Research on Electrical Automation Metal Pipe Cutting Device

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Abstract: This article analyzes the key points in the design of electrical automation metal pipe cutting devices. The content of this article includes cutting principle analysis, power supply structure design, transducer design, horn design, controller selection, touch control screen circuit design, sensor circuit design, emergency stop control circuit design, executive circuit design, etc. The author studied the amplitude detection experiment, process parameter experiment, cutting experiment analysis, etc., whose purpose is to improve the orderliness of the metal pipe cutting process and improve the final construction quality of the pipe.

1. Introduction
In the industrial production process, metal pipe fittings are commonly used structural parts, especially in some large mechanical equipment, metal pipe fittings play a very important application role. Under the requirements of precision production, the application advantages of automation technology are also highlighted. Relying on automation technology to improve the design of the cutting device can not only speed up the production of metal pipe fittings, but also improve the precision of the production process and improve the production quality of metal pipe fittings.

2. Design Essentials of Electrical Automation Metal Pipe Cutting Device

2.1 Analysis of Cutting Principle
The application principle of the automatic cutting device is: under the command of a certain degree of process, the cutting tool will cut the raw materials sequentially. During the cutting, follow the order of first coarse adjustment and then fine adjustment until the material can meet the established requirements and improve the final production quality of the material. Based on previous production experience, we can understand that the material will undergo a process of deformation under the influence of vibration. At this time, the static stress when destroying the integrity of the material will continue to decrease, and the specific deformation is also related to the vibration displacement of the tool during processing. According to the correlation between the characteristic stress and the stress curve, we can understand that the displacement of the automated cutting tool is assumed to be L, and h is the yield deformation during material cutting, d is the applied thickness of the cutting material, and t is the vibration of the cutting tool Period, t₀ is the time point when the material starts to be cut and destroyed, a represents the average stress generated in the unit vibration period, a₀ is the dynamic stress, and v represents the feed speed of the cutting device. Then according to the stress curve, we can understand that dynamic stress and other parameters have the following relationship:

\[ a₀ = \left( \frac{a}{2\pi h} \right) \left( \frac{v}{4\pi} \right) \left( \arcsin \left( \frac{h}{L} \right) - a \left( \frac{1}{2} + \frac{1}{2} \right) \right) \] ①

In practical applications, we also need to pay attention to the specific changes of various parameters to improve the reliability of the system operation process.
2.2 Power Structure Design
As shown in Figure 1, in the design process of the automatic cutting device, the entire power supply is mainly composed of an oscillation stage, an amplifier stage, a matching device and a power supply. The oscillating stage generates a sinusoidal signal of the frequency required for the operation of the transducer, which is amplified by the amplifier stage and transmitted to the transducer through the matcher. Then, the voltage of 220V or 380V and alternating current with a frequency of 50Hz are converted into ultrasonic frequency electric signals, so that the auxiliary power system starts to carry out the corresponding work content. At the same time, we also need to do a good job in the design of the power supply circuit in the specific application process, and the specific design content refers to the corresponding specifications. In addition, in order to avoid the unstable power supply pressure causing bad conditions in the materials, and to improve the rationality and compliance of the distribution content, we also need to set up a backup power supply module, which can be switched to the backup power supply in time to maintain the initial working state after encountering sudden problems.

![Figure 1 Schematic Diagram of Power Supply Structure Design](image)

2.3 The Design of the Transducer
In the automatic cutting device, relatively many sources of kinetic energy are used. At present, the most widely used ultrasonic cutting device is the accuracy and speed of 60-70% higher than that of ordinary cutting devices. The transducer is also applied to the cutting device during use, and its main function is to carry out the orderly conversion of energy. The transducers frequently used in practical applications include the following two types. The first type is piezoelectric transducer. The main principle of its use in applications is to use piezoelectric ceramics to generate the inverse piezoelectric effect under the action of electricity, and after polarization treatment, it will cause periodic vibration under the action of electrical signals or media, thereby adjusting the role of device working status. The second type is magnetostrictive transducer. The main principle of its use in applications is to use a magnet to generate a magnetostrictive effect under the action of electricity, thereby completing the displacement adjustment of the cutting device. The most commonly used tool in this article is a sandwich piezoelectric transducer, which is mainly composed of a front cover, piezoelectric ceramics, electrode sheet, insulating tube, back cover and bolt structure, which combines two structures. The comprehensive performance of it has strong use value.

