IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 6 Ver. V (Nov. - Dec. 2016), PP 184-190
www.iosrjournals.org

Field Measurement and Signal Post-Processing Using Micro ADV In a part of HIRAKUD Command Area

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Abstract: *Flows in open channels are turbulent and velocity measurements should be done at high frequency to overcome the problem like formation of small eddies and the process of viscous dissipation. The acoustic Doppler velocimetry(ADV) is so designed that it can record the instantaneous velocity components at a single-point with comparatively high frequency. Here, in this study, two ADV instruments i.e. Flow Tracker ADV, MicroADV are analyzed. The objective of the research is to find out the efficiency and limitations of ADV instruments in flow measurement. In this work using Flow Tracker ADV, velocity data at different sections of a canal were recorded and simultaneously, discharge was also calculated. MicroADV was used to record real time velocity data in X-axis (along the length), Y-axis (along the width) and Z-axis (along the depth). A software package named Horizon ADV was used to collect data using MicroADV. The time series graphs of velocity, SNR and Correlation Score was collected in a computer.The data sets were analyzed, andthe results demonstrated that the data obtained from acoustic Doppler velocimeterrequires suitable post-processing before the use of same. For the purpose of post-processing of ADV data, WinADV software was used. After that the post processed data was compared with the raw velocity data, and a conclusion was reached that ADV data shouldn't be used without post-processing because the ADV data are biased with disturbances like signal aliasing, spiking, navigation disturbances. The graphs obtained from different stations using MicroADV were studied carefully and it was found that spikes were present in almost every result. So the despiking method is considered useful here. WinADV software removes spikes, small disturbances, and large disturbances. The WinADV was found to be reliable software for signal-post processing*

I. Introduction

In field applications, acoustic Doppler velocimetry (ADV) is considered as a popular technique. But it is found that the ADV signal outputs is effected largely due to effects of turbulent velocity fluctuations in flow, Doppler noise, signal, shear due to turbulence and other disturbances. Evidences included by high levels of noise and spikes in all velocity. In turbulent flows, the ADV velocity outputs are a combination of various parameters like Doppler noise, fluctuations in the velocity,installation of vibrations and consideration of other disturbances. The shear across the sampling volume and boundary proximity may be further affected the signal adversely (Chanson et al. 2007). Spikes may be caused by aliasing of the Doppler signal. Here in the study focus data generation and collection using acoustic Doppler velocimeter (ADV) in high-frequency turbulence of a canal. The ADV is well-suited to study turbulent velocities in shallow-waters. This was found grossly incorrect and ADV data post-processing technique which includes, Velocity signal check, Pre-filtering (Event detection and removal), Despiking (Small disturbance detection and removal).WinADV was used to post-process the data obtained from ADV. Field work data were systematically analyzed. The results indicated that acoustic Doppler velocimeter data needs to be used only after the suitable post-processing by considering all the turbulent velocity properties which may be affected during the process. The aim of the study describes in detail the operation of acoustic Doppler velocimetry (ADV), and its applications in canal for measuring velocity, and discharge. There are two instruments for studying namely Flow Tracker ADV for measuring 1-D flow velocity and discharge and another instrument called MicroADV for measuring 3-D flow velocities. Though ADV is a robust instrument for measuring velocity, the data collected using MicroADV are generally erroneous because of Doppler noise, signal aliasing, velocity fluctuations, installation vibrations and other disturbances. The aim of the study is to post-process the data collected using MicroADV and to study the use of Flow Tracker ADV in canal.A number of researchers have worked on Acoustic Doppler Velocimeter (ADV) with an aim to improve the data recorded from ADV over a period of three decades and most of them showed that ADV data shouldn't be used without proper post-processing. Nikora and Goring (1998) developed a technique to reduce the Doppler noise influence on measurements of turbulence using the Acoustic Doppler Velocimeter (ADV). Voulgaris and Trowbridge (1998) evaluated the accuracy of the acoustic Doppler velocimeter (ADV). Kim et al. (2000) estimated bed stresses in the bottom boundary layer of the York River estuary from 3D near-bottom velocities measured by Acoustic Doppler Velocimeters (ADVs). Song and Chiew (2001) measured the mean and turbulence characteristics in non-uniform open-channel flows using a 3D acoustic Doppler velocimeter.Nikora

