Research on hot stamping production line and digital twin system based on industry 4.0

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This article explores the application of Industry 4.0 concepts in the hot stamping production line and digital twin system, focusing on their role in lightweight automotive technology. It provides a detailed overview of key technological research in digital hot stamping production lines, including the application of digital mechanical servo presses and digital pump-controlled hydraulic presses, as well as the monitoring systems for hot stamping production lines and production processes. Additionally, it outlines the architecture of the digital twin system, covering real-time data collection and monitoring, digital simulation and modeling, intelligent analysis and prediction, production optimization, and intelligent decision-making. The article concludes with a discussion of closed-loop control based on big data modeling and intelligent decision-making, along with future research prospects. Through this exploration, the article demonstrates the potential application of digital production and intelligent control in hot stamping forming technology, driving the industry towards intelligent and efficient development.

Keywords: Hot stamping; Industry 4.0; Smart manufacturing; Internet of things; Digital twin.

1. Introduction

Lightweight technology is a pivotal factor in achieving energy efficiency and reducing emissions in the automotive industry. The hot stamping technology of high-strength steel plays a significant role in achieving lightweighting while ensuring vehicle safety. This technology leverages material plasticity and excellent forming properties to significantly reduce forming loads, enabling the production of complex stamped parts, eliminating the impact of rebound, and enhancing part accuracy [1].

The hot stamping direct forming process involves sequential steps such as dropping, heating, forming, quenching, cutting, and surface treatment to obtain the final part, and it is widely utilized in practical production. As high-strength steel materials and processes continue to advance, the development of hot forming equipment, particularly hot forming lines, has progressed rapidly [2].

The rise of customized production has necessitated the adaptation of hot stamping production lines to accommodate the "multi-species and small batch" production mode, which places greater demands on new materials, processes, and quality management.

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Consequently, there is a growing need for intelligent hot stamping forming processes and their control.

The amalgamation of digitalization and information forms the bedrock of intelligent manufacturing. In the initial exploration of hot stamping processes and test lines for high-strength steel, the focus was on the development of a digital hot stamping test line. In a groundbreaking achievement, the high-performance metal sheet forming team at Huazhong University of Science and Technology (HUST) introduced the world's first set of mechanical servo hot forming test lines in October 2011, equipped with a comprehensive digital monitoring and inspection system [3]. This pioneering initiative aimed to establish a stable hot forming test environment, facilitate access to materials, forming process parameters, and product quality data, thereby laying the groundwork for intelligent production. Furthermore, the Fraunhofer Institute in Germany unveiled an "Industry 4.0" compliant hot forming test line in May 2015, enabling the monitoring of the test process and tool data (Experiments, Tool, and Monitoring Technology) [4]. Similarly, Nippon Steel & Sumitomo Metals highlighted in their 2016 technical report the development of a test line to validate the technical characteristics of materials and components for automotive applications [5].

In a collaborative effort, Huazhong University of Science &Technology (HUST) and Dongguan Haust Automotive Parts Co. Ltd. achieved a significant milestone by jointly developing the world's first 6000KN digital mechanical press hot stamping line in 2014. Subsequently, they successfully completed the development of three additional 8000KN mechanical servo hot stamping lines, which were put into practical application in 2017 [6].

Industry 4.0 presents viable solutions for AI-driven mass production, automation, assembly, and processing. The data-rich I4.0 framework enables informed decision-making by harnessing the surplus data generated from diverse systems. The overarching operation of I4.0 can be categorized into multiple systems, encompassing emergency response systems, supervisory control, open-loop control, alarms, and monitoring systems. Each of these systems can be further divided into sensing, communication, and actuator modules to ensure the seamless and efficient operation of the industrial system [7]. This underscores the potential of integrating digital twin technology into industrial applications. Various initiatives have concentrated on incorporating digital twins into different stages of the product lifecycle, including design, production, forecasting, and equipment maintenance management. However, the ultimate objective is to leverage digital twins to enhance the reliability, flexibility, and predictability of the product production cycle. This paper aims to explore the utilization of a digital twin for hot stamping production to continuously optimize the production process, proactively maintain equipment, and continually process data. This research commenced in 2014, and by 2017, the holistic monitoring of the entire process was achieved, marking the initial step based on the concept of Industry 4.0. The current endeavor involves investigating the application of digital twin technology for hot stamping production systems, signifying a milestone in this paper.\

2. Research on key technologies for digitalized hot stamping lines

At present, two primary types of digital hot stamping presses are practically viable. These include the digital mechanical servo press and the digital pump-controlled hydraulic press. In China, an 8000KN servo hot stamping press was deployed and commenced production in 2017 [8]. Furthermore, in 2023, the pressure capacity of the digital mechanical servo hot stamping press had increased to 12000KN, as depicted in Figure 1. Additionally, in the research findings and applications by AP&T, the utilization of digital servo-motor pump-controlled servo-hydraulic pressure has also been demonstrated in test applications, as illustrated in Figure 2.

