Research and Application of Multi-layer Box Furnace for High-Performance Sheet Metal Hot Stamping Production Line

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Abstract. The hot stamping forming process of high-strength steel mainly focuses on the key processes of billet heating, forming, quenching and cooling, and heating the billet to austenitizing temperature is the key technology of the hot stamping forming process. In view of the high requirements for workpiece support in the multi-layer box furnace (9–11 layers), in order to ensure its reliability, we cooperate with relevant units to develop heat-resistant ceramic support tubes. In the case of satisfying the structural stability and service life, the hollow tube structure is compared with the solid core ceramic structure, the heating furnace heats up faster, and the overall structure weight is reduced. Through a large number of tests, it not only ensures the reliability of its life, but also the cost is much lower than that of traditional heat-resistant steel. At the same time, the weight of each furnace bottom is reduced. During the service life, the deformation tendency of the furnace bottom is effectively reduced, and it can be used for high-strength steel. Forming of steel, high-strength aluminum alloy sheets - production or trial of reinforced parts.

Keywords: Hot stamping · Multi-layer box heating furnace · Lightweight thermal insulation material · FIFO queue management

1 Introduction

So far, the hot stamping process of high-strength steel has mainly focused on many aspects such as billet heating, forming, quenching and cooling, variable strength forming, hot stamping 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 composition of the parts after subsequent quenching and cooling [1]. The selection of heating process parameters and strategies needs to be determined according to the test results. The 22MnB5 billet can be completely uniformly austenitized by holding at 950°C for 3 min, and a complete martensitic structure can be obtained after final quenching. The heating methods generally include radiation heating, conductive heating, induction heating and

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contact heating. The most widely used method at this stage is the use of radiation heating furnace to heat the billet.

Multi-layer box furnace production line This multi-layer box furnace has good air tightness and batch flexibility, and is suitable for new mold testing, new technology and material testing; no 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 [2].

2 Structure and Material of Multi-layer Box Heating Furnace

The multi-layer box heating furnace breaks through the serial heating mode of the roller hearth heating furnace, and adopts the independent parallel heating working mode, which has the characteristics of small footprint, low energy consumption, flexibility, etc., and no moving mechanism in the furnace avoids Defects of roller hearth furnaces. In order to seek a multi-path heating process management strategy for the multi-layer box heating furnace, the relationship between the energy consumption of the heating furnace and the production batch and the energy consumption optimization strategy should also be considered under the conditions of considering the basic influencing factors. The problem of orderly heating of the multi-layer box heating furnace has improved the flexibility and automation level of the multi-layer box heating furnace.

2.1 Overall Structure Design of Multi-layer Box Heating Furnace

The furnace door of the multi-layer box furnace is frequently opened and closed, which affects the temperature uniformity in the furnace. The flexible design of the furnace door opening mechanism, the thermal energy supplementation in the furnace zone and the intelligent temperature control are the key technologies to ensure the temperature uniformity in this type of furnace. Online monitoring and control of the protective atmosphere (including dew point parameters) in the furnace to reduce the oxidation of the uncoated sheet during the heating process is the key technology for this type of furnace to use the uncoated sheet to produce hot stamping parts (Fig. 1).

2.2 Supporting Structure Material of Multi-layer Box Heating Furnace

In view of the high requirements for workpiece support in the multi-layer box furnace (9–11 layers), in order to ensure its reliability, we cooperate with relevant units to develop heat-resistant ceramic support tubes. In the case of satisfying the structural stability and service life, the hollow tube structure is compared with the solid core ceramic structure, the heating furnace heats up faster, and the overall structure weight is reduced. Through

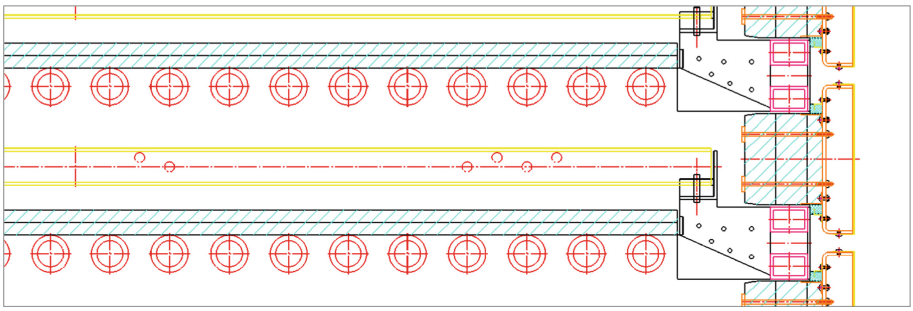

Fig. 1. Furnace layer structure, heating element and furnace door structure.

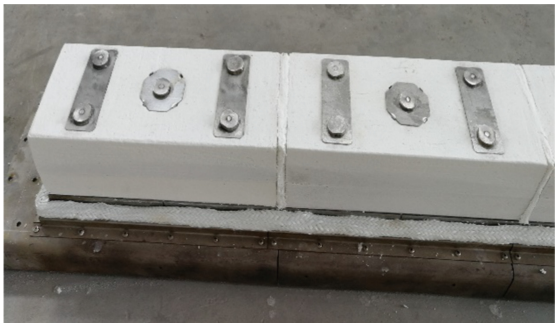

Fig. 2. Lightweight ceramic fiber refractory insulation material.

a large number of tests, it not only ensures the reliability of its life, but also the cost is much lower than that of traditional heat-resistant steel.

