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Research on Intelligent closestool cleaner

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ABSTRACT. *With the development of sensor technology, GPRS and other key technologies in many fields, cleaning robots have gradually been able to realize the automatic cleaning of the family and public health. Intelligent cleaning robots free people from heavy manual labor, greatly reduce labor costs, and improve work efficiency. At present, the intelligent cleaning robot on the market is mainly used in the household cleaning. The main functions completed by the cleaning robot: can automatically enter the room, can automatically clean and vacuum, or can clean the designated location under remote and manual control.Toilet hygiene is often the key to maintaining cleanliness. However, due to the humidity of the toilet environment and the complexity of the terrain which are relatively bad for robots, cleaning robots are rarely seen in toilet hygiene. In toilet hygiene, closestool cleaning is particularly important. This design will aim at the cleaning of the closestool. It uses planetary gears, guide rails and other mechanisms and at the same time combined by the MCU and its control of the color sensor, pressure sensor composed of the control system to realize automatic closestool cleaning.*

KEYWORDS: *closestool cleaning robot, planet gear, SCM, sensor*

1. Research background and significance

Closestool serves as the product of modern science and technology, has good comfort, good water-saving performance, and strong flushing ability. With its obvious advantages, the closestool has become the development trend of public toilet equipment, and has been widely used in hotels, trains, and aircraft. However, the problem that closestool sanitation is not well guaranteed is still restricting the overall popularization of toilet in the public domain. In a 1991 survey of 528 women in the UK, 85% of them squatted on the closestool while urinating, 12% used seat covers and only 2% sat directly on the closestool. It's fair to say that intestinal infectious diseases are a common problem for all toilet seats.[1]

The intelligent cleaning robots studied in this project are mainly used in toilet areas in schools, airports, stations and other public places to help cleaning staff save time and energy, better clean the toilets, and allow them to be put into other cleaning

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tasks. A number of cleanups are carried out at the same time, effectively improving work efficiency, avoiding a dirty and messy working environment, and bringing cleaners a better working experience. As technology continues to improve, the robot will also be used to clean toilets in home bathrooms.

2. Scheme design

2.1 Design ideas

(1) Considering the complexity of the terrain of the toilet, the closestool cleaning device should be designed to be fixed, which needs to be artificially fixed in the center of the toilet and is easy to carry.

(2) The shape of the curved surface of the toilet is very complicated for the machine work. It is necessary to find the suitable mechanical structure correctly, and use related sensors to achieve efficient cleaning work of the cleaning mechanism. At the same time, the shape design of the cleaning brush is also extremely important.

(3) Considering that the toilet environment is relatively humid, it should be ensured that the materials used by the designed institutions have certain anti-rust performance, and the electrical components should also be insulated.

2.2 Mechanism design

2.2.1 Mechanism design of cleaning brush head

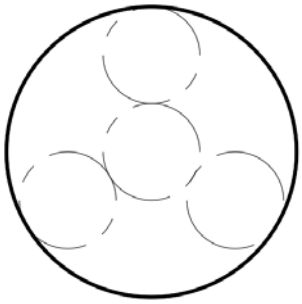

Figure 1 schematic diagram of cleaning brush head

As shown in Fig.1, the cleaning brush uses a planetary gear structure. Planetary gear transmission has the characteristics of small mass, compact structure, power splitting and strong carrying capacity, and is an important transmission form for reducing the volume and weight of the transmission system and achieving uniform

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load transmission. Planetary gear transmission belongs to modern advanced mechanical transmission. It changes the fixed axis to the dynamic axis transmission. It also can be used for deceleration, speed increase, variable speed transmission, and the synthesis and decomposition of motion. Due to the effective use of the power split and the coaxiality of the input and output during the transmission process and the reasonable use of internal meshing, the planetary gear transmission has very obvious advantages compared with the ordinary fixed-shaft gear transmission.[2]

The brush is mounted on each gear, and the planet wheel can be rotated along the fixed internal gear. The center gear is the driving wheel, and the middle opening is used to release the cleaning fluid. The three gears meshed with it are the driven wheels which have middle opening to release the clear water and revolve around the sun gear while rotating, thus achieving efficient cleaning.

