. A high-speed RB can travel quickly, and a 3-m riverboat (3mRB) can be used if flow is rapid. Table 2 shows the ADCP commands for each day of observation. Data were collected on 8 days: 24/4/2015, 28/4/2016, 19 and 20/4/2018, 18 and 19/12/2018, and 18 and 19/4/2019. The April observations were made by the Japan Society of Civil Engineers Flow Measurement Subcommittee; the December observations were made under low-flow conditions. The ADCP commands were those used by other organizations. The discharge values employed were those of Ojiya Observatory; the information had been deposited in a Hydrological and Water Quality Database. For missing data, the discharges were estimated. Table 3 shows the number of ensembles and average discharge for each day of observation.

Table 1. Moored boat specifications.

Name		Riverboat (RB)	HighSpeed Riverboat (HSRB)	3m Riverboat (3m RB)
Appearanze				
Boat type		Trimaran	Fast flow velocity type:Trimaran	
Corresponding flow velocity(m/s)		～3.5	～6.0	
Size(cm)	Length	120	152	300
	Width	80	124	130
	Height	18	18	18
Weight of all equipment included battery and boat(kg)		25	35	50

Table 2. ADCP commands.

	Apr-15		Apr-16		Apr-18		Dec-18		Apr-19	
Boat type	**RB**	**3mRB**	**RB**	**3mRB**	**RB**	**3mRB**	**RB**	**HSRB**	**RB**	**HSRB**
Measurement mode	**12**				**1**					
Sub-Pings	**3**									
Measured layer thickness(m)	**0.2**									
Number of measurement layer	**50**									
Ensemble time(s)	**1.6**	**1.5**	**1.7**	**3**	**1.6**	**1.5**	**1.6**	**1.4**	**1.6**	**1.4**
Number of Water-Pings	**3**			**5**						
Bottom track function	**5**									
Number of Bottom-Pings	**3**			**5**						
Standard deviation of velocity error in fixed observation(m/s)	**8.51**				**11.42**					
Measurement coordination	**Earth coordinate**									

Table 3. Ensemble numbers and average discharges on each day of observation.

year	2015	2016	2018				2019	
day	4/24	4/28	4/19	4/20	12/18	12/19	4/18	4/19
Ensemble number	375	1888.5	592	2470.5	11855.5	8771.5	230.5	1473.5
Average discharge(m^3/s)	1520	545	985	911	411	500	533	626

3. RELATIONSHIP BETWEEN FLUCTUATION AT EACH DEPTH AND VELOCITY VALUE

The relationships between pitch and roll by depth, as well as flow velocity, are shown in Figure 1; the contours indicate flow velocity. Data were unavailable for the grayed-out region of Figure 1. The white data of Figure 1 were derived from an ADCP moored to an RB. The ADCP emits four beams from four transducers angled at 20º from the center. Thus, normal observations are possible if pitch and roll are less than 20º; we set both values to □ 15º, consistent with the method used in previous studies. We first investigated the effects of pitch. The flow velocity distribution was normal at a pitch of approximately 0º. However, flow velocity data became less accurate as the pitch increased. Many observations were missing when the pitch was greater than 6º. At a pitch of greater than 9º, flow velocity data were nearly absent. We then investigated the effects of roll; when this ranged from -8º to 0º, the vertical distribution of the flow velocity was poorly recorded, but began to improve when roll was approximately 10º. At a roll of 12º to 26º, no flow data were missing; however, the flow rates were very low. When the ADCP was moored to a 3mRB and the pitch ranged from 0º to 10º, no data were missing and all data were of high quality; these findings were also observed when roll ranged from -4º to 8º.