Fig. 1 XD12000KN Digital Mechanical Servo Hot Stamping Press

Fig.2 AP&T PHS 2.0 Servo Hydraulic Hot Stamping Press

In the hot stamping line system, the communication function of CPS (Cyber-Physical Systems) technology enables collaborative work between equipment, enhancing the flexibility and efficiency of the production process. CPS technology facilitates intelligent scheduling, fault prediction, and optimized decision-making in hot press line systems. Figure 3 presents a case study of an Industry 4.0-based thermoforming production line system and unit system application, showcasing the practical implementation of these advancements.

For hot stamping presses, the standard process encompasses rapid press slide descent, press forming, holding (cooling), and swift slide return. Digitized equipment can effectively regulate the stroke and speed of the press slide movement, a capability unattainable with conventional mechanical presses. Leveraging digitized mechanical structures, high-precision servo motors, and encoder detection enables servo presses to achieve exceptionally accurate control of forming position, thereby realizing high-precision forming processes.

Traditional valve-controlled hydraulic presses are still the primary hot stamping hydraulic presses today, but their slide position control accuracy is not as precise as that of mechanical servo presses. However, the new generation of digital pump-controlled servo hydraulic presses have the fundamental feature of digitalization by directly driving a closed-loop hydraulic pump through a servomotor. Although the forming position control accuracy and stability of "pump-controlled" digital servo hydraulic presses are slightly lower than that of digital mechanical servo presses due to micro-leakage in the hydraulic circuit system, digital control of the hydraulic pump, and the closed-loop characteristics of the hydraulic cylinder. Overall, digital mechanical servo presses excel in forming position control accuracy and stroke error compared to pump-controlled digital servo hydraulic presses. This implies that digital mechanical servo presses may be more suitable for processes that require high forming position control accuracy and stroke precision. After compensating for closed-loop hydraulics, pump-controlled digital servo hydraulic presses are better suited for higher pressure and holding force requirements. Research progress indicates that the control valves of the press's hydraulic system have been replaced by servomotors, allowing for complete electrical control of speed, position, and pressure. The prerequisite for intelligent manufacturing is the integration of digitalization and informatization, and the main drive system of the press should conform to CPS specifications. The main drive of mechanical servo presses consists of servo motors and a drive system, fully meeting CPS specification requirements. The new generation of pump-controlled servo hydraulic presses is also advancing along this line, achieving digitalized movement of the press cylinder through the closed-loop control of the servo motor-servo hydraulic pump and cylinder, thereby serving as the foundation for intelligent manufacturing equipment.

3. Monitoring systems for hot stamping lines and production processes

3.1. *Monitoring of hot stamping lines*

The digital mechanical servo hot stamping line monitoring system has been under research and development since 2014, as depicted in Figure 3. At Huazhong University of Science and Technology, Wang et al. devised a responsive control system for a 6000 kN servo-mechanical press [9]. They implemented a straightforward logic control with only two rules, as illustrated in Figure 5. This system allows the servo press to consistently apply downward displacement compensation at BDC (bottom dead center), ensuring improved cooling and quenching consistency by maintaining contact pressure between the die and the workpiece [10].

The roller bottom heating furnace and multi-chamber furnace, among the heating equipment in the hot stamping line, possess distinct characteristics and adaptability. Special control strategies need to be considered in the control system of the multi-chamber furnace.

Following a comprehensive analysis and evaluation of the manufacturing system, RIIMS (Rapid Iterative Improvement Manufacturing System) necessitates the manufacturing system to have rapid auto-configurability. This capability is crucial for deploying optimized production solutions, evaluating new solutions, and obtaining feedback for the next iteration. Runtime iterative optimization comprises two components: a manufacturing simulation system for scenario validation and automated configuration of the production line for the swift deployment of production scenarios [11].

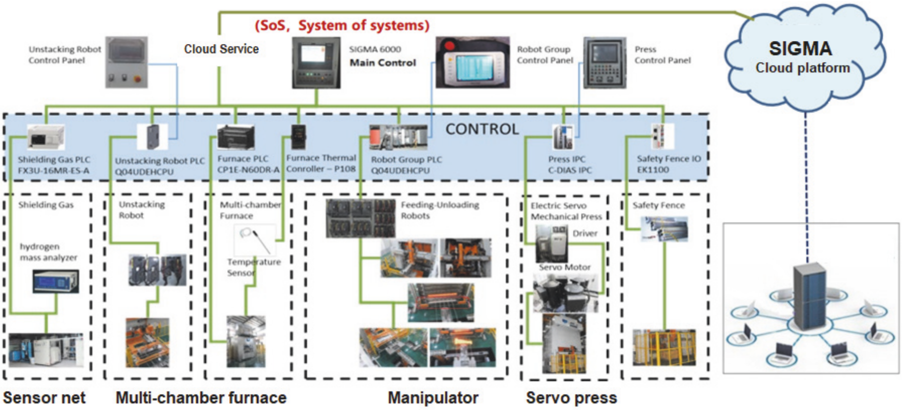

Fig. 3 Mechanical servo hot stamping line and monitoring system

The operational sequence of all equipment follows a rational time flow, theoretically resulting in the production of qualified parts. The objective of the production process control system is to regulate the timing of all equipment operations to ensure orderly production.

