Research and Application of High-Performance Conveying System for Multilayer Chamber Furnace Hot Stamping Production Line

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Abstract. High-strength steel/high-strength aluminum hot stamping production lines are popularized around the world. In addition to presses, the conventional key equipment is mostly roller bottom continuous heating furnaces or multi-module multilayer chamber furnaces, as well as the supporting production line automatic conveying system. With the needs of small batch customization and flexible manufacturing, multilayer chamber furnaces are also developing towards high-beat, multi-layer and multi-module to meet the challenges of production requirements. In this paper, based on the research and application of the high rigidity and high-speed in-and-out system of the 11-layer multilayer chamber furnace heating furnace, the progress of the automation technology of the new generation of hot stamping production line is described.

Keywords: Hot stamping · High-strength steel · High-strength aluminum alloy · Automatic conveying · Intelligent manufacturing

1 Introduction

Lightweight technology is one of the key technologies to achieve energy saving and emission reduction in automobiles, and high-strength steel hot stamping technology can greatly reduce weight while ensuring the safety of automobiles. Under the condition of hot stamping, the material has good plasticity and formability, and the forming load is greatly reduced, which can form complex hot stamping parts at one time and eliminate the effect of springback, and improve the accuracy of parts [1]. The advantages of high-strength steel hot stamping technology have made it develop rapidly and considerably once it is introduced.

So far, the hot stamping forming process of high-strength steel has mainly focused on many aspects such as billet heating, forming, quenching and cooling, variable strength forming, hot stamping forming of new materials, friction and wear between die and billet, and numerical simulation technology of the whole process. Heating the billet to the austenitizing temperature is the first step in the hot stamping forming process. The heating temperature and holding time determine the mechanical properties and microstructure

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composition of the parts after subsequent quenching and cooling. The heating methods generally include radiation heating, conductive heating, induction heating and contact heating. The most widely used method at this stage is to use the radiation heating furnace method to heat the billet. The radiation heating method is more suitable for the hot stamping forming process of AlSi coated high-strength steel to ensure the coating performance and the welding performance after forming.

As the beat of the production line continues to increase, the number of box-type heating furnaces also continues to increase. As a result, the number of layers of the box-type heating furnace continues to increase, and the Z-direction (vertical) movement stroke of the feeding and discharging manipulator continues to increase. Faced with the challenges of the hot stamping industry, the research and development of high-performance blank conveying systems requires updating the original traditional structure, improving the structural rigidity of the system, and improving the agility and stability of the movement.

2 Multilayer Chamber Furnace and Conveyor System

This multi-layer box furnace has good air tightness and batch flexibility, and is suitable for new mold tests, new processes and material tests without moving mechanism in the furnace. There is no contact friction between the billet and the furnace bottom; the floor space is reduced by more than 50%. Since each furnace floor is an independent motion control system, each furnace has the advantage of working in parallel, but when a furnace fails, the control system can automatically change the process to avoid shutdown accidents. The conveying system of the multi-layer box furnace production line is more complicated than that of the roller hearth furnace, so the rhythm of the production line is lower than that of the roller hearth furnace production line [3]. The multi-layer box furnace production line is equipped with modules according to the production capacity, generally two modules, and a few systems consist of three modules, as shown in Fig. 1.

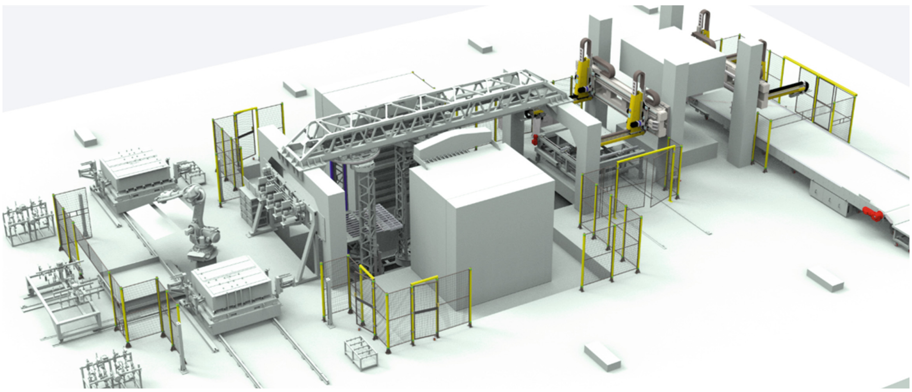

Fig. 1. Hot stamping line with high-performance conveying system for multi-layer chamber furnace.

