Research and application of hot stamping line based on digital mechanical servo presses

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This paper discusses the research and application of hot stamping production line based on digital mechanical servo press. With the improvement of automobile lightweight and safety performance requirements, the wide application of high-strength steel parts has become the development trend of automobile manufacturing industry. Hot stamping forming technology has become an important choice to meet the requirements of high-strength steel body structure parts due to its forming performance and complex configuration forming ability. However, the traditional hot stamping line still has some challenges in meeting the requirements of forming high-strength steel parts. The new generation of hot stamping production line is based on digital mechanical servo press, adopting advanced hot stamping forming technology and automated conveying system, which is able to meet the demand for hot stamping processing of large and complex high-strength steel body parts made of high-strength steel materials, and to improve the production efficiency and product quality.

Keywords: High-strength steel; Hot stamping; Servo press; Automatic transmission; Roller hearth furnace.

1. Introduction

With the continuous improvement of automobile lightweight and safety performance requirements, the wide application of high-strength steel parts has become the development trend of the automobile manufacturing industry. Hot stamping and forming technology has become an important choice to meet the requirements of high-strength steel body structure parts due to its excellent molding performance and ability to form complex configurations [1]. However, the traditional hot stamping line still has some challenges in meeting the requirements of high-strength steel parts forming, including the limitations of forming quality, production efficiency and product consistency. For this reason, the research and application of the new generation of hot stamping lines is particularly important [2].

Mechanical servo-driven presses offer the flexibility, speed and position control characteristics of hydraulic presses with the speed, accuracy and reliability of mechanical presses [3]. Servo-driven presses have the ability to improve the metal forming process conditions and productivity, and a hot stamping line based on a 6000 KN mechanical servo press-multi-layer box furnace has been built in 2014 [4]. Through the excellent motion control performance of the servo press, the study was carried out to optimize the hot stamping process [5]. From the hot stamping of high-strength steel materials, industrial and hot stamping forming equipment progress, in recent years has made great progress. From

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the traditional fast hydraulic press bit the main equipment of the production line, began to move towards the digital mechanical servo press based on the digitalization of the hot stamping production line, the road of information, and become an important technical case of automotive lightweight high strength steel hot stamping production.

The purpose of this paper is to discuss the research and application of a hot stamping line based on a digital mechanical servo press, and to explore its potential impact on the production of high-strength steel parts by analyzing the key technologies involved in this line. In addition, this paper will summarize the progress of current research and look forward to the potential application of this technology in the future automotive manufacturing industry.

2. New generation hot stamping line

The new generation hot stamping line is an innovative line based on digital mechanical servo presses with advanced hot stamping and forming technology and automated conveying system, which is capable of meeting the demand for hot stamping of high-tensile steel materials for large and complex high-tensile steel body parts, and improving production efficiency and product quality. The innovative line consists of three key components: a digital mechanical servo press, a low-energy short-line roller-heating furnace, and a digital servo automated transmission system. Together, these components revolutionize the hot stamping process, enabling the increased precision, efficiency and quality required for the hot stamping of high-strength steels, as well as multi-component integrated hot stamped parts.