and Goring (2002) suggested a new method for detecting and replacing spikes in acoustic Doppler velocimeter data sequences. Fugate and Friedrichs (2002) demonstrated a novel application of the acoustic Doppler velocimeter (ADV) to estimate in situ particle fall velocity at a single point without affecting the ambient turbulence in an estuary. Chanson et al. (2008) studied the analysis of turbulent velocity measurements in small estuarine system based upon long-duration high-frequency velocity records by ADV. Chanson (2008) demonstrated that the ADV metrology is a robust technique well-suited to steady and unsteady turbulence measurements in open channel flows. Brown and Chanson (2011) collected some turbulent velocity data using ADV in an inundated street during the Brisbane river flood in 2011. Romagnoli et al. (2012) presented experimental results on an error analysis of acoustic Doppler velocimeter (ADV) turbulence measurements in free hydraulic jumps incorporating an ADV signal processing technique. Khorsandi et al. (2012) worked on the validation of acoustic Doppler velocimeters (ADVs) for the measurement of turbulent flows. Islam and Zhu (2013) developed an algorithm which can be used in despiking the acoustic Doppler velocimeter (ADV) data. Acoustic Doppler velocimeter (ADV) data can be contaminated by spikes from various sources.
Chen and Chiew (2004) made a study on the theoretically and experimentally the velocity distributions of turbulent flow in an open channel with bed suction. Nezu and Azuma (2004) measured simultaneously both the particle and fluid in a particle-laden two phase open channel flows by means of discriminator particle-tracking velocimetry. Kozio (2013) investigated the changes in spatial turbulence intensity of a compound channel and he also studied the influence of rigid and the emergent floodplain vegetation on it.

II. Methodology

Flow tracker adv Flow Tracker ADV is an instrument which can be used to measure velocity and discharge in a flow of water. This is a instrument based on Doppler effect. Flow Tracker ADV is a instrument of Sontek Inc. It is a hand held ADV which uses the power of DC.

Fig.1 Photo of Flow Tracker ADV

Microadv

MicroADV is an instrument which can be used to measure velocity in X, Y and Z- axis simultaneously. The instrument have a 3 headed probe. This is a instrument based on Doppler effect. MicroADV is a instrument of Sontek Inc. and its frequency is 16MHz. It is a hand held ADV which uses AC power. The salient features of MicroADV the acoustic sensor consists of two or three acoustic receivers (for 2D or 3Dprobes) and one acoustic transmitter. The sensor can be mounted on a stainless steel stem (25or 40-cm long) or on a 100-cm flexible cable. The acoustic sensor can be oriented looking down, to the side (mounted on a 90° adapter), or up (with a bent stem and a 90° adapter).The sampling volume is the volume of water (≈0.3 cm3) in which the ADV makes velocity measurements. Depending on probe configuration, this volume is nominally located either 10 cm from the acoustic transmitter.

Fig. 2 Photo of MicroADV

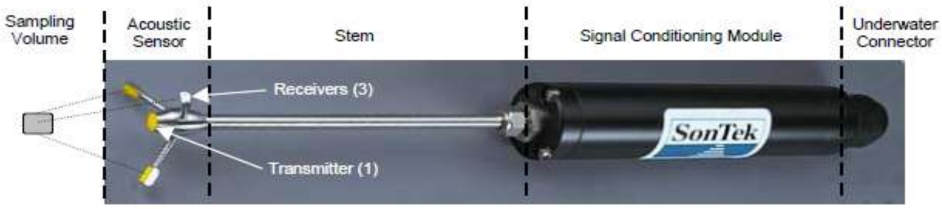

Fig. 3 Different parts of MicroADV

The standard 16 MHz ADV probe consists of the acoustic sensor, the stem (or cable), and the end cap attached to the signal-conditioning module. For probes that will be deployed in saline environments, sacrificial zinc anodes attached to the stem for corrosion protection. The signal-conditioning module is a cylindrical Delrin housing with internal receiver electronics. The probe is mounted at one end of the Delrin housing, while the other end cap is connectedto a high-frequency cable using a 16-pin wet-mateable connector. The signal conditioning module is 5.3 cm (2.09 in) in diameter by 28.5 cm (11.2 in) long. The dimensions of the probe vary with 2D and 3D probes, distance to the sampling volume, stem or cable length, and sensor orientation.
The high-frequency cable to the processing module carries analog signals from the probe to the digital processing electronics. This cable is highly sensitive to noise. The cable is connected to the signal-conditioning module using a 16-pin wet-mateable connector.