This hot stamping production system utilizes a distributed control framework, facilitating real-time exchange of production operation information via high-speed Ethernet. It comprises three primary components: production equipment (presses, conveyor robots, heating furnaces, etc.), production control system, and production support system, as depicted in Figure 4. Within this system, all control nodes possess autonomous control capabilities. They function as relatively independent unit systems that can communicate through the industrial Internet to achieve coordinated control behavior for executing instructions. Moreover, they engage in information exchange with other nodes, primarily production process control nodes, to facilitate collaborative operation and control.

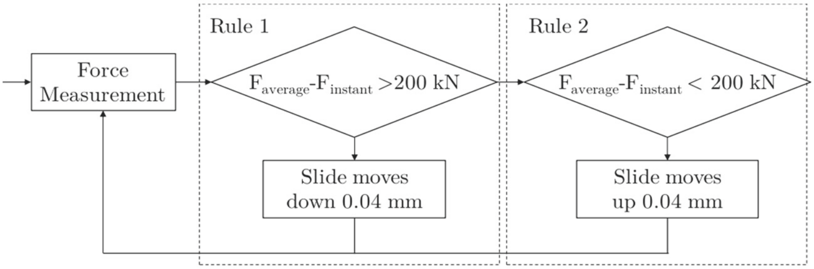

Fig. 4 Block diagram of servo-press force control system [9]

To substantiate the implementation of RIIMS, a straightforward case study is presented and summarized in Figure 5. The case study was conducted using the SIGMA hot stamping line in Dongguan, China, to illustrate the effectiveness of hot stamping in enhancing strength and reducing weight. In comparison to the traditional stamping process, the hot stamping process involves a significant change in heat and the high-temperature state of its blanks, albeit only during partial transportation. Given the nature of the hot stamping process and the requirement for automation, the automated conveyor systems and hot stamping equipment operate at high speed. In the event of a failure, the equipment may potentially cause damage to each other. The primary objective of applying RIIMS to hot stamping lines is to enhance the reliability and flexibility of the system to prevent accidents.

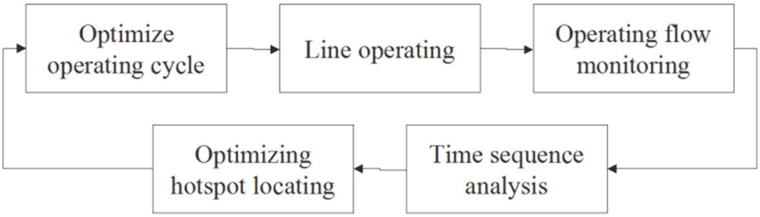

Fig. 5 Workflow of runtime iterative optimization [10].

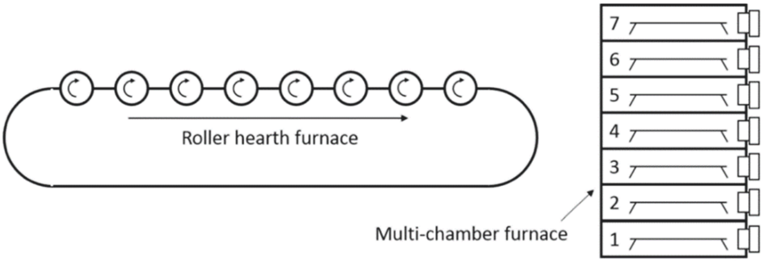

Fig. 6 Structure of roller hearth furnace and multi-chamber furnace

The multilayer chamber furnace introduces greater complexity to the automated system for feeding and discharging compared to the hot stamping line with a roller bottom heated furnace. Approximately ten to twenty small chambers enter the line, and each furnace door should operate in a sequential process, as depicted in Figure 6. It is essential to first outline the individual organization of each chamber and its proper coordination with downstream equipment. Subsequently, a scheduling strategy for all chambers needs to be devised to address the timing disparity between heating and molding. The production process entails heating and holding in a furnace, with cold and heated blanks transported via robots, including the Unstacking Robot (UNR), the Furnace Feeder Robot (FFR), the Furnace Output Robot (FUR), the Press Part Feeder Robot (PFR), and the Press Output Robot (PUR), as illustrated in Figure 7. Owing to the extensive range of equipment types and the intricate interplay between different equipment categories, the hot stamping process model must be adapted to manage the operation of the multi-chamber furnace and all the robots.

In this model, the operation of the heating furnace, press, and conveyor robots is segmented into finite states based on the hot stamping process. This entails defining the state transition rules for each manufacturing cell and the correlations between the cells. All finite state machine (FSM) cells are independent digital machine systems, where the output states are solely determined by input states and triggers.

The digital servo press, the automated system for feeding and discharging of the multi-chamber heating furnace and its door, and the automated conveyor system interconnecting all the unit equipment fully comply with the specification requirements of CPS (Cyber-Physical Systems) and the Industrial Internet, as depicted in Figure 7.

