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# Development of special electric tools for bolt fastening in narrow space

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## Abstract

**In this paper, the advantages and disadvantages of existing bolt tightening schemes and bolt tightening tools at home and abroad are compared. Aiming at the problems of small torque range and low precision existing in bolt tightening tools in China, a torque bolt tightening scheme based on the speed difference of series excited motors is proposed, and the overall scheme of the control system is designed, and the mathematical model of the control system of special electric tools for bolt fastening is established. The working direction of wrench is changed by using bevel gear right-angle meshing, which can be widely used in narrow space and effectively solve the problem of bolt fastening in narrow space during tower assembly.**

## Keywords

**Narrow space; Bolt fastening; Electric tool.**

## 1. Introduction

Fastening screws of electric tools are not only related to product performance, but also important parts related to safety of electric tools. Too loose, too tight and broken fastening screws are one of the important reasons leading to the failure of electric tools. In addition to reducing the structural size, it is necessary to completely change the traditional vertical structure design of the electric wrench to solve the problem of bolt fastening in the narrow space of the installation and construction site.

In industrial production, there are four commonly used bolt pretightening force control schemes, which are torque method, torque/rotation angle method, yield point method and elongation method. Among them, the torque control method has become mature, and the bolt tightening wrench with constant torque has been applied in power system, railway, machinery and other industries [1]. Compared with foreign countries, China's special electric tools for bolt fastening are still relatively backward at present, among which large-sized bolts with fixed torque are mainly hydraulic and pneumatic wrenches, which are heavy in equipment, limited in torque range and poor in precision, and are difficult to meet the use needs of power systems and other industries. Every year, they spend a lot of foreign exchange to buy foreign products. In this paper, the special electric tool for bolt fastening is taken as the research object, and the special electric tool system for bolt fastening in narrow space is developed. On the basis of integrating theory with practice, the trajectory planning control and optimization method of the special electric tool for bolt fastening are obtained, which provides a solution for the engineering application of the integration of identification equipment, tightening system and industrial robot.

## 2. Tool design description

The designed special electric tool for bolt fastening is used to assemble and disassemble bolts and nuts connected to angle steel of iron tower. It includes insulating crank arm, angle steel clamping device and connector. The insulating crank arm is inverted U-shaped. The bottom of

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the right side wall is provided with a screw head fixing seat for fitting the bolt head, and the bottom of the left side wall is provided with an installation hole coaxial with the screw head fixing seat. The angle steel clamping device is installed in the middle of the left side wall of the insulating crank arm for clamping the insulating crank arm on the angle steel of the iron tower, and the connector is movably sleeved in the mounting hole at the bottom of the left side wall of the insulating crank arm. The left end of the connector is provided with a nut connector for sleeving a nut, and the right end is provided with an electric wrench connector for connecting an electric wrench [2]. See Figure 1 and Figure 2 for details.

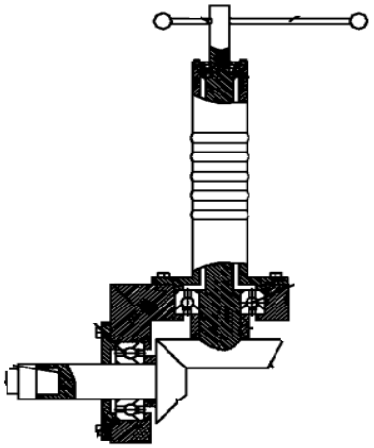

Figure 1Tool design plan

Figure 2 Tool physical drawing

As an improvement of the utility model, the angle steel clamping device also comprises a jacking screw which is screwed on the right end of the sliding guide post. The jacking screw rod can be freely adjusted to adapt to angle steels with different thickness dimensions. Compared with the prior art, the utility model has the advantages that composite standard insulating materials are adopted on the electric tools, so that people do not need to use insulating gloves, thus greatly improving the operability of people and effectively eliminating potential safety hazards caused by not using insulating gloves. Electric tools can automatically and intelligently prompt the

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torque standard corresponding to the bolt model, ensure the torque composite standard, and effectively prevent the randomness of operators. Through the special electric tools for bolt fastening, the bolt fastening work is finally realized, the manual labor force is no longer needed for assembly and disassembly, and the labor force of personnel is greatly reduced.

## 3. Key technology of special electric tools for bolt fastening in narrow space

### 3.1. Horizontal displacement transmission in narrow space

Integral bridge is widely used in all kinds of locomotives at present. The special electric tool for bolt fastening designed in this paper adopts integral axle housing as the basic component to design the transmission structure, in which the motor is mainly fixed on the reducer housing, the output shaft of the motor is connected with the reducer through keys, and the output shaft of the reducer is connected with the left and right half shafts through splines, in which the power is mainly transmitted to the half shafts and wheels through the reducer, further driving the special electric tool for bolt fastening forward [3]. The motor is arranged in parallel with the axle housing, in which the main reducer is designed as a split housing, and the left and right housings are connected by bolts.