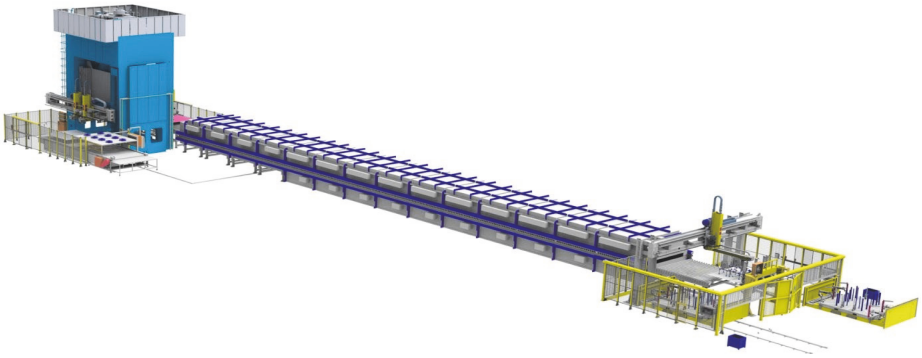

Fig. 1. Digital mechanical servo hot stamping line

3. Key technology studies

3.1. *Digital mechanical servo hot stamping presses*

With the in-depth promotion of Industry 4.0, digitalization and intelligence have become an inevitable trend in the development of machinery manufacturing. As the core equipment of the stamping process, the stamping press is also experiencing the transformation from the traditional hydraulic type to the digital mechanical servo type. This paper will focus on

the development status of digital mechanical servo hot stamping press, technical characteristics and its application prospects in industrial production.

Digital mechanical servo hot stamping press is a new type of press integrating digitalization, Informa ionization and intelligence. It adopts advanced digital servo technology, characterized by high precision, high efficiency and high reliability, and can be widely used in automobile manufacturing, home appliance production, metal product processing and other fields. Compared with the traditional hydraulic press, the digital mechanical servo hot stamping press has the following significant advantages: first, the digital mechanical servo hot stamping press has higher stamping precision and more stable stamping effect. Due to the digital servo technology, the motion control precision of the press can reach 0.01mm, which ensures the high precision and quality of the stamped parts. Secondly, the digital mechanical servo hot stamping press has higher productivity and lower energy consumption. The machine adopts advanced automation control system, which can realize one-button operation, significantly shortening the production preparation time and operation time, and improving the production efficiency. Meanwhile, the energy consumption of the machine is about 30% lower than that of traditional hydraulic presses due to the adoption of advanced energy-saving technology.

For the drive below 10000KN, as shown in Figure 2a, is jointly developed with professional motor manufacturers of thermoforming machinery dedicated 45000nm low speed servo press direct drive servo motors, the drive adopts a more powerful general purpose DC bus shunt drive technology, with better dynamic performance and control characteristics, to overcome the problem of the motor cannot be synchronized due to the gear pairs of the mesh gap is too large to drive the motor, only by the Motion control can not achieve accurate synchronization of multiple motor loads, and to ensure the control accuracy of speed, position and pressure [6].

For the main drive motor of the 12000KN servo press, as shown in Fig. 2b, four servo motors are used to drive the spindle in parallel by coupling through a gearbox to realize the low-speed and large-torque output required by the press, as well as the required force-energy output characteristics.

In short, digital mechanical servo hot stamping press is one of the important achievements of the current digital transformation of the machinery manufacturing industry. It integrates digitalization, Informa ionization, intelligence in one, with high precision, high efficiency, high reliability, low energy consumption, low maintenance costs and other advantages, can be widely used in various manufacturing fields. With the in-depth promotion of Industry 4.0 and the continuous development of intelligent manufacturing technology, digital mechanical servo hot stamping press is expected to play a more important role in the future, providing strong support for the transformation and upgrading of the manufacturing industry.

In order to adapt to the hot stamping forming parts scale increases year by year, the die width also synchronously increase the need, the press adopts a wide table design, the size of the table 1.

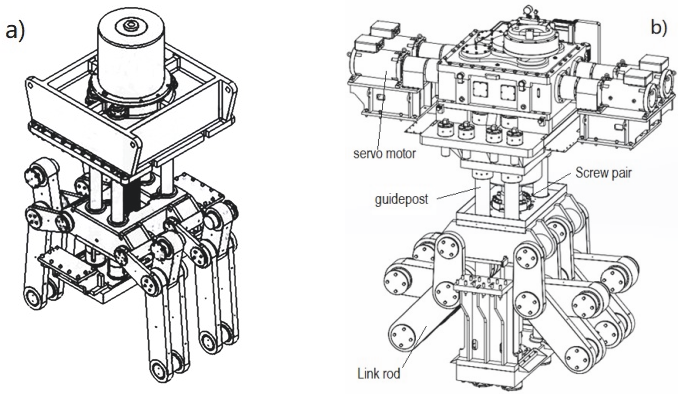

Fig. 2. Main drive system of a digital servomechanical hot stamping press with single motor drive (2a) and multi-motor parallel drive (2b)

