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Deep Ocean Hydrographic Element Acquisition Device Based on Edge Computing Technology

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ABSTRACT

The subsea environment of the ocean is complex, and it is very easy to cause damage to the offshore production facilities, the complete and effective hydrographic data analysis of the operating waters is the key factor to ensure that the offshore production facilities complete the optimization calculation. In this paper, in order to enhance the understanding of the laws of deep-sea subsea hydrology, a deep ocean hydrographic element acquisition device based on edge computing technology is proposed. The device can collect seawater temperature, salinity, current speed, and other hydrological environment data, it can realize real-time and efficient edge calculation of hydrological data, so that it can ensure real-time transmission of data, and then create an information database of hydrological environment elements in the operating waters. The device is connected to a winch fixed on the platform deck by steel cable, and the automatic lowering of the device is finished by using an automatic console. After the device into the water, the data acquisition device begins to operate. Data is collected at designed water depth points and the device completes the calculation of the data optimization, the data through the cable transmission to the platform surface console device, so far, the device finishes a data collection. Then, the device repeats the process until the completion of all the water depth points. In order to reasonably explain the applicability of the device in seawater, the finite element model of the hydrologic acquisition device is established by using OrcaFlex software. The offset of the device is taken as the reference index, and the environmental conditions are selected for finite element simulation analysis. Based on edge computing model, the use of the device described in this paper can reduce the processing time of the data, greatly release the arithmetic resources in the center of the offshore operation facility and improve the utilization rate of the arithmetic resources.

KEY WORDS: Edge computing; Offshore production facilities; Deep ocean; Hydrologic element acquisition device; Finite element

INTRODUCTION

Marine hydrological environment is complex, due to the different sea areas, the hydrological law has a greater difference. So, the combined effect of the sea current and wave load will have a great impact on the production facilities of the offshore platform. For the comprehensive calculation of the structural strength and safety, we need a large number of hydrological data as the analysis support. The traditional way of obtaining hydrological data, often faced some problems, such as slow data analysis, data inaccuracy, take up the center of the arithmetic resources and so on. It was noted (Manu lgnatius et al, 2023) that an intelligent wireless data transmission scheme is proposed, it used Acoustic Doppler Current Profiler (ADCP) with edge computing. By using this scheme, it has reduced the overall cost and improved the safety of device operation. It was noted (Abhishek Sharma et al, 2020) that an edge IIoT solution was proposed, which is based on the theory of edge computing. It has increased oilfield well data's ability through a combination of physical and data-driven, which in turn enables the management of remote well health and safety and ultimately improves well performance. Shukla, S et al. (2023) discussed that several new wells in the Green Field, located in western Libya, used an edge computing platform to complete the virtual traffic calculation. This solution can increase production capacity significantly and enable the rapid digitization of the field. Miguel Gonzalez et al. (2022) discussed that a new mud viscosity/density system based on electromechanical tuning fork resonators, which is integrated into edge computing systems, it not only can improve data collection but also accelerate deployment of machine learning models. It was noted (Jinxin An et al , 2021) that an autonomous underwater vehicle (AUV) was introduced, which improves the safety and reliability of the AUV by establishing a safety analysis framework. Nithiwat Siripatrachai et al. (2021) discussed that a machine learning platform deployed on edge computing. The platform can autonomously control the optimization of unconventional and non-conventional gas wells, the result shows that this method is able to reduce fluid loading, manual intervention and increase production. Mario Torre et al (2020) described a trainable multiphase flow metering system based on machine learning that enables real-time data measurements from hundreds of Wells. Jason D. Flanagan et al (2016) discussed that an ADCP deployed off the west coast of Ireland. They analyzed and compared wave data which was collected under extreme conditions. Zhong Cheng et al (2023) introduced that the importance of data acquisition and data processing of digital oilfield construction. Based on the theory of edge computing, this paper proposes a deep ocean hydrological element acquisition device and method, which can realize the collection of hydrological elements in different locations and different waters, and it also greatly releases the central computing power resources to realize the intelligence of data collection.

