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Research Article

Acoustic Doppler Current Profiler to Measure Current Velocity

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ABSTRACT

Doppler speed log, an instrument that measures the speed of ships through the water or over the sea bottom was used before adcp. The first ADCP which was commercial, was based on concept of a commercial speed log . The speed log was refabricated to measure water velocity more precisely and to allow measurement in range cells over a depth profile. Henceforth, the first vessel-mounted ADCP was made. TRDI produced its first ADCP, a self-contained instrument designed for use in long-term in 1982. TRDI produced its first vessel-mounted ADCP In 1983. By 1986, TRDI had made five different frequencies (75-1200 kHz) and three different ADCP models (self-contained, vessel-mounted, and direct-reading). The concept of Doppler signal processing has established itself with the instruments afterwards. Speed logs used relatively simple processing with phase locked loops. The first generation of ADCPs used a narrow-bandwidth, single-pulse, autocorrelation method that computes the first moment of the Doppler frequency spectrum. This method was the first to produce water velocity measurements with sufficient quality for use by oceanographers.

Measurements of current velocity of streams, rivers, oceans are very important for:

Some examples of adcps are:

DETAILED DESCRIPTION

For finding the current velocities we assume that these particles move at the same velocity horizontally as same as the water

Adcp use doppler effect by transmitting sound signals of same frequencies and capturing the echoes which are returned and collected from the scattered particles in the water.

- The factors on which the measurements rely are :-
- When there is change in density of water the sound is scattered or reflected.
- The frequency of the reflected sound is increased or decreased in direct proportion to the rate at which the reflectors are approaching the instrument.
- The particles which can reflect back the sound signals are “clouds of planktonic organisms-
- Fish without swim bladders
- Gellies
- Copepods
- Euphausiids

The ADCP works by listening hydrophone for the sound that bounce offs the small particles.

Sound reflects back after coming in contact with small particles like mentioned above due to high frequencies

Structure

Adcps are multi-beamed structures having 3-9 beams which radiates acoustic energy at a fixed frequency but the choice of frequency is subject to use for any particular application and then the frequency of the acoustic energy of the backscattered particles in the water column is noted and calculated. The position of this is either downward or upward as this machine words on (column data)

The ADCP transducer configuration is called the Janus configuration, in reference to Roman god who looks both forward and backward. The Janus configuration is particularly good for rejecting errors in horizontal velocity caused by tilting (pitch and roll) of the ADCP

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The standard narrow-band ADCPs has 4 different transducers structured in a manner with beams pointing at an angle of 20 -30° to the plane of the transducers.

$$R_i = \frac{Z_i}{\phi . 180/\pi}$$

Since the transducers on an ADCP are at angles, the slant range (R) is calculated using the equation: (where φ is the transducer angle in degrees.)

COMPONENTS

Components	Usage
temperature sensor	To note the temperature
electronic amplifier	To transmit sound signals
a receiver	To receive sound signals
a clock to measure the traveling time	To estimate the sound velocity
compass	To know the heading
and a pitch/roll sensor	To know the orientation
analog-to-digital converter digital signal processor	To sample the returning for determining the Doppler shift.

Now through calculations of trigonomatry,3D velocity the components are calculated by Doppler shifts measured with three to four sonar beams. Sometimes fourth beam is used to calculate error velocity also.

Working

The velocity of the current will be equal to the change in frequency: -

We know, velocity is defined as amount of distance covered in a unit time period in a particular direction.

Velocity=distance / time

Here,

$vw=\lambda/T$

$vw=f\lambda$ [f=1/T]

On move away from the ADCP , the sound they hear of the scattered particles is Doppler-shifted to a lower frequency which is proportional to the relative velocity between the scattered and ADCP the sound of the back scarred later appears to the ADCP as if the scatterers were the same as the sound source .Hence, the ADCP hears the backscattered sound Doppler-shifted a twice. So, as the ADCP both transmits and receives sound, the Doppler shift is doubled

$Fd = 2\ Fs(V/C)$

Therefore, velocity is proportional to the doppler shift. So if we know the actual frequency ,speed of sound in water we can easily calculate the velocity of current.

