Industry Science and Engineering Vol. 2 No. 3, 2025

Research on the System Integration Design of Efficient Winding and Scraping Tube Machine

Zhang Jian[1,#], He Caifu[2], Chen Xuejun[3,4,*], Lin Haibo[3,4,#], Zhu Lichao[3,4]
[1]*College of Sino-German , Taizhou Vocational & Technical College, Taizhou, Zhejiang, China*
[2]*Institute of Process Control and Equipment Provincial Enterprise ,Zhejiang Chengxin Medical and Chemical Equipment Co., Ltd. Taizhou, Zhejiang, China*
[3]*College of Mechanical and Electrical Engineering, Taizhou Vocational & Technical College, Taizhou, Zhejiang, China*
[4]*Taizhou Key Laboratory of Robotics and Intelligent Equipment, Taizhou, Zhejiang, China*
[#]*These authors contributed equally*
**Corresponding Author*

Abstract: This article mainly introduces the relevant knowledge of the curling tube, including its definition, characteristics, types and selection, application fields, as well as the system structure and working principle of the curling tube forming machine. Bent tube improves heat transfer efficiency by increasing the heat transfer area, and is widely used in various fields such as refrigeration and chemical engineering. Based on the characteristics of the curling tube, the system structure of the curling tube forming machine was analyzed, including the host structure, heating device, and control system, and its working principle was explained. At the same time, the article provides a detailed discussion on the software and hardware structure requirements of the curling machine, including software requirements for control algorithms and logic, user interface, data processing and storage, as well as hardware requirements for sensors and actuators, control units, communication interfaces, etc., providing reference for related research.

Keywords: Wound Sheet; Scraping Tube Machine; System Integration; Heat Transfer

1. Introduction

With the increasing development of industry and agriculture, energy shortage has become one of the major global issues. Countries around the world are searching for new energy sources and ways to save energy, and efficient heat exchangers are effective equipment for developing, utilizing, and conserving energy. The finned tube is the most basic and important heat exchange element in a heat exchanger, and its quality directly affects the working performance of the heat exchanger. A finned tube is a type of pipe that increases the heat transfer area by adding finned tubes. In a heat exchanger, the finned tube serves as the heat exchange surface and plays an important role in heat exchange. By adding fins, the surface area of the pipeline can be significantly increased, thereby improving heat transfer efficiency. The curled tube has the advantages of compact structure, light weight, and small footprint, which makes it widely used in various occasions that require efficient heat exchange. Due to its large surface area, the curved tube can come into contact with the fluid more fully, thereby improving the efficiency of heat exchange. The compact structure and the design of the finned tube enable it to provide a larger heat exchange area in a smaller space, improving the efficiency of the heat exchanger. Bent tube is usually made of corrosion-resistant materials, such as stainless steel, copper, aluminum, etc., to maintain stable performance in various corrosive media. The finned tube has a wide range of applicability, and can maintain stable heat transfer efficiency under high temperature, high pressure, low temperature, and low pressure conditions, suitable for various working conditions.

As a key component of heat exchange equipment, the type and selection of finned tubes have a significant impact on the heat transfer performance and stability of the system. According to the different shapes, materials, and arrangements of the curled tubes, they can be divided into various types. The coiled fin tube increases the surface area of the tube body and improves heat dissipation efficiency by

wrapping the fins around the tube body. This design is suitable for occasions that require rapid heat dissipation, such as cooling systems in industries such as petrochemicals and metallurgy. The rolled blade tube is tightly integrated with the tube body through rolling technology, which makes the contact between the blade and the tube body more intimate and improves the thermal conductivity.

When selecting the type of curling tube, comprehensive consideration should be given based on actual needs and working conditions. The thermal conductivity of materials, the properties of fluids, temperature differences, and flow rates all have an impact on heat transfer efficiency. In terms of thermal conductivity, metal materials such as aluminum, copper, and carbon steel are commonly used as foil materials, among which aluminum is widely used due to its good thermal conductivity and corrosion resistance. The properties of fluids, such as viscosity and specific heat capacity, can also affect heat transfer efficiency. In practical applications, it is necessary to select the appropriate type and arrangement of finned tubes based on the characteristics of the fluid to improve heat transfer efficiency. As an efficient heat exchanger component, the performance and characteristics of the finned tube make it play an important role in various industrial applications. With the continuous advancement of technology and changes in the market, the application prospects of the curling tube will also become broader.

