The designs of iron roughneck working torque real time monitoring scheme and the hardware system

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Abstract

The iron roughneck, a full automatic making-up or breaking-out device instead of the traditional hydraulic tongs, has been applied in production practice and become the essential equipment in automatic pipe handling system on marine drilling platform. When the iron roughneck is at working, real time monitoring and controlling of the working torque is necessary. It can ensure the torque value is under control when drilling tools are made up or broken out so as to protect the drill screw threads and prolong the service life of drills. Based on the measurement and control of the working torque of the iron roughneck, the scheme, which treats testing hydraulic cylinder working pressure as the measurement information, is determined. The hardware circuit including sensors, single chip microcomputer, alarm, feedback control and so on is designed to provide hardware conditions for the test and control of the iron roughneck working torque. Finally, the simulation experience used to test alarm function of the system is carried out.

Keywords: The iron roughneck, Working torque, Real time monitoring, Hardware, Design

1 Introduction

With the gradual depletion of land oil and gas resources, oil and natural gas exploitation has been transferring from land to ocean slowly [1]. In the Marine energy exploitation, semi-submersible drilling platform has unparalleled advantages compared with other platforms. Semi-submersible drilling platform has many characteristics, such as strong kinematic capability, strong wind and wave resistance, large deck area and loading capacity, high efficiency, high automation and intelligent level [2]. Pipe tool occupies an extremely high proportion in semi-submersible drilling platform tools, such as drill pipe, drill collar, casing, tubing, riser, downhole tools, etc. (hereinafter jointly referred to as the pipe) [3]. Known as high-tech and revolutionary products, iron roughneck, a higher degree of automation tool, is used for making up and breaking out pipe connections. It can reduce the number of wellhead operators as well as labor intensity, and improve work efficiency as well as production security, thus it has been widely applied on semi-submersible drilling platform [4]. Real time measurement and control of the working torque is particularly important. When making up and breaking out, if the pipe connection is not tight according to the specified torque value of different types of pipes, it is easy to damage and scrap. In order to ensure the torque value during the process of pipe making-up or breaking-out is scientific and reasonable, the automatic measuring and control system, which makes MCU as the core, is designed and used to measure and control this torque.

2 The core, is designed and used to measure and control this torque

2.1 SELECTION OF TORQUE MONITORING SCHEME

Generally, torque measurement means using a special torque mete to measure tiny deformation of rod or beam, which is under torque directly [5]. Obviously, it is difficult to achieve for oil pipe. In engineering practice, it is impossible to install each oil pipe joint with a torque mete, because on the one hand, this structure interferes with the iron roughneck operation; on the other hand, it may affect the normal operation of oil pipe in oil well. Therefore, the direct torque measurement is difficult to fulfill. Only by measuring the amount of other correlation quantity, then through the association theoretical analysis and field numerical calibration, can the torque be measured indirectly.

The connection of oil pipe joint is to be completed by roughneck making-up and breaking-out operations [6]. As long as a value of one link in making-up or breaking-out torque transmission process can be measured, its theoretical value can be achieved through association and the method of practicality demarcation. In this way, the loss of friction can be eliminated, and the actual torque value can be obtained indirectly [7].

Iron roughneck's torque is gained through a hydraulic cylinder acting on a pipe by pushing a rod to drive the clamp head. That is to say, by measuring the pressure of the hydraulic cylinder, the torque value on the pipe can be gained. Through the sensor, the hydraulic cylinder pressure value is picked up as well as transformed into electrical signals, connected circuit analyze signals and the pressure value is displayed in real time.

There are two working states. The first is that hydraulic cylinder piston is out and push tong jaw to bite pipe. The

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second is that the bottom of tong's body circles around the centre of pipe to finish making up or breaking out action.

In the first working state, the pipe and the tong dies are only under pressure and have not received the friction. The maximum output torque $T_{\max}$ can be used to calculate the maximum pressure of pipes and tong jaw at the moment. The force analysis is shown in Figure 1.