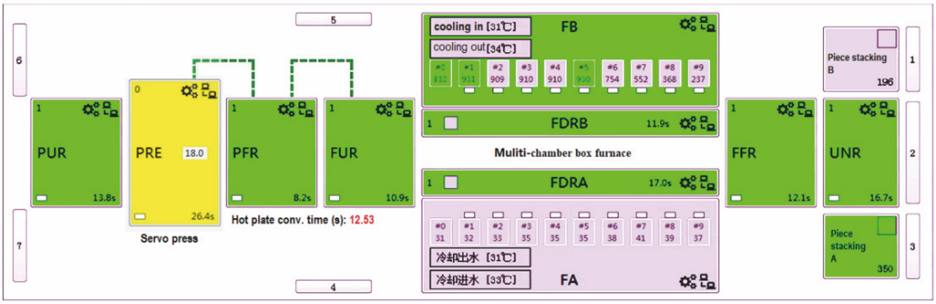

Fig. 7 Industry 4.0 based SIGMA thermoforming line and CPS unit system (1-Unloading hand unit, 2-servo press unit, 3-loading robot unit, 4-multi-chamber furnace and robot unit, 5- loading robot unit)

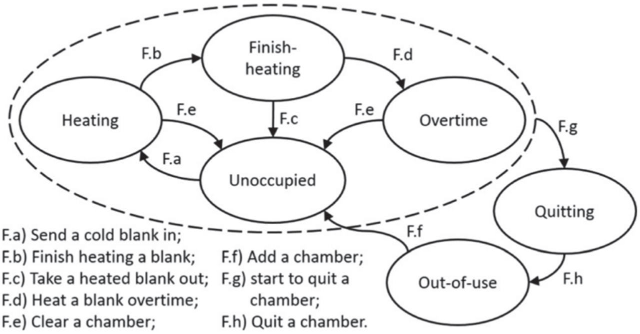

Fig.8 State transition of chambers

The chamber states progress through unoccupied, heating, and finish-heating phases. If the heating duration exceeds the specified limit, the blank inside will not meet the quality standards, leading the chamber to transition to the overtime state. Typically, the heating time limit is set at 20 minutes. In the event that a blank is heated beyond the time limit or encounters abnormal contact with the fork, the chamber must revert to the unoccupied state by unloading the defective blank, as indicated by trigger F.e in Figure 8.

3.2. *Real-time monitoring of production process*

The production process support system comprises a production process database, a production operation database, and a production analysis module. Factors influencing product formation and quality standards are continuously monitored by an autonomous "sensor monitoring network." This network operates independently, providing real-time data to the production process and beyond, irrespective of production line support system downtime, as depicted in Figure 9. For physical quantities that cannot be directly monitored by sensors, the "software sensor" approach has been employed to detect and calculate localized, small quantities using rational functional relationships. In cases where direct sensor usage is not feasible, "software sensors" have been utilized to detect localized, small quantities of physical parameters directly, and the overall measured physical quantity is calculated using rational functional relationships [12]. The solution to this challenge lies in a mechanical servo press with precise control of variable loads and positions, coupled with an intelligent control system supported by a big data planning model. The production process database (refer to Figure 10) records the actual or preset production process parameters of all production equipment in the line, corresponding to the configuration parameters of the equipment. This database provides the production process parameters of a specific product to the production control system, which then deploys these parameters to the production equipment [13]. Importantly, the database is hosted on a cloud computing platform and can be accessed via the Internet cloud platform system.

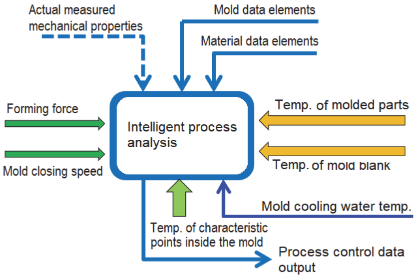

Fig. 9 Monitoring of many factors affecting hot stamping molds

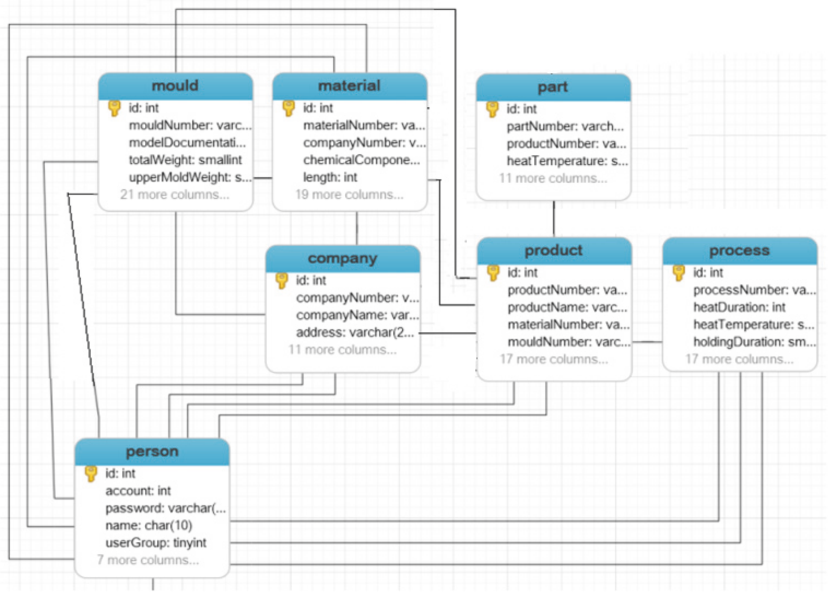

Figure 10 Production process database recorded by the data monitoring system

3.2.1. *Real-time monitoring and unit optimization control*

The hot stamping production line utilizes various sensor types for real-time monitoring and data acquisition of critical parameters, such as temperature, pressure, and speed. In the hot forming-reinforcement process, the mold plays a crucial role in rapidly reducing the part's temperature by extracting the energy from the hot blank.

