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Research Article

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Research and Application of Mold Circulating Cooling Water System and Energy Saving Technology for Hot-Stamping Production Line

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Abstract

Hot stamping production line is a key way to lighten the weight and improve the strength of automobile body. The mold circulation cooling system plays an important role in hot stamping production, which directly affects the performance and cooling effect of formed parts. This study aims to explore the research and application of the modification and energy-saving technology of the mold circulating cooling water system in hot stamping production line. By analyzing the design characteristics of the cooling water system, the structure is optimized to improve cooling efficiency and reduce energy consumption. An automotive parts company introduced new equipment and retrofitted the existing system to improve efficiency and reduce energy consumption. The results of the study showed that the retrofitted system increased cooling efficiency by 20%, reduced energy consumption by 15%, and achieved a significant improvement in the performance uniformity of formed parts. In addition, automatic switching between steel and aluminum plates further reduced production costs. The study shows that optimizing the cooling water system structure and applying energy-saving technologies are crucial for improving productivity, reducing energy consumption and achieving green production.

Keywords: Hot Stamping, Die Cooling System, Circulating Water System, Monitoring System, Low Energy Consumption

1. Introduction

Hot stamping production line is an important way to realize automobile lightweighting and improve the strength and safety of the body [1]. The mold circulating cooling system plays a vital role in hot stamping production line, which directly affects the cooling and quenching effect and performance uniformity of formed parts [2]. In order to improve the efficiency of hot stamping production line and energy saving and environmental protection, the mold circulating cooling water system and energy saving technology become the main target of research. The design of the die circulating cooling water system is crucial for hot stamping production lines. By analyzing the design characteristics of the cooling water system, the design process of the cooling water channel is divided into key aspects such as cooling water channel arrangement, cooling water channel size, cooling water flow rate, and cooling water temperature. In addition, the structure of the cooling water system is optimized to improve cooling efficiency and reduce energy consumption.

This study aims to explore the research and application of the modification and energy saving technology of the mold circulating cooling water system in hot stamping production line. An automotive parts limited company introduced brand-new cooling towers, chillers and other equipment into its Chao Kou base, aiming to improve the system efficiency and reduce energy consumption by remodeling the existing circulating and chilled water systems. The remodeling project described in this paper includes a comprehensive range of equipment installation and piping remodeling construction.

1.1 Hot Stamping Forming Strengthening and Cooling System

One of the key technologies of hot stamping is the process control of forming-cooling reinforcement. For a typical hot forming steel such as 22MnB5, the critical cooling rate must be >27°C/Sec. for rapid cooling in the die after heating automatization. As shown in Figure. 1, the hot blank heat is transferred to the mold during hot stamping [3]. The temperature of the mold is also non-uniform during the forming process. The mold wipes out the cooling water channel, and the cooling water from the inlet to the outlet, the temperature will increase along the way, as shown in Figure 2.

During hot stamping and forming, the die plays a vital role in rapidly reducing the part temperature by extracting energy from the hot blank. During the cooling process from 800°C to 180°C, the die needs to absorb about 380 kJ/kg of thermal energy. As shown in Figure 3, if a water-cooled mold is not used, a "hot spot" may form after a few hot stamping cycles, which may result in the affected area of the part blank not reaching the necessary hardness [4]. Maintaining a relatively constant cooling rate in the mold during the molding cooling cycle is a critical issue in mold design and manufacturing. Conventional methods include incorporating cooling water channels within the mold to regulate the cooling of the molded part and the phase change of the material. By monitoring the water temperature difference (Tx) and water flow rate (q) between the inflow and outflow of cooling water into and out of the mold, the heat flux can be quickly calculated. This calculation is then used as a parameter to control the water flow rate to achieve the goal of regulating the mold cooling rate.