The whole furnace is designed with lightweight refractory insulation materials. The furnace door, furnace wall, furnace roof and other parts of the box furnace are designed with lightweight ceramic fiberboard products and aluminum silicate fiber blankets. The electric furnace has the advantages of energy saving, quick start, uniform furnace temperature, and excellent dynamic and static characteristics of temperature control (Fig. 2).

2.3 Furnace Door Mechanism

The furnace door of the multi-layer box furnace is controlled by a numerical control manipulator, and the selection of furnace layers and the control of the rhythm are precisely realized by the numerical control system. Therefore, how to improve the radiation conduction efficiency by further optimizing and reducing the height of the furnace, using high-quality lightweight thermal insulation materials and heat-resistant material furnace structure, and completely closed furnace door, so that the heating efficiency is high.

3 Multi-furnace FIFO Process Control

There is no moving mechanism in the hearth of the box furnace, which makes the internal structure simple and easier to manufacture. The sheet material is not used in the box furnace, which is beneficial to reduce the surface wear of the sheet material and maintain the surface quality. Box furnaces are divided into single-layer box-type furnaces and multi-layer box-type furnaces. Single-layer chamber furnaces are used for pilot lines due to low production efficiency. The multi-layer box furnace improves the production efficiency and can be used in large-scale production. The temperature control of different furnace chambers of the multi-layer box furnace is basically independent of each other and is distributed. It cannot ensure that all furnace chambers have the same temperature, which may cause fluctuations in the performance of the final product. This problem needs to be solved by certain control methods [3].

The orderly scheduling of the furnace is a necessary condition to ensure the orderly operation of the production line. Due to the limitation of the hot stamping process, the heating cycle of the billet in the heating furnace is determined, so the billet that enters the heating furnace first must reach the "heating completed" state first. Therefore, the furnace management adopts 5 FIFO queues, which are the empty furnace queues, heating furnace queue, heating completed furnace queue, heating timeout queue, and exit queue, as shown in Fig. 3. Combining the queue with the finite state machine, for the furnace, the queue is its current state. The trigger condition of the furnace transition queue is the input event of the state transition. State and queue are basically equivalent. The normal working furnace consists of cold billet feeding into the furnace (FFR.b and F.a), heating time limit (F.b) and hot billet taking out of the furnace (F.c and FUR.a) 3 trigger events in empty furnace queue, heated furnace queue, heating complete Circulation in the furnace queue. When the billet stays in the furnace for longer than the maximum heating time limit, the furnace enters the heating timeout queue. If a furnace appears in the heating timeout queue, the production process control system instructs the FUR and PFR robots to perform a scrap removal operation to empty the furnace. The furnace then enters the empty furnace queue and enters the normal production cycle again. In order to minimize the output fluctuation of the production line caused by the furnace hearth being occupied

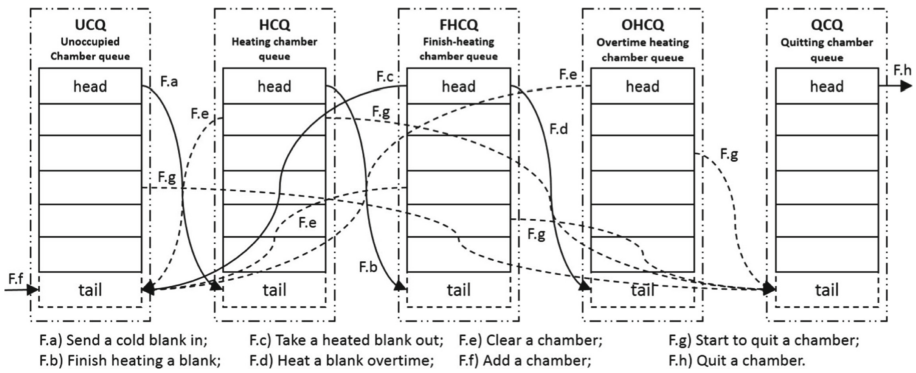

Fig. 3. Chamber queues and scheduling.

by scrap, the operation of removing scrap from the furnace hearth in the furnace queue for heating overtime will take priority over the operation of adding hot material.

4 Conclusion

Just like the advantages of lightweight and high-strength technology brought to the structure of automobile body, the research and development and design of lightweight furnace lining hot stamping box heating furnace makes the electric furnace have the advantages of energy saving, furnace temperature uniformity, excellent temperature control characteristics, and rapid heating and start-up. Excellent performance. The density of the furnace lining is only 1/7 of the known inlet line, the heat capacity is low, and the furnace surface temperature rise is low. For the proposal of dual carbon, it has brought the development and progress of effective energy technology in the main energy consumption process of automobile manufacturing. The heating time of the electric furnace is 1.0 h, while the known inlet line is 20 h. This performance effectively solves the contradiction of production capacity under the difficult conditions of the country with insufficient power at this stage. The furnace temperature uniformity of the light lining is much better than that of the heavy lining, and the temperature difference in the furnace is only 1/3–1/5 of the heavy lining. Excellent temperature control dynamic and static characteristics, can quickly achieve furnace temperature control goals, reduce furnace temperature overshoot, overshoot, and undershoot.

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