Horizon Adv

The HorizonADVprogram consists of a flexible and dynamic user interface designed to perform the data collection and display process. The program can be used with either a single ADV or with several ADVs working in parallel. HorizonADVrequires the use of either Windows 2000 or XP or 7 and is designed to combine a high degree of flexibility, allowing you to use a single package for all the ADV requirements.
HorizonADVcan be used to:

- Collect data using a single ADV instrument.
- Collect data using multiple ADVs connected to a Multi-Port system
- Configure ADV systems.
- Display data files collected using ADV systems.

Winadv

WinADV is a software package which was developed by US Bureau of Reclamation and has been further improved through cooperative efforts of Reclamation, Sontek and Nortek. This software is used for post processing of acoustic Doppler velocity data. WinADV provides an integrated environment for viewing and processing data collected using acoustic Doppler velocimeters (ADVs).The main screen of WinADV is applied toshow ADV data in the form of graphin a time series such as velocity data graph and signal quality graph. The Graphical controls permit the user to choose the parameters for plotting, modify the graph style, and to selectprobes from the data files consisting of data for multiple ADV probes supplementary formsgive forthe review of ADV configuration, data files and summary statistics that can be imported to spreadsheets, graphics or other analysis software.WinADV helps in quickly view of the time series graphs, histograms, or FFT's of the various velocity data .The data collected with the help of the moving, or traversing probes, an equation indicating the position of the probe as a function of time can be entered so that ADV data may be directly plotted ad indicated versus the probe position. Velocity data can be transformed from model to prototype scale with the help of scaling factors. The settings of elements of the visual interface and preferred output options are can be saved in INI files or the System Registry to save the user from the need to reconfigure the program each time it is run.

Study area

The present experiment is carried on one of the canals of the Hirakud canal system, Odisha, India. This area is situated in the western part of the Odisha from 21°05'N to 21°55'N latitude and 83°55'E to 84°05'E longitude. Hirakud Reservoir is a multipurpose scheme intended for flood control, irrigation and power generation. The Dam is built across river Mahanadi at about 15 km upstream of Sambalpur town in the state of Odisha. The Hirakud canal system consist of three canal system namely Bargarh Main canal, Sason main canal, Sambalpur distributary. The Sambalpur distributary emerges from the left dyke of the Hirakud Reservoir. The Senhapali distributary, emerges out of the power channel of the Hirakud system to provide irrigation to villages Chaunrpur, Senhapali, Berhampura, Baguria, Bakbira, Jharpali, Tihikipali. The CCA of Senhapali distributary is found to be 1896.67 ha.

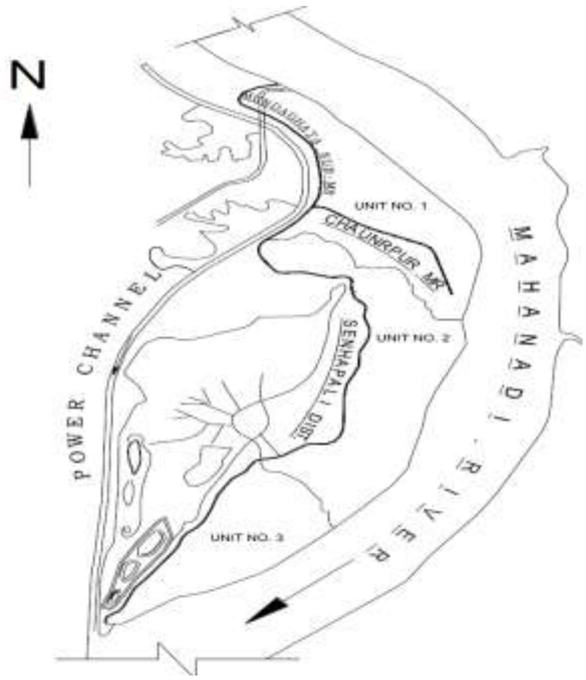

Fig. 3 Ayacut Map of the Senhapali Distributary system

In the command area there are two cropping seasons namely Kharif from June to December and Rabi from Jan to May. The major crops are Paddy, Wheat, Pulses like Arhar, Mung and Biri, Oilseeds like Groundnuts, Til, Mustard, and Sugarcane, where Paddy is the dominant crop.