Figure 1: Temperature Distribution in the Die, °C [3]

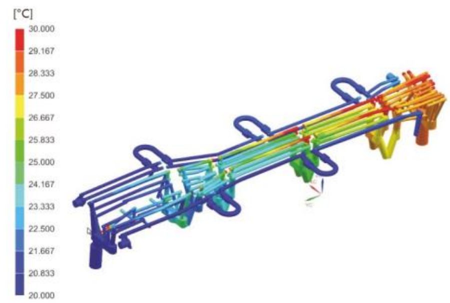

Figure 2: Temperature Distribution in the Die Cooling Channels, °C [3]

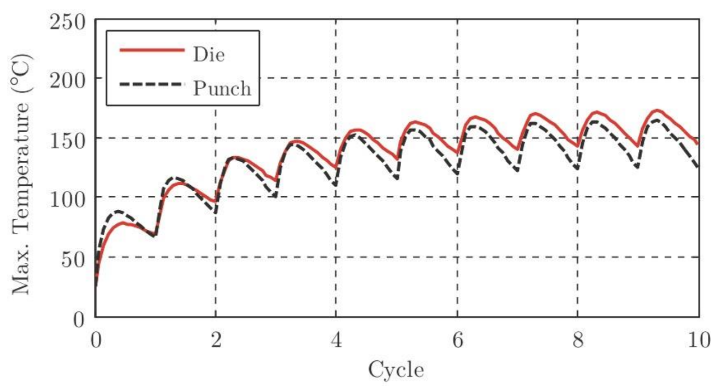

Figure 3: Temperature Variation in a Fixed Beat Continuous Hot Stamping Die

1.2 Efficient Circulating Water-Cooling Equipment

The scope of the study covers a number of areas, such as the construction of equipment and facilities for additional air compressor circulating water systems, pump frequency conversion for existing pump houses, equipment modification for additional circulating water chilled water systems, and rooftop cooling tower replacement. The system design is aimed at meeting the site process requirements and improving the energy saving level, and realizes the efficient operation of the system through the reasonable settings and control strategies of the chiller units, chilled water pumps and other equipment.

1.3 Variable Frequency Permanent Magnet Motor Drive System

Ordinary pumps usually use fixed-frequency motors, running at a fixed speed, cannot adaptive adjustment according to the actual needs of the system, so the energy utilization rate is relatively low. The inverter pump is equipped with a frequency converter, which can adjust the speed of the motor, thus automatically adjusting the water flow and water pressure according to the actual needs of the water to achieve the effect of constant pressure, and this automatic adjustment function makes the inverter pump energy-saving compared with the ordinary pump, and its principle is shown in Figure 4.

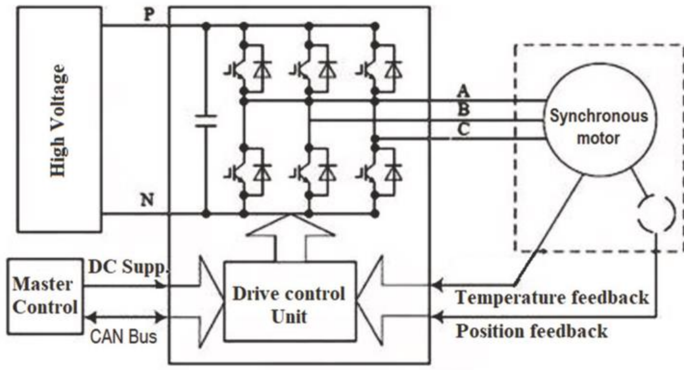

Figure 4: Schematic Diagram of Variable Frequency Permanent Magnet Motor Drive Control System

According to the requirements provided by the owner, the designed system flow rate is 320m3/h and the temperature is 32℃. The main equipment includes inverter screw chiller, chilled water pump and so on. The system design pursues energy saving, all fans and power equipment selection of energy efficient products, well-designed control strategy to ensure system operating efficiency. High-efficiency circulating cooling system equipment shown in Figure 5. The high and low temperature water connected to the mold in the tube heat exchanger, and the low-temperature water conveyed by the cooler for heat exchange, which in turn reduces the water temperature at the end of the mold piping. The water in and out of the mold is in a closed recirculating loop, which reduces the problem of scale generation in the waterways of the mold at high temperatures. Circulating water reduces water consumption.