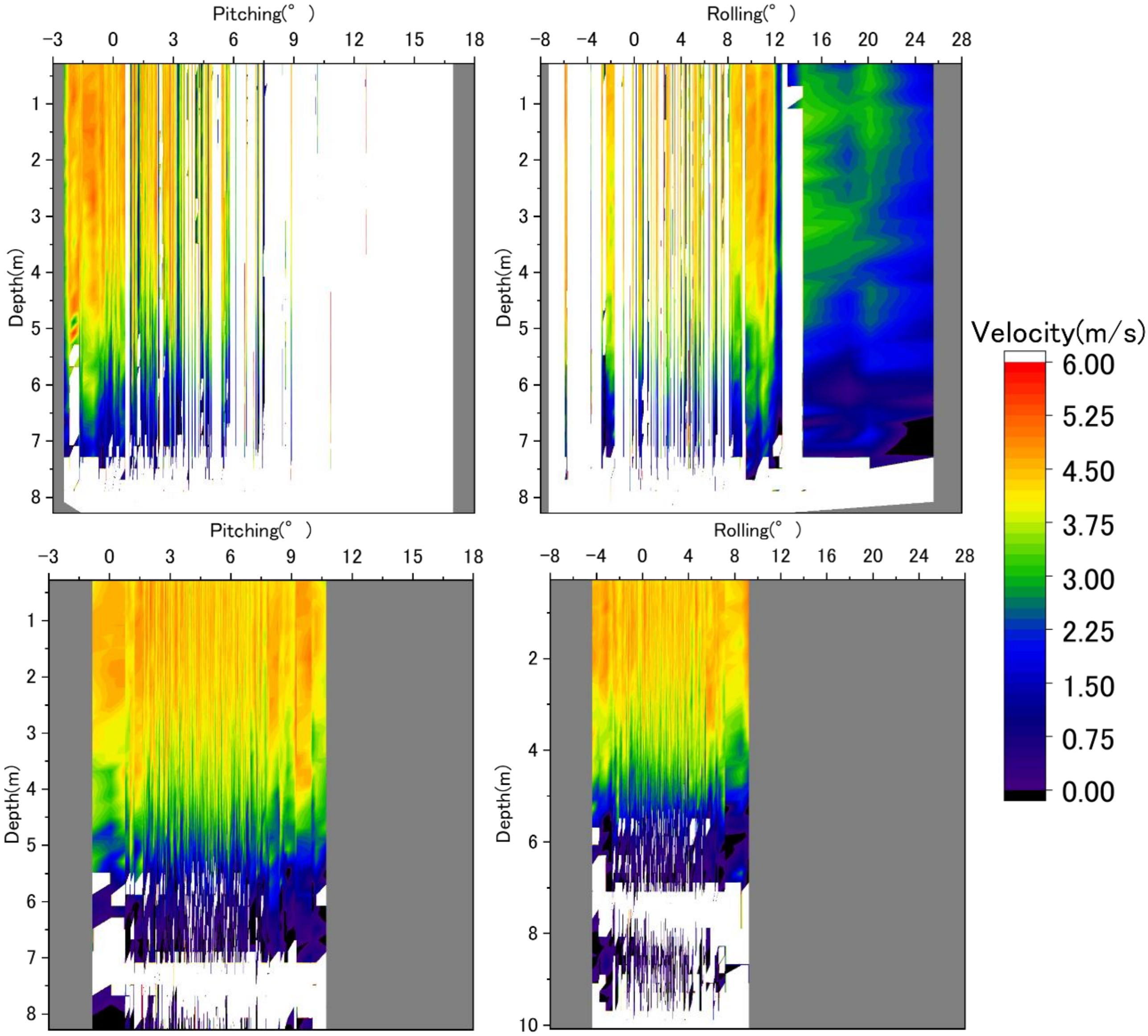

Figure 1. Relationship between pitch and roll by depth, as well as flow velocities.

4. EFFECT OF DIFFERENCE OF MOORING BOAT ON ΔPITHING

Figure 2 shows the relationship between the "ΔPitch" and flow velocity at 1-m intervals from the surface. ΔPitch is the pitch fluctuation for each ensemble (i.e., the difference between pitches of current and previous ensembles). The blue data were derived from an ADCP moored to an RB, while the red data were derived from an ADCP moored to a 3mRB. For the RB, the flow velocities at both large and small ΔPitch values were near the node. When flow velocities varied, ΔPitch values were near zero. In the 3mRB data, any causal relationship between ΔPitch and flow velocity was also small, even at greater depths.

