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# Research on BaaS Level Measurement and Control Device of 5000m$^3$ Storage Tank Based on Vision Sensing

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***Abstract:*** *The BaaS liquid level measurement and control device of 5000m$^3$ storage tank in oilfield based on visual sensing aims to solve the safety, environmental protection and digital problems of tank level monitoring in the field of petroleum and petrochemical energy. The device consists of three modules: level measurement, data analysis, and safety and environmental protection. Relying on intelligent visual perception and control, blockchain and other technologies, the remote digitization of the 5000m$^3$ storage tank level signal in the oilfield is realized, and the blockchain + knowledge graph + privacy computing + Internet of Things creates a trusted data base to realize the real-time matching of product objects and ledgers.*

***Keywords:*** *Intelligent visual perception, Control block chain, Intelligent redundancy arrester, Sealed square box*

## 1. Introduction

The green transformation of domestic energy enterprises is accelerating, and the new generation of information technology integrates traditional industries to help energy enterprises make green transformation. At present, there is no research on combining the stability of mechanical float level monitoring device with intelligent wireless monitoring at home and abroad, and the research prospect is considerable.

### *1.1 The upgrade of petroleum equipment meets the national strategic needs*

At present, China is at the key historical node of national rejuvenation, and the strategic position of oil and gas energy is prominent. Oil and gas resources are not only important chemical raw materials, but also important strategic resources for the survival and development of China. Their products are widely used in various fields of national economy. Petroleum industry is the pillar industry of the national economy and plays an extremely important role in the national economy. China produces about 150 million tons of oil and gas every year, but uses 700 million tons. In today's environment of crude oil resource shortage, the problem of oil and gas loss is quite serious. Every year, it is also faced with oil and gas loss of nearly 10 million tons and gas loss of economic loss of nearly 10 billion yuan, among which the oil loss caused by liquid level measurement is gradually obvious. Due to the inaccurate torque transmission of mechanical float level gauge and the top of the tank is not sealed, the intelligent oil and gas loss caused cannot be realized is about 2-3 million tons. At the same time, the loss of oil and gas not only causes economic losses, but also causes environmental pollution problems, which is not conducive to environmental protection. In recent years, the oil field is in the development period of high moisture content, with decreasing production capacity, high moisture content, and many open Wells. The oil depot, especially the joint station oil tank, has higher requirements for the accuracy of measurement than before. Due to the previous measurement methods and manual measurement oil have different disadvantages; high failure rate, safety risks, manual measurement labor intensity, long oil quantity time. At present, there are two kinds of single well oil quantity in Zhongyuan, which is difficult to meet the needs of oilfield development, production and management. According to the characteristics of oil field liquid level measurement, it is a difficult problem to find a safe, reliable, convenient and fast oil volume measurement method with a high level of automation.

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### *1.2 Digital petroleum and petrochemical equipment has a broad prospect*

As big data, Internet of things, artificial intelligence and 5G a new generation of information technology to accelerate with the traditional oil and gas industry, energy production mode become more intelligent, collaborative, safe and efficient, speed up the formation of new kinetic energy, promote oil and gas enterprises to the digital modern operation mode transformation, realize the transformation and upgrading of industry and value growth. Level gauge is widely used in oil tank operation in the process of tank level monitoring, has become an indispensable tool, with the development of microelectronics and computer technology, measurement is developing in the field of intelligence, the liquid level gauge accuracy, environmental protection, intelligence also put forward higher requirements, new level gauge has become a new development direction of liquid level measuring instrument. [1-4]This means that the new liquid level meter has a broad market and development prospects. The level gauge is widely used in petroleum industry. The level monitoring device is installed in oil tank operation to prevent accidents such as tank roof and evacuation. In addition, the accuracy of the measurement of the liquid level in the oil tank will directly affect the trade settlement, which is directly related to the economic interests of operators and consumers, and also puts forward higher requirements for its measurement accuracy. With the development of microelectronics technology and computer technology, measurement is developing to the field of intelligence, and the liquid level measurement instrument used for liquid level measurement has also made great progress. A variety of more functional and adaptable instruments have been developed to adapt to the high requirements of liquid level measurement.[5-8]

### *1.3 The market demand is promising*

In the petrochemical industry, the commonly used liquid level measurement means are usually divided into two categories, capacitive liquid level meter, inductor liquid level meter and so on represented by the contact type and ultrasonic sensor, radar sensor represented by the non-contact type. Contact level counting range is small and easy to electrochemical reaction with the solution in the polishing process, the contact sensor will become a vulnerable product, with high cost.[9] Although ultrasonic sensors and radar sensors have high accuracy, they are expensive and local measurement. Due to the fluctuation of the liquid level, they are in a non-static state, which will cause large measurement error and cannot meet the requirements of liquid level measurement accuracy.