As shown in figure 1, F1 and F2 are positive pressure of tong jaw towards pipe. The angle of V-block is 120º, so the angle between Fl and F2 is 120º. It can be detonated by θ. When the jaw of screw impact tong outputs torque, the pressure on the pipe is F=f/ μ . In this equation, "f" indicates the static friction force of pipe created by the friction plate, and " μ " is the coefficient of maximum static friction. When the friction plate rotates with a pipe in it, it will be influenced by frictional force of four friction plates. So, the output torque can be expressed as $T = 4fR = 2fD$. In this equation, "D" refers to the diameter of the pipe. From $T_{\max} = 2f \bullet D_{\min}$, to $f_{\max} = \dfrac{T_{\max}}{2D_{\min}}$ then, $F_1 = F_2 = \dfrac{f_{\max}}{\mu}$

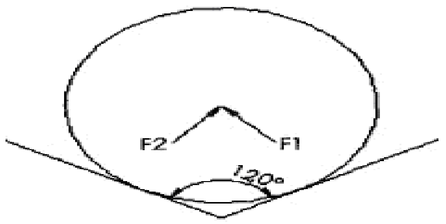

FIGURE 1 The pressure of the tong jaw

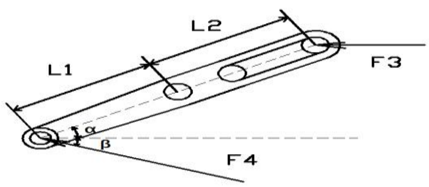

FIGURE 2 The pressure of the propelling rod

In this way, in the first state, the level of positive pressure exerted by pipe is:

$$N_{\max} = 2F_1 \cdot \cos\frac{\theta}{2} = \frac{T_{\max} \cdot \cos\frac{\theta}{2}}{\mu \cdot D_{\min}} \quad (1)$$

The pressure of tong jaw is exerted by hydraulic cylinder through the propelling rod. The thrust of hydraulic cylinder F4 is pushed back by the tong jaw counter force F3. Combining with the working principle of hydraulic cylinder, the hydraulic system working pressure *P* can be deduced by the hydraulic cylinder thrust F4. Finally, the measurement of the torque can be converted into the measurement of hydraulic cylinder's working pressure. In this process, the propelling rod plays the role of force saving level. The pressure of the propelling rod can be seen in Figure 2. According to the torque equilibrium equation, the following equation can be derived.

$$F_4 L_1 \sin(\alpha + \beta) = F_3 L_2 \sin\alpha \quad (2)$$

In this process, the thrust of the clamping hydraulic cylinder is F4. When it clamps, the reaction of tong jaw towards the propelling rod when tong jaw clamps pipe is F3=Nmax:

$$F_4 = \frac{L_2 \sin\alpha \cos\frac{\theta}{2}}{\mu D_{\min} L_1 \sin(\alpha + \beta)} T_{\max} \quad (3)$$

The transfer process of the torque is shown in figure 3. The power of making-up and breaking-out of connections is exerted by the making-up and breaking-out on the hydraulic cylinder driving to the tong jaw. By measuring the torque of any part between hydraulic cylinder and the tong jaw, the torque of making-up and breaking-out can be obtained. For example, by measuring hydraulic cylinder force, the torque of making-up and breaking-out can be gained indirectly. Below strain method and pressure method can be discussed respectively as two indirect testing schemes.

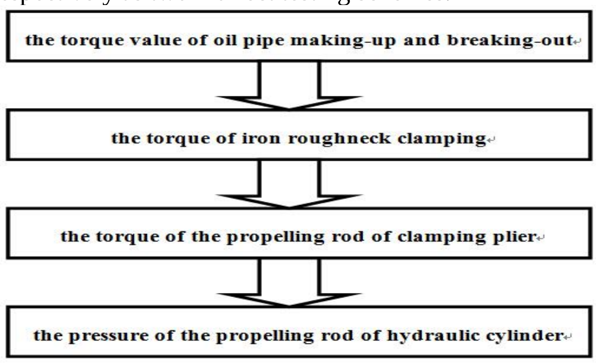

FIGURE 3 The transfer process of the torque

2.1 THE STRAIN METHOD TESTING SCHEME

The power of making-up and breaking-out is provided by the hydraulic cylinder, Which's piston rod force is a part in torque transfer process. The strain gauge should be stuck to the piston rod. By measuring strain of the piston rod, which is impacted by axial force, the axial force of piston rod can be converted. Therefore, the torque can be gained when making up and breaking out connections.

2.2 THE PRESSURE METHOD TESTING SCHEME

The hydraulic cylinder provides power to making-up and breaking-out. Thus, according to measuring the pressure of liquid in the hydraulic cylinder, and after that, by converting of pressure transfer process, the force of hydraulic cylinder piston rod can be gained. Thereupon, the torque of pipe can be obtained while making up and breaking out. The pressure of liquid in the hydraulic cylinder can be tested by the pressure sensor, which is fixed on hydraulic pipeline.

2.3 THE REQUIREMENTS OF DRILLING PLATFORM

Both of the two methods mentioned above can measure the torque of pipe when making up and breaking out connections. Because of the particularity of marine drilling platform, the design of testing systems should meet the following requirements when considering the working conditions of the iron roughneck.