Table 1 Main parameters of 12000KN digital mechanical servo presses

Name (of a thing)	Parameters
Nominal pressure KN	12000
Table top size (left/right/front/rear) mm	3600 x 2500
Slide stroke mm	1000
Maximum mold height, mm	1300
Mold height in mm	400
Number of slide strokes (max.) SPM	0-14 (fast down 1000mm/s)
Main motor power KW	267x4
External dimensions, mm	5200x3800x12000
Overall fuselage stiffness	1/8000

In order to adapt the new presses to the stamping of multiple parts in one die, as well as to the stamping of integrated gates with multiple parts, it is necessary to increase the working surface of the press. With a larger press table, the actual deformation of the large-table press base is greater in absolute terms when loaded under the same stiffness conditions. At the same time, the uneven loading of a die with multiple parts will lead to an increase in the deformation of the die base, which will lead to a decrease in the parallelism of the mold clamping surface, resulting in a decrease in the pass rate of the product due to poor mold clamping. In order to meet the requirements of stamping large molds with multiple parts in one die and integrated gates, the rigidity requirements of the press body will be higher, from 1/8000 to 1/12000, and the special rigidity requirements of the press can be customized according to the type of hot stamped products.

The main drive system of the servo press adopts servo motor as the driving force, through the vertical deceleration mechanism and the heavy-duty screw vice, the rotary motion of the motor is transformed into the axial motion, and finally, through the four-elbow rod mechanism, the motion of the press slide is driven (see Fig. 2b). Multi-motor synchronous drive (see Figure 3), is through the gearbox coupling drive, driving the vertical screw vice, to achieve the press slide of the functional movement in all directions.

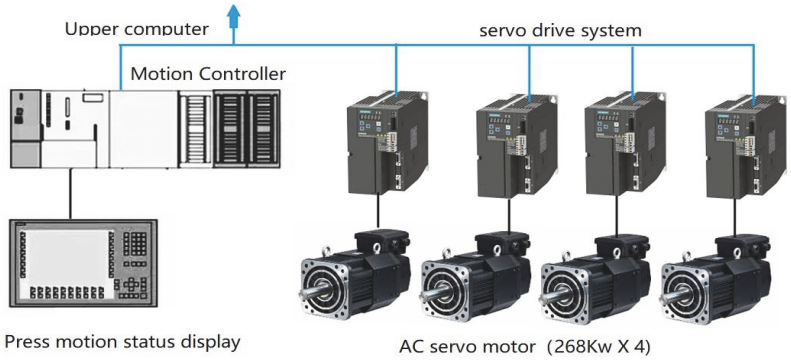

Fig. 3. Schematic diagram of multi-motor synchronous drive

Digital mechanical servo hot stamping press is an advanced technology that can be programmed to control its slide motion as shown in Figure 4. Where, S0-is the press slider upper dead center; S3-slider movement lower dead center.V1-slider fast downward; V2-slider deceleration; V3-close mold forming; V4-slider fast return.T1+T2is the time of slider downward; T3-start time of molding; T4-pressure holding time.

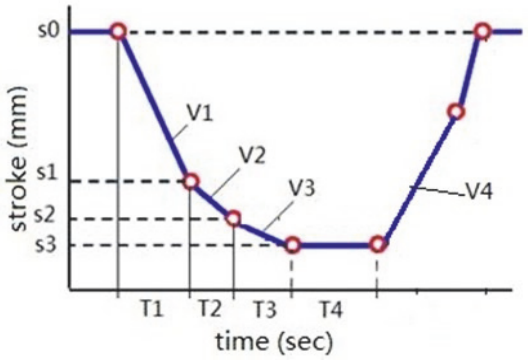

Fig. 4. Servo control of slide motion speed and stroke of servo press [4]

It is possible to program the movement of the press slide (and upper die) according to different hot stamping and forming process parameters to obtain the best process specification for the formability of high-strength steels, in order to reduce the risk of cracking during the sheet in-line process, and also to control the optimum holding pressure and holding time, thus having the potential advantage of realizing an intelligent process [7].