2. The System Structure and Working Principle of the 2-Piece Tube Forming Machine

2.1 Heat Transfer Theory of Curled Blades

Bent sheet, also known as rib sheet, refers to an extended surface attached to the base surface. It can be rolled or wrapped as a whole from a pipe, embedded with metal sheets, and processed.

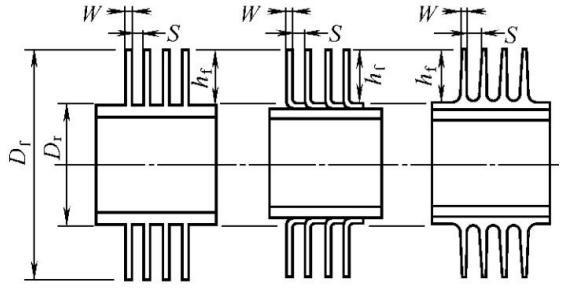

Figure 1. Typical Structure of Curled Blade

2.2 System Structure of Curling Tube Forming Machine

As a key equipment, the curling tube forming machine plays a crucial role in industrial production. Its performance directly affects the quality and production efficiency of downstream products. The following is a detailed analysis of the structure of the curling tube forming machine.

In terms of host structure, the main components of the curling tube forming machine include rollers, bearings, transmission devices, and other parts. These components together form the core of the molding machine, responsible for achieving stable transmission and molding of the curling tube. As a key component, the surface quality of the drum directly affects the surface performance of the curling tube. Bearings and transmission devices are responsible for transmitting the power of the motor to the drum, ensuring its smooth operation at high speeds. The precise coordination of these components provides reliable hardware support for the forming of the curling tube.

In terms of heating device, it is an important component of the curling tube forming machine. Its main function is to heat the curling tube for subsequent molding operations. Heating devices usually include electric heating boxes, heating rods, temperature sensors, etc. These components together form a complete heating system, ensuring that the curling tube reaches the appropriate temperature before forming. By precisely controlling the heating temperature and time, precise control of the surface properties of the curling tube can be achieved.

In terms of control system, the control system is the core control component of the curling tube forming machine. It mainly includes the electric control box, sensors, terminal blocks, and other parts. These components together form a complete control system, responsible for monitoring and controlling the various operations and functions of the molding machine. By precisely setting control parameters and real-time monitoring feedback signals, real-time monitoring and precise control of the operating status of the molding machine can be achieved.

2.3 Software and Hardware Structure Requirements for Curling Machine

2.3.1 Software structure requirements for curling machine

(1) Control algorithms and logic. The control algorithm and logic of the curling machine software are directly related to the precise control and efficient operation of the curling tube. The software should have functions such as start control, stop control, temperature control, humidity control, etc. By using precise control algorithms such as fuzzy control, PID control, etc., real-time monitoring and adjustment of the operating status of the curling tube can be achieved. When starting the control, the software should be able to ensure that the curling tube starts at the set temperature and humidity, avoiding adverse effects on crop growth. When stopping the control, the software should be able to smoothly close the curling tube to prevent damage to the equipment due to the closing process being too fast. Temperature and humidity control are important functions of the curling machine software, which ensure that the temperature and humidity inside the greenhouse are always maintained within the appropriate range through real-time monitoring and adjustment.

(2) User interface. The user interface is an important component of the curling machine software and should have friendly and intuitive features. The software displays real-time data feedback to users through the user interface, such as temperature, humidity, operating status, etc. These data are of great significance for users to understand the environmental conditions inside the greenhouse, adjust control strategies, and discover potential problems. The user interface should provide functions such as parameter settings, status monitoring, and operation control, making it convenient for users to manage and control the environment inside the greenhouse. By optimizing the user interface design, the software's usability and user experience can be improved, reducing the learning cost and difficulty for users.

(3) Data processing and storage. Data processing and storage are essential functions of the curling machine software. The software should be able to process real-time data from sensors, such as temperature, humidity, etc. These data are of great significance for users to understand the environmental conditions inside the greenhouse, adjust control strategies, and discover potential problems. The software should store the processed data locally or in the cloud for subsequent analysis and optimization. Through data processing and storage functions, users can conduct long-term monitoring and analysis of the environmental conditions inside the greenhouse, identify potential problems and opportunities for improvement.