During the cooling process from 800°C to 180°C, the mold is required to absorb approximately 380 kJ/kg of thermal energy. Failure to use a water-cooled die can lead to the formation of "hot spots" after several hot stamping cycles, potentially resulting in the affected area of the part blank failing to achieve the necessary hardness, as elaborated in Figure 11 [14]. Maintaining a relatively constant cooling rate of the mold during the forming-cooling cycle is a pivotal concern in mold design and manufacturing. The traditional approach involves incorporating cooling water channels within the mold to regulate the cooling of the formed part and the material's phase change. By monitoring the water temperature difference (Tx) and water flow rate (q) of the mold's cooling water inflow and outflow (refer to Fig. 12 for specifics), the heat flux can be promptly calculated. This calculation is then utilized as a parameter for controlling the water flow rate, thereby achieving the objective of regulating the mold's cooling rate.

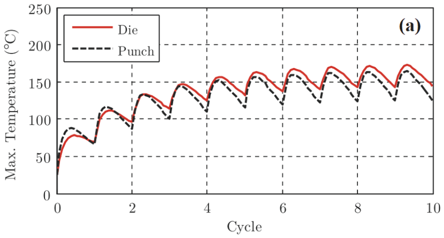

Fig. 11 Mold temperature variation for continuous hot stamping with fixed beats

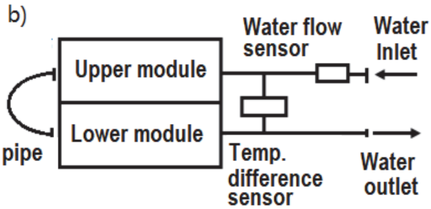

Fig. 12 Cooling system water temperature and flow rate monitoring

The mold cooling waterways are equipped with water temperature sensors and flow meters at the inlet and outlet, facilitating the detection of temperature differentials and flow rates of the incoming and outgoing water by the hot stamping line's monitoring system. Calculation provides the heat dissipation energy of the mold, enabling adjustment of the water flow rate to maintain the temperature differential between the hot formed part material and the mold, thereby ensuring that the proportion of phase change martensite in the formed part approaches 100%. In cases where the initial working temperature of the mold is found to be excessively low (e.g., due to ambient temperature changes), the system automatically delays the activation of the cooling water until the mold temperature reaches a preset value, thus minimizing unnecessary energy consumption. During hot stamping production, the hot sheet material transfers substantial heat to the mold, leading to a rapid increase in mold temperature. The mold's cooling waterways expel the accumulated heat through a specific flow of cooling water. To expedite the transfer of heat from the sheet to the cooling water, hot stamping dies are typically constructed from die steel with high thermal conductivity, necessitating specific water pressure and flow rates for cooling. A long-cycle intelligent control model (refer to Fig. 13 for specifics) is employed to illustrate the optimization method for intelligent control over the long hot stamping process [15]. By leveraging real-time temperature data and synchronizing the mold to regulate the control temperature at different production stages (refer to Figure 14a), the correlation between mold cooling water temperature and production stages is depicted in Figure 14b.

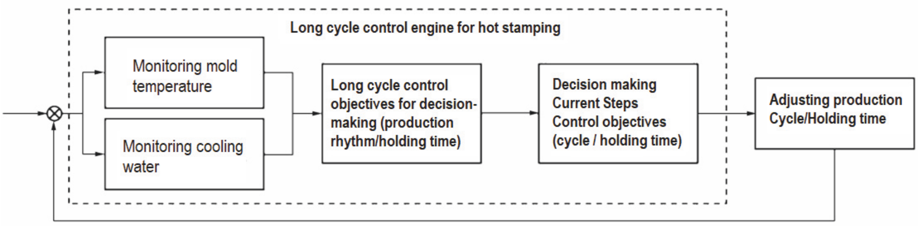

Fig.13 Optimization method of long-period intelligent control in hot stamping production based on physical sensing data [15]

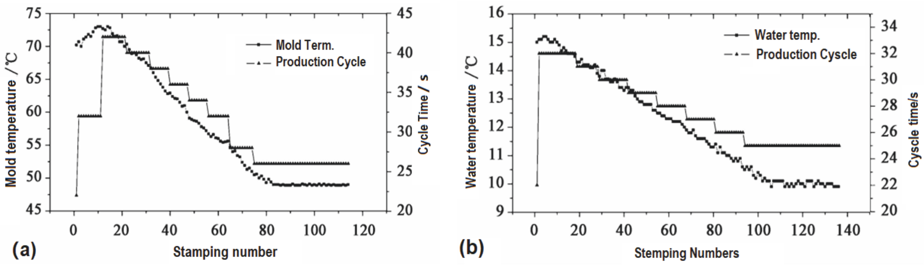

Fig.14 Using long-term intelligent control methods: a) Online adjustment of mold temperature; b) Online adjustment of cooling water temperature [15]

