Research on Servo and Drive System of Hot Stamping Mechanical Servo Press

X. Fang(✉), J. Chen, W. Zhang, and W. Li

Jiangsu Xuzhou Metal Forming Machine Group Co., Ltd, Xuzhou 221116, China
727851852@qq.com

Abstract. The hot stamping mechanical servo press adopts the driving and control technology of high-torque direct-drive servo motor and high-speed heavy-load screw drive system, which reduces the driving chain, improves the overall driving efficiency and control accuracy of the press, and improves the dynamic response characteristics. Meanwhile it can follow the shrinkage of the parts dynamically according to the change of pressure and position, perfectly match the requirements of the hot forming process.

Keywords: Hot stamping · Servo · Press

1 Introduction

The hot stamping technology of high strength steel plate is to heat the special steel plate (boron alloy steel plate with tensile strength of 400–600 MPa at normal temperature) to the austenite temperature range, quickly move to the mold, fast stamping, quench and cool the parts through the mold in the pressure retaining state of the press, and finally obtain the ultra-high strength stamping parts (The strength is 1500 MPa or higher).

After the hot blank is put into the mold, the hot blank should be stamped immediately, so as not to affect the formability of the steel plate too much. After forming the mold to close the mold pressure for a period of time, on the one hand, in order to suppress the rebound, control the shape of the parts, on the other hand, the use of cooling channel set in the mold to quench the steel plate, so that the parts form uniform martensite structure, obtain good dimensional accuracy and mechanical properties.

The hot forming press is one of the key equipment in the process realization, which is responsible for the hot forming and quenching process. At present, the presses in nearly 100 hot stamping production lines worldwide are provided by several European suppliers, such as Sweden AP&T Company, Germany SCHULER Company, etc., and they are all hydraulic machines. However, because the traditional hydraulic press does not have the function of fast closing and stamping, the rapid hydraulic press developed for hot forming alone has high cost, noise and high energy consumption. And traditional eccentric type mechanical press because of the transmission system adopts the basic structure of the crank connecting rod type, the top dead center on the mechanical structure and the bottom dead center, so can't according to the change of pressure and position, dynamic

Y. Zhang and M. Ma (Eds.): ICHSU 2022, AHMST 2, pp. 433–438, 2023.
https://doi.org/10.2991/978-94-6463-114-2_58

following parts contraction continues to pressure, ensure parts joint state, improve the quality of parts, can not meet the requirements of hot stamping process. Therefore, we need a new press solution that can match the requirements of hot stamping process and avoid the disadvantages of the existing hot stamping hydraulic press.

2 Technical Solution

High-speed development of the servo press in recent years, due to cancelled the flywheel and clutch, brake, ac synchronous servo motor to replace the traditional ac asynchronous motor direct drive, and USES the digital control system, can make the slider at any position in the process of running speed adjustment, the movement of the slider and the positioning accuracy is high, has the characteristics of flexibility, high speed and high efficiency. The application of mechanical servo press directly driven by servo motor has just entered the field of hot stamping production.

After analyzing and studying the process curve of hot stamping (Fig. 1), it is concluded that the digital mechanical servo press does not need hydraulic power system and its energy consumption is greatly reduced. By adopting pure mechanical transmission structure, it can realize flexible and precise control of slider displacement, speed and output pressure, and its motion and control characteristics are very beneficial to realize hot stamping process. Therefore decided to adopt the servo drive system as the main driving parts, at the same time in order to avoid the disadvantage of traditional hydraulic press and the traditional mechanical press can not meet the requirement of the hot stamping process, the shortcomings, the main drive system decided to take the form of mechanical transmission type hydraulic press, that is to abandon the traditional mechanical press crank connecting rod type basic mechanical structure, The linear reciprocating mechanical transmission structure of hydraulic press is adopted. Finally, the servo drive system with high flexibility, high response, high precision and low energy consumption is formed as the power source, and the linear reciprocating mechanical transmission structure of the hydraulic press as the main implementation of the overall solution to meet the requirements of hot stamping forming process.