Hydrologic element acquisition device

The natural environment of the sea is complex and changeable, and it is difficult to acquire hydrographic environmental parameters. Existing mainstream marine hydrographic environment data acquisition devices mainly include buoy data acquisition, throwing data acquisition, voyage data acquisition and ADCP etc. Xu, Caiyun et al. (2017) introduced a new type of the buoy technology, it can measure environmental data dynamically while sailing. Kao, Chia Chuen et al. (2003) introduced a data quality check method based on buoys. Shuyun Yuan et al (2023) discussed a new type of unmanned ship for data collection, and they predicted the new type of data acquisition device. Nagao, Masayuki et al. (2018) introduced a method for measuring sediment suspension velocity caused by ship waves, they measured speed by using ADCP. Masayuki Nagao et al. (2018) showed that ADCP measurements of deep ocean current rates need to be checked for validity. Buoy data acquisition and voyage data acquisition are not suitable for deep-sea hydrologic data collection because these data collection devices are mostly suitable for shallow sea water. For throwing data acquisition, it is difficult to recover the data acquisition device. The above acquisition equipment and methods are not applicable to deep-sea hydrographic data acquisition. For ADCP, it can get the hydrological data at different seawater depths by changing the frequency of transducer, but, because of the high impurities in the water , interference of similar frequency sound sources, and the characteristics of acoustic wave itself, it is easy to cause the low accuracy of hydrological data acquisition .Based on the edge computing technology, the deep-sea hydrological element acquisition device can overcome the problems of seawater depth, water impurities, and sound source interference, and it can improve the measurement accuracy and transmit hydrological element data in time.

Hydrologic element acquisition device equipment composition

The hydrologic element acquisition device mainly consists of surface console, winch, deck operation room, plastic-coated steel cable, cable guide frame, cage, and Hydrologic element acquisition sensor.

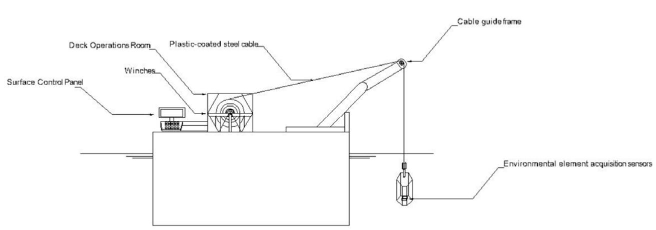

Fig 1 Hydrologic element acquisition device

(1) Deck Operation Room

Deck operation room is fixed on the platform deck, it is used for placing the surface console and winch, it can minimize the impact of high humidity, high temperature, high salt environment on the console and winch. So, it can avoid the failure of the instrument caused by environmental factors.

(2) Surface Console

The surface console is deployed in the deck operation room, the surface console is used to control the winch. It also can process and save the hydrological environment data which is collected by the hydrologic element collection sensors in time.

(3) Winch

The winch is controlled by the surface console, it connects with the plastic-coated steel cable, it can lower and recover the cable through rotation.

(4) Plastic-coated steel cable

The cable is plastic-coated to minimize the corrosion of the marine environment. In this way it can increase the life of the cable. Inside the plastic-coated steel cable, it has two parts in, one is cables and the other is communication cable. The first end is connected to the winch, and the last end is connected to the cage. It can transmit the power and data information.

(5) Cable guide frame

In order to extend the plastic-coated steel cable, the cable guide frame is installed at the edge of the platform deck. In this way, it can prevent the causing structural damage during the recovery process, when cage from colliding with the deck edge.

(6) Cage

The cage is connected to the plastic-coated steel cable to protect the hydrologic element sensors from damage, during the collection process. It also can improve the stability of data collection.

(7) Hydrologic element acquisition sensor

The hydrologic element collection sensor is placed inside the cage, it connects with the plastic-coated steel cable. The sensor has a data processing module, which can realize the data pre-processing after data collection, it also can realize data filtering and complete the initial screening of data.

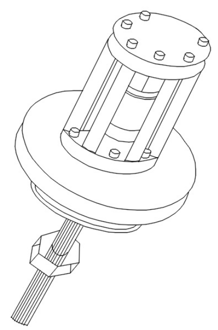

Fig 2 Hydrologic element acquisition sensor

Working principle of hydrological elements acquisition device

According to the actual environment, we input the collection parameters and then get the relevant collection of data, the main collection process is divided into the following steps:

(1) Input Sea depth, Point stop time, Cable lowering speed, Cable recovering speed, Number of points, Heaving limit, then we complete the basic parameter settings and click the data acquisition button in the surface console;

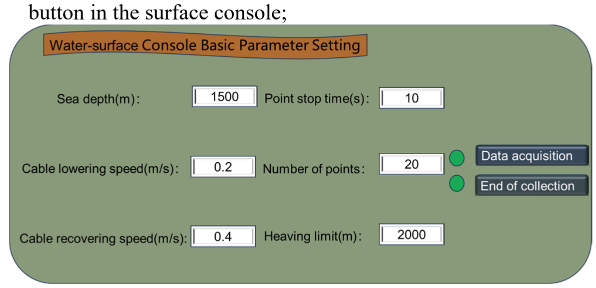

Fig 3 Water-surface console screen

(2) The winch receives the data acquisition command, then the motor starts to run, and the plastic-coated steel cable drives the hydrologic element acquisition sensor to lower at a uniform speed;

(3) The cage and the hydrologic element acquisition sensor enters the water, and the hydrologic element acquisition sensor starts to collect hydrological data;

(4) With lowering of the cable to reach the predetermined collection points, the winch stops the lowering of the plastic-coated steel cable.