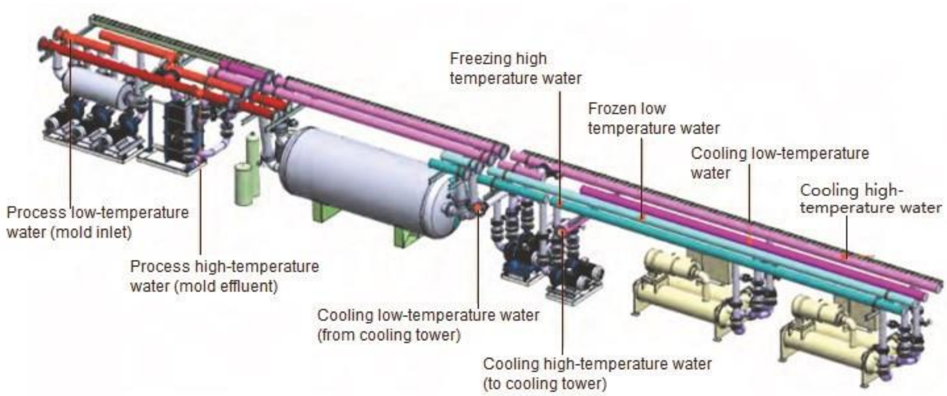

Figure 5: Hot Stamping Production Line Molds (Including Multi-Line Molds) Efficient Circulation Cooling System Equipment

1.4 Monitoring System Based on Industrial Internet

The design and installation of remote control and monitoring system is one of the key points of this project. The system needs to have a number of functions, including real-time operation status display, remote start/stop, equipment monitoring, fault alarm, etc. Through remote centralized control, the entire cooling system can realize intelligent operation, improve production efficiency and monitoring convenience. The system can be customized or extended with the following monitoring data:

• System parameter monitoring: circulating water/chilled water temperature, circulating water/chilled water flow rate, water quality parameters (such as PH value, conductivity, dissolved oxygen, etc.), equipment operation status (such as pumps, valves, compressors, etc.), system pressure, ambient temperature and humidity, and power supply lightning protection status.

• System control: start/stop and speed adjustment of circulating water/chilled water pumps, opening and closing of valves, start/stop and load adjustment of compressors, control of heaters and dehumidifiers, alarms and troubleshooting. Setting and adjustment of system parameters Circulating water and chilled water remote control and monitoring system can be realized in the following ways: 1) Monitoring and controlling the operating parameters of precision air-conditioning and general airconditioning using intelligent interface, such as return air temperature, return air humidity, chilled water in and out temperature, etc. 2) Use PLC digital acquisition gateway and communication protocol to realize the automatic control of circulating water and chilled water system, such as frequency conversion constant pressure water supply.

• Industrial Internet cloud platform connection: realize remote monitoring and data collection, real-time display and record various parameter change curves, and alarm notification for abnormal faults.

2. Application Results and Cases

2.1 User Requirements

Welding process circulating water: According to the feedback of circulating water flow from the site, there is one circulating water pump that can meet the process demand, with circulating water parameter Q=320m3/h and inlet/outlet water temperature 28℃/35℃.

• Air compressor circulating water: new air compressor circulating water parameters Q = 40m3/h, inlet and outlet water temperature 32/42 ℃.

• Refrigeration machine circulating water: new refrigeration machine circulating water parameters Q = 206m3 /h, cooling water in and out of the water temperature

• 32 ℃ / 37 ℃; the original refrigeration machine circulating water parameters Q = 150m3 /h, cooling water in and out of the water temperature of 32 ℃ / 37 ℃.