2.3.2 Hardware structure requirements for curling machine

(1) Sensors and actuators Sensors are the "eyes" of the curling machine, responsible for real-time monitoring of parameters such as temperature and humidity of the curling tube. These parameters are of great significance for judging the operating status of equipment, predicting faults, and timely maintenance. Sensors should have high sensitivity and accuracy to ensure rapid capture of abnormal signals during device operation, providing strong support for timely intervention. The actuator is the "hand" of the curling machine, which adjusts the operating status of the curling tube according to the output instructions of the control unit to achieve precise control. The actuator should have fast response and reliable performance to ensure that it can respond quickly and accurately after receiving control instructions, achieving precise control.

(2) Control unit. The control unit is the "brain" of the curling machine, responsible for receiving sensor signals, processing control algorithms, and driving actuators to perform actions. The control unit should have high performance and stability, ensuring real-time processing of sensor signals, accurate judgment of equipment operating status, and timely driving of actuators for adjustment. A high-performance control unit can also achieve more precise control and improve the operational efficiency of the curling machine.

(3) Communication interface. The communication interface is a bridge for connecting and exchanging data between the curling machine and other devices or systems. With the continuous development of modern agricultural greenhouse construction, the curling machine needs to be linked with other intelligent devices to achieve more comprehensive environmental control. The communication interface should comply with industry standards, support common communication protocols and connection methods, and ensure seamless connection and data exchange with other devices or systems.

3. Working Principle of the Curling Tube Forming Machine

3.1 Transmission and Heating

The main body of the curling tube forming machine is transported through a drum, which ensures a stable transmission speed of the curling tube during the forming process, thereby improving production efficiency and product quality. The heating device heats the curling tube to a suitable temperature for molding. This step is crucial because the temperature directly affects the forming effect of the curling tube. By precisely controlling the heating temperature, it is possible to ensure that the curling tube maintains sufficient plasticity and toughness during the forming process, thereby avoiding problems such as cracking and deformation.

3.2 Molding Process

After the curling tube reaches the appropriate temperature, the molding mold of the main body part is formed. This stage is the core and most critical step of the curling tube forming machine. The shape and size of the molding mold directly affect the appearance and performance of the curling tube. By precise design and manufacturing of molding molds, it is possible to meet the needs of different customers and achieve personalized product customization. The molding process also requires real-time monitoring of the temperature and transmission speed of the curling tube to ensure the accuracy and stability of the molding effect.

