Design of Underwater Grinding Device for Nuclear Power Plant

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Abstract. In order to solve the problems of difficulty in cleaning the inner wall of the hammer-shaped component in the RIC system of the nuclear power plant and the low surface accuracy after cleaning, a profiling cleaning system was designed. First, the working principle of profiling cleaning is introduced to ensure that the surface accuracy after cleaning meets the installation requirements. Secondly, in order to ensure the normal operation of the profiling airbag, a mechanical model between the air supply volume of the air pump and the force on the conical inner wall is derived. Finally, in order to accurately control the output torque of the motor, the PID method is used to control the output torque of the motor. The system can increase the success rate of cleaning the inner wall of the hammer-shaped component in the RIC system and improve the efficiency of nuclear power plants.

Keywords: Copying cleaning system, Nuclear power plant, Air bag stress model, PID control.

1. Introduction

After the failure of thermocouple in nuclear power plant, it is necessary to clean the foreign matter in the inner wall of the hammer assembly in RIC system, including the treatment of burrs and the recovery of impurities, so that the hole size and precision of the hammer assembly can meet the requirements of assembly. Moreover, the treatment of burrs and the recovery of impurities are related to the effective implementation of this project. At present, the main cleaning methods for the inner wall of the pipeline are rigid contact treatment, sand blasting treatment and dry ice cleaning. Rigid contact treatment mainly refers to electric drill treatment and grinding wheel treatment in daily life and chemical industry application. Its advantages are significant effect, suitable for many scenes, high cleaning efficiency. The disadvantage is also obvious, the contact between the electric drill and the oxide layer is rigid to rigid contact, in the cleaning process is easy to appear stuck, affecting the cleaning efficiency; At the same time, its copying ability is poor, it is difficult to achieve high-precision cleaning, and the impurities after treatment are not easy to recycle, the workload will increase; In addition, it is not suitable for flammable and explosive, underwater and other special scenarios[1]. Sandblasting treatment can put the workpiece surface rust, oil and so on all impurities dirt completely removed, at the same time, the workpiece surface sandblasting will form the surface of the hair surface, is conducive to coating and bonding. The use of sand blasting treatment for machining parts burr cleaning, that is, through the treatment of fine particles to clean the surface of high precision cleaning, while having a high profile ability. However, as far as this project is concerned, the dirt after sandblasting treatment is too much, which is easy to react with boric acid solution, causing pollution to the boric acid pool, and the impurities are difficult to recover [2][3]. Dry ice cleaning mainly uses high-density dry ice particles to impact the surface of the object to be cleaned, but this cleaning method cannot be used in a small clean space, so the above three impurity treatment methods are not applicable to this project[4][5]. Based on the comparison of the above two cleaning methods for impurities in the inner wall of hammer shaped components, it is not difficult to see that the traditional cleaning methods can't meet the cleaning requirements of this project, the portable device is too rigid, and the device with high efficiency is easy to pollute the boric acid pool. Therefore, in order to reasonably and effectively solve the hammer assembly wall of foreign matter and oxide layer cleaning, this project plans to design a new scheme. In this scheme, a set of airbag copying cleaning device and grinding bit are designed to take into account the rigidity of the inner wall of hammer assembly and the effective recovery of impurities after cleaning treatment.

2. Mechanical Mechanism Design of Copying Cleaning System

The main function of the copying cleaning structure is to clean the inner wall of the conical component. The inner wall view and partial section view of the conical

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component are shown in Figure. 1. It can be seen from Figure. 1. In order to make the accuracy of the inner wall holes meet the installation requirements after cleaning, the overall schematic diagram of the copying cleaning mechanism designed in this paper is shown in Figure. 2:

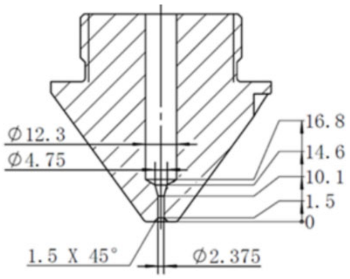

Fig. 1. Taper component wall

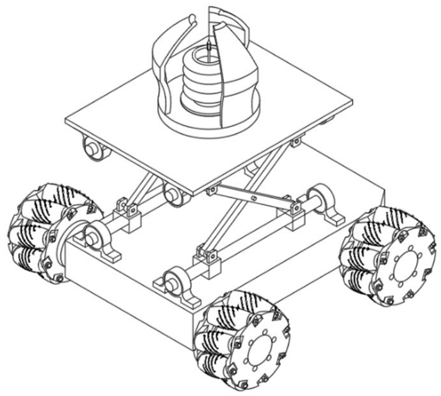

Fig. 2. Schematic diagram of copying cleaning system

Figure. 1 shows that the minimum inner wall diameter of the conical assembly is only 2.375mm, so when cleaning the inner wall, the centering mechanism is needed to ensure that the cleaning tentacle smoothly enters the inner wall hole under the action of the lifting platform. Centering mechanism adopts floating automatic centering fixture, with its floating characteristics, the cleaning tentacle automatically and accurately centering.

Section view of copying grinding mechanism is shown in Figure.3, which is mainly composed of grinding net 2, airbag 3, sealing gasket 4, bellows 5, drainage hole 6, chassis 7 rotating disk 8, charging chamber 9, charging pipeline 10, sealing ring 11, motor 12, motor bracket 13 and connecting ventilation needle 14. When to clean inner hole, the first 14, abrasive mesh 2, airbag will connected pores 3 processing into the hole, after filling line to infuse air plenum chamber 9 and 10 again by the top allied interface even vent needle 14, 141 and 142 from gas plenum chamber bottom allied interface to airbags within 3 bag 3 drives the lapping network expansion, 2 At this time, the motor 12 is started, the output shaft of the motor is connected with the air needle 14 of the United States, and even the ventilation needle 14 is also connected with the rotary disk 8. The air bag 3 and the grinding net 2 are fixed on the rotary disk 8, rotating with the rotary disk 8, so as to complete the grinding of the processed surface.

In the process of grinding process, to ensure that debris does not escape into the water, to avoid such as nuclear power plant spent fuel pools of water quality requirements higher application site contamination, the invention designs the liquid extract this step, the water inlet of the pump to connect to port 6 of the present invention, as grinding treatment processing hole cleaning, Remove clean debris at any time along with the liquid in bellows 5.

During processing, sealing gaskets are pressed against the surface of the workpiece to improve pumping efficiency and avoid debris scattering in the water. At the same time, because of the elasticity of the bellows, the sealing gasket can always fit the surface to be machined.

After the processing is completed, the gas in the air bag is discharged through the ventilation needle 14, the inflation chamber 9, and the inflation pipeline 10. At this time, the air bag is reduced, and the processing parts can be removed to process the next hole. Airbag inflation and contraction are shown in Figure. 4.

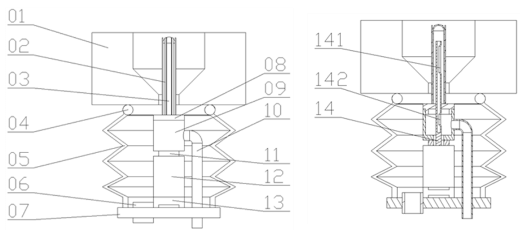

Fig. 3. Section view of grinding mechanism

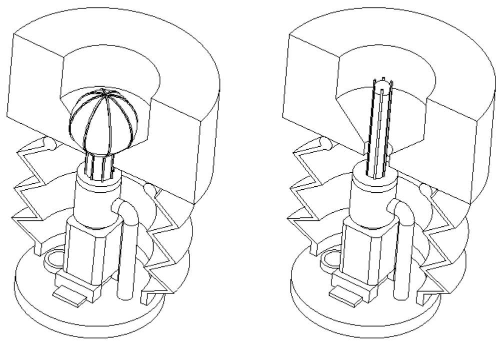

Fig. 4. Schematic diagram of airbag inflation/contraction

3. Design Criteria for Each Subequipment

In order to ensure that the catheter end plug cleaning device can successfully complete the cleaning work without being damaged due to excessive feed or unable to stick to the inner wall of the catheter end plug due to too small feed, it is necessary to model the catheter end plug cleaning device. The force of the catheter end plug is shown in Figure. 5:

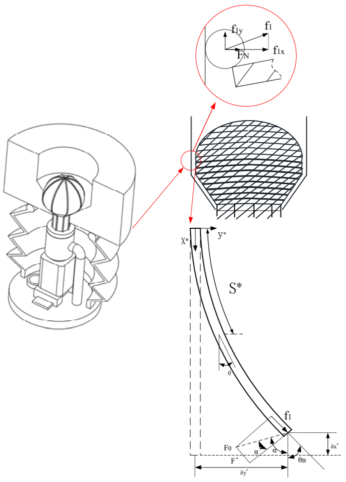

Fig. 5. Catheter end plug cleaning device is stressed

When establishing the mechanical model of the pipe end plug cleaning device, it can be assumed that the dirt is a rigid ball and the grinding net is a flexible beam. During the cleaning process, the grinding net is in contact with the dirt. At this time, the grinding net exerts a positive pressure on the dirt, thus generating a force to cut the dirt. According to the bending degree of lapping net, cleaning state can be divided into three kinds: large deflection, small deflection and critical state. When the bending degree of lapping mesh is small, the force analysis of flexible lapping mesh can be assumed as the cantilever beam model. When the deformation of the flexible lapping net is large, the flexible beam model with large deflection is used for analysis [6].

Differential equation of deflection line of beam structure:

$$EI\frac{d\theta}{ds}=M \tag{1}$$

In the above formula, E is the elastic modulus; I is the moment of inertia; $d\theta/ds$ is the curvature of the beam; $M=-F'x=-Fx$,where, $F'x$ is the positive pressure of the dirt on the grinding net, and x is the axial distance of the coordinate system.

Under small deflection, the distance is the same as the axial distance, and the deflection Angle is the same as the slope, so $d\theta/ds$ can be approximated by d^2y/dx^2 . Therefore,

$$EI\frac{d^2y}{dx^2}=-F'x \tag{2}$$

Then the terminal position shape variable is:

$$\begin{cases} y=\dfrac{F'L^3}{3EI} \\ \theta=\dfrac{F'L^2}{2EI} \end{cases} \tag{3}$$

In the above formula, L is the length of grinding mesh; y is the displacement of grinding mesh.

When the deformation of the flexible lapping net is large, it obeys the flexible beam model, at this stage, the cantilever beam model cannot be used. The deflection differential equation of the beam needs to be solved:

$$\begin{cases} \dfrac{d\theta}{ds^*}=\dfrac{E}{EI}[\cos\alpha(\delta_y^*-y^*)+ \\ \qquad \sin\alpha(L-\delta_x^*-x^*)] \\ \dfrac{dx^*}{ds^*}=\cos\theta,\dfrac{dy^*}{ds^*}\sin\theta \end{cases} \tag{4}$$

Dimensionless:

$$\begin{cases} \dfrac{d\theta}{ds}=\beta f \\ [\cos\alpha(\delta_y-y)+\sin\alpha(1-\delta_x-x)] \\ \dfrac{dx}{ds}=\cos\theta,\dfrac{dy}{ds}=\sin\theta \end{cases} \tag{5}$$

After the positive pressure generated by the grinding net on dirt is obtained, the amount of air pump output to the air bag can be calculated by $p=F/s$.

4. General Safety Criteria

The electrical part of the conduit end plug cleaning device consists of four parts: the motor control system that drives the conduit end plug cleaning device to clean, the motor control system that drives the lifting of the conduit end plug cleaning device, the control system that drives the negative pressure recovery, and the motor control system that drives the lifting platform. Figure. 6 and Figure. 7 shows the electrical control system. In case of accidents, multiple protective measures should be taken to recover the foreign bodies generated and foreign bodies are strictly prohibited to fall into the boric acid pool[10].