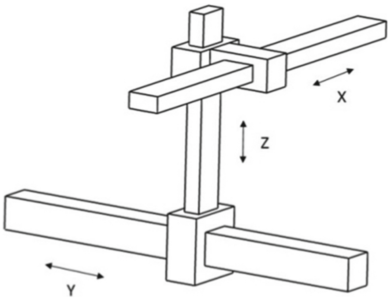

Fig. 2. Definition of the motion direction of the cartesian coordinate manipulator.

2.1 Automatic Conveying System

In the design scheme of the conveying system for thermoforming blanks, one of the schemes can use multi-joint robots and mechanical jaws to realize the loading and unloading of heating furnaces and presses [4], which has the advantages of flexible path planning, stability and reliability. Another solution is to use the Cartesian coordinate manipulator, which is more common in industrial manipulators, which has the advantages of high motion accuracy and reliability in three-dimensional space, especially high linear conveying speed. Since the production line has a complete path for straight conveying, the Cartesian coordinate manipulator is a reasonable choice to realize the hot and cold blank conveying system of the thermoforming production line.

The general principle of the Cartesian coordinate manipulator is shown in Fig. 2. The more complex and comprehensive Cartesian coordinate manipulator has six degrees of freedom, including three rotational degrees of freedom. In this study, based on the general Cartesian coordinate manipulator, a new set of Cartesian coordinate manipulators are designed through structural optimization. Part of the structural model is shown in Fig. 3. Generally, the Cartesian coordinate manipulator adopts a single-degree-of-freedom single-stroke, and the optimized Cartesian coordinate manipulator adopts the structure of single-degree-of-freedom double-stroke (i.e., double-speed) in many places in the linear motion direction. This research mainly focuses on the kinematic analysis of the optimized Cartesian coordinate manipulator and the research on the cooperative work strategy of multiple manipulators.

2.2 High Rigidity and High Speed Feeding and Discharging Conveying System

In the conventional multi-layer box furnace, the "material fork" is used to enter and exit the furnace: the material fork supports the blank into a certain layer of the heating furnace. After the blank falls on the guide rail in the furnace, the material fork is driven by the manipulator to leave the furnace. Prepare for the next process. The reclaiming action is that after the fork enters the furnace, it lifts up the heated billet and leaves the furnace under the operation of the manipulator. There is a rotary action for both incoming and outgoing materials, and at different furnace layer heights, the rotary and lifting form a compound motion, and the Z-direction moves and performs R-rotation. When the furnace layer is continuously increased (11 layers in this case), the rigidity

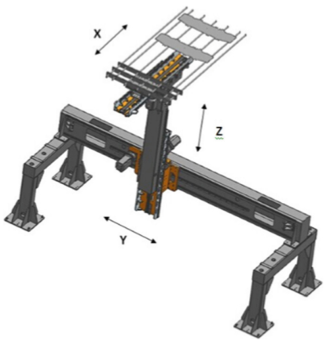

Fig. 3. The structure model of the conventional cartesian coordinate manipulator.