III. Results and Discussion

In Senhapalidistributary system, the acoustic Doppler velocimetry system provided instantaneous values of the three velocity components. It was oriented with the *xy*-plane being horizontal, the *x*-direction aligned with the flow direction and positive downstream, and the *z*-direction positive upwards, which is described below in the table 1.There are 2 sections in Senhapali distributary. The name of the section are S1, S2. In each section there are 10 station points. At 0.10m depth from the water surface, there are 5 station points at 5 different locations. Similarly, at 0.20m depth from the water surface, there are 5 station points at 5 different locations. The names of every station are given in matrix manner. The format of the station name as follows,

(Station name)(Section name) x (station name) (depth)

(S)(1/2) x(1/2/3/4/5)(1/2)

Table 1 Velocity data collected from Senhapali Distributary

Section Name	Distance from left (m)	Depth from water surface (m)	V_x (cm/s)	V_y(cm/s)	V_z(cm/s)	V_{mean} (cm/s)	Mean SNR (dB)	Mean Corr (%)
S1x11	0.20	0.2	4.70	3.12	-2.1	5.72	13.024	90
S1x12	0.20	0.1	5.17	-11.69	1.43	6.09	9.67	91
S1x21	1.00	0.2	7.21	9.88	-2.7	6.59	9.423	96
S1x22	1.00	0.1	7.83	11.34	-3.8	7.65	12.70	87
S1x31	1.60	0.2	7.96	11.67	-6.39	8.34	11.073	96
S1x32	1.60	0.1	9.08	15.79	3.28	9.09	11.498	86
S1x41	2.20	0.2	4.97	-10.20	4.02	6.98	15.395	78
S1x42	2.20	0.1	6.27	-11.04	-4.03	7.02	9.755	99
S1x51	3.00	0.2	5.71	8.08	4.82	5.83	8.273	81
S1x52	3.00	0.1	6.90	-10.22	-1.83	6.37	10.26	91
S2x11	0.20	0.2	4.47	9.12	1.61	4.59	9.715	86
S2x12	0.20	0.1	5.17	10.67	0.87	4.98	10.657	79
S2x21	1.00	0.2	4.01	9.29	-1.79	5.36	9.85	96
S2x22	1.00	0.1	6.34	-10.7	2.74	6.08	9.357	97
S2x31	1.60	0.2	6.78	12.09	-5.97	7.84	11.657	87
S2x32	1.60	0.1	8.36	13.60	-3.09	8.67	15.785	88
S2x41	2.20	0.2	5.06	9.20	1.92	5.10	11.025	90
S2x42	2.20	0.1	5.20	12.04	-1.03	6.37	10.96	97
S2x51	3.00	0.2	6.02	5.37	-1.20	4.12	11.795	89
S2x52	3.00	0.1	7.29	9.56	0.83	4.76	10.25	98

The first graph shows the velocity variance with time. The time period of 10 seconds is selected as data collecting time. The unit of measurement of velocity is cm/s. The graph consists of 3 lines red, blue and green which indicates the instantaneous velocity along X-axis (along the length of canal), Y-axis (along the width of canal), and Z-axis (along the depth of canal) respectively. If measurement is taken from the left side of the canal (from upstream), then the value of velocity along X-axis is positive and vice-versa. The second graph shows the variation of SNR values with time. The unit of measuring SNR values is dB.There are 3 lines red, blue and green which indicates the SNR along X-axis (along the length of canal), Y-axis (along the width of canal), and Z-axis (along the depth of canal) respectively. The SNR value is determined by the ratio of the strength of the return signal from the water to the ambient electronics noise level (signal to noise ratio or SNR).The third graph shows the correlation scores along X-axis, Y-axis, and Z-axis. There are 3 lines red, blue and green which indicates the instantaneous velocity along X-axis (along the length of canal), Y-axis (along the width of canal), and Z-axis (along the depth of canal) respectively. Correlation coefficient is a quality parameter which is a direct output of the Doppler velocity calculations. Correlation is expressed as a percentage: perfect correlation of 100% indicates reliable, low noise velocity measurements; 0% correlation indicates that output data is dominated by noise with no coherent signal used for velocity calculations. Correlation is used to monitor data quality during collection, and to edit data in post processing