The gear used in the brush head mechanism is made of 20CrMnTi steel material, which is processed and obtained by a gear shaping machine, and is subjected to tempering and heat treatment. After quenching, the surface hardness can reach HRC58 ~ 62, and the core hardness HRC30 ~ 45, so as to improve its wear resistance and fatigue strength. Finally, surface grinding is carried out to achieve dual goals of high quality and low working noise. During work, it is necessary to ensure that suitable lubricating oil is added. At the same time, due to its humid working environment, it is necessary to add rust inhibitors, and a single type of rust inhibitor is difficult to achieve the desired rust prevention effect. Choose additives with good oil solubility, easy to add and harmless to human body.

The gear transmission mechanism should also ensure that it is not too large, so as not to reduce the cleaning efficiency of the toilet corner. The design parameters are shown in Table 1 below

Table 1 brush head gear parameters

	Number of teeth	The modulus	Pressure Angle	Facewidth
Driving gear	26	1	20 °	8 mm
Driven gear	26	1	20 °	8 mm
Rotation output transmission ratio	1.5			
Revolution output transmission ratio	4			

2.2.2 Brush head screw expansion mechanism

The cleaning brush head is connected to the spiral telescopic mechanism shown in Fig.2 above, and the stepping motor is used to control the forward and reverse rotation of the side screw to make the slider reciprocate, thereby realizing the telescoping function of the cleaning brush at work. The screw is made of 304 stainless steel into a T-shaped screw, with the lead of 8mm, the pitch of 2mm, the diameter of 8mm, and the length of 150mm. The mechanism has the characteristics

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of strong straightness, stability and high precision, which meets the precise control of the contact of the cleaning brush head and the surface of the toilet when in use, and improves the cleaning ability of stubborn stains.

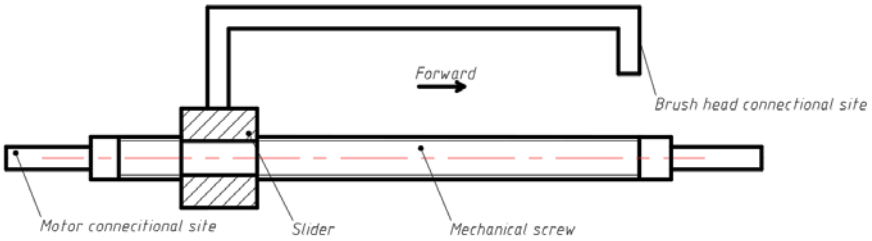

Figure 2 schematic diagram of screw telescopic mechanism

2.2.3 Spatial motion mechanism of brush head

The spatial movement mechanism of brush head is composed of the following two parts:

(1) Planetary rod output rotation mechanism

The mechanism uses a structure similar to the brush head, but only uses the planet rod as the output, which can effectively reduce the size of the mechanism and obtain a larger transmission ratio in a limited space, thereby driving the brush head to rotate. The gear design parameters are as follows

Table 2 gear parameters of rotating mechanism

	Number of teeth	The modulus	Pressure Angle	Facewidth
Driving gear	24	1	20 °	8 mm
Driven gear	36	1	20 °	10 mm
Output transmission ratio	5			

(2) Incomplete gear swinging mechanism

Since the brush head only needs to swing up and down at a certain angle to achieve complete cleaning of the toilet, and does not require a complete 360 ° swing, the use of incomplete gears can greatly reduce the size of the mechanism, reduce its weight, and save on manufacturing materials. At the same time, its output transmission ratio is 4, and the swing point is as close as possible to the center of the entire brush head mechanism, thereby reducing the output torque of the motor.

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2.2.4 Fixed mechanism of cleaning instrument

The left side of the mechanism is a left-hand thread drive and the right is a right-hand thread drive. When the screw rotates, the clamping working surfaces on both sides can be moved in a mirror image based on the center of symmetry, thereby clamping on the outer wall of the toilet, realizing the overall fixing of the cleaning instrument, and preventing the occurrence of jitters during work. And it can ensure that the cleaning instrument is located in the center of the toilet, reducing the work complexity and work schedule.