Then the hydrologic element acquisition sensor is ready to collect the hydrological environment elements at collection point;

(5) When the sensor completes the data acquisition, the internal data processing module starts data processing and eliminating the large deviation value data. When the module completes data screening, the data is transmitted through the communication cable data back to the surface console;

(6) The surface console receives the data and starts data screening. Then, the console will save data again, the cable continues to be lowered to the next target point, until the sensor completes all data collection work;

(7) After the data acquisition is completed, the surface console clicks the End of collection button, then it recovers the cable, and carries out the collection operation until the cage and the data acquisition sensor are recovered to the platform;

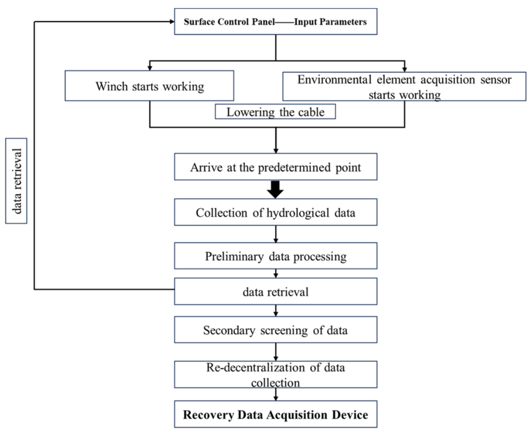

Fig 4 Data acquisition process

Principle of data verification

A data acquisition sensor is installed in a deep-sea full depth hydrologic element acquisition device, the actual contact between the sensor and the water environment can overcome the problems of seawater impurities, this can improve the accuracy of data collection.

At the same time, for the accuracy of the collected data, we can compare and verify the historical hydrological data. For the deep current velocity, such as the current velocity in 500-1500 meters of water depth, we may not have historical measured data. We can compare and revise the deep data by combining the existing shallow historical data trend. The Fig 5 shows the principle of the revise.

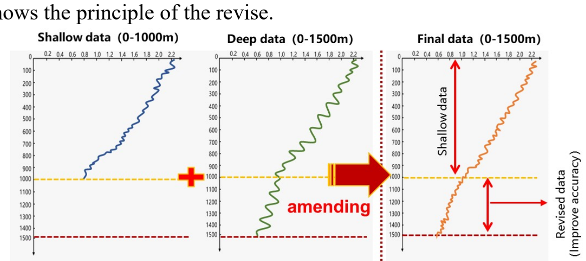

Fig 5 Data revise principle

Of course, such a verification method should be based on the comparison of historical hydrological data in the field waters. Therefore, we suggest that the hydrological element acquisition device proposed in this paper should be installed on the oil platform and sailing research ship which has the relevant historical hydrological data.

Finite element simulation of hydrological elements acquisition device

The Marine environment is complex and changeable, so, the hydrological elements acquisition device will get multiple effects of environmental loads such as wind, wave and current. Because of those loads, it will make the device have some offset. In order to ensure that the device can have a normal operation at sea, the finite element simulation calculation of the hydrological elements acquisition device offset is carried out by using OrcaFlex software under different working conditions.

Wang (2021) and Zhang et al. (2019) discussed that OrcaFlex software for Marine structures, especially subsea pipeline structures, has a powerful computational processing power, and can simplify the model, so as to obtain more accurate calculation results.

Environmental conditions

The environmental parameters of wind, wave and current are shown in the Table 1, the different environmental conditions can help simulation calculations easier.

Table 1 Environmental parameters

Return period	Wind		Wave		Current	
	Speed (m/s)	Direction(°)	Height(m)	Period (s)	Surface current(m/s)	bottom current(m/s)
10	28	180	8.6	12.4	1.82	0.26
20	31.4	180	10.7	13.3	1.92	0.28
25	32.6	180	11.4	13.6	1.96	0.28
40	35.2	180	13.1	14.2	2.03	0.29
50	36.5	180	13.9	14.5	2.06	0.3
100	40.8	180	16.8	15.4	2.17	0.32

The current speed is shown in the Table 2 below, Depth range is 0m to 1500m.