A. High reliability. Because the iron roughneck is used at the wellhead, whose working condition is poor, and needs to work for a long time, testing systems need to last long time and have no faults. Generally, they need no repair and maintenance.

B. High anti jamming and stability. The iron roughneck must overcome the strong electromagnetic and mechanical vibration interference and be less influenced by temperature and humidity.

C. When testing, it does not disturb the making-up and breaking-out. It can test where it could be used in real time.

D. Small size and light weight, it is convenient for installation.

E. It must be cost-effective and high substitutability.

Analyzing the strain scheme, influenced by the pressure changes of the hydraulic system, the hydraulic cylinder piston rod achieves back-and-forth motion and the strain gauge stuck to the piston rod will follow. It is easy to cause the faults of the signal transmission line. The value of strain of piston rod is limited, too. Thus, it needs high sensitive strain gauge and high anti jamming, or it would have a bad effect on measuring accuracy.

Analyzing the pressure scheme, the position of sensor cannot change a lot, and it cannot rub and disturb other parts of iron roughneck, either. Putting sensor near to the hydraulic cylinder so that it is convenient for the distribution of data acquisition circuit. It also makes sure the position of the subsequent single chip circuit board do not change. In this way, the stability of signal monitoring and processing is increased.

3 Overall concept design

By using single chip microcomputer real time monitoring scheme, there are enormous economic and social benefits, such as it can perfect the quality and performance of products, improve labor productivity and laboring condition. In practical terms, whether the operation is convenient or not, workers labor intensity is high or lower and working efficiency is high or low depend on the level of single chip microcomputer real time monitoring scheme of the product. This scheme can not only realize the logical control of hydraulic solenoid valves, but also fulfill pressure regulation function of the system. It can achieve real time monitoring of running parameters and control points of the system. It has the functions of the LED display about the working conditions of system and giving alarm notice when the pressure is beyond limitation. Therefore, using single chip microcomputer real time monitoring scheme is significant in the improvement of iron roughneck automation. Figure 4 shows the overall design diagram.

The pressure monitor system designed consists of MCU control circuit, pressure detection circuit and peripheral circuit. Firstly, through pressure detection circuit, the pressure data at tested point can be gained. Then, analog signals can be conversed by sending to the A/D conversion circuit and the digital signal is inputted to signal chip microcomputer to be handled. At last, analyzing the data by comparison with signal chip microcomputer and real-time pressure data is displayed in the display circuit. When the pressure exceeds the specified value, single chip microcomputer issues instructions and sends an alert at the same time. If it is lower than the specified value, the hydraulic system will continue pressurizing.

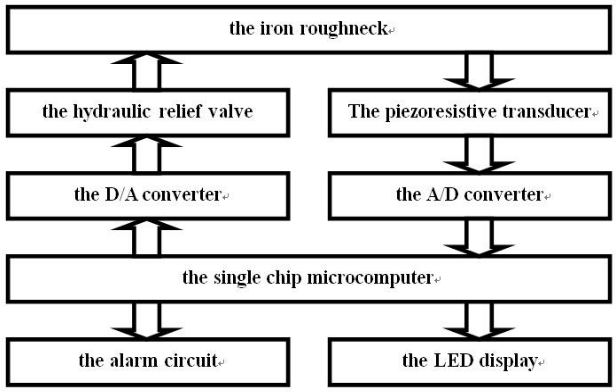

FIGURE 4 The overall design diagram

This scheme adopts piezoresistive pressure transducer, this type of sensor is widely applied in hydraulic systems. It is cheap and in good running condition when operating [8]. It can meet the requirements of the multi-aspect system design. A/D converter should use ADC0808 (ADC0809), for it is good in function, performance and operability and has very high performance-cost ratio [9].

4 The hardware circuit design

This circuit is drawn up using Proteus software. Following are details about the operation of each part of this circuit.

4.1 THE SENSOR CIRCUIT

Piezoresistive transducer is that resistance varies with force. This circuit simulates the real piezoresistive transducer by using a bridge. As shown in figure 5, RV3 indicates strain resistance when sensor is pressured. By adjusting the value of RV3, the stressed process of sensor is simulated. When RV3=50Ω, it means there is no pressure on sensor. At that time, the full-bridge circuit output is 0. Reducing RV3 refers to pressuring sensor. At that time, there will be a voltage output between RV3 and R3. This voltage can be amplified to 0~5V by the following two inverting amplifier.