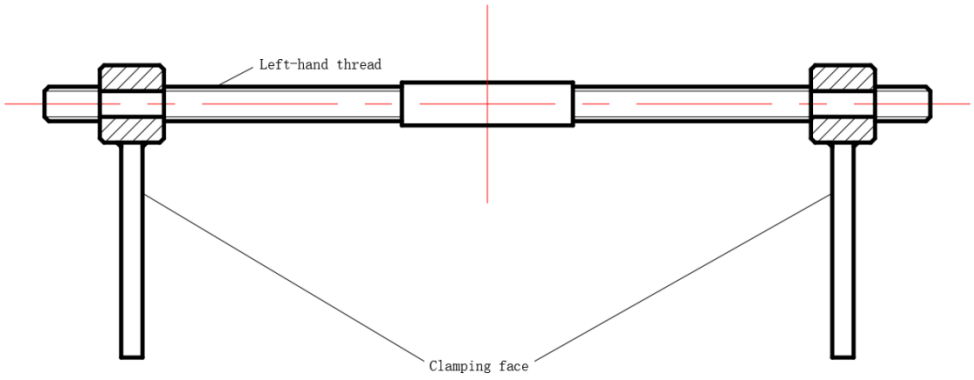

Figure 3 schematic diagram of fixed mechanism

2.3 Motor selection

2.3.1 Brush head motor

Brush head motor uses WS-3650 brushless motor. The brushless DC motor is composed of a motor body and a driver, and is a typical mechatronics product. Since the brushless DC motor is operated in a self-controlled manner, it will not add a start winding to the rotor like a synchronous motor that starts under heavy load under variable frequency speed regulation, and will not cause oscillation and step out when the load changes suddenly. The basic performance parameters are as follows

Table 3 performance parameters of brush head motor

Ws-3650 brushless motor parameters	
Working voltage	DC 12V/24V
Rated speed	6000 r/min
Rated torque	$7.5 \times 10^{-4}\ N.m$
Rated current	2.5 A
No-load current	0.25 A

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2.3.2 Telescopic mechanism motor

42BYGH47-401A stepper motor is used for the motor at the telescopic mechanism. Stepper motor is one of the key components of electromechanical integration. It is a high-precision actuator which can convert the pulse signal into angular displacement, that is, when giving a pulse, the stepper motor will rotate an angle, so the control accuracy is high. Thus widely used in various automation control systems and robots.[3] The main performance parameters are as follows

Table 4 Performance parameters of stepping motor

42BYGH47-401A stepping motor parameters	
Step Angle	1.8°
Holding torque	0.55 N. m
Working voltage	24 V
Rated current	1.5 A
The rotor inertia	68 g. cm^2

2.3.3 Space motion mechanism motor

The two parts of space motion mechanism adopt MG995 servo motor. The servo motor can control the speed and position accuracy very accurately, and can convert the voltage signal into torque and speed to drive the control object. The rotor speed of the servo motor is controlled by the input signal and can react quickly. In the automatic control system, it is used as an actuator and has the characteristics of small electromechanical time constant, high linearity, starting voltage, etc. It can convert the received electrical signal into angular displacement or angular velocity output on the motor shaft. Therefore, at work, the angle output function can be used to rotate the cleaning mechanism by a certain angle to achieve full cleaning. The main performance parameters of the motor are as follows

Table 5 Servo motor performance parameters

MG995 servo motor parameters	
Working voltage	4.8～6V
Working temperature	0℃～55℃
Dead band	2M1520M/330HZ(4.8V)
Operating speed	0.16s/60°
Stall torque	14.25kg. cm(197.93OZ/IN）

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2.4 Control module

2.4.1 Main control board

Master plate using Arduino Mega2560 control board, which is based on the ATmega2560 micro control board, with 54 digital I / O ports (of which 14 can be used as PWM output ports), 16 analog input ports, 4 UARTs (hardware serial port), a 16 MHz crystal oscillator, also includes a USB interface, power jack, ICSP interface, and reset button: almost includes everything necessary to support the operation of the micro-controller board. Its main working parameters are shown in the following table