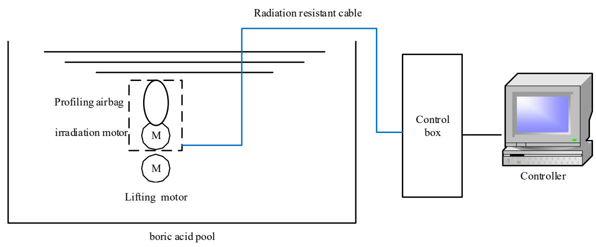

Fig. 6. Electrical diagram of pipe end plug cleaning device

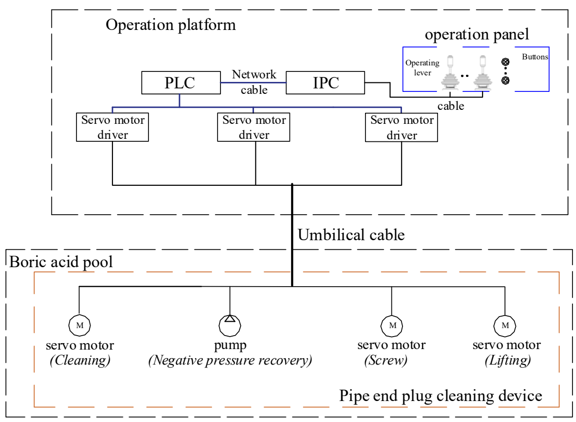

Fig. 7. Electrical schematic diagram of pipe end plug cleaning device

In order to realize the cleaning of the catheter end plug, the air bag profile cleaning structure is adopted. When the cleaning structure is in place, the cleaning face opens, and the catheter end plug cleaning device obtains the torsion force provided by the strong irradiation resistant servo motor through the transmission parts, so as to realize the cleaning of the catheter end plug inside. At the same time, the negative pressure recovery unit is activated to drain clean dirt from the inside of the catheter end plug. Considering the operating space narrow and strong radiation environment, use will be easily affected by the irradiation motor drive is installed in the control box outside the pool boric acid solution[7], strong resistance to radiation servo motor under the pool boric acid solution to guarantee the feasibility, among them, strong resistance to radiation between servo motor with the corresponding driver by strong resistance to irradiation on multi-core cable connection

In order to realize the free rise and fall of the pipe end plug cleaning device, a strong radiation resistant servo motor drives the cleaning device, so that it can obtain longitudinal movement power to achieve the lifting function of the pipe end plug.

In order to ensure that the catheter end plug cleaning device can work normally and safely, the logic shown in Figure. 8 is used to control it. The specific process is as follows:

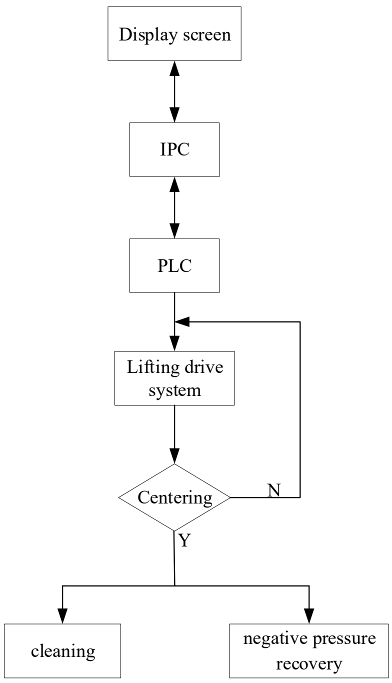

Fig. 8. Catheter end plug cleaning device control logic

According to the impurity information feedback from the display screen, the operator gives instructions for cleaning the pipe end plug to the industrial computer through the operating rod and button.

