Research on the PLC-based Full-automatic Punching Machine for Transformer Insulating Strip Material

Lijun Xu¹,a, Youlian Duan¹,b, Jiwei Wang¹,c and Xiaojing Hou¹,d

¹Electrical and Information Engineering, Xinjiang Institute of Engineering, Urumqi, China

a xulijun612@163.com, b 865155548@qq.com, c 306316875@qq.com, d 540378820@qq.com

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Abstract. To meet transformer enterprises' demand for the process automation of insulating strip material, this paper develops a kind of automatic punching machine for punching the flexible non-metallic strip by integrating detection and sensor technology, information processing technology, automatic control technology, servo drive technology and precision machinery technology integration. By the trial running, this punching machine is proved to be stable with high operating precision. Its popularization and application can improve the labor productivity of the industry and reduce the production cost of transformer enterprises.

Introduction

There are about 1,000 transformer manufacturers in China, about 20 of which are large-scale manufacturers. The annual output value of transformer products reaches about RMB 50,000,000,000. Currently, all blanking processing technics of insulating strip in domestic transformer manufacturing industry are manual processing. That is, the materials are continuously fed by the workers to the working positions of the punching machine and mould which blanking the strip materials into semi-finished products of various lengths and shapes. Such operating mode has a series of problems such as heavy labor intensity, high noise, finger injury caused by repetitive movements, low ratio of fishing products, material waste and low production efficiency, etc. Although the engineering technicians of many enterprises have made a lot of technological innovation according to their own circumstances, the above problems have not been fundamentally solved. A good solution to the above problems is to replace the existing semi-automatic punching machine with the numerical control punching machine by microprocessor control[1]. Automatic punching machine has been used in China for about 20 years, but with the diffusion of domestic technology and the introduction of foreign technology, the design and manufacturing technics of numerical control punching machine have been accepted by more and more manufacturers and are converted to products in the market. For instance, Jinan Jiemai, Jiangdu Yawei and other enterprises have made great progress in the product maturity, advanced technology and other aspects. However, most automatic punching machines produced by all existing manufacturers are used for the production of sheet metal, and there is no enterprise producing the automatic punching machine for punching the insulating strip material of transformers. Because the insulating strip material is quite different from metal material in nature for its rough surface, soft texture, non-magnetism and other features, it cannot be processed by the existing automatic punching machines and the automatic punching machine which can automatically punch such insulating material is urgently needed by the industry[2].

Voest-Alpine, an Austrian company, designed and manufactured the automatic punching machine with Vastar sequence action which can punch sheet metal parts[3]. Compared with the original automatic punching machine, it achieved a lower cost of capital construction and higher productivity. However, it is mainly suitable for punching roll or sheet metal materials.

Teng Honghua and Zhang Shengquan et al. conducted a research on the mechanical & electrical integration of small-sized automatic punching machine feed mechanism and designed a kind of feed
system for the rapid step feeding of small-sized punching machine, but it did not specifically solve the feeding method of non-metallic materials[4].

Wang Wei and Sheng Xiaoming et al. designed the feeding and blanking pneumatic manipulator of punching machine based on PLC control, which solved the feeding and blanking problems such as low efficiency, poor accuracy and security risks and achieved downtime feeding and blanking. If the procurement cost of enterprises permits, this technology can be combined with the punching machine said in this paper to further improve the automation level of the equipment. At present, Japan AMADA, Germany SCHULER and many foreign large-scale automation equipment manufacturers have already developed the automatic punching equipment for flexible non-metallic materials. However, considering the cost performance, there are few domestic companies importing such equipment for their high prices due to technical barriers, tariffs and other reasons[5].

Udy develops a kind of automatic punching machine for punching flexible non-metallic material by integrating the detection and sensor technology, information processing technology, automatic control technology, servo drive technology, precision machinery technology, and overall system technology[6]. This punching machine is featured with miniaturization, precision, digitization, automation, integration and low price, which can meet the urgent need of insulating strip material process automation of transformer enterprises.

1. Structure of punching machine

As shown in Fig. 1, the punching machine consists of the raw material elevator mechanism, feeding mechanism, detection device, punch pin and control device.

(1) Control device. As the core unit of the punching machine, control device is constituted of Mitsubishi FX2N-48MT-001, FX0N-3A analog module and Delta DOP-B07S201 touchscreen.

(2) Raw material elevator mechanism. Adopting the screw lifting principle, the raw material elevator mechanism is designed to lift the material to be processed onto the feeding position and automatically drop to charge material after the material is used up. This mechanism can be manually adjusted to fit the placement of materials of different sizes and uses the step motor drive.

(3) Feed mechanism. As the most important controlled device of the entire automatic punching machine, the performance of this mechanism can determine the work efficiency and processing quality of the entire punching machine. It is designed to automatically identify the smoothness of the material to be delivered and select a delivery way to send the material to the punching pin for process at a certain speed and accuracy. The device adopts the step motor driver and is controlled by fuzzy-neural network PID algorithm.