Table 6 main control board parameters

Arduino Mega2560 control board parameters	
Working voltage	5 V
The clock frequency	16 MHz
EEPROM	4 KB
SRAM	8 KB
The Flash memory	256 KB
I/O port DC current	40 mA

2.4.2 Sensors

(1) Piezoresistive pressure sensor: The piezoresistive pressure sensor is mainly based on the piezoresistive effect, describing the resistance change produced by the material under mechanical stress, connected to the Wheatstone bridge, and the corresponding pressure value is obtained through signal processing. Installed on the cleaning mechanism, used to feedback and adjust the expansion and contraction state of the cleaning mechanism.

(2) Color sensor: The color sensor detects the color by comparing the color of the object with the reference color that has been taught previously. When the two colors coincide within a certain error range, the detection result is output. Installed on the cleaning mechanism, through color inspection to determine whether the cleanliness meets the standard.

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2.5 Work control process

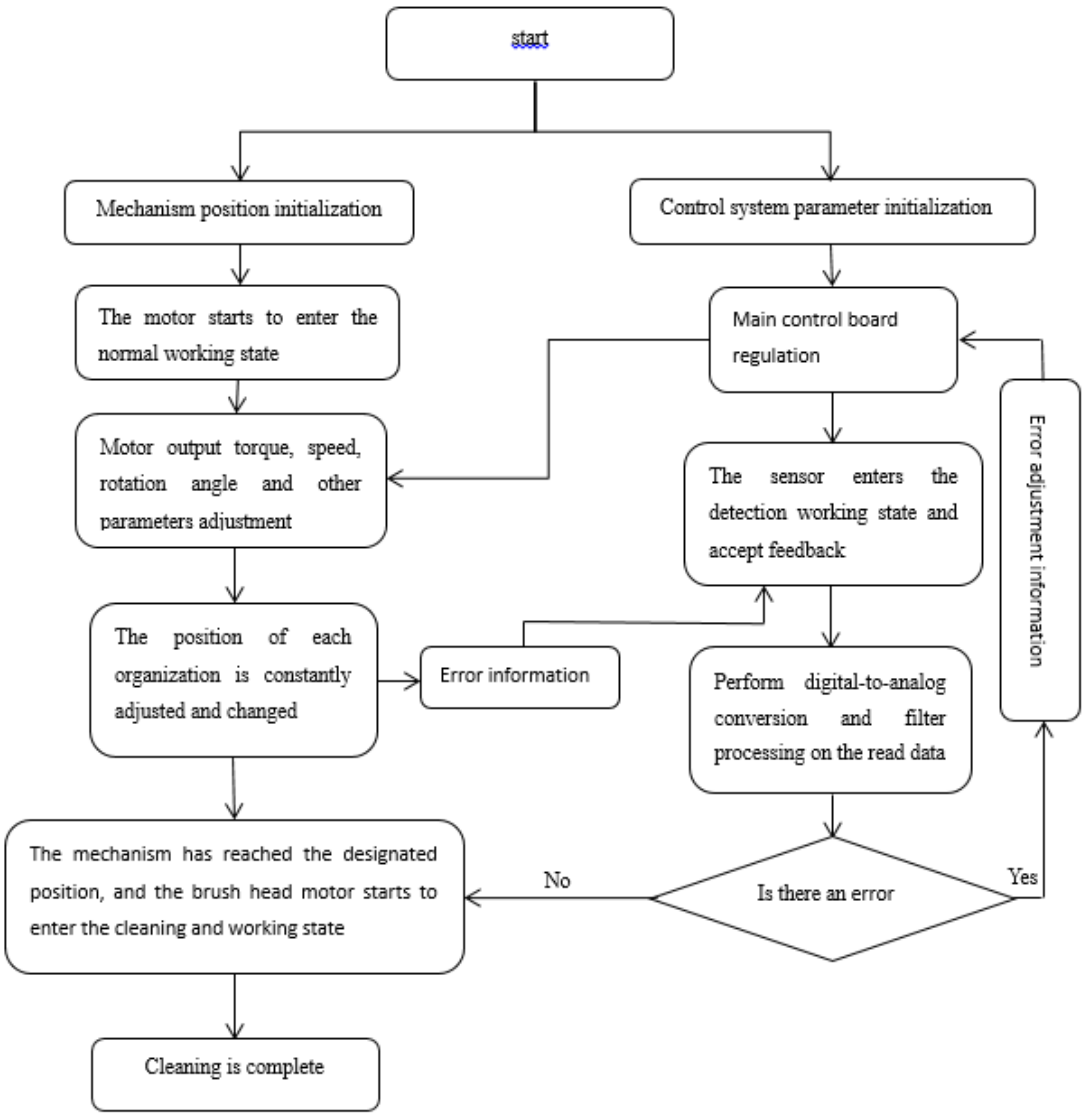

Figure 4 Flow control diagram

3. Actual model design

Using CATIA 3D modeling software, the cleaning instrument was modeled and