Relying on intelligent visual perception and control, block chain and other technologies, the oilfield is 5000$m^3$Remote digitalization of storage tank liquid level signal, blockchain + knowledge graph + privacy computing + Internet of Things to create a trusted data base, to achieve real-time matching of product objects and ledger. The device consists of three modules: liquid level measurement, data analysis and safety and environmental protection. The liquid level measurement module is composed of lighting system, optical camera system, computer processing and analysis system and display and recording system. The data analysis module is composed of BaaS blockchain trusted warehouse receipt service platform and the remaining life prediction system, and the safety and environmental protection module is composed of sealed square box device and intelligent fire resistance device.

## 2. Liquid level measurement and control system based on machine vision

### *2.1 System composition*

The depth camera is used to monitor the liquid level in real time and process the data, and control the solution in and out with real-time feedback measurement results. The system includes four modules: liquid level information acquisition module, liquid level control module, upper computer operation module and production work module. The liquid level information acquisition module is composed of depth camera and image processing system.[11-14]The depth camera processes the collected color image and depth image incoming image processing system and calculates the liquid level height. The liquid level control module is composed of liquid level control system, inlet pump, B solenoid valve, outlet pump and A solenoid valve, which controls the output of liquid level information acquisition module to the liquid level control system. The upper computer operation module is composed of industrial controller and display, liquid level value and working status of interface operation control equipment. The production operation module is composed of oil tank, circulation tank, A pipe and B pipe.

The depth camera, image processing system, industrial control machine and liquid level control system are connected in turn; the industrial control machine is connected to the liquid level control

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system, the oil tank is provided with an outlet pump, the side wall of pipe A is connected to the outlet of the outlet pump through the oil tank, the other end of pipe A is connected with the circulating tank; the circulating tank is provided with the inlet pump, one end of tube B is connected with the inlet pump outlet, the other end of pipe B is connected with the oil tank; the outlet pump and the inlet pump are connected with the liquid level control system.[15-16]Valve A is provided on pipe A and valve B is provided on pipe B; both valves A and B are connected to the liquid level control system. The industrial controller is connected with a display.

### *2.2 Core technology*

STEP 1 Installation equipment: the depth camera is installed directly above the oil tank, in order to ensure the measurement accuracy and ensure that the optical axis is perpendicular to the liquid level; for the display characteristics and imaging requirements of the oil field environment and liquid level instrument, the light source is determined as the LED surface light source and the lighting scheme is the front open field diffuse.[18-20]Considering the integration of the system and the transmission speed of video data, select the CMOS camera with USB interface.

STEP 2 Image acquisition: connect the industrial control machine and the depth camera, open the depth camera on the operation interface of the industrial control machine, conduct image acquisition, capture and record the change of the liquid level of the oil tank.[21-25]

STEP 3 Image preprocessing: zero calibration of the depth camera to screen the depth information of non-measured areas;

STEP 4 Calculate the liquid level according to the image: set the upper and lower threshold height, that is, the depth value beyond the measurement range is set to zero, and the depth value of the measured area meets the average as the height of the oil;

STEP 5 The level control system adjusts the opening and closing size of valves A and B. The ADRC control system is selected for the liquid level control system. The color threshold segmentation is introduced to determine the position of the instrument display part in the image, and the image distortion reduces the measurement error. Then the Canny operator is applied to detect the edge of the liquid level interface, and the adaptive median filter and histogram analysis are added to improve the adaptive energy of the algorithm. Finally, a window search peak detection algorithm and a camera self-calibration method based on Lagrange interpolation are proposed, and the numerical amount of liquid level is obtained by template matching.

STEP 5.1. Transfer the actual liquid level height H into the ADRC control system, adjust valve A and valve B to control the oil tank liquid level at the set height $H_0$dwell

STEP 5.2, will set the value $H_0$Transfer to the ADRC control system, through the differential tracker output $v_1$, $v_2$:

$$\begin{cases} \dot{v}_2 = \text{fhan}\ (v_1 - v,\ v_2,\ r_0,\ h) \\ \dot{v}_1 = v_2 \end{cases}$$

Where v is the curve of the set fluid level, $v_1$Is the fastest convergence of v, $v_2$Is that of its derivative, $r_0$And h

$_0$Is the controller parameter, and the $r_0$Represents the urgency of the transition process, $h_0$Is the sampling period, the fhan ($v_1$,$v_2$,$r_0$, H) is the fastest integrated function;

STEP 5.3. The actual liquid level value H is output at z through the expansion state observer$_1$, $z_2$, $z_3$:

$$\begin{cases} e = z_1 - H \\ \dot{z}_1 = z_2 - \beta_{01} e \\ \dot{z}_2 = z_3 + b_0 u - \beta_{02} fe \\ \dot{z}_3 = -\beta_{03} fe_1 \end{cases}$$