3.3 Control System Design and Algorithm Implementation

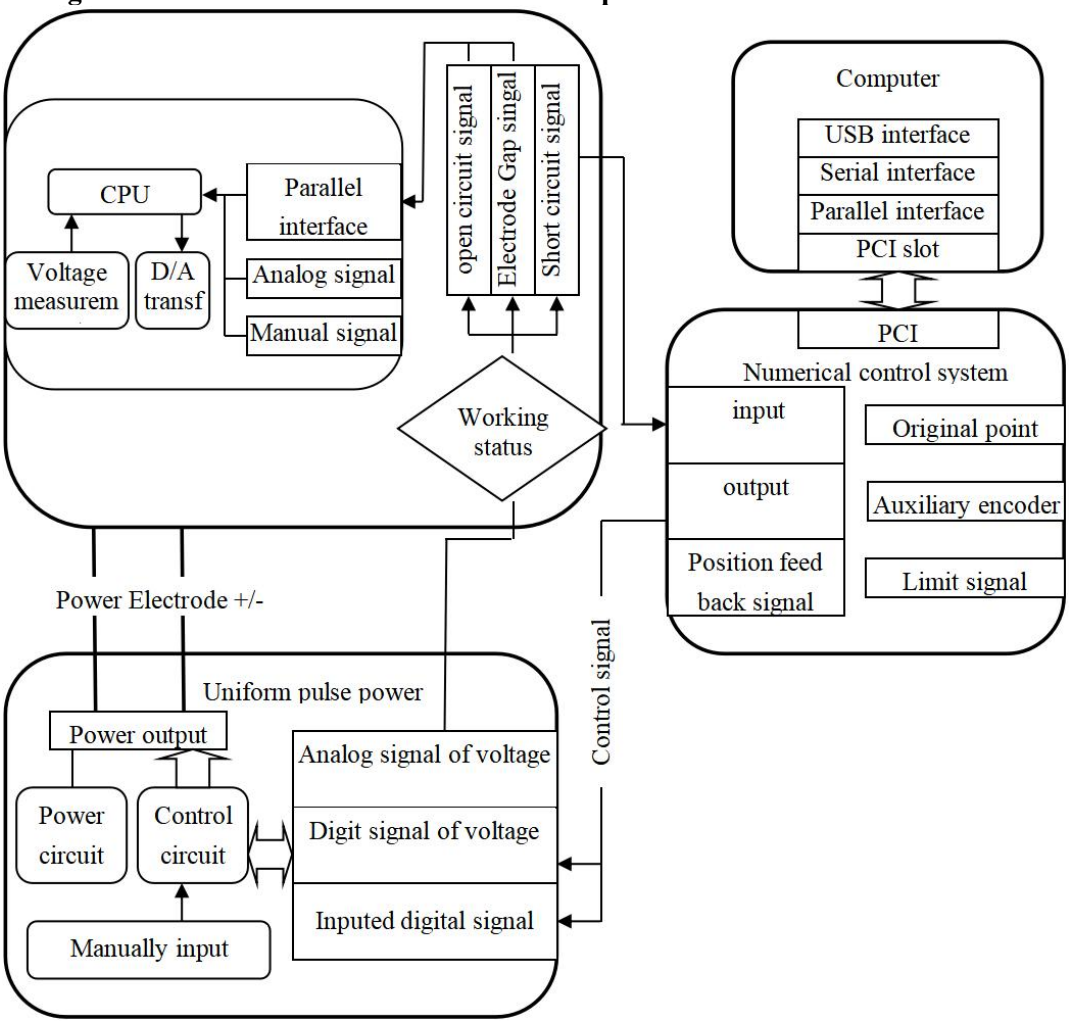

Figure 2. The Structure of Micro-EDM Transmission Modular

In terms of control strategy, the working principle of the wound finned tube is based on heat exchange and air flow, and changes the temperature inside the building by adjusting the heat dissipation power and ventilation volume. In response to this characteristic, PID control, fuzzy control, or optimization algorithms can be used to control the working state of the wound blade tube. PID control can monitor errors in real time and quickly adjust control parameters, making it suitable for systems that require rapid response. Fuzzy control can simulate human

decision-making processes and control complex systems, but its computational speed is relatively slow. Optimization algorithms can be based on mathematical models and constraints to find the optimal control strategy for system performance.
In terms of algorithm implementation, according to the selected control strategy, corresponding algorithms need to be implemented to control the working state of the wound blade tube. This includes control logic, data processing, etc. Control logic is the key to implementing control strategies, as it determines what actions the system takes under what conditions. Data processing is responsible for converting the data collected by sensors into signals that can be used for control, and filtering and denoising the data to improve control accuracy and response speed. By implementing reasonable algorithms, it is possible to ensure that the coiled tube plays the best role in animal husbandry, improving the control accuracy and response speed of the temperature inside the shed.
The control system plays a crucial role in the curling tube forming machine. By monitoring the temperature, transmission speed, and other parameters of the curling tube in real-time through sensors and connectors, potential problems can be detected and resolved in a timely manner, ensuring the smooth progress of the molding process. The control system can also adjust the operation of the heating device and the main unit according to actual needs to optimize production efficiency and product quality. The intelligence and automation characteristics of the control system have also improved the reliability and stability of the equipment, reducing the risk of manual intervention and errors.

3. Implementation and Application Fields of Curved Tube

In the field of chemical engineering, corrugated tubes also have a wide range of applications. Heat exchange process is essential in various chemical reactors, distillation towers and other chemical equipment. And the curling tube has become an indispensable component in these devices due to its excellent thermal conductivity and stable structural characteristics. In chemical reactors, finned tubes can ensure that reactants are thoroughly mixed and reacted inside the equipment, thereby improving reaction efficiency. In the distillation tower, the curling tube can stably control the temperature at the bottom of the tower, ensuring the smooth progress of the distillation process.