According to the operating principle of piezoresistive transducer, pressure data acquisition circle can be built, as shown in figure 5.

$$U_0 = \left(\frac{R_1 + \Delta R}{R_1 + \Delta R + R_3} - \frac{R_4}{R_3 + R_4} \right) U_e \quad (4)$$

In this equation, U_o single-armed bridge output voltage. U_e single-armed bridge input voltage. ΔR the strain resistance when sensor is pressured. $\Delta R = RV_3$

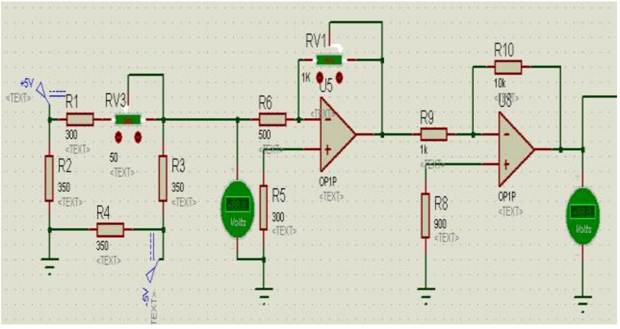

FIGURE 5 The sensor circuit

To simplify the bridge circuit, two adjacent bridge arms resistance is sure to be equal in design, that is, $R_2 = R_3 = R_4 = R_0 = 350\Omega$. Branch is used to simulate the changes of electric resistance when the piezoresistive transducer is under pressure, and $R_1 + \Delta R = 350\Omega$.

When $Rv_3 = \Delta R = 0$, the output voltage is maximum.

$$U_{0\max} = \left(\frac{R_1}{R_1 + R_3} - \frac{R_0}{2R_0}\right)U_e \approx 0.3846V \quad (5)$$

When $Rv_3 = \Delta R = 50\Omega$, the output voltage is minimum, $U_{0\min} = 0$.

That is, the variation range of U_0 is $0 \sim 0.3846v$, because the variation range of discernible input voltage of A/D is 0~5V. The magnification of middle amplifier circuit is required to be $A_{uf0} = \frac{5}{0.3846} \approx 13$, and the minimum magnification of amplifier circuit is 13, or it can not meet requirements of the design. Using two inverting amplifier in design to share the needed magnification.

The maximum magnification of the first level amplifier circuit: $A_{uf5} = \frac{Rv_1}{R_6} = -2$.

The magnification of the second level amplifier circuit: $A_{uf8} = \frac{Rv_{10}}{R_6} = -10$.

The total maximum magnification in design is $A'_{uf} = A_{uf5} \times A_{uf8} = 20 \geq A_{uf0} = 13$. This result satisfies the design requirements of the whole circuit. So this amplifier circuit is feasible.

4.2 THE MEMORY CIRCUIT

The memory circuit is shown in figure 6 The storage type is 62256. After receiving WRITE command from single chip microcomputer, it receives the data from U3 unit (Store data latch). After receiving READ command, D0~D7 ports can send out a data. This data has no influence on the three LED latches. Because, at that time, the three LED latches' enable signals (LEDA, LEDB, LEDC) are invalid. Thus, the real-time display of nixie tube will not be influenced.

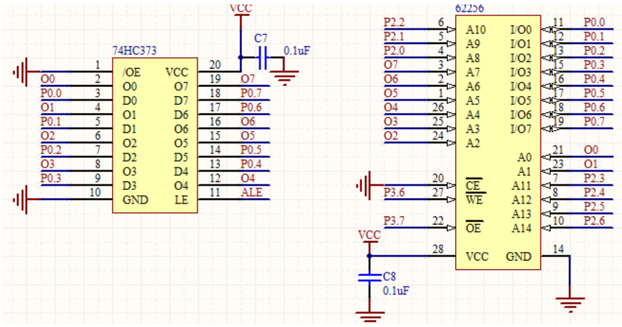

FIGURE 6 The memory circuit

4.3 THE ALARM CIRCUIT

The alarm circuit is shown in Figure 7. The design of interface circuit of single tone alarm is simple. Its sounding element uses piezoelectric buzzer. Compared with electric buzzer, its structure is much simpler; it uses less power; and it is more convenient when used in single chip microcomputer system. When designing alarm circuit, man-machine principle is toke into consideration. The red LCD light is used and when reaching the alarm pressure, the single chip microcomputer controls LCD flash through inner interrupt control to make it striking.