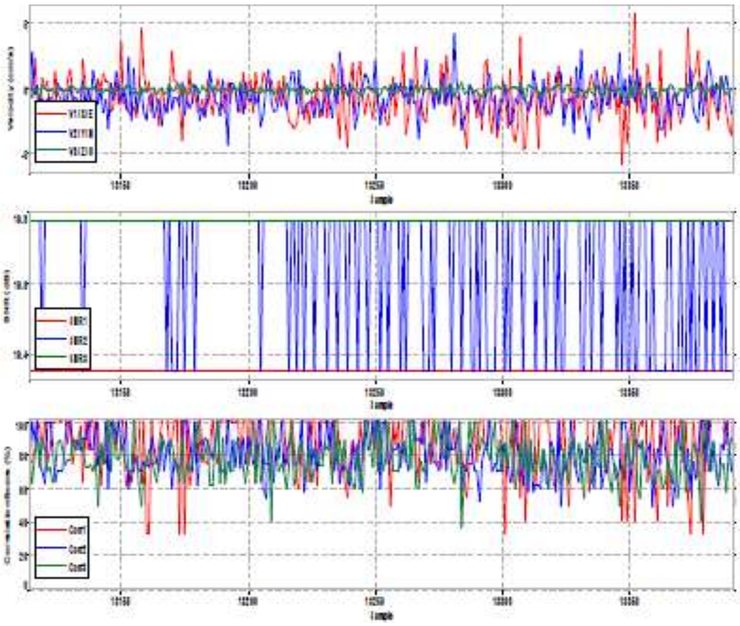

Fig 4: Raw Data from station S2x32

In Senhapali Distributary, station S2x32 the above data shows the correlation values are fluctuating in a range of 30% to 100%. The SNR data remains constant for both X-axes and Z-axis. But the SNR value of Y-axis suddenly increases throughout the sampling process. It rotates between the SNR values of X-axis and Z-axis. The velocity values along Z-axis are fluctuating within a short range. The velocity data along X-axis fluctuates within highest range, while the velocity values along Z-axis fluctuates within shortest range.