Due to the stability and accuracy of the infrared camera temperature measurement system, it features a rapid system response and high precision, which facilitates monitoring the mold loading and unloading temperature field in the hot forming production line, as detailed in Figure 15a. The temperature field of the hot stamped formed part after molding is shown in Figure 15b. When installing the camera, it is important to eliminate the influence of distance on the measurement accuracy of points on the axis. The emissivity at the specified angle of view of the thermal camera should be less than the specified angle of view of the camera. Furthermore, for monitoring applications beyond this range, automatic correction of the angle of view and thermal image resolution errors is performed to ensure sufficient engineering accuracy and response for mold loading and unloading temperature monitoring for use in hot forming lines [16].

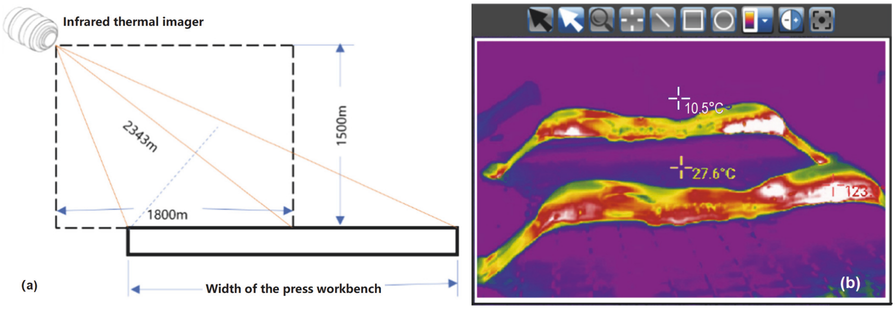

Figure 15 Infrared thermal imager for press worktable: a) Installation angle limited by space; b) The temperature field image of the hot formed part after software correction.

In the context of reducing the impact during the closure of the hot stamping die, both theoretical analysis and experimental findings indicate that decreasing the stretching rate of the hot billet is closely correlated with the quality of the forming process. The specific relationship is illustrated in Figure 16. In the case of a digital servo press, the slide speed before die closure can be tailored to meet the process requirements for different parts, plate thicknesses, and deformation depths. The press and speed profiles across the entire hot stamping process are detailed in Figure 17. Notably, during the holding period, the cooling of the plate is particularly sensitive to the load of the servo press. Consequently, minor load force fluctuations may be observed in the curve as the servo press adjusts the downward press volume to compensate for the cooling contraction of the plate.

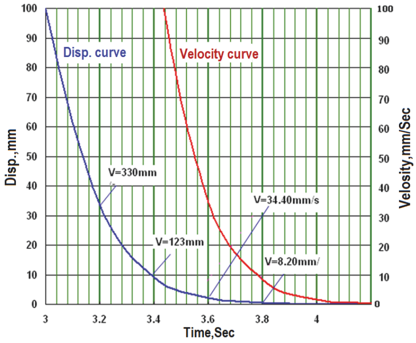

Fig. 16 Slider displacement and speed monitoring before mold closing

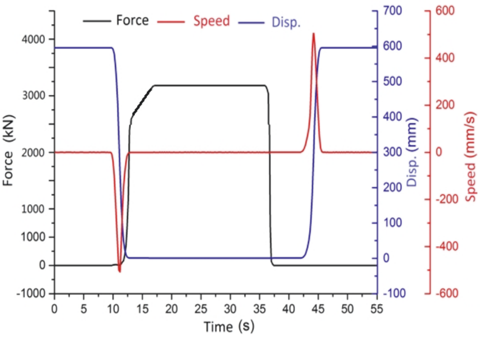

Fig. 17 Forming force - holding pressure monitoring

3.2.2. *Architecture of the digital twin system*

Based on the concept of Industry 4.0, the digital twin system can be employed to digitally simulate and model the equipment units of a hot stamping line and the hot stamping forming process [17]. The digital unit equipment systems represent relatively independent physical systems that are interconnected via the industrial internet. The simulation of the forming process encompasses material flow, stress distribution, and the forming process to proactively detect potential issues and optimize the process parameters.

The architecture of the digital twin system for hot stamping production in automotive parts, as depicted in Figure 18, encompasses the following elements:

(1) Real-time data acquisition and monitoring: Utilizing sensors and a real-time monitoring system on the production line, the digital twin system can acquire and monitor the key parameters of the hot stamping process in real time, including temperature, pressure, speed, and other relevant information.

(2) Digital simulation and modeling: Employing simulation software to digitally model and simulate the hot stamping process, including material flow, stress distribution, and the forming process, to predict and optimize the production process.

(3) Intelligent analysis and prediction: The digital twin system utilizes artificial intelligence and big data technology to conduct process optimization, production prediction, and fault diagnosis by analyzing real-time data and simulation models, thereby enhancing the stability and reliability of the production process.