Table 2 The current speed data

Depth(m)	Return period					
	10 (m/s)	20 (m/s)	25 (m/s)	40 (m/s)	50 (m/s)	100 (m/s)
5	1.82	1.92	1.96	2.03	2.06	2.17
79	1.6	1.9	1.9	2	2.03	2.05
237	1.5	1.79	1.8	1.93	1.96	1.98
394	1.5	1.78	1.79	1.93	1.96	1.98
552	1.4	1.65	1.72	1.87	1.9	1.95
710	1.39	1.63	1.65	1.86	1.89	1.91
868	1.35	1.52	1.6	1.76	1.79	1.79
1026	1.29	1.46	1.54	1.75	1.78	1.79
1183	1.25	1.35	1.48	1.64	1.67	1.68
1341	1.18	1.26	1.32	1.58	1.61	1.68
1499	1.15	1.26	1.3	1.39	1.42	1.45
1500	0.86	0.96	0.28	0.29	0.3	0.32

Finite element model of hydrologic element acquisition device

OrcaFlex software is used to build the model, which is divided into three parts. They are floating body unit, steel cable unit and hydrological elements acquisition device unit.

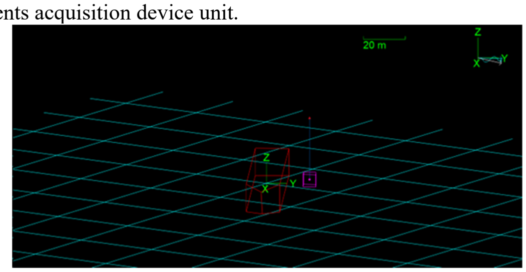

Fig 6 Device finite element model

（1） floating body

The length of the floating body is set to 91.5m, the mass is set to 100t, the moment of inertia tensor is shown in the Table 3 below, and the center of mass are shown in the Table 4 below.

Table 3 The moment of inertia tensor

Direction	X ($t.m^2$)	Y ($t.m^2$)	Z ($t.m^2$)
Value	254.9e3	0.0	0.0
	0.0	5.98e6	0.0
	0.0	0.0	5.98e6

Table 4 The center of mass

Direction	x	y	z
Value(m)	2.53	0.0	-1.974

(2) steel cable

The steel cable adopts the wire unit structure for simulation, and the relevant parameters are set as shown in the following Table 5.

Table 5 Steel cable parameters

Category	Value	Unit
outer diameter	0.024	m
Mass per unit length	0.00162	t/m
Axial stiffness	295	kN
Poisson ratio	0.3	\
Section length	30.0	m

The outer diameter is set to 0.024m, the mass per unit length is set to 0.00162t, the axial stiffness is set to 295kN, and the Poisson ratio is set to 0.5.

(3) Hydrological elements acquisition device

The weight of the hydrological elements acquisition device is set at 200t, the center of mass is shown in Table 6 below, the volume is 281.762m^3, and the center of volume is shown in Table 7 below

Table 6 The center of mass

Direction	x	y	z
Value	0.0	0.0	2.5

Table 7 The center of volume

Direction	x	y	z
Value	0.0	0.0	2.567

Offset calculation and analysis of hydrological elements acquisition device

We choose the return period 10 as the environmental conditions to finish the time domain analysis of the model. The simulation time was set at 500s, the step length at 0.1s, and the cable length at 9.8m, the offset at the connection point 1 between the cable and the device was calculated. The offset in x, y and direction was shown below

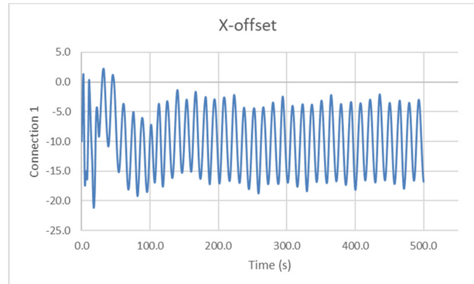

Fig 7 Connection point 1 X-offset

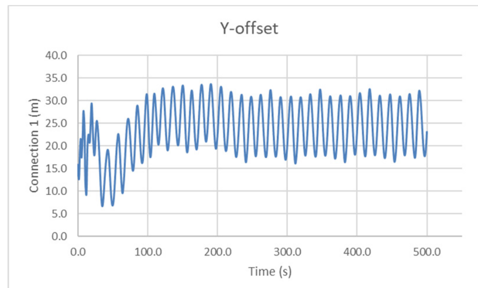

Fig 8 Connection point 1 Y-offset

It can be seen from Fig 7 that the maximum offset of the device in the x direction is in the negative x axis, and the occurrence time is 17.6s, with a maximum value of 21.2236m.