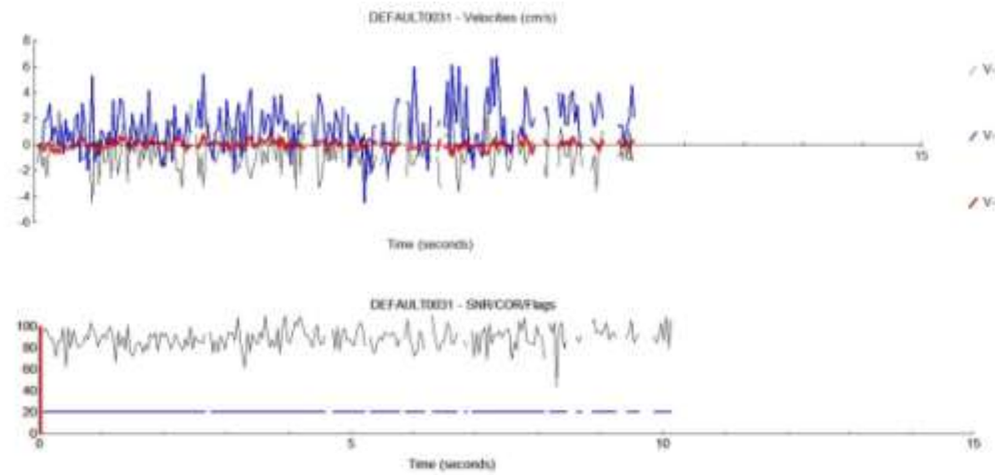

Fig 5 Post-Processed data of SenhapaliS2x32

The graph shown (Station S2x32) above shows that the post-processed velocity data for the station. The velocity values have high value of correlation score. The mean correlation score is 88%. So the value of mean velocity is reliable and the mean velocity is accurate.Spikes were present very less during the sampling time. The sample volume was garbage free. Due to which the spikes weren't present at most time. The mean SNR is found to be 15.785dB. This is an ideal value as per quality control standards. The post-processed mean velocity is found to be 2.76cm/s. The post-processed velocity along Y-axis is found to be 13.62cm/s. The turbulence along Y-axis is very high, so that the value of velocity is also high. The post-processed velocity along X-axis and Z-axis is found to be 8.35cm/s and -3.09/s respectively. The values of velocities along X and Z directions were decreased but the velocity along Y-direction increased after post-processing. The post-processed mean velocity is found to be 8.65cm/s. According to quality control standards, the SNR values should be greater than 10 dB and the correlation value should be greater than 70%. So the data is accurate as per the quality control standards.The graphs of post-processed data illustrate the outcomes of ADV data post-processing for an entire field study. The post-processed data set which may be compared with the un-processed data set. Both graphs are plotted with the same horizontal and vertical scales. The comparison shows the successful detection and removal of all major disturbances (vertical probe displacement, navigation) and of a lot of spikes and noise.

In the graphs showing velocity values, the velocity values randomly changes in all the three directions. The see-saw shaped graph shows the flow is turbulent. The velocity values are random in each canal, differs from station to station. It shows the velocity data is of turbulent in nature. The turbulent flow is characterized by random, irregular and haphazard movement of fluid particles, making it impossible to predict the motion of a fluid particle with respect to time and space. This type of motion gives rise to velocity fluctuations in all the directions. The velocity in a turbulent flow consists of a time average portion and a fluctuating part. The time average portion is the mean velocity through which the fluctuating part oscillates. The most essential feature of a turbulent flow, as brought out from the present investigation of the phenomenon, is the fact that at a given point, velocity and pressure are not constant with time but exhibit very irregular fluctuations of high frequency. Turbulent motion, once established, has a random, haphazard and irregular nature which makes exact description difficult. Because of this random nature, the turbulent analysis using the ADV becomes difficult. The results of all the three canals show turbulent velocity. Due to different types of disturbance, the results become more complicated. To remove the complication, the post-processing must be used.

IV. Conclusions

The present theoretical investigation supported by experimental observation is made for use of acoustic Doppler velocimetry (ADV) in canals and signal post-processing. On thebasis of the investigations concerning Flow Tracker ADV, MicroADV, HorizonADV, and WinADV, the following conclusions are drawn.Flow Tracker ADV is a ADV instrument which was used in this experiment to measure flow velocity and discharge in a canal. The values were found to be less than the discharge capacities of the canal. As the harvesting season is nearer, the discharge is reduced. Gradually, the discharge will become nil as there will be no flow of water in canals. It was found that Flow Tracker ADV is a robust instrument for measuring one dimensional velocity and discharge in a canal. The present investigation has shown that acoustic Doppler velocimetry (ADV) is a well-suited metrology for small shallow-water system. The present study wasfocused on the analysis of velocity measurements in a canal system based upon long duration high-frequencyvelocity records. HorizonADV software is found to be useful software for collecting data using ADV due to its simplicity, reliability, and user friendly user interface. The data analysis showed conclusively thatdetailed post-processing technique was applied using WinADV software. The software was used successfully to three long-durationfield studies during which ADV signals were recorded at highfrequency. Comparative analyses of un-processed (raw) and post-processed velocity data highlighted thenecessity of an advanced post-processing method. WinADV software removes spikes, small disturbances, and large disturbances. The conclusion is that WinADV software is reliable software for data processing from ADV. The water particles are in random motion in all different direction which causes turbulence. The graphs are of see-saw shaped which shows the sudden increase and sudden decrease in velocity. While theacoustic Doppler velocimetry is a relatively simple technique, thepresent results illustrated that unprocessed ADV data should not be used to study the turbulence field, including time-averaged velocity components because the ADV data is biased with disturbances like spikes, signal aliasing,

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