2.2 New System Design

According to the original condition provided by the owner and the technical requirements provided by the water supply and drainage profession: the circulating water flow rate is 320m3/h, the temperature is 32℃, and it needs to be cooled down to 28℃ by the chilled water connected to the plate exchange, and the total load is calculated to be 1488kw. □ adopted a frequency conversion screw chiller, cooling capacity Ql = 272.6RT (958.6KW); set up two chilled water pumps, one of which is running, the other standby. The new refrigeration system is connected in parallel with the original system and then connected to the original/new plate heat exchanger respectively.

• The chilled water pump and chiller are connected in series and then in parallel; when adding machine, the corresponding chilled water pump is started first and then the chiller is turned on; when reducing the machine, the chiller is turned off first and then the corresponding chilled water pump is turned off, and the corresponding motorized butterfly valve of the chiller is turned off.

• The chilled water adopts primary pump variable flow system, and the chilled water pump adjusts the flow rate according to the differential pressure at the end by frequency. Differential pressure sensors are set at the end of the most unfavorable loop. When the sensed value exceeds the set value, the controller adjusts the frequency to reduce the flow rate of the water pump and vice versa. In order to protect the pump motor, the pump must not exceed the maximum design flow rate.

• The design parameters of chilled water are 7℃ for water supply and 12℃ for return water.

2.3 Efficiency Improvement

Due to the adoption of frequency conversion screw chiller, the chilled water adopts primary pump variable flow system, which can automatically adjust the water pressure and pump flow through the end water differential pressure sensor data according to the actual water flow needs of the hot stamping production line. The COP of the chiller unit is 5.87>4.94, which meets the requirements of Article 3.2.9 of GB55015-2021; the IPLV of the chiller unit is 8.5>7.00, which meets the requirements of Article 3.2.11 of GB55015-2021.

An automobile manufacturer adopts the above research results to optimize the circulating cooling water system of the molds and other auxiliary equipment of the hot stamping production line. After the modification, the cooling efficiency of the inverter screw chiller increased by 20%, the energy consumption was reduced by 15%, the performance uniformity of the molded parts was significantly improved, and the production cost was further reduced. The frequency conversion screw chiller can realize the optimized distribution of energy consumption, making the cooling curve closer to the ideal state, thus improving the overall energy-saving effect. In conclusion, the research on the mold circulating cooling water system and energy-saving technology of hot stamping production line is of great significance for improving production efficiency, reducing energy consumption and realizing green production.

3. Conclusion

This study focuses on the research and application of the modification and energy-saving technology of the die circulating cooling water system in hot stamping production lines, and significant results have been achieved by optimizing the design of the cooling water system and introducing energy-saving technology. The variable frequency screw chiller has obvious advantages in energy saving compared with traditional refrigeration equipment. The modified system has achieved satisfactory improvement in both cooling efficiency and energy consumption, with cooling efficiency increased by 20% and energy consumption reduced by 15%. These improvements not only increase productivity, but also significantly enhance the performance uniformity of the molded parts and further reduce production costs.

Initiatives to introduce new equipment and system optimization, such as the introduction of brand new cooling towers, chillers and other equipment, as well as the modification of existing systems, have brought substantial benefits to the hot stamping line. Through the intelligent operation of the monitoring system, production efficiency was improved while monitoring convenience was enhanced. This comprehensive retrofit solution demonstrates the importance of the application of energy-saving technologies and the optimization of the cooling water system structure, which provides strong support for companies to achieve green production and economic benefits.

Therefore, the results of this study show that by optimizing the cooling water system structure and applying energy-saving technologies, production efficiency can be effectively improved, energy consumption can be reduced, and the goal of green production can be achieved. These results are not only of positive significance for the automobile manufacturing industry, but also provide useful reference and inspiration for other industries in terms of energy conservation and environmental protection.

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