(4) Detection device. The infrared sensor, travel switch, proximity switch, raster and a variety of detection devices are used to accurately detect the punching machine and send the signal to the PLC for control.

(5) Punching pin. This device is used for the material punching process, which will not be taken as the focus of the research.

2. Work process analysis

The automated workflow of punching machine is shown in Fig. 2.

(1) Check the strip material after the power-on self-test. Prompt whether to operate if there is strip material; prompt to feed if there is no strip material. Each time of the first operation is only single cycle, and then prompts whether to enter repeated cycles; detect if there is any strip material on the stock supporting plate after punching a strip of material. If the detected value of the sensor is 0, it will stop to prompt to fill material.

(2) When the elevator is set to lift and the feed detection sensor is 1, start the material rubbing motor. The strip material should be detected by the feeding state detection sensor within 3 seconds, or the lifting step motor will move downward and then move upward to restart the material rubbing
motor. If the value of feeding state detection sensor is still 0 after repeating 3 times, alert and check the baffle plate and feed inlet.

Figure 1. Drawing of punching machine.

![Diagram of punching machine]

(3) When the feeding state detection sensor is 1, it indicates that there is material rubbed out and then the feed step motor will start to rotate; in order to ensure the material rubbed out is a single layer, the single-layer sorting roller is set for the single-layer sorting of material. When the single-layer sorting sensor is 1, it indicates the single-layer sorting is successful. The feed motor will continue to work and the material will pass the strip material drawing roller. When the front end of the material reaches the feed head and tail position sensor, the lifting step motor will decline 3mm in order to reduce the
material drawing resistance and prevent the next material is robbed out, and the material robbing motor will stop. The material conveying speed is detected by the raster in the whole process and displayed by the output per unit time.

Due to the non-metallicity of the insulating strip material, this punching machine uses the rubber roller to rub out the material. But the surface smoothness of each batch of materials is different. For the materials with rough surface, the rubber roller can better rob out the material from different travels by frictional force; but for the materials with smoother surface, the rubbing effect of the roller will be worse. In order to maintain the feeding stability, this punching machine uses the self-organizing neural network with learning function and forms the fuzzy-neural network PID control by the fuzzy PID control algorithm[7,8]. For the material with different roughness, the relation between the regularity and input samples is established through the learning process. Adaptively adjust the network according to the information of input samples in order to make the latter network adapt to the input samples.

The pressure of roller can be adjusted according to the changes in surface roughness of the material to keep the rubbing speed within a certain precision in order to ensure the production efficiency and product quality. If the material is difficult to be robbed out for the smooth surface, the control system will automatically switch the material rubbing method into strong chuck instead of rubbing roller, which can ensure both the feeding speed and energy saving. The shapes of material rubbing mechanism and feed mechanism are respectively shown in Fig. 3 and Fig. 4.

![Figure 3. Material rubbing mechanism.](image)

(4) When the feed head and tail position sensor is 1, the feed step motor will work. When the strip material reaches the specified position below the punching pin, the punching machine operation indicates 1, the punching pin will move downward to punching; when the detecting sensor of the punching pin is 1, determine whether to continue set the punching machine operation indication according to the operation mode (single step, single-cycle or repeat). If it sets, the feed step motor continues to rotate in order to repeat the above work process. Throughout the process, continuously detect if there is sudden stop, interrupt, zero setting of strip detection sensor, and other signals. When the zero setting of strip detection sensor is detected, the punching machine will stop after processing the current strip material, the lifting step motor will quickly drop to the lower limit position and prompt to load strip material.
When the state of the feed head and tail position sensor begins to drop, it indicates the tailing material has reached. Then the feed step motor will rotate in reverse for several steps to draw out the tailing material and enter the next cycle.

3. System software design

The system uses Mitsubishi FX2N-48MT-001PLC as the controller and adopts Delta DOP-B07S201 touch screen as man-machine interface.

By adopting the modular design method, the system software designs each working process into the subprogram which can be transferred by the main program when required, making the structure simple and clear for debugging and modification.

The control of step motor adopts the PLSY instruction, which can convert the number and frequency of pulses into the set stroke and speed by the step motor controller, such as: PLSY K1000 D1000 Y0.

Because the control strategy of the feed mechanism is complex, it will be discussed in future articles.

4. Conclusion

In the trial running, the punching machine has shown a good stability and operation precision. In the 24-hour continuous operation, there was no technical anomaly occurring. It is expected that the application of the equipment can improve the equipment efficiency by 2 times, enhance the labor efficiency by 8 times, and increase the production cost per person by 16 times. After the volume production, the single machine cost can be controlled within RMB 200,000. For its miniaturization, precision, digitization, automation, integration, low price and other features, the punching machine has very high cost performance and rate of return on investment. Besides, the promotion and application of the punching machine can significantly improve the labor productivity of the industry, reduce the product costs and enhance the competitiveness of domestic transformer enterprises.

Summary

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References