Industrial computer analysis of the control panel issued instructions to PLC control instructions, drive cutting fork mechanism lifting and complete alignment.

After the alignment is completed, the completed signal is transmitted to PLC. PLC drives the catheter end plug cleaning device to lift. After lifting in place, the cleaning face opens to clean the dirt. At the same time, the negative pressure recovery device drains the dirt from the inside of the catheter end plug. In order to achieve the best cleaning effect, fuzzy PID algorithm is adopted to control the output torque of the highly irradiation-resistant servo motor [8].

In order to ensure the smooth cleaning process of the inner wall of the pipe end plug, it is necessary to control the output torque of the motor. In order to ensure the robustness of the control process, the fuzzy PID algorithm is used to control the output torque of the motor reasonably.

Due to the narrow working environment of the pipe end plug cleaning device and the strong corrosion of the boric acid solution pool, the torque of the irradiation-resistant servo motor can not be obtained directly by using the torque sensor. However, according to the relationship between the motor current and torque, the motor torque can be measured indirectly through the motor current. Among them, the motor current and torque have a positive change relationship. During the operation of the motor, a large current means a large torque. By controlling the size of the current, the size of the torque can be controlled, indicating that the current ring is also a torque ring.

As shown in FIG. 10, the fuzzy PID control algorithm is used to control the torque of the motor and realize the cleaning of the pipe end plug. The fuzzy controller adopts the structure of two inputs and three outputs, in which two inputs are the deviation and the change rate between the measured value and the set value of the motor torque. The output is the modified values of PID parameters K_p、K_I、K_D. The input quantity enters into the fuzzizer first, and is transformed into the corresponding theory domain after certain fuzzification rules. Then the control quantity is deduced according to the database and the corresponding inference rules. Finally, the control quantity is defuzzified, so as to output the corresponding three parameters. The method is the same as "mobile platform equipment". The measured torque can be converted from the current to the measured torque based on the current-mechanical relationship conversion model [9][10].

$$M = kI \tag{6}$$

In the above formula, M is the motor torque; I is the motor current; K is a constant.

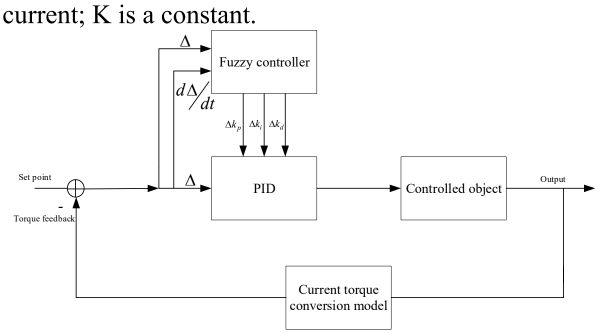

Fig. 9. Flow chart of torque control based on fuzzy PID

5. Conclusion

The inner wall aperture of the hammer component in RIC system is small and difficult to clean. In this study, a set of copying cleaning mechanism is designed for the cleaning of the conical inner wall. The copying cleaning mechanism can fit the grinding net and the conical inner wall well, and ensure that the inner wall can meet the requirements of installation accuracy after cleaning. At the same time, a set of negative pressure recovery system is designed to ensure that the debris can be extracted from the boric acid solution in time in order to cause pollution by falling into the boric acid solution.

In order to ensure that the air bag can clean normally and the conical wall is not damaged due to excessive force, the relationship between the force on the conical wall and the air pump output to the air bag is established in this paper. In order to ensure that the output torque of the motor can normally complete the recovery of debris and the cleaning of the inner wall, this paper introduces the process of using PID to control the negative pressure recovery system and the output torque of the motor of copying cleaning structure.

The application of profile-copying cleaning in the process of inner wall cleaning of hammer components in RIC system of nuclear power has successfully solved the problem that the conical inner wall is difficult to clean and the debris cannot be recovered after cleaning, greatly improving the success rate of inner wall cleaning, enhancing the competitiveness of enterprises and maximizing the production benefit.

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