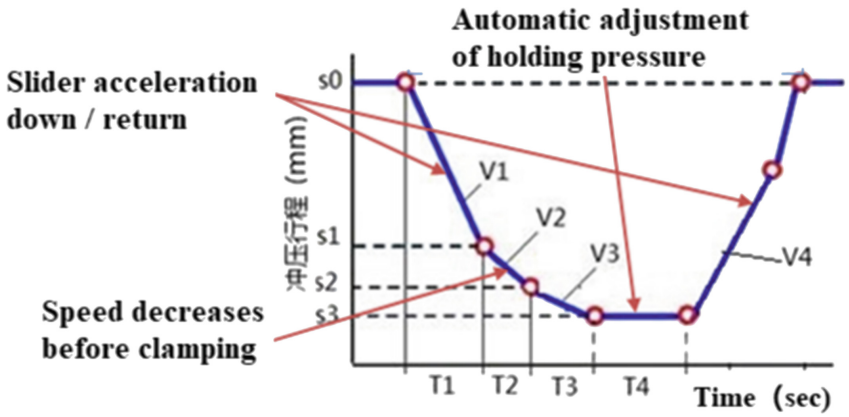

Fig. 1. Curve of hot stamping process.

3 Servo and Drive System

Servo is a feedback control system of mechanical displacement and acceleration. Its main function is to make the output mechanical displacement or rotation accurately track the input displacement or rotation. Servo drive technology represents the development trend of forming machine tool industry in the future, with its high efficiency, energy saving, intelligent environmental protection, high precision and high stability and other functions will bring revolutionary change and development to the forming machine tool industry.

The core of servo drive system is ac synchronous servo motor with high capacity and large torque. At present, the servo drive system used in the servo press mainly has two kinds of solutions, one is the use of high speed servo motor matching reducer for torque output; The other is to use a specially designed low speed and high torque servo motor to directly output torque.

If the first scheme is adopted, due to the limitation of output torque of servo motors, it is bound to adopt multiple servo motors for synchronous drive. In the preliminary work, the driving system scheme of 6000 kN hot-forming servo press adopts multiple drivers to drive multiple high-speed servo motors in parallel, and the parallel shaft reducer is connected with the press screw through multiple inputs. The disadvantage is that the meshing clearance of multiple gear pairs increases the difficulty of manufacture and joint adjustment and affects the control accuracy and smoothness of press. When the mechanical rigidity is insufficient (the drive chain is long), especially under the different load stroke of the slider, the drive control system can not synchronize the motion caused by the error of the motor and the drive system. It is difficult to realize the precise synchronous control of the motor with high load only by the drive control. The motor movement load is not synchronous due to the difference of mechanical rigidity between each motor and deceleration system, which affects the control accuracy and efficiency, and loses part of driving energy. Therefore, it is necessary to study the low speed and high torque servo motor direct drive system to reduce the transmission chain and lift the overall control precision and response characteristics of the press.

The plan now is associated with professional motor manufacturers developed hot forming machinery dedicated 45000 nm low speed servo press direct-drive servo motor, drive adopts the more powerful the common dc bus parallel drive technology, has better dynamic performance and control characteristics, overcome the more caused by the gear pair meshing clearance can not synchronous motor drive, The difficulty of accurate synchronization of multiple motor loads can not be realized only by motion control, and the control precision of speed, position and pressure is ensured.

4 Main Drive and Mechanical Transmission System

The forming and quenching process in hot stamping process is a kind of parallel process, which not only requires the continuous and stable pressure keeping of dynamic parts according to the change of pressure and position, but also puts forward the nearly harsh standard of dynamic response time of machine tool 0.1 s. At present, the fastest response time of hydraulic press and crank press at home and abroad is more than 0.2 s, see Fig. 2.

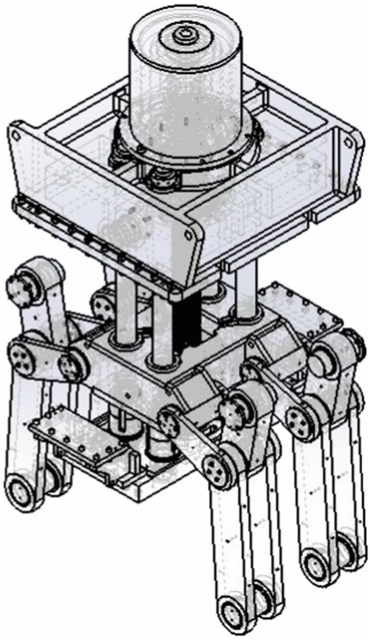

Fig. 2. Drive and mechanical transmission system.