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analyzed 1: 1. Check whether there are any problems such as mechanism interference in its actual assembly and working process, and check whether its work schedule meets the cleaning needs, then optimize and adjust it through analysis. The final 3D model is shown in figure 5 below

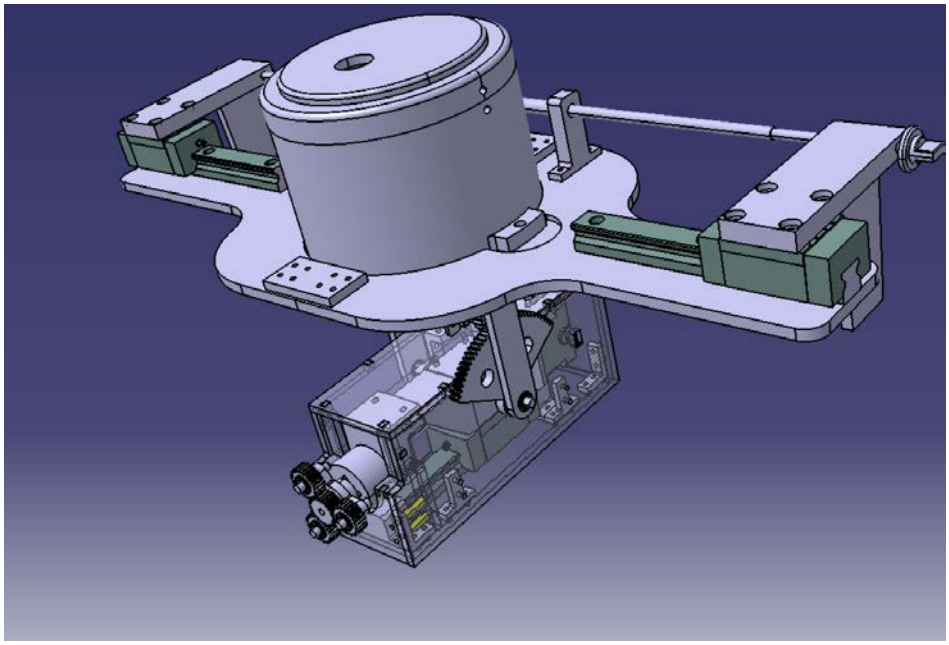

Figure 5 3D model diagram

4. Design innovation

(1) Planetary gear cleaning brush: Revolving at the same time of rotation, which greatly improves the cleaning intensity and cleaning efficiency, and the proper combination of the drainage system can achieve the effect of water saving and environmental protection.

(2) Stepping motor + spiral telescopic mechanism + pressure sensor: The rotary motion is transformed into a linear motion with high motion accuracy, which can accurately clean every space area of the toilet, and can effectively avoid the impact of mechanical parts and increase the service life of the instrument.

(3) Planetary rotation mechanism: The mechanism occupies small space, has a large speed reduction ratio, works smoothly, and has no noise.

(4) Automatic control of the mechanism is realized by using the single-chip microcomputer system and sensors, and the execution information can be fed back in time.

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