It can be seen from Fig 8 that the maximum offset of the device in the y direction is in the positive y axis, and the occurrence time is 191.3s, the maximum value is 33.3309m.

The water depth of 0-1500 m is divided, we calculate the offset of the device in the x and y directions at different water depths. The calculation results are shown in the Fig 9. The maximum offset occurs in the x direction of the device, with a maximum value of 39.12m and a depth of 40m.

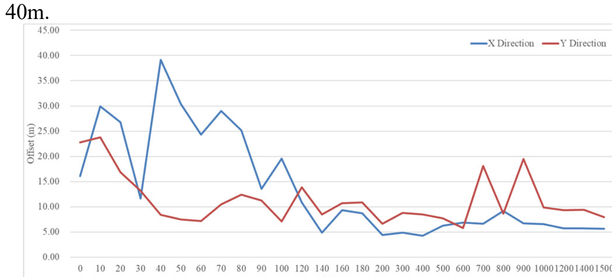

Fig 9 X-Y Offset calculation result

Edge computing deployment scheme

The above hydrologic element acquisition device is used to measure the collection of the current rate, current direction, temperature and salinity of the sea current, and the collected hydrological data can be used to realize the construction of the information database of hydrological elements, and it can also be used as the basic data for the calculation of the structural safety of the platform facilities.

In order to realize simple and fast data processing operation, it is necessary to design intelligent data transmission solution for the hydrological elements acquisition device, so as to complete the edge computing processing mode.

Edge Computing Model Architecture

After the hydrologic elements acquisition sensor enters the seawater, it carries out the data acquisition work, in order to speed up the data processing speed and improve the accuracy of data acquisition, it is proposed to carry out the data edge calculation from two parts of the device.

Hydrologic elements acquisition sensor faces a more complex environment. The data which is accepted by sensor is more complicated, so it needs the preliminary hydrological information data processing. Hydrologic elements acquisition sensor internal built-in filter to remove noise, vibration and other environmental factors caused by instability, followed by internal algorithms for common errors in data correction.

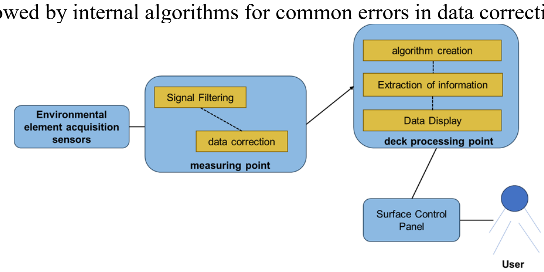

Fig 10 Edge computing architecture

The data is collected by the hydrologic element acquisition sensors are transmitted by communication cables to the surface console, which has a built-in embedded system to receive, process and analyze the data. By building appropriate algorithms to identify and extract key information, the amount of data transmitted to the computing center or cloud is reduced, reducing bandwidth usage and computing power resources.

Edge Computing Interaction Experience

The interactive capability of edge computing is to enable users to have effective and intuitive interaction with edge devices. According to the environmental conditions of the hydrological environment elements collection, the processing interface of edge computing results is designed to ensure the simplicity and beauty of the interface and to avoid complex graphical information hindering the user's understanding.

Users can connect with the surface console to obtain the hydrological data information processed by the surface console, which can be presented to the user in the form of data tables and data graphs.

CONCLUSION

(1) This paper introduces the composition equipment of the hydrological elements acquisition device, and discusses the working principle of the data acquisition device. Based on the above content, we systematically come up with a method and device suitable for deep-sea hydrological elements data acquisition;

(2) In this paper, the subsea feasibility of the device is analyzed by finite element analysis and the subsea offset is taken as the evaluation index. The result shows that in the return period 10 condition, the hydrological elements acquisition device will have a certain subsea offset. For the structures with large spacing, the device has little influence on the subsea structure. If the structure is small in spacing, the impact of the device on the subsea structure should be considered, such as installing positioning devices and installing anti-winding equipment.

(3) Based on edge computing technology and combined with the hydrological element acquisition devices and methods, a data edge processing model is innovatively proposed. In the future, we hope that through the deployment of edge equipment and the data acquisition device and method, the collected data can be processed in time, the bandwidth pressure can be reduced. We also hope that it can improve utilization rate of central computing power resources and can make the high-speed flow of data.

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