Where H is the output of the system, u is the control amount of the system, $b_0$For the control quantity gain, $z_1$Is the state trace of H, $z_2$yes $z_1$State trace of the derivatives, $z_3$yes $z_2$State trace of the derivative, $\beta_{01}$,$\beta_{02}$,$\beta_{03}$Is the observer gain, $f_e$=fal(e,0.5,$h_0$)，$f_{e1}$=fal(e,0.25,$h_0$); bias in statistics $e_0$, $e_1$,

$e_2$The final control amount u is obtained by the nonlinear proportional integral differential module, and the inlet water valve and the outlet water valve are controlled, and the liquid level is finally adjusted to the set height $H_0$。

## 3. Development of the sealing device

The sealing device developed is based on the basis of the original liquid level meter, using the principle of sealing oil for sealing, by installing the guide pulley in the device to guide the steel wire outside the tank, and adding sealing oil in the device for oil and gas sealing, playing the role of sealing inside and outside the tank. The shape of the device is square box, guiding the wire rope through two fixed pulley before steering outside the tank, and sealing oil is added to the middle box to seal the inside and outside of the tank.[10] Through the trial operation of the device, change the original "U" oriented design structure to improve the pressure capacity of the device; optimize the nonvolatile liquid medium with high density, low setting point and high boiling point as sealing oil to improve the stability; install the seal oil gauge, grasp the seal oil level at any time to prevent the oil spill; and install the discharge wire plug to replace the seal oil and discharge water in winter.

## 4. Development of intelligent redundant flame arrester

Because the oil tank liquid level meter device has no fire resistance function, there are fire hazards and lack of essential safety problems, so the intelligent redundant liquid level meter fire resistance device is developed to prevent the flame spread of flammable gas and flammable liquid steam. The intelligent redundant liquid level meter is composed of detector, flame retardant and online purging system. The detector is used to detect the temperature of the device and transmit information to the flame device for quick switching. The flame arrester device can quickly switch between the fire resistance function and the normal operation of the liquid level meter. [26-28]The online purge system is used to detect and purge the expansion material produced after the fire resistance device.

### *4.1 Theory evidence*

When the liquid level is measured, the main pipe of the liquid level gauge is in the open position, the ball valve of the spare pipe is closed, and the liquid level gauge is in normal operation, the flame retardant device does not carry out any fire resistance behavior, which will not affect the detection level of the liquid level meter. Set the temperature detector.[17] When the temperature detector detects fire or high temperature, the device starts the control valve to switch between liquid level meter and flame resistance quickly. A three-way connection device is provided between the liquid level gauge pipe hole and the arrester pipe hole. The device designs a thermistor. The thermistor curve of the semiconductor material is: the resistance value is 5 kΩ at 25℃, and the temperature change of 1℃ causes a resistance change of 200 Ω. When the high temperature is detected, the temperature sensing detector transmits the signal to the switching function valve on the fire resistance device to quickly switch the flame retardant device to the ball valve of the spare pipe to prevent the high temperature point and the fire point.

### *4.2 Key technology*

Set fire resistance device net, with stainless steel mesh of 0.25-0.33mm diameter, composed of multiple layers overlapping, using 20-30 mesh metal mesh, 5 layers. Increase the heat transfer and wall effect while reducing the level gauge pressure. Using stainless steel material, each layer of fire resistance gap value is different, from outside to inside as MESG> =0.90); 0.90> MESG> 0.50; MESG <=0.50 value and so on. When the last layer of fire resistance net works, the receptor will transmit the signal to the alarm, generating the alarm signal to the staff to reduce the danger of the device. When the flame retardant, the flame retardant layer will automatically select the appropriate flame retardant element gap according to the MESG value of the medium. When the gap value of the flame retardant element is greater than the MESG value of the medium, the flame will penetrate the flame retardant element and cannot play the role of preventing the flame propagation. When the gap value of the flame retardant element is less than the MESG value of the medium, the flame propagation can be prevented. The arrester shell is made of cast iron and cast aluminum alloy with magnesium content no more than 0.5%. The shell is qualified for hydrostatic test and tested for 2.4MPa without leakage. Core piece pressure ring, installed at the pipe end. Matching flange gass, studs and nuts on seat surfaces. The gasket inside and connecting the flame retardance uses a flame retardant ring, which is made of metal

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material and filled with flame retardant expansion core material inside.

## 5. Construction of the trusted warehouse receipt platform of BaaS blockchain technology

Tank liquid level parameter data refers to the measurement and monitoring data of the liquid level height, volume and temperature in the oil tank. These data have the characteristics of real-time, large data volume, high precision requirements and security requirements. Through the application of blockchain technology in the data sharing of oil tank liquid level parameters, we can realize the security sharing, real-time update and traceability of data, solve the trust problem in data sharing, and improve the credibility and sharing efficiency of data. The decentralized nature of blockchain can also reduce the participation of intermediate links and simplify the process and cost of data sharing.