3.2. *Roller bottom heating furnace*

Roller bottom heating furnace is widely used in metal material heating equipment, with obvious advantages, but also has some shortcomings. Firstly, it can realize uniform heating of the billet to ensure the consistency and stability of the material during processing. Secondly, compared with other heating methods, the roller bottom heating furnace usually has high energy consumption. In addition, it is through the precise temperature and time

control, the furnace body heating area is equipped with five partitions, can realize the temperature zoning control and gradient heating, to realize the precise control of the heating process, to meet the heating needs of different materials.

However, roller-hearth furnaces have some disadvantages, such as high energy consumption in some cases, which requires improved technology to reduce energy costs. In addition, under certain circumstances, roller-hearth furnaces may have difficulty in achieving a completely uniform heating of the workpiece, which may affect the quality of the product. In addition, roller-hearth furnaces typically require high maintenance costs for upkeep and repair.

In order to improve the heating efficiency and to reduce the energy consumption, the roller bottom heating furnace was analyzed for heat loss with a view to discovering the factors responsible for high energy loss. According to the literature analysis [8], it was found that the thermal radiation from the outer surface of the roller-heating furnace, lost energy consumption, accounted for 30% of the total energy consumption of the heating furnace. The actual test results of the new roller bottom heating furnace showed that, in addition to thermal short-circuit areas such as the furnace mouth, the maximum temperature of the shell is not higher than the ambient temperature above +40 ℃ at the limit temperature of the furnace. Corresponding measures, is the use of high adiabatic properties of lightweight insulation materials, do the furnace wall of the outer layer of the insulation layer. Secondly, shorten the total length of the heating furnace to reduce the exterior area of the furnace body to reduce heat dissipation.

In addition, advanced heating control system is adopted to realize precise control of heating temperature, time and zone to improve heating uniformity. Finally, a more durable and easy-to-maintain heating furnace structure is designed to reduce maintenance costs and extend equipment life. Through these improvements and innovations, the roller bottom heating furnace can better meet the needs of hot stamping production.

The tail end of the roller transmission furnace adopts servo blocking + servo centering and jacking mechanism, which can ensure that the position of the blocker and the centering device can be adjusted through the recipe during the production change without the need to adjust individually each time, thus saving the time of the production change and improving the effective production utilization rate of the line, as shown in Fig. 6.

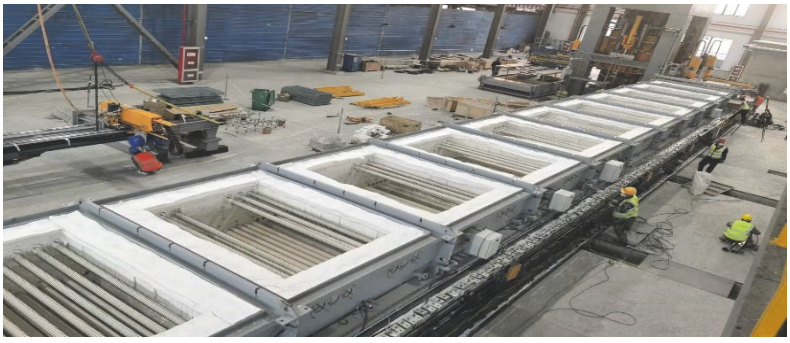

Fig. 5. Heating furnace insulation and components installation process

Fig. 6. Digital servo blocking system at the discharge end of the heating furnace

3.3. *Automatic transmission system*

The automatic conveying system plays a key role in hot stamping lines, realizing automated conveying and positioning of blanks and formed parts to improve production efficiency and product consistency. Starting from the charging end of the heating furnace, the whole heating process realizes automatic conveying. The automatic conveying system that dismantles the stomp and feeds the blanks into the heating furnace is shown in Figure 7.

