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Study on Application of ADCP in Hydrology of Navigation Safety and Estuary Regulation

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Abstract.ADCP (Acoustic Doppler Current Profile) is a new type of current surveying sonar device and is used by acoustic wave Doppler Effect in the early 1980s, and it can measure the speed of relative underwater and the velocity of relative flow. ADCP has been applied widely in flow measurement of the field of marine and inland river and water transport engineering, for example: navigation safety and estuary regulation,etc.. Mainly discussion of theory of ADCP and its application on navigation safety and estuary regulation in the paper. In the future the ADCP is one of the four kinds of advanced marine observation of speed measuring instrument, will be multifunctional, intelligent, lightweight, for development of modern IT and , and applied in scientific research and engineering.

Keywords: ADCP; doppler effect; acoustic technology; frequency shift; profile; IT.

1. Introduction

ADCP (Acoustic Doppler Current Profile) is a new type of current surveying sonar device and be used by acoustic wave Doppler Effect in early 1980s, as an one of the four kinds of advanced marine observation of speed measuring instrument (LIU, 2016),has been applied widely in flow measurement of the field of marine and inland river and water transport engineering (ZHU, 2007),for example: navigation safety and estuary regulation, marine engineering,real time electronic chart (ZHUO, 2010), study on shallow seas and bays on the continental shelf (LIAN et al., 2015), underwater archaeological, rescue and salvage, etc. (LU et al., 2006).

In order to provide present confirmation data for integrated physical modeling research in navigation safety and estuary harness project, as a new type of current surveying sonar device ADCP is used. According to the scope of work agreed by both contract sides the project was required to carry out twelve hydro-metric stations surveying. The exact station location would be decided by Owner and research department.

2. Theory of adcp work

ADCP used of the principle of acoustic Doppler to measure the frequency shift information of layered water medium scattering signals, and uses vector synthesis method to obtain the vertical profile water velocity of currents, i.e. the vertical profile distribution of water flow. There is no disturbance to the tested flow field, and no mechanical inertia or wear. It can measure the three-dimensional values and absolute directions of flow velocity in several layers on a profile at once (HUANG, 2013).

When ADCP emits a sound wave pulse signal into the water-body, it is reflected by the suspended and moving scatterer in the water, and then ADCP receives and processes the echo signal (YANG et al., 2004). According to the Doppler principle, due to the relative motion between ADCP and the scatterer, there is a Doppler frequency between the frequency of the emitted sound wave and the frequency of the scattered echo, and this frequency change completely depends on the motion speed of the reflector. By measuring the Doppler frequency shift, the relative velocity between ADCP and the scatterer can be directly calculated.

3. Example of adcp applied

3.1 Background and the Scope of Project

The project lies in the Pahang River Kuala, Malaysia.Service for physical/numerical modelling, and to overcome the siltation problems at the Sg. Pahang estuary in order to achieve the safe navigation of fishing vessels to and from the LKIM Complex and provide adequate navigation channels, berthing and mooring areas,provide shelter against wave attack at the LKIM pier at all times (HAN et al., 2007).

Refer to the local tidal tables, to carry out over a 26-hour duration coinciding with the same spring and middle and neap tidal season together. The observation items include current velocity and direction, sediment concentration, suspended sediment grading analysis and salinity.

To deploy sailing section current measurement along observation site (include 1# to 12#) using RDI ADCP, and Seawater samples are collected.

3.2 Plan and Preparation

We make a good plan and sufficient preparations for the work according to the weather forecast and the project arrangement. All known as below:

Table 1: Schedule time

Tidal type	Begin Date	Start Time	End Time	Remarks
Spring Tide	01.19	21:00	After turn current next day	Begin measure ahead of start time, and total time over 26-hours
Middle Tide	01.09	10:00	After turn current next day	
Neap Tide	01.14	09:00	After turn current next day	

Main Surveying Equipments

Table 2: The Main Outdoor Equipments

Name	Model	Function
Acoustic Doppler Current Profile	RDI WorkHorse	Current velocity and direction observation
Survey vessel	200 horsepower	Boat for ferry personnel and equipment