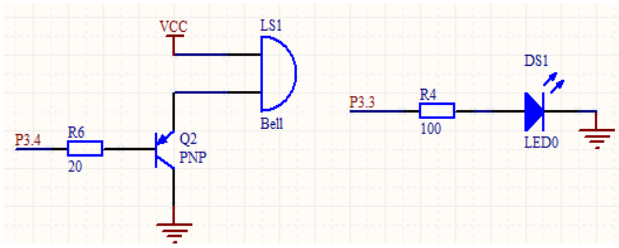

FIGURE 7 The alarm circuit

4.4 THE FEEDBACK CONTROL CIRCUIT

The feedback control circuit is shown in figure 8. Its design ideas are as follows. Strong power is controlled by weak power. When pressure exceeds alarm pressure, the single chip microcomputer sends out low level through P3.5 port to turn on the electromagnetic relay. Hydraulic relief valve opens and sends excess pressure back to hydraulic oil tank through overflow loop. At the same time the indicating lamp of hydraulic relief valve (D2) lights after electrifying, this indicates the hydraulic relief valve is decompressing.

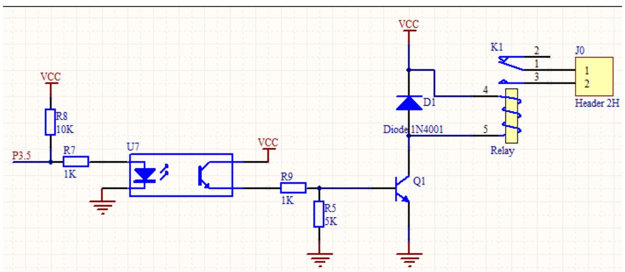

FIGURE 8 The feedback control circuit

5 The circuit simulation

Simulation can be done through the combination of hardware circuit, which is built by Proteus software and corresponding procedure. Setting 25MPa as alarm pressure, that is to say, when the pressure of hydraulic cylinder reaches 25MPa, the system alarms and relieves and maintains pressure through feedback circuit acting on hydraulic circuit. Then, test system can control the iron roughneck.

As shown in Figure 9, when the pressure is lower than 25MPa, the circuit does not alarm and the feedback circuit does not work. As shown in figure 10, the LED alarm lamp "ALARM" in the alarm circuit flashes and buzzer LS1 alarms when the pressure is higher than 25MPa. Electromagnetic switch RL1 in the feedback circuit opens. The switch acts on hydraulic circuit and plays the role of real-time monitoring.

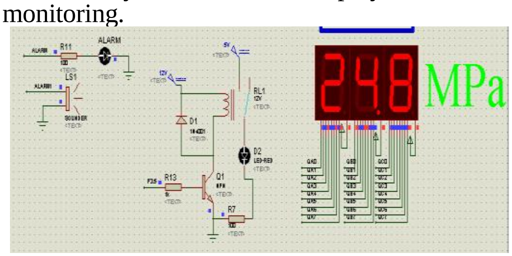

FIGURE 9 The first simulation circle

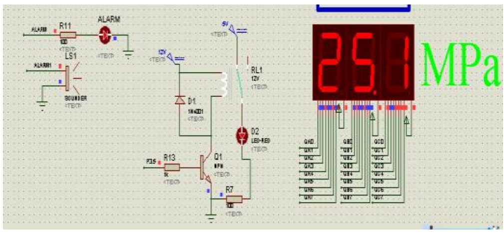

FIGURE 10 The second simulation circle

The calibration experiment is carried out before system operating. The calibration experiment consists two parts, which are torque demarcation and pressure demarcation. The course of torque demarcation experiment is that by giving standard torque value, the corresponding working pressure of hydraulic cylinder is measured, and by using curve fitting method, the law of hydraulic cylinder pressure varying with the torque is calibrated, that is, ascertaining functions $f(\alpha,\beta,D_{\min},L)$. The course of pressure demarcation experiment is that the pressure value on the display is shown by giving standard pressure value to the sensor, and by adjusting the magnification of amplifier circuit, there is a one-to-one correspondence between the pressure shown and the standard pressure.

6 Conclusions

This article emphasizes the iron roughneck working torque real time monitoring system of semi-submersible platform. Based on the available iron roughneck data both at home and abroad together with requirements of domestic iron roughneck controlling torque. The test system scheme of converting iron roughneck clamping pliers torque into hydraulic system pressure is determined. The hardware circuit including sensor, A/D converter, single chip microcomputer, overvoltage alarm, LED display and feedback control is designed. All the components in this design are universal. The cost of installation and maintenance is low. In this scheme, the design of iron roughneck working torque real time monitoring scheme can be totally achieved by LED display and real-time data storage. Finally, using Proteus software, the circuit diagram of iron roughneck working torque real time monitoring scheme is drawn. Debugging and simulation of the alarm function in the test system are also very successful. All these designs provide a sound theoretical basis for field application.

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