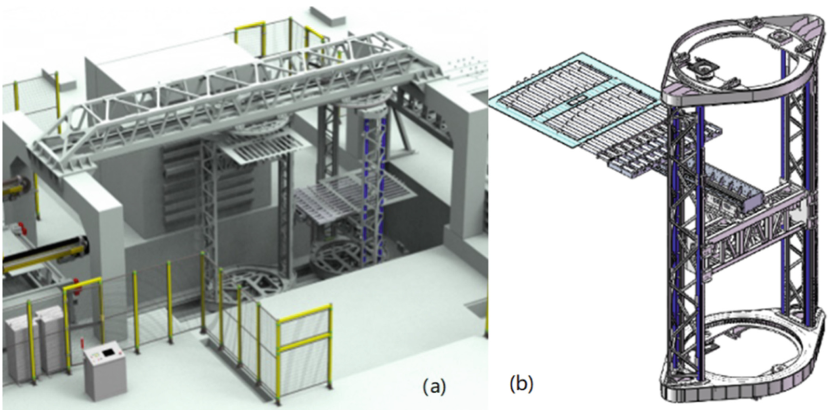

Fig. 4. High-rigidity and high-speed feeding and discharging conveyor system: (a) Two sets of feeding and discharging systems in Y-axis, (b) Dual-guided Z-axis feeding and discharging system.

of the conventional single-column rotary mechanism is insufficient, and it is difficult to maintain the balance between rapidity and stability, as shown in Fig. 3.

This study adopts a double-column (Z-axis) guide structure with movable supports at the upper and lower ends to ensure the basic stability and motion rigidity of the fork movement. The upper and lower guide rail support structure includes the mechanism of Z-direction rapid movement and rotary movement, as shown in Fig. 4.

3 Structural Features and Technical Parameters

There are two sets of feeding and discharging manipulators for 2 multi-layer box furnaces, A and B. Its structural features are: the Z axis is vertical, the effective stroke is 3500 mm, the rated speed is $V_z = 0.98$ m/s, and the maximum speed is $V_{zMax} = 1.96$ m/s. The entire feeding and discharging mechanism faces the direction of the press, the effective stroke of the Y-axis is 4500 mm, the rated speed $V_y = 1.47$ m/s, the maximum speed $V_{yMax} = 2.94$ m/s; the effective stroke of the X-direction double-speed telescopic shaft of the fork entering and leaving the furnace is 2800 mm, and the stroke in the furnace is 2800 mm. 1850 mm, rated speed $V_x = 1.97$ m/s, maximum speed $V_{xMax} = 3.94$ m/s; rotation rated angular speed $\omega_r = 92.82$ degrees/s (large ring gear), maximum angular speed $\omega_{rMax} = 185.64$ degrees/s, maximum turning radius R = 1850 mm. When not extended, the radius of gyration is 1500 mm, when fully extended, the radius of gyration is 3500 mm.

The double-column (Z-axis) guide structure improves the rigidity of the structural system, improves the stability of the Y-direction fork movement, and avoids the difficulty of the Z-direction single-end support structure. With the Z-direction of the feeding and discharging manipulator, the stability decreases. The Y-direction mechanism for entering and leaving the furnace is designed with high rigidity and light weight, which lays the foundation for improving the long stroke and high-speed movement of the furnace.

Two sets of feeding and discharging mechanisms cross and avoid the movement in the X direction, and perform feeding and discharging operations for the two 11-layer box-type heating furnaces A and B, and the conveying cycle can be less than 13 s. The heating time for a typical AlSi coated panel is 330 s with a cycle time of 15 s. The heating time for the uncoated panel was 300 s and the cycle time was 14 s.

The maximum blank size that can be satisfied is 2000 mm × 1800 mm, and the maximum load-bearing blank weight is 30 kg. The minimum size of the blank that can be gripped and conveyed is 330 mm × 100 mm.

4 Conclusion

The feeding and discharging system of the high-performance box heating furnace, from the research of structural innovation and high-precision automatic control requirements, realizes the 15 s cycle time (SPM) of the thermoforming production line. Among them, the double-guided Z-axis structure and the upper and lower double supports of the Y-axis motion system control the guided motion, which play a key role. The system has been put into use, and it is planned to further optimize the strategy according to the actual engineering needs to improve the stability and agility of the control system.

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