Introduce of the main equipments

Table 3: The parameters of ADCP（600KHz）

Item	Parameters	Item	Parameters
Depth cell size	0.5m	Transducer Depth	0.5m
Pulse interval	Tp000000	Blanking Distance	Wf50(0.5m)
range	36m	Record items	MA10111
Precision of velocity	±0.25%*velocity±2.5mm/s	Beam angle	20°
Structure shape	Four beams, raised	GPS update	5Hz

3.3 hydrology survey deployment

The work in hydro-metric stations 1# to 12# include water depth, current velocity and direction,were carry out the technical method as followed:

In the normal condition,should finish observation after over 26-hour and the total record include a set of turned current data.Once no turned current obtained, should finish observation after two hours forecasting slack water time.Record list should be integrated and true.

In hydrometric station 1# to 12# include current velocity and direction, were carried out by being taken to the station and lowered into the sea bed for the duration of data collection. The gymbal mounted on the three legged spider frame ensures that the ACDP will stay vertical at all times.

3.4 Process of Measurement Using ADCP

The ADCP transducer was put into seawater and stayed at position 0.5m lower than the surface, fasten at port of boat. The measurement continued for over 27 hours.

Before observation, the setting up configuration was carried on the basis of rough depth using WinADCP software supplied by the manufacturer. The configuration for the data collection was as follows:

The rough water depth is 8 meters, depth cell size is 0.5meter, transducer depth is 0.5 meters, blanking distance is 0.5 meters, and then divided into 16 depth cells.

At the same time as ADCP, the direct reading current meter was using to measure the current velocity of the surface, that is the position 0.2m lower than the actual surface.

Middle Tide

Complete middle tide during 10:00 9 January to 16:00 10 January.

At six o'clock 10 January, 1# to 12# are observed by ADCP. The measurement method is the ADCP transducer was put into sea water and stayed at position 0.5m lower than the surface, the sampling rate of data is at 30 minute intervals.

According to statistics of middle tide data, known as below:

The number of Current velocity data is 836， the number of current direction data is 836, the number of water samples is 636, number of salinity and sediment concentration data is 1272.

Neap Tide

Complete neap tide during 09:00 14 January to 14:00 15 January.At fourteen o'clock 15 January, station 1# to 12#, began observation and finished the tidal season successfully.

According to statistics of neap tide data, known as below:

The number of current velocity data is 1705, the number of current direction data is 1705, the number of water samples is 1065, number of salinity and sediment concentration data is 2130.

The news reported Japan, Taiwan China and Indonesia suffer earthquake in 16 January, and that evoke seaquake in Indonesia.

Spring Tide

Complete spring tide during 23:00 19 January to 01:00 21 January:On 19 January all eleven stations began observation at twenty-three o'clock and finished at one o'clock 21 January over 30-hour.

According to statistics of spring tide data,known as below:

The number of current velocity data is 1461, the number of current direction data is 1461, the number of water samples is 891, number of salinity and sediment concentration data is 1782.

3.5 1Summary

All number of data in whole hydrologic survey is:the current velocity data is 4002, the current direction data is 4002, the water samples is 2592, number of salinity and sediment concentration data is 5814.

3.6 Data Processing and Analysis

At the request of offering result, hydrologic survey must process the data of current velocity and direction, suspended sediment concentration and salinity in groups, detailed methods as followed:

3.6.1 The Current Velocity and Direction Data

The current velocity and direction data were converted into table format and computed average velocity and direction value of every perpendicular line data.

Data Processing of ADCP

Data is collected from Adcp using the "Winriver" software supplied by the manufacturers. Winriver is easy to operate, has a artistic appearance, shows varied current velocity using corresponding color, and shows related information when your cursor stop a certain depth cell, draws vector diagram and calculates current flow. The setting up configuration can recoded and restored by winriver, so we can playback the collected data by calling original parameters, and ensure integrity of raw data.

At the request of six-position method, we selected six groups data include the current velocity and direction of water surface, 0.2H, 0.4H, 0.6H, 0.8H and water bottom, where H is the water depth.

