Research and development of digital twin system for screw press

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Digital twin technology has a strong ability to synchronize virtual and physical products. Therefore, in order to overcome the information blocking problem faced by the traditional screw press in the working process, this paper proposes a three-dimensional digital screw press system framework based on real-time data driven by the virtual and real interaction ability of digital twin technology. The on-line monitoring of the press state, operating parameters and equipment abnormal warning function based on strike energy and motor temperature is realized, which significantly improves the strike efficiency and quality of the press. This solution has been applied to the actual production process of the 1600kN electric servo screw press, verifying its feasibility and practicality.

Keywords: Digital twins; Screw press; Online monitoring; Intelligent manufacturing; Industrial Ai.

1. Introduction

With the diversification of automotive products and the development of high-strength steel materials and processes, there has been a surge in the development of hot stamping equipment and hot stamping production lines[1].Screw press is one of the most widely used equipment in the forging industry[2].However, in the actual working process, the screw press is faced with the challenge of information occlusion and untimely feedback in the production process, which makes it difficult to guarantee the processing quality. Digital twin technology integrates intelligent sensing technology, co-simulation technology, data analysis technology and intelligent control technology, which can effectively realize the synchronization of virtual products and physical products. In view of the outstanding advantages of digital twin technology, based on the five-dimensional structure model of digital twin, this paper proposes a three-dimensional digital screw press system framework based on real-time data-driven. The system uses the virtual and real interaction ability of digital twin technology, which not only realizes the visual online monitoring of screw press, but also realizes the warning function of press state, operation parameters and equipment abnormality, which is mainly based on striking energy and motor temperature. It also reduces the cost and improves the production efficiency.

2. Five-dimensional framework for the digital twin system of screw press

Tao et al.[3-6] proposed a five-dimensional digital twin model architecture, which consists of five components: PE (physical entity), VE (virtual entity), Ss (services), DD (digital twin data), and CN (connections). As shown in Figure 1, based on this five-dimensional

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digital twin model, a framework for the five-dimensional digital twin system of screw press operation is constructed. It comprises five main parts: a physical entity module, a digital twin module, a data perception module, a visual interaction module, and a communication connection.

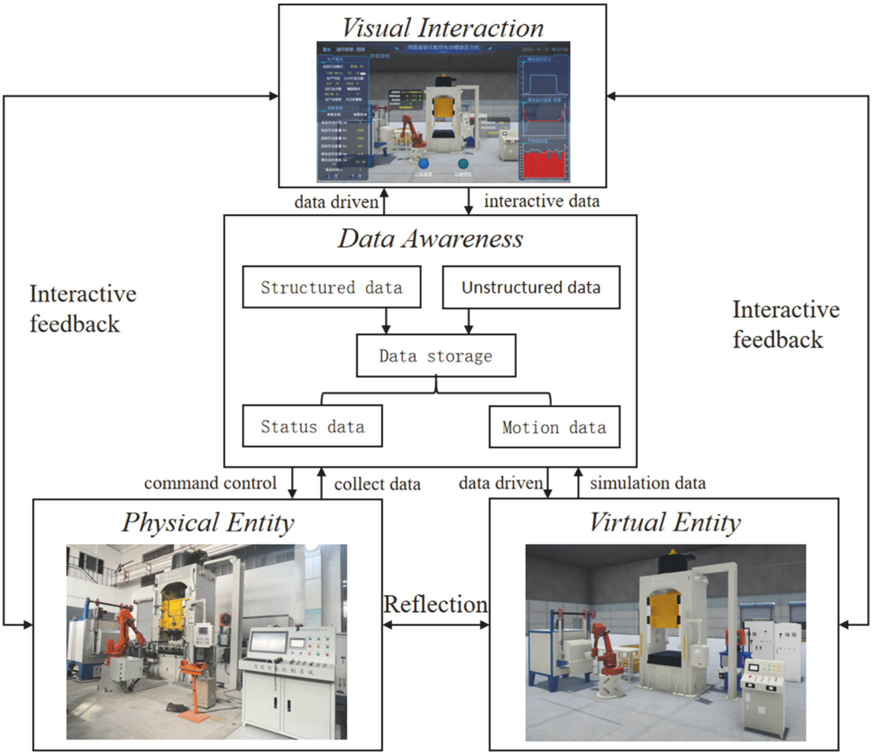

Fig.1 Five-dimensional structural framework of digital twin system for screw press