After analysis and study, the main drive system decided to adopt the linear reciprocating mechanical transmission like hydraulic press, that is, the transmission structure of heavy load sliding screw pair and optimized multi-point elbow mechanism is the first one in China. The input torque of the servo motor is greatly reduced by the addition of the elbow mechanism, and the equivalent driven inertia of the optimized transmission parts on the screw is reduced from 76 kg·m^2 to 61 kg·m^2, which greatly improves the dynamic characteristics of the servo motor and reduces the cycle time. Including overloading sliding screw pair is the core component of the main transmission system, thread of linear velocity is greater than 4 m/s, and the current domestic manufacturing of the screw nut linear velocity are less than 2 m/s, in the long run, prone to wear and fatigue invalidation through the processing method, heat treatment process, and analyzed the structure of lubrication, Solve the problem of reliability and stability.

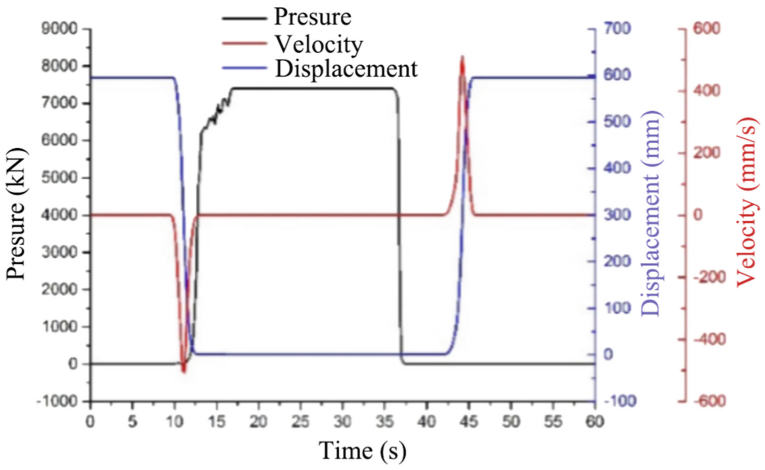

Fig. 3. Real time state diagram of motion and pressure.

5 Conclusions

Practice has proved that the hydraulic press type linear reciprocating mechanical execution structure, which is composed of innovative high-speed heavy load sliding screw and four sets of towing mechanism, with low speed and high torque servo drive system as the core, realizes the optimization of transmission chain and improves the overall transmission efficiency, control accuracy and dynamic response of the press. The equivalent moment of inertia of the transmission system is reduced by 25%, the transmission efficiency is increased by 6.8%, and the acceleration time is shortened from 0.6 s to 0.25 s. The design of high speed and heavy load sliding screw and towing rod structure improves the movement speed of the slider when no load (speed is more than 800 mm/s) and reduces the input torque of the servo motor. At the same time, the design also improves the repeated positioning accuracy of the bottom dead center (0.01 mm), and realizes the position tracking and torque compensation of the bottom dead center when holding pressure in the process of cold shrinkage. According to the change of pressure and position, the slider can dynamically track the shrinkage of parts, ensure the fitting state of parts, improve the quality of parts, fully meet the requirements of hot stamping process, as shown in Fig. 3.

References

1. X. Fang, Z. M. Ke, L. Dou, X. Y. An and L. Wang, Application of mechanical servo press in hot stamping production line, in *International Conference on Advanced High Strength Steel and Press Hardening,* (Hefei, China, 2018).
2. L. Wang, B. Zhu, Q. Wang and Y. S. Zhang, Modeling of hot stamping process procedure based on finite state machine (FSM), *International Journal of Advanced Manufacturing Technology* **89**, 857 (2017)

3. L. Wang, X. Y. An, B. Zhu, Y. L. Wang and Y. S. Zhang, Research on intelligent process and production method of hot stamping, in *International Conference on Advanced High Strength Steel and Press Hardening,* (Xian, China, 2016).
4. Q. Wang, L. Wang, Y. S. Zhang, L. M. Yao and Z. M. Ke, Mechanical link servo press on hot stamping line, in *International Conference on Advanced High Strength Steel and Press Hardening,* (Changsha, China, 2015).