(4) Production Optimization and Intelligent Decision Making: Leveraging the real-time data and predictive analysis provided by the Digital Twin System, the hot stamping production of automotive parts and components can implement intelligent optimization and decision-making processes, such as adjusting molding parameters, reducing energy consumption, and increasing production capacity.

This is a process where Digital Twin Product, Digital Twin Production, and Digital Twin Performance converge with each other [18]. From the physical system to the virtual system, it is essential to integrate the following data and virtual system data to establish what is referred to as the "SIGMA" cloud platform (including data storage):

- Maintenance History
- Operational History
- Real Time Operational Data
- Aggregated Data

SIGMA Cloud platform

Conversely, the following process is required to move from a virtual system to a physical system:

- Design and Performance Improvements
- Device Diagnostics and Prognostics
- Predictive Maintenance
- Optimized Operations

This interaction and fusion of virtual-physical system data represent a validation and tuning process, as well as a crucial data handling process for continuous improvement. The data validated by the physical system is normalized by the virtual system and utilized to adjust the physical system until the desired outcome is achieved. Figure 18 illustrates an execution system comprising a fully digitized production system (physical system) with digital design, hot stamping simulation, and an automated conveyor system connecting each of the distinct digitized units.

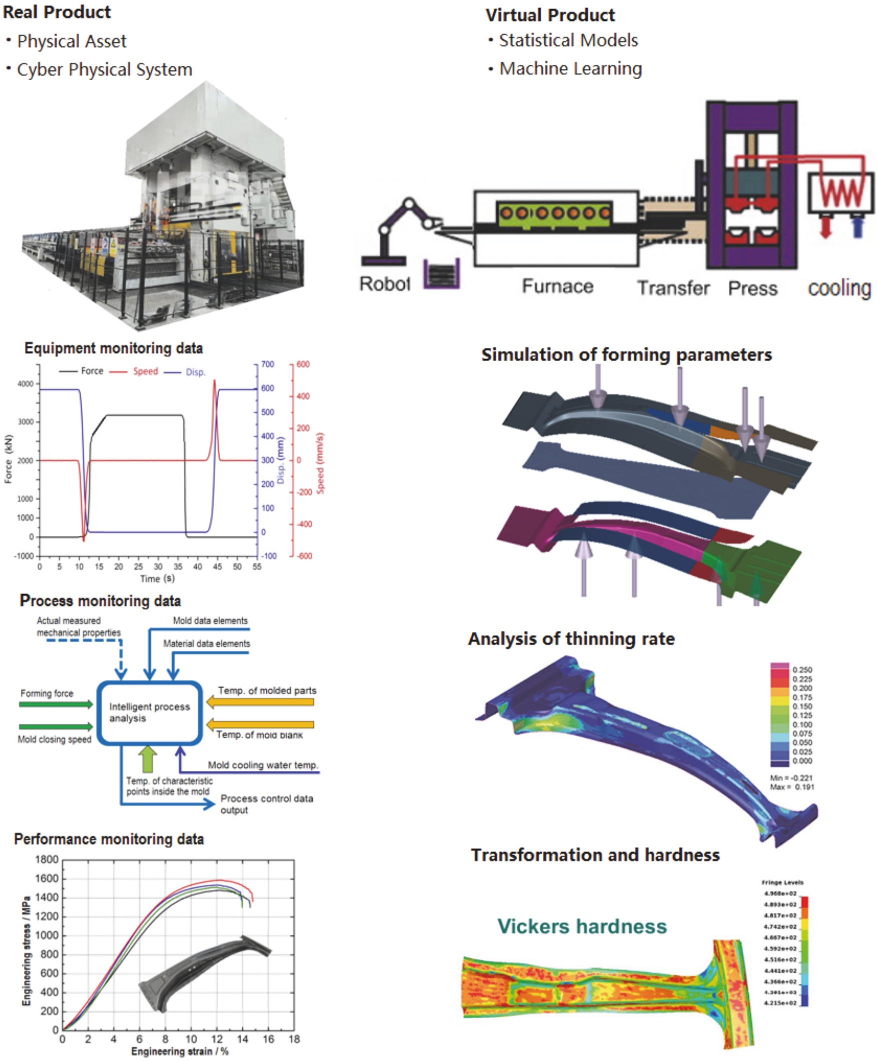

Fig. 18 Digital twin system architecture for hot stamping production

4. Closed-loop control based on big data modeling and intelligent decision-making

4.1. *Modeling based on monitoring data*

In the digital twin system based on the concept of Industry 4.0, big data modeling becomes a vital component of the continuous improvement mechanism. The monitoring system of the digital hot stamping line continuously generates a substantial amount of production equipment and forming process data, laying a solid foundation for the realization of intelligent and innovative process methods. Leveraging prediction technology of artificial intelligence and big data modeling to analyze real-time data and simulation models enables the realization of process optimization, production prediction, and fault diagnosis, thereby enhancing the stability and reliability of the production process. Furthermore, for the simulation of multi-physical field coupling of hot forming of high-strength steel and the simulation of sensitive factors of forming defects, it simplifies the computational load of big data models, narrows the industrial window, and improves decision-making efficiency.