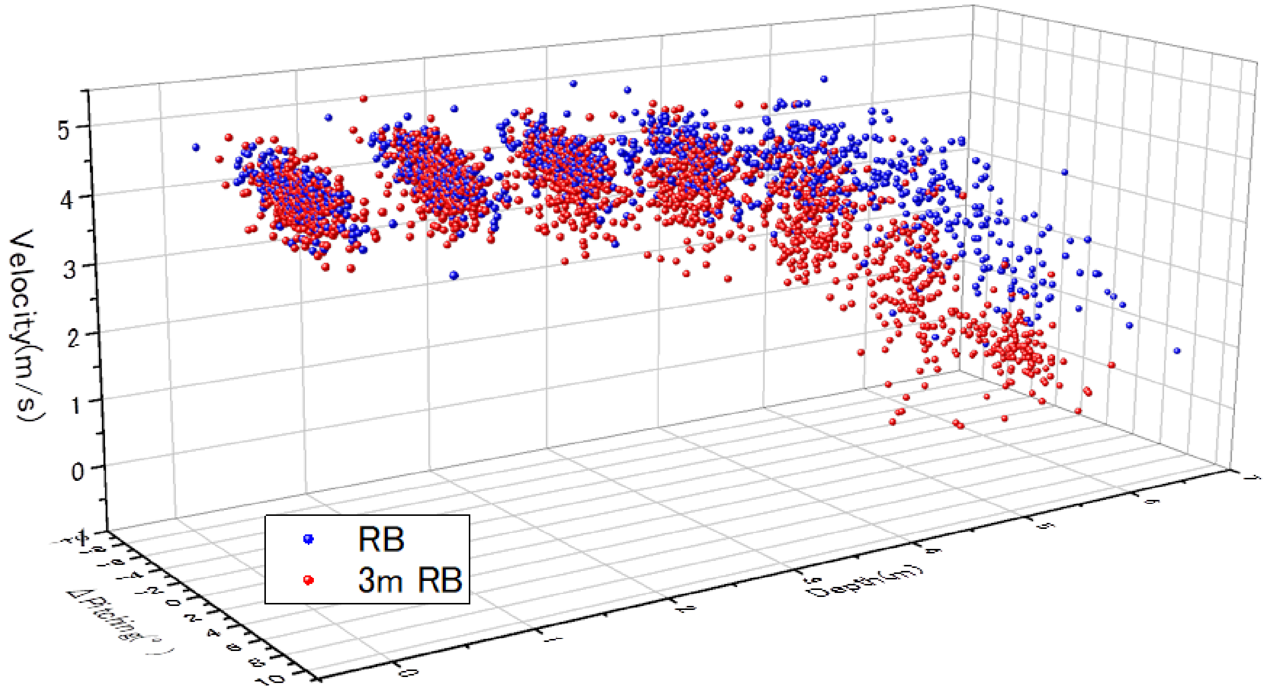

Figure 2. Relationship between "ΔPitch" values and flow velocities at 1-m intervals below the surface.

5. CONCLUSION

We evaluated the effects of mooring boat type on the data collected by an ADCP. We focused on pitch and roll, which are the motions of a moored boat. We explored the relationships between pitch and roll, as well as flow velocities at different depths. When the ADCP was moored to an RB, both pitch and roll greatly reduced flow velocity data collection; roll also triggered flow velocity underestimation. When the ADCP was moored to a 3mRB, neither pitch nor roll affected the flow velocities. We next focused on the ΔPitch parameter, which is the pitch fluctuation within an ensemble. The ΔPitch affected the horizontal and vertical flow velocities only minimally when the ADCP was moored to either an RB or a 3mRB. The mooring boats differed markedly in terms of both pitch and roll; however, these parameters did not affect the flow velocities when the ADCP was moored to either a 3mRB or an RB. However, the uncertainty was greater when the mooring boat was an RB, rather than a high-speed RB or a 3mRB.

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