The key system components of the special electric tools for driving bolt fastening are mainly determined by the driving motor and the power battery pack, so calculating the parameters of the motor and the battery pack and selecting the appropriate products become the main work of the parameter matching design of the electric drive system [4-5]. Firstly, according to the design performance index of special electric tools for bolt fastening, the parameters of driving motor are calculated. Secondly, according to the design requirements of special electric tools for bolt fastening and the selected motor, the specific parameters of the power battery pack are determined. Finally, the motor and battery pack are selected according to the calculated parameters.

### 3.2. Stereo reverse displacement transmission

Industrial robots have belt drive, chain drive and gear drive, among which gear drive is characterized by being able to drive the power between any two shafts, with stable transmission, compact structure, small footprint and high efficiency, but it is not suitable for long-distance transmission due to the impact and vibration in the transmission process; Chain drive is characterized by high transmission efficiency, constant average transmission ratio, and can be used in low-speed and heavy-duty working environment, but chain drive has poor motion stability and can not maintain constant instantaneous transmission ratio; The characteristics of belt drive are smooth transmission, vibration reduction and overload protection, but the structure of belt drive is not compact, and its transmission accuracy and efficiency are low. Based on the advantages and disadvantages of the above three transmission modes, combined with the field working environment, this design adopts gear transmission mode for three-dimensional reverse displacement transmission.

In view of the trajectory planning, operation range, actual load, production tempo and efficiency of industrial robots in actual production, and the advantages of ABB industrial robots in the same type of robots, such as large operation range, high precision, good real-time performance and large payload, IRB4400/60 is selected as the industrial robot designed for this purpose [6]. The robot is easy to program, the controller is suitable for Ethemet, Profibus-DP and other standard field networks, and it is easy to communicate with peripheral devices.

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## 3.3. Anti-loosening technology of extension interface

The main body of the electric tightening tool consists of mechanical and electrical parts. One part is the actuator to complete the tightening action, and the other part is the control system to accurately control the output torque. At present, the advanced electric tightening tools can precisely determine the torque, and can also integrate the angle control function, which can control the rotation angle of the tightened bolt. Some even have the yield point control function, which can make the bolt screw to the position just past the yield point of the bolt, and then control the electric tightening to stop automatically, so as to maximize the application ability of the bolt. Figure 3 shows the functional modules and basic working principle of a typical electric tightening tool.

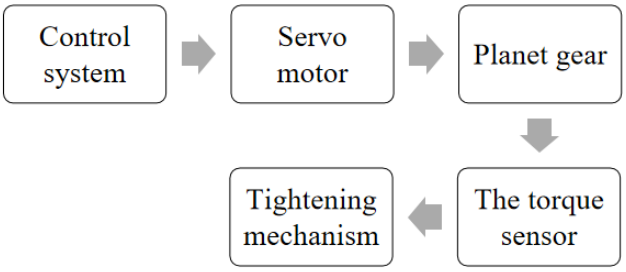


Figure 3 Function module and basic working principle of electric tightening tool

The working process of a typical electric tightening tool can be briefly described as follows. After the control system of the electric tightening tool receives the tightening instruction provided by the outside, it will send the instruction to the servo motor according to the preset tightening process requirements, and the servo motor will drive the front planetary gear set to rotate, and then drive the front tightening mechanism to tighten the bolt or nut. At the same time of tightening action, because the tightening mechanism is directly connected with the torque sensor, the sensor will monitor the torque value transmitted by the bolt in real time, and then the sensor will transmit the torque result to the control system through the electrical signal, and the controller will judge when to stop the servo motor or reduce the rotating speed of the servo motor. Ensure the assembly quality and precision of tightening.

One end of the torque sensor in the electric tool is connected with the input shaft of the planetary gear, while the other end is connected with the output shaft of the motor. The sensor usually adopts a hollow elastomer structure. On the one hand, the thin-walled structure is more prone to elastic deformation, which enables the strain gauge to reflect the torque on the elastic shaft more accurately. At the same time, it can make the structural design of the whole tool more compact, reduce the weight of the whole tool and conform to the ergonomic design. The mechanical properties of strain gauges and the performance of sensors will directly affect the accuracy of the whole power tool.

## 3.4. The interface technology of electric tool extension transmission module is studied

Based on the constant torque control scheme and mechanical structure of special electric tools for bolt fastening, the overall scheme of the control system for special electric tools for bolt fastening is studied around the system functional requirements. With modular design idea, the stable and reliable operation of special electric tools for bolt fastening is ensured. After several optimizations, the overall scheme of the control system for special electric tools for bolt fastening is finally determined as shown in Figure 4.