3. Key technology

3.1. *Construction of virtual twin model*

This paper adopts Unity3D as the visualization development platform. Taking the 1600kN electric servo screw press as an example, the three-dimensional model is constructed in SolidWorks and exported in STEP format. Subsequently, the model is converted into FBX format using 3DMax software, which can be read by Unity3D, and relevant properties can also be edited. Figure 2 presents the physical geometric model and virtual geometric model of the 1600kN electric servo screw press.

3.2. *Acquisition and transmission of multi-source dynamic data*

In this paper, RS485 is chosen as the primary output interface for data acquisition sensors, while the OPC UA standard protocol is selected for gathering multi-source heterogeneous data due to its benefits like long transmission distance and easy parsing. The data collection routes in this system can be categorized into three main types. The first involves directly parsing the transmission protocols of instruments and equipment with data output interfaces to acquire data, such as setting the striking stroke and energy. The second approach includes installing sensors on equipment without data output interfaces to capture data, such as real-time speed and displacement of the slide block. Various data types stored in the enterprise's MES system are also accessible. Once data collection is done, extraction and transmission are necessary. To fully capture operational data from the entire press equipment, a simple and reliable cloud box is utilized for remote transmission of dynamic data during press operations. Taking the main operational data of the slide block as an example, real-time displacement, speed, and pressure can be directly parsed from the press's PLC and uploaded to the PostgreSQL cloud database in real-time using the MQTT transmission protocol. Data cleaning operations are performed to ensure data quality and consistency if anomalies like redundancy or missing values are detected in the received database. Lastly, the MQTT communication protocol is employed to transmit the real-time json-formatted data structure to Unity3D. This not only drives the real-time operation of the press's digital twin but also enables real-time curve plotting for display and analysis.

Fig.2 Physical and virtual geometric model of 1600kN electric servo screw press

4. Implementation and verification of digital twin system for screw press

4.1. *Online monitoring of digital twin system*

To achieve the visualization monitoring of the forging process for screw presses, this paper constructs a proportional model visualization monitoring system for the 1600kN electric servo screw press in a digital twin scenario based on the five-dimensional model of digital twins. The overall operation flow of the system is shown in Figure 3. When processing begins, the data acquisition and transmission devices enter the working state simultaneously and send the collected data to the digital twin processing visualization system in real-time. Before entering the visualization monitoring system, users need to select the real-time mode or historical mode based on their actual needs and log in with the correct account password and other relevant information. The virtual equipment model in the digital twin virtual processing scene achieves real-time synchronization and simulation with the operating status of the real equipment. Functions such as transparent production, instant fault alarm, and workshop situation reproduction have been initially achieved, which can fully meet the needs of real-time monitoring in enterprises.