2.4 The Design of the Horn
When cutting metal pipe fittings, the main function of the horn is to adjust the amplitude of the cutting process, and to ensure the compliance of the amplitude content on the basis of ensuring that the vibration frequency meets the requirements. In the context of the application of automation systems, we need to maintain compliance with the operating error value of the horn. The displacement of the cutting tool is generally above 100μm, and the vibration displacement of the transducer is generally below 10μm. This also requires us to adjust the cross-sectional area, energy density, etc. of the horn design process to enhance the practical value of the horn selection results. From the current application situation, there are many types of horns to choose from. When we choose the horn, we also need to
consider the material magnification factor, shape factor and other content. At the same time, we can also combine the theoretical modeling content to make the most appropriate application choice. At this stage, the most widely used horns include conical horns and stepped horns. We can make effective choices based on actual application conditions, thereby enhancing the practical value of application results.

2.5 Controller Selection
In the application process of the automatic cutting device, the controller is a very core application content, which is also the basic condition to ensure that the entire equipment system can efficiently complete the cutting work. We can combine specific application requirements and choose a controller chip with strong working stability, strong functionality, strong working stability, and strong operating economy in actual application selection. The STM32F103ZET6 chip has been well applied in the use of many cutting devices. Meanwhile, the chip also has strong compatibility, which can be compatible with transmission information to ensure the integrity of data information transmission. Besides, we also need to install an advanced timer in the controller structure, which is used to supervise the module operation process to improve the stability and timeliness of the system operation process. Moreover, during the operation of the system, it also has a strong storage function, which can smoothly complete information interaction with the touch control screen. So as to reduce the burden of processor operation, improve the anti-interference ability of system operation, and optimize its performance parameters.

2.6 Touch Control Screen Circuit Design
In the application process of the automatic cutting device, the touch control screen circuit is also the key content in the design process. In the actual operation process, we should pay attention to the following design content. First, we should ensure the friendliness and simplicity of the interface. This is also the basic condition to ensure the smooth operation of the interface. We can combine the previous design experience, in the design process of touch control screen, should include manual control module, automatic control module, production parameter control module, password setting module and so on. Simultaneously, today's time will also be displayed in the window, which is convenient for querying past operation records. Second, we also need to upgrade the module structure in the module design. In the meantime, we also need to record and monitor daily work data. When an abnormal situation occurs, a pop-up window will appear on the screen to indicate the location of the fault. This can not only speed up the troubleshooting of faults, but also protect the equipment to ensure the stability of the equipment's working state.

2.7 Sensor Circuit Design
The sensor circuit is shown in Figure 2. The controller STM32 has abundant external interrupt resources. We can take full advantage of this advantage and configure the external signal acquisition port as an interrupt input type so that the controller can "capture" various sensor signals in real time. This can speed up the controller's response to sensor signals, so as to avoid the delay or even loss of "events" caused by reading the input signal in the "query mode". The sensor's working power supply is DC 24V, NPN normally open output mode. In order to isolate the external electromagnetic interference and realize the conversion from 24V level to 3.3V level, we can use "photocoupling" to input the signal to the controller. Practice has proved that because the signal line from the sensor to the controller is long, it is easy to be interfered by clutter and cause the device to malfunction. The filter circuit composed of 103 high-frequency ceramic capacitors and 2k resistors in the circuit can effectively eliminate the "burrs" in the signal and improve the quality of the input signal. The signal line is shielded, which can further improve the stability of the circuit.
2.8 Emergency Stop Control Circuit Design