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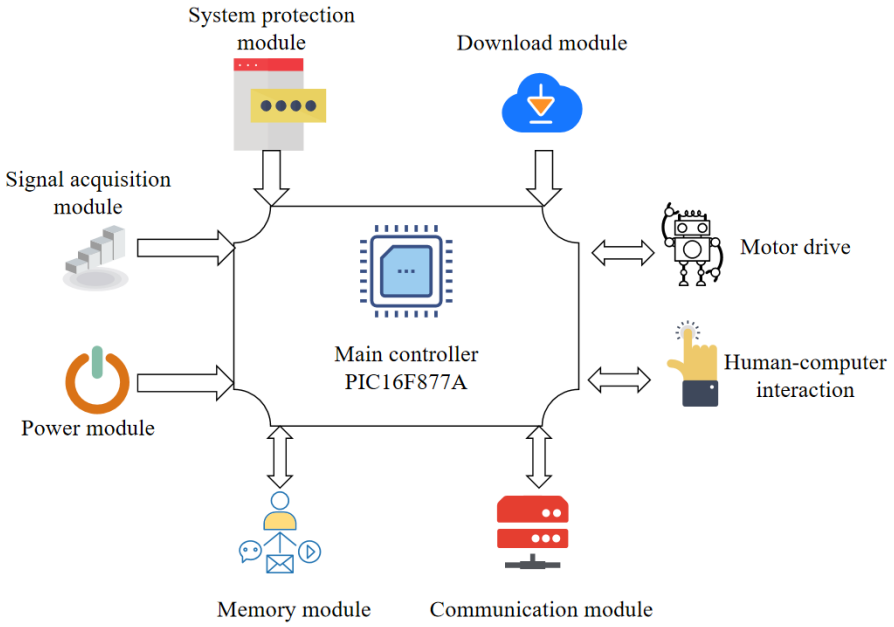


Figure 4 Block diagram of overall scheme of control system

The control system of special electric tools for bolt fastening consists of main controller module, signal acquisition module, man-machine interaction module, motor drive module, system protection module, download module, power supply module, storage module and communication module. PIC16F877A chip is selected as the main controller of the system, which has the advantages of powerful function and low power consumption. the built-in CCP module and 10-bit resolution A/D conversion module can simplify the peripheral circuit of the system In the signal acquisition module, the rotation speed sensor based on Hall principle is used to acquire the rotation speed signal of the series excitation motor. The power module converts 220V AC into 5V DC for the control system to run. The memory module records system parameters and equipment operation; The Bluetooth protocol is used to communicate with the host computer, which ensures the traceability of the running state of the special electric tools for bolt fastening.

## 4. Effect and benefit

Through the actual test, the equipment can automatically tighten 10 bolts according to the requirements of process drawings, and the operation is also very simple and convenient, which can perfectly replace the manual hand-held electrician tool tightening, eliminate the time of manually pressing the button to locate the equipment position and manually pressing the button to exit, and save a total of 45 seconds of working hours. Since the equipment was put into production, through online optimization, the starting rate of the equipment has stabilized to over 99.3%; The qualified rate of tightening is stable above 99.7%. The data show that the equipment has good stability and can ensure the tightening quality.

## 5. Summary

The special electric tool for bolt fastening provides a solution for efficiently fastening bolts in a narrow space without changing the structure of the original electric wrench. Aiming at the problem of bolt tightening with irregular position distribution, the kinematics model of special electric tools for bolt tightening is established. By solving and deducing the forward and inverse solutions of robot kinematics, the position and posture of the tightening tool as the end effector of robot in space under the coordinate system are confirmed. By studying the bolt distribution position, tightening process and sequence of gear chamber cover, the way of robot trajectory

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planning is confirmed. Finally, the trajectory program of industrial robot movement during bolt tightening is designed. It has been verified by many trials in the field that it meets the use requirements and achieves the expected use effect. It has the characteristics of reliable performance, high torque output precision, convenient operation and safe use, and has a certain use and promotion space.

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## References

[1]. Zhang Weifang, ma xinghai, Xiao guangcai, et al. application and research of bolt automatic tightening technology in rocket body manufacturing [J]. electric tools, 2018, no 198 (04): 11-16.
[2]. Cai Xiangjing. Design of portable electric tools for bolt assembly and disassembly of grounding down lead [J]. Electrical Technology and Economics, 2019, 000(002):P.31-33.
[3]. Sheng Junhao, Hao Weitao, Lu Xianchuan, et al. Development of a live operating rod with bolt fastening in substation [J]. Public Electricity, 2019, 34(04):25-26.
[4]. Su Qi Award, Huang Yan, Zhong Liqiang, et al. Research and application of live working robot and self-lifting online device for bolt fastening of transmission lines [J]. Guangdong Electric Power, 2019, v.32; No.260(09):127-135.
[5]. Yan Qi. Development and application of special wrench for bolt disassembly [J]. China Chemical Trade, 2019, 011(008):31.
[6]. Chen kai, CHEN, Kai. development of intelligent tightening machine for rail bolts of double-axis passenger dedicated line [J]. manufacturing automation, 2017, 06(v.39):100-103.