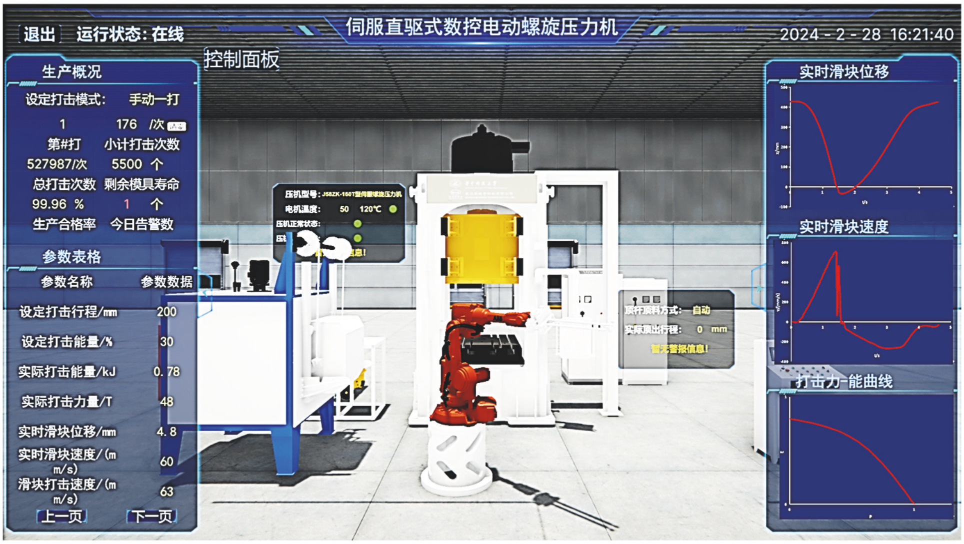

Fig.3 Three-dimensional visual monitoring interface of 1600kN electric servo screw press

4.2. *Equipment anomaly warning of digital twin system*

The equipment status of key forging equipment such as presses directly affects the forming quality of the equipment. Therefore, it is necessary to conduct real-time monitoring of some critical states. The visual large screen, safety alarm information board and jacking material information board of the digital twin system realize this task, mainly monitoring the state and operation parameters of the screw press, which are mainly based on striking energy, copper nut temperature, motor temperature, lubrication state of the press and jacking system. For instance, as shown in Figure 4, if the monitored temperature of the copper nut exceeds the normal temperature range, the alarm indicator light will turn red, indicating an alarm state. The alarm information column will also display a message reading, "Copper Nut Temperature Too High!" Additionally, the system's alarm lights and sounds will be triggered to allow managers to quickly detect any abnormalities.

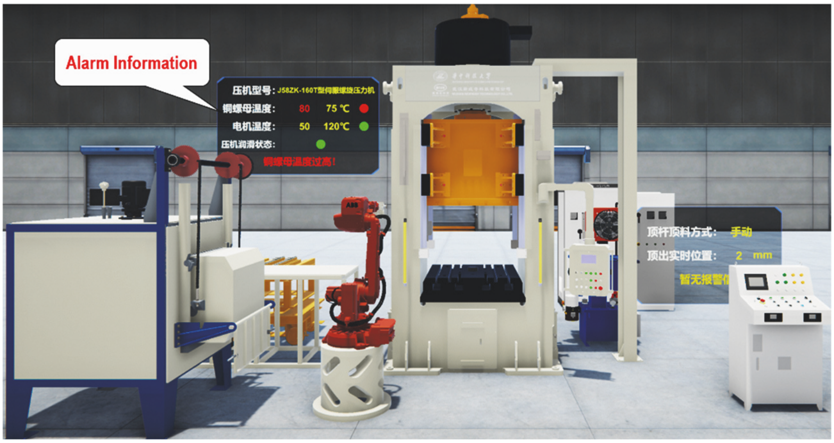

Fig.4 Visual alarm interface of 1600KN electric servo screw press

The usage and damage status of the mold have a direct relationship with the quality of forged parts produced by the press. The visualization system's left large screen in Figure 3 displays the real-time production overview of the press. By observing and analyzing the daily alarm count and production yield as the total number of blows accumulates, it can be seen that as the total number of blows approaches the mold's lifespan, the number of alarms increases, while the product yield decreases. If a sudden drop in production yield occurs, the first consideration should be the cause of mold damage. Additionally, when the production yield falls below 85%, the system will trigger an alarm to remind operators to inspect and replace the mold, thereby avoiding waste and improving product yield.

5. Conclusions

Based on digital twin technology, this paper collects data on the status and operation of screw presses using the OPC UA protocol and utilizes the subscription feature of MQTT clients to transmit real-time data from the presses. This approach enables the construction of a screw press twin visualization monitoring system. The system possesses several functions, including online monitoring of screw presses driven by historical and real-time data. It also facilitates real-time monitoring of critical data such as striking energy, copper nut temperature, motor temperature, product yield, and press lubrication status. Additionally, the system can generate alerts for equipment anomalies. This study provides effective exploration and practice for the application of digital twin technology in manufacturing, demonstrating its significant potential in this industry.

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