Method for processing of "blank zone"

ADCP have "blank zones", that is, a depth zone where data accuracy is questionable due to echoing effect, therefore, not recorded by the ACDP. The total blanking distance depends on the acoustic frequency setting, the limit of pulse transform time and the effect of the acoustic interference about riverbed. Every perpendicular line data consists of effective current data and two blank zones(figure 1). The upper blank zone is closed to water surface, its thickness is about the sum of transducer depth(0.5m), blanking distance(0.5m), and the half of depth cell size(0.25m), that is 1.25m. The lower blank zone is closed to sea bottom, called side-lobe zone, its thickness is lie on the beam angle of ADCP, such as the angle is 20° then the thickness of side-lobe zone is 0.06 time water depth. So the position 0.2m lower than actual surface is in the upper blank zone, the position 0.2m upper than actual bottom is in lower blank zone.

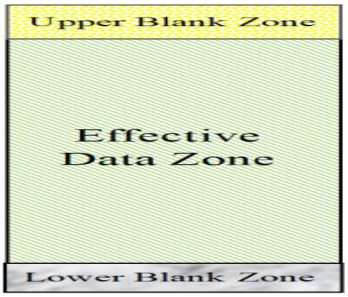

Figure 1: The diagram of blank zone and effective data zone

The disposal of current in blank zone is to form estimating model of current velocity by contrasting standard distributed numerical model of perpendicular line and actual current flow status. The current velocity of surface and bottom in blank zone are all from the estimating model(FAN et al., 2006).

The relationship formula of current velocity on surface and current velocity on the first depth cell is:

$$Vsurface=V1c\times\zeta \quad (1)$$

In that, V1c is the current velocity of the first depth cell;

ζ is the experience surface value in estimating model.

The relationship formula of current velocity on bottom and current velocity on the last depth cell is:

$$Vbottom=VcL\times\zeta \quad (2)$$

In that, VcLis the current velocity of the last depth cell;

ζ is the experience bottom value in estimating model.

4. Result

By comparing the actual current value and calculated current value, we found the imputed results meet the requisition of related specifications,the statistic shows the correlation coefficient reaches 96%,the quality is controlled(QC is good).

5. Conclusions

The work was carried out strictly in accordance with the related established procedure in Quality System ISO9001. The measurement data on-site was examined by survey team, processed achievement was checked by technology executive, final report was approved by assistant chief engineer. Summarizes as below:

One of the four kinds of advanced marine observation of speed measuring instrument, the ADCP be applied to project of navigation safety and estuary regulation,provided detailed and reliable basic data for physical & numerical model research and achieved good result.

The ADCP has the characteristics of time-saving, high-resolution, high-precision(LIU et al.,2015), massive and full information, energy efficient, especially suitable for testing under complex flow conditions;and can obtain 3D measurement of current velocity and direction. Able to automatically eliminate environmental factors and eliminate gross error; can obtain concentration profiles of suspended solids,provide a reliable data source for calculating sediment transport rates and studying sediment transport patterns; Especially,it can measure the clearance flow between underwater pebbles(ZHANG et al.,2013), which traditional method cannot achieve at all. Compared with traditional method,ADCP is a dynamic current measurement method, can demonstrate its superiority in complex conditions, wide sections and large flow data collection,reducing the labor intensity of traditional work and increasing data security. So as soon as it appeared, it received high attention from the oceanographic community, believing that it applied the Doppler principle to reveal the spatiotemporal distribution characteristics of ocean currents and can describe the motion state of fluid particles. ADCP also has further expanded application in areas such as sediment concentration in water bodies(GAO et al., 2022), investigation of underwater geographic and geomorphologic characteris, and testing of 3D flow patterns.This has promoted research on ocean currents and waves, and also provided effective ocean boundary layer data for numerical prediction of the marine environment(WU et al., 2009).

In future, the ADCP will be multifunctional, intelligent, lightweight, for development of modern IT and , and applied widely in scientific research and engineering, and can be play a greater role in the beautiful marine ecology of the ocean.

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