Now ,each beam can measure only the velocity of water column along its axis. So, minimum 4 beams having transducers are projected in the water in 3 axis (x,y,z)

Each velocity will have two components namely cos θ and sinθ having conditions:-

- assumes current Homogeneity in a Horizontal Layer
- two pairs of opposing acoustic beams, and that each beam measures a velocity that is actually a weighted sum of the local horizontal and vertical velocities

$u1=v\sin\theta+w\cos\theta$ $\quad$ $u2=-v\sin\theta+w\cos\theta$

Now where θ is the angle of the acoustic beam from the vertical (20° in this case) and u, v and w are the horizontal and vertical velocity components. So that:

-
-
-

Sound Speed Corrections

ADCP automatically computes sound speed and corrects velocity based on measured temperature and assumed salinity

Measured Velocity Correction

The difference between a velocity measured by one set of three beams and a velocity measured by another set of three beams at the same time

Vcorrected=Vuncorrected(Creal/CADCP)

ADCP which is of narrow band having transmission of pulse of length which is fixed and ranging few milliseconds then the frequency shift, denoted as (Δf) of the backscattered signal is directly proportional to the relative velocity (vcosθ) component along the axis of the acoustic beam between the transmitted signals and backscattered particles. We calculate for a given source

$$v_k = \frac{(\Delta f_k/f)c}{\cos\theta_k}$$

vk - the relative current velocity for bin k at depth

Dk - depth range and is for

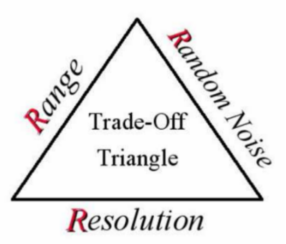
θk - the angle between the relative velocity vector and the line between the scatters and the ADCP beam

c - speed of sound at the transducer

Δf - frequency shift measured by the instrument

This velocity is for the velocity forward or backward as cos component resolves the horizontal component

PARAMETERS AFFECTING ADCP SETUP



A-Resolution

- Resolution (Depth) vs. Random Noise – when depth resolution is developed the random noise will also be developed.
- Resolution: Depth vs. Time – depth resolution when doubled without any increment the random noise will require 4 x the measuring period
- Resolution vs. Deployment Length – when number of depth is doubled the cells doubles the power

B-Range

- Range vs. Frequency – Twice the acoustic frequency will reach about half as far distance
- Resolution vs. Range – Doubling cell size injects more energy into the water
- Range: external factors – Cold and fresh water can support more precise profiling along with suspended materials.

C-Random Noise

- Dynamic Conditions – When there is much turbulence, great change in velocity across the depth cell, pitch and also roll of the ADCP mounting the velocity precision gets affected.

DATA READING

- ADCP.dll:
- Support for DVL.
- Supports Rowe and Nortek devices
- autolines.dll: Used for generating planned lines based on multibeam coverage.

The ADCP system usually uses a downward-looking profiler which broadcasts a forward, right- and left-lateral acoustic signals. In order to calculate discharge, the cross-product velocities are integrated over the water depth and, then, integrated, by time, over the width of the cross-section. The general equation for calculating water discharge through a surface, s, is modified as:

$$Q_t = \int^{T} \int^{d} \left(\left(V_f \times V_b \right) k \right) dz \cdot dt$$

where

Qt = total river discharge (cms)

Vf = mean water-velocity vector, in meters/second

Vb = mean vessel-velocity vector, in meters/second

k = a unit vector in the vertical direction

dz = vertical differential depth (meters)

dt = differential time (seconds)

ADVANTAGES

- To measure the current depth profile required the use of long strings of current meters which is no longer needed.
- Measures small scale currents
- ADCPs measure the absolute speed of the water
- Measures a water column up to 1000m long

DISADVANTAGES

- High frequency pings yield more precise data, but low frequency pings travelfarther in the water
- ADCPs set to "ping" rapidly also run out of batteries rapidly
- Bubbles in turbulent water or schools of swimming marine life can cause the instrument to miscalculate the current
- Users must take precautions to keep barnacles and algae from growing on the transducers.

CONCLUSION

The use of this instrument has broadened the usage of the water bodies and its properties to a higher and more précised manner. This has helped the mankind to calculate the complex quantities and large data value easily and swiftly. This can also help as an alert system in case of heavy or extreme turbulences in the water bodies .So that people may get conscious and help themselves well in time.

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