After being conveyed and heated by the roller-heating furnace, the blanks arrive at the discharge end and are guided by the digitally controlled positioning table - after lifting, they are picked up by the press loading manipulator and conveyed directly to the molds of the press. In order to adapt to the needs of different molds, the press loading manipulator transmission system, designed with ± 90 ° horizontal rotation function, for the original design for the "straight-through arrangement" and "L-type arrangement" of the production line of molds, can be applied to, for the production of the flexibility brought about by the expansion of the scope of application, the press loading manipulator conveying system. Expanding the range of applications, as shown in Figure 8.

Fig. 7. Automatic transmission system for dismantling and heating furnace feeding

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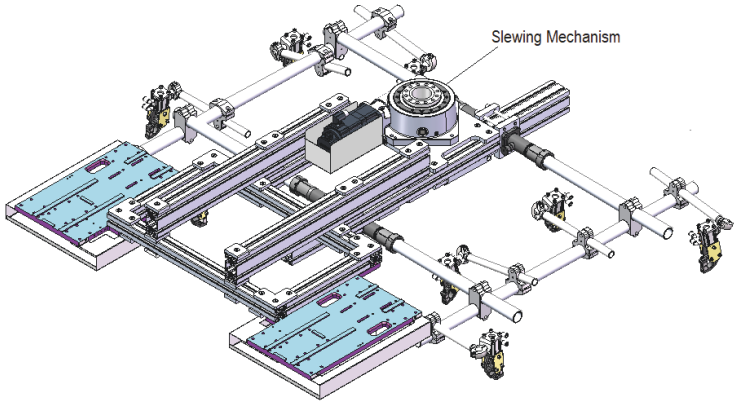

Fig. 8. Hot billet loading robot and rotary end pickup mechanism

Fig. 9. Automatic transmission system for discharging and loading materials

4. Application of hot stamping lines

The hot stamping line based on digital mechanical servo press has been successfully applied to the production of hot stamped parts made of high strength steel for automobile body. The main line adopts L-shape arrangement (see Fig. 9), and at the same time it is equipped with rotatable end pick-up mechanism, which can be applied to the molds originally designed for the "straight-through arrangement" and "L-shape arrangement It can be applied to the molds originally designed for "straight through arrangement" and "L-arrangement" production lines.

The production line can run from 10 to 20 seconds. The blank size can be up to 2800X2300mm, The plate thickness range is 0.8-2.3mm. It can be applied to the hot stamping production of AlSi coated plates, zinc-based coated plates and uncoated plates, as well as laser spliced plates, which provides an advanced solution for the hot stamping processing of the new type of high-performance metal plates. The production line has been put into production application, in which one die with multiple production molds, as shown in Figure 10.

Fig. 10. Mold diagram for hot stamped products with multiple parts in one die

5. Conclusion

This paper investigates the key technologies and application prospects of a hot stamping production line based on digital mechanical servo presses. The new generation hot stamping production line covers digital mechanical servo press, roller-hearth furnace and automatic conveying system, which lays the foundation for the production of hot stamping process for new materials, and realizes the requirements of high strength steel hot stamping parts for the enhancement of processing accuracy, efficiency and quality. The digital mechanical servo hot stamping press will play a more important role in the future with its advantages of high precision, high efficiency, high reliability and low energy consumption. High-efficiency roller-hearth furnaces increase heating efficiency and reduce energy consumption through improved technology to meet the demands of hot stamping production. Automated conveying system realizes automatic conveying and positioning of blanks and formed parts, improving production efficiency and product consistency. The new presses have been successfully applied to the production of hot stamped parts made of high-strength steel for automobile bodies, providing an advanced solution for the hot stamping of new high-performance metal sheets. The application of these technologies will provide strong support for the transformation and upgrading of the manufacturing industry.

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