The primary concern lies in the selection of accurate and computationally efficient modeling methods. In online process control, simplified models and fast predictions can be employed. For extended production cycles, offline control methods may be considered, and process parameters of the production line system can be adjusted after achieving the target performance of the actual part inspection. By delineating the relationship between multi-parameter input and output variables, a simplified linear model can be developed, and regression calculations can be used to ascertain reasonable upper and lower process window parameters for quality control guidelines.

4.2. *Decision-making control of hot stamping process*

Given the current constraints of on-line inspection methods, real-time monitoring of the in-mold temperature change process and the state of tissue phase transition is not yet feasible. Nonetheless, the model based on big data and the multi-objective correlation analysis algorithm, along with the non-linear regression calculation method, can facilitate quality control residence decision-making within a specific range and effective adjustment over an extended period, as detailed in Figure 19.

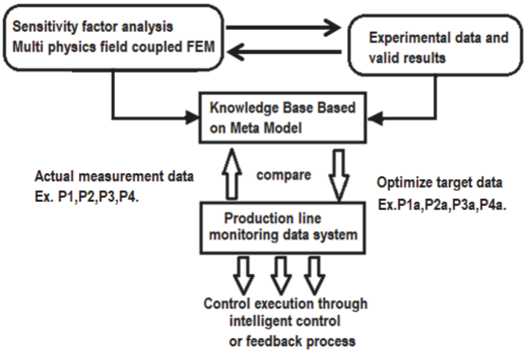

Fig. 19 Schematic diagram of decision control system based on big data modeling

The application of intelligent decision and control technology and the optimized execution of hot forming process data are based on the following method: initially, an independent linear model analysis is conducted for the four quality parameters P1 (cooling water temperature difference), P2 (out-of-die workpiece temperature), P3 (holding pressure), and P4 (holding time), which predominantly influence the process. This is done to establish the boundaries of the optimization data window as the control adjustment specification parameters. Subsequently, the execution of quality control parameters P1a, P2a, P3a, and P4a is estimated using the measured variables and the default values of the next execution process. If the estimated quality parameters fall outside the predefined window values, the controllable variables must be adjusted to ensure that the quality parameters are brought back within the desired range. For the "on-line long period" control range, more general linear models can be utilized, along with non-linear models for precise control of the outputs of the decision parameters.

In this instance, a one-factor autocorrelation model and a finite cross-correlation model were employed to evaluate the outcomes, as depicted in Figures 20 and 21. The core of the framework is to commence with the analysis of the acquired data, identify the relevant data, cleanse the data, and tailor it to suit specific requirements. This process demands experience and a deep understanding [19].

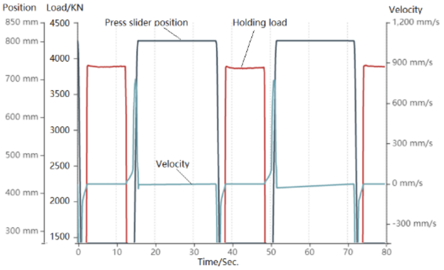

Fig. 20 Continuous monitoring data of press operation

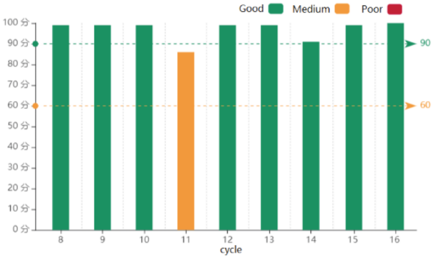

Fig. 21 Forming quality score for decision analysis

5. Conclusions and outlook

Through the exploration of the digital production line and the monitoring system of process parameters, coupled with the establishment of the digital hot stamping production line, we have achieved the initial milestone in the context of Industry 4.0. This milestone encompasses the digital monitoring and control of the hot stamping production system, along with the integration of the CPS system of the equipment with the industrial Internet. The current production line has undergone rigorous validation through several years of practical applications. Consequently, we have successfully developed a 12,000KN mechanical servo hot stamping press and a gas-fired roll bottom heating furnace that complies with the CQI-9 standard. Both of these facilities were operational by the end of 2023.

The distribution of strength and elongation of a hot-stamped formed part after it exits the mold at room temperature can be effectively addressed through MBN nondestructive testing [20]. However, it is important to note that this method is solely an offline sampling inspection approach. Furthermore, imperceptible material necking defects, commonly referred to as " invisible cracks," can be detected using EMAT methods, and the location of the necking line can be determined [21]. Nevertheless, these detection methods are not optimal for continuous on-line monitoring. The measurement of material temperature and temperature field distribution of hot-stamped and formed workpieces within the die presents a significant challenge. The rate of change and distribution of temperature can indirectly provide insights into the phase change and toughness of the part material, which is crucial for controlling the forming process. Presently, efforts have commenced to address this challenge by exploring the use of "software sensors" as a potential solution.

The advancement of Multi Part Integrated Hot Stamping (MPI) for car bodies has led to an escalating demand for large digital servo presses. The emergence of new multi-station hot stamping processes has further amplified the need for digital presses and automation equipment. This trend underscores the promising potential of applying digital production and intelligent control in hot stamping technology, thereby propelling the industry to evolve further towards intelligence and efficiency.

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