4. Conclusion

The high-efficiency heat exchange equipment with wrapped fins produced after the successful development of the winding machine can be widely used in mixing reactors, fermentation tanks, single cone screw vacuum dryers, double cone vacuum dryers, filtration, washing and drying three in one equipment, scraper evaporators and other heat exchange equipment consisting of an inner cylinder, upper head, lower head, jacket and mixer. The fins are wrapped around the inner cylinder and lower head of the above-mentioned equipment, and the fin winding methods include forward spiral winding and reverse spiral winding. The fins form a certain angle with the horizontal line. The wrapped fin high-efficiency heat exchange equipment reduces the total mass of conventional heat exchange equipment by more than 20%, and has a significant energy-saving and consumption reducing effect, which is of great significance for promoting the application and development of fin heat exchange equipment.

Acknowledgements

This work was supported byGeneral Research Project of Taizhou Vocational and Technical College for the Year 2025 (2025YB24),and 2023 Taizhou City Science and Technology Plan Project (Industrial) First Batch of Projects (23gya13),Taizhou Talent Link [2022]No.2).Lin Haibo Taizhou Master Studio received funding from the Taizhou Municipal Human Resources and Social Security Bureau(2022) and Taizhou Vocational College School Name Technician Studio Supported by Taizhou Education Bureau (2023).

References

[1] Wu Yong. Digital Design of CNC Aluminum Strip Winding Machine [D]. Master's Thesis, Harbin University of Science and Technology,2005:4-5.
[2] Dai Xiaohua, Wang Wen et al. A review of research on open CNC systems [J]. Combination machine tools and automated machining Technology, 2000, (11):5-7.
[3] Zhou Zude, Wei Renxuan, Chen Youping. The Current Status, Trends, and

Countermeasures of Open Control Systems [J]National Machinery Engineering, 1999, 10 (10): 1090-1093

[4] Chen Honglin, Niu Xiaoming. Design of Automatic Control System for High Frequency Welding Spiral Fin Tube Production Line [J]. Automation Technology and Applications, 2002, 21 (4): 18-20

[5] WANG N H. The application of PLC in Bag Precipitator Controlling. Proceeding of the 4th International Confi. On Applied Electrostatics. Dalian, 2001: 115-118.

[6] Wang Yuhan, Kang Liang, Wu Zuyu. Research on User oriented Configurable Open CNC System[J] Machine Tools and Hydraulics, 2000, (5):24-26.

[7] Guo Yongbo. Research and Development of CNC Aluminum Strip Winding Machine [D]. Master's Thesis, Harbin University of Science and Technology,
2007:4-6.

[8] Cai Lan, Wang Xiao. Numerical Control Processing Technology [M]. Beijing: Chemical Industry Press, 2006:56-68.

[9] Wu Jun, Wang Yuehong, Ma Qingxin. Development direction and trend of CNC machine tools [J]. CNC machine tool market Field, 2008, (3):76-79.

[10] Ma Wensuo, Zheng Wenjie, Li Song'an. A simple aluminum fin heat dissipation tube winding machine [J]. Research and development,2001，(10):23-24.

[11] Sun Zhiyong, Zhao Yanjiang. Numerical Control and Electronic Control Technology [M]. Beijing: Machinery Industry Press, 2002:123-128.

[12] Fu Jianxun, Wang Haiyan. Processing principle and process analysis of aluminum finned heat dissipation tubes [J]. Mechanical engineering Teacher, 2005, (7):79-80.

[13] DONG S. Torque and Current Control of High-speed Motion Control Systems with Sinusoidal-PMAC Motors. IEEE/ASME Transactions on Mechatronics, 2002: 18-22.

[14] Lu Zesheng. Process Automation Control [M]. Beijing: National Defense Industry Press, 1999:173-186.

[15] Er Guihua, Dou Yuexuan. Motion Control System [M]. Beijing: Tsinghua University Press, 2006:15-18.

[16]SERGEY E L. Nonlinear Control of Servo-systems Actuated by Permanent magnet Synchronous Motors[J]. Automatic, 1998, 34(10): 1231-1238.

[17] Xu Xu, Che Yanbo. Motion controllers and their applications in modern motion control systems [J]. Machine tools and Hydraulic. 2007, 35 (7): 155-157