### *5.1 Key technologies*

The technology first determines the participants of the consortium chain (the participants are determined, including oil depot management agencies, regulatory agencies, suppliers and other relevant parties, forming the participants of the consortium chain)

Second, design smart contracts and data storage mechanisms (design smart contracts that dictate the rules and conditions for data upload, access, and transactions.)[26-27] Design a data storage mechanism to determine how to store and manage tank level parameter data)

Build a consortium chain network again

(Deploy the blockchain network and build the infrastructure of the consortium chain, including the setting and connection of nodes)

Then data collection and upload (install the tank level sensor, collect the tank level parameter data in real time, and upload the collected data to the consortium blockchain network in an encrypted way)

Then carry out data validation and consensus mechanism (design data validation rules to ensure that the uploaded data conforms to the specified format and scope.) The consensus mechanism is used to verify and confirm the data to ensure the consistency and credibility of the data)

Finally, data sharing and rights management (design data sharing rules, determine the scope and permissions of data that can be shared between participants, and configure rights management mechanisms to ensure that only participants with corresponding permissions can access and manipulate specific data).[28]

### *5.2 Experiment and result analysis*

#### *5.2.1 Experimental environment and datasets*

Experimental environment: An oil tank liquid level parameter alliance chain composed of 5 participants was built, and the Ethereum blockchain platform was used for experiments.

Data set: 100 tank level parameter data samples were prepared, including tank number, level height, temperature and other parameters.

#### *5.2.2 Implement the oil tank liquid level parameter alliance chain*

The allocation participants: including oil depot management agencies, oil tank operators, regulatory agencies, etc., each participant has a node.

The design smart contract: realize data upload, verification, access rights and other functions.

The building the alliance chain network: Deploy the alliance chain network on the Ethereum platform, and configure the communication and consensus mechanism among the nodes.

Data collection and upload: Participants use sensors to collect the tank level parameter data and upload the data to the alliance chain through the smart contract.

## 6. Liquid level meter remaining life prediction system

The roof of the metal oil tank is seriously weathered in the open air, leading to the potential failure of the liquid level gauge. The determination of the remaining service life of the device plays an important role in the maintenance of the whole device.

Theoretical basis: by obtaining the metal density on the top of the metal, the relative atomic mass and valence electrons of the metal material, in order to obtain the interference current density at the defects at the top of the metal can, the allowable corrosion thickness threshold at the defects of the metal can is obtained by accelerating the corrosion experiment, and the discharge coefficient is determined according to the average discharge time of the metal tube from the grounding electrode of the DC transmission line. For the defect area, according to the tube parameters, discharge coefficient, current density at the defect and the allowable corrosion thickness threshold, in order to determine the remaining life of each defect, the remaining life at each defect is positively correlated with the density, valence electrons, allowable corrosion thickness threshold, discharge coefficient, and negatively correlated with the relative atomic mass and current density; Determine the remaining useful life of the metal can top based on the remaining life of at least one defect.

Technical method: $x^{(0)}$ The DC resistivity data of the oil level meter is taken as the original sequence; the original data is processed to improve the smoothness of the original data. In preparation for the high-precision prediction model GM (1,1), the original data is accumulated (1-AGO) for the 1-AGO sequence to determine the corresponding sequence of the model time and use the improved model —— the prediction value model at any time. $x^{(1)}$ $x^{(1)}$ $z^{(1)}$ $x^{(0)}$ 5000m$^3$BaaS low power level meter; the wireless sensor module can be placed close to the signal source, and has certain data processing capability to ensure the accuracy of the signal acquisition; The wireless sensor is suitable for low power consumption operation, and can be data collected and send without external power, saving resources. SD-DS intelligent oil tank liquid level monitoring device energy saving, environmental protection, efficient, automatic design in the product life cycle development process of the important role, improve product quality, reduce cost and improve the competitiveness of enterprises.

## 7. Conclusions

In this study, the environmental protection module was set by the sealing direction device, the security module was set by the intelligent arrestor + self-supply system, the digital module was set by the low-power wireless transmission system, and the residual life prediction module was set by the gray prediction modeling. Based on the basic principle of block chain, the characteristics and requirements of the liquid level parameter data of the tank. The four modules realize zero loss, zero risk, low power consumption and digitalization of the oil tank liquid level detection system. The oil tank liquid level detection system realize the compatibility of dynamic measurement and sealing, safety of pipe network system, reliability of mechanical level meter, solve the problems of traditional mechanical level meter not sealing, lack of essential safety and poor reliability, and achieve zero loss, zero risk, low power consumption and digitalization.

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