In practical applications, in order to ensure the safety of line operation, we also need to design the emergency stop control circuit. It can suspend in time when the cutting device fails to avoid further deterioration of the problem, thereby improving the safety of the system in the working process. The specific circuit design points are shown in Figure 3. Under normal working conditions, the entire system circuit is in a stable working state, and the entire circuit is in a state of access. At this time, the electrical coupling PC817 in the line will also complete the state adjustment with the help of PE15 in the controller structure after the level conversion processing, and the working status screen at this time is displayed as "0". When the cutting device is working, it will be in a self-locking state when the system is in an emergency stop state due to an emergency. The electrical coupling PC817 in the circuit will also complete the state adjustment with the help of PE15 in the controller structure after the level conversion processing, and the working status screen at this time will be displayed as "1". At this point, the system will immediately stop working and stabilize the entire workflow [1].

2.9 Executive Circuit Design

In addition to the design content mentioned above, we also need to do a good job in the design of the implementation circuit in specific applications. The automatic cutting device mainly uses the PG port to complete the application output of the system, and is used to drive the equipment inside the system to maintain the stability of the entire system operation process. During the operation of the circuit, a 220V single-phase AC power supply is used to assist the entire operation. The electrical coupling PC817 in the line will also adjust the working status of other circuit devices in the system after the level conversion process, so that the metal pipe can be in a stable working state, so as to meet the requirements of stable operation of the system. The subsequent operation information will also be fed back to other application systems in time to satisfy the safety of the system operation process [2].
3. Research on Application Test of Cutting Device

3.1 Amplitude Detection Experiment
Amplitude detection is a very important work content when analyzing the performance of an automatic cutting device. Its purpose is to check the compatibility of the working state of the tool with the theoretical design content, and to monitor the working state of the tool to ensure the integrity of its output power. In the specific inspection process, it mainly chooses the optical method to complete the content. First of all, we will use the sensor to detect the waveform changes during the tool work. Subsequently, we will use the correlation software to process the collected data information, analyze the amplitude changes of the monitoring points involved in the amplitude waveform, and compare the waveform analysis to the stability of the content of the link. If the fluctuation range is within a reasonable range, the cutting device meets the application requirements, otherwise, the parameters need to be readjusted and then tested to meet the specific application requirements [3].

3.2 Process Parameter Experiment
When analyzing the performance of the automated cutting device, we also need to conduct process parameter experiments to check the eligibility and practicability of various process parameters. Moreover, in this process, we can also understand the working status and judge its reliability. In the specific detection process, the sensor mainly uses the sensor to detect the waveform changes during the working period of the tool. Subsequently, the system will process the collected data information using correlation software, analyze the processing error of the metal pipe fittings, the error fluctuation range, and compare the curves to analyze the stability of the process parameters in this link. If the fluctuation range is within a reasonable range, then the cutting device meets the application requirements, otherwise, the parameters need to be re-adjusted before testing to meet the specific application requirements [4].

3.3 Cutting Experiment Analysis
Except to the above detection content, when analyzing the performance of the automated cutting device, we also need to practice, placing it in a suitable position for cutting experiments to evaluate the practical value of the cutting device. In the specific detection process, we can use the sensor to detect the waveform changes during the work of the tool. Meanwhile, we can check the quality of the finished product, collect the corresponding parameter information, use the software to comprehensively process the data, draw the corresponding change curve, and evaluate it after comparing the standard curve. If the fluctuation range is within a reasonable range, the cutting device meets the application requirements, otherwise, the parameters need to be readjusted before testing to meet the specific application requirements [5].

4. Conclusion
In summary, the automated transformation of cutting equipment based on ARM control solves the problems of traditional cutting equipment that requires human participation in the whole process, low safety and low efficiency. Furthermore, it also realizes automatic control, reduces the work intensity of metal pipe fitting production workers, and improves work efficiency. If this equipment is commercialized, it will be welcomed by the market and contribute to the improvement of industry productivity.

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