Application of Digital Twin Technology in Flexible Packaging Production

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Abstract. Digital twin technology is widely used, and all industries can improve the level of science and technology through digital twin technology to a certain extent, especially production enterprises. Through the digital twin technology, the physical model is fully used to build the 3d digital model of real production line data, and the function of online management and control of physical entities through virtual entities is realized. Based on the concept of digital twin, this paper puts forward a digital twin system which can be applied in flexible packaging production workshop, which is of positive significance to improve the industrial production efficiency.

1. Introduction

The printing industry is an important component and supporting industry of the national economy[1]. In recent years, due to the impact of environmental pollution control and other related policies, the development of the industry has been subject to certain restrictions. Here, compared to traditional book printing, flexible packaging printing still maintains a better development status, especially the gravure flexible packaging printing industry has achieved certain development under the huge market pressure and environmental pressure[2]. Chinese traditional manufacturing industry has always been a pillar industry for China's economic development[3]. The traditional manufacturing industry has been operating in a labor-intensive, low-end mode characterized by simple, extensive and high energy consumption[4]. However, with the continuous development of the times, the production capacity and technological level are constantly updated, manufacturing and information industries The combination is getting closer, and the mode of guiding production with data information is accepted by more production companies. Germany proposed the "Industry 4.0" plan, and China proposed "Made in China 2025", focusing on the Internet of Things, intelligent simulation, and industrial big data.

Shaping the Industry 4.0 ecosystem needs to focus on the combination of various technologies and resources[5]. Digital twin technology can realize the precise mapping relationship between physical entities and their digital virtual entities. Integrating the physical entity simulation model and industrial production parameters into the virtual model can realize many functions such as three-dimensional monitoring, remote operation and maintenance, production guidance, predictive maintenance, and product redesign[6]. As a discrete and labor-intensive enterprise, flexible packaging printing companies apply digital twin technology to the production process to realize the parameter perception.
of the production process, which is of positive significance for reducing labor costs, improving production efficiency, and tracking production quality.

2. Digital Twin

Digital twin is to make full use of physical model, sensor update, operation history and other data, integrate multi-discipline, multi-physical quantity, multi-scale, multi-probability simulation process, complete the mapping in the virtual space, thereby reflecting the full life cycle of the corresponding physical equipment Process[7]. The digital twin "object-oriented" programming idea abstractly encapsulates real-world objects as "classes" in the program. The "class" is defined as having the attributes and functions of real objects. It is to execute and control these steps in sequence in a main program according to the steps of the event. At the same time, the "process-oriented" programming idea is to execute and control these steps in turn in a main program according to the steps of things. Each step has a hierarchical relationship and sequence, which can describe and abstract the causal relationship of events or processes in the real world in the time dimension[8]. For flexible packaging printing companies with discrete production and process changes, the "process-oriented" thinking is more conducive to tracking and describing the entire life cycle of the entire production process.

The name of the digital twin gives more scientific and technological mystery. The digital twin was originally called the "information mirror model". As the name implies, the real world is formed into a three-dimensional information body through virtual technology to realize the non-contact perception of real things. A pattern in which the physical world in the physical dimension and the virtual world in the information dimension coexist and blend together. As an emerging and rapidly developing technology, digital twins provide a new direction for advancing the whole process perception and high-quality production of flexible packaging production.

3. Application of digital twin in flexible packaging production

3.1. Composition of flexible packaging production line

Traditional flexible packaging production workshops mainly include the following: raw material workshop, printing workshop, laminating workshop, curing workshop, slitting workshop, post-press processing workshop, transfer workshop, and finished product workshop.

3.1.1. Traditional physical production line

As a traditional physical production line, flexible packaging production is represented by traditional production methods. Operators carry out material handling, material loading and unloading, machine operation, operating status inspection, and semi-finished and finished product inspections.

3.1.2. Digital twin production line

Applying digital twin technology to traditional physical production lines requires a combination of multiple adaptation technologies. For example, modeling software can realize all-round simulation of the production environment and construct the "twin" digital workshop of the physical workshop. In the process of constructing a simulation model, not only the physical dimensions must be simulated, but also the main actions of the main machines must be simulated to achieve higher-quality all-element monitoring.

3.1.3. Workshop information and data communication

The long-term production process includes a large amount of data communication and storage, including not only production process information, but also equipment operating conditions, production environment parameters and other information. In the process of upgrading and transforming traditional enterprises to modern production, some enterprises have gradually used MES system (production information management system) and ERP system (integrated management
information system). However, the following problems need to be solved urgently: most companies only use a single system for production management; a small number of companies use multiple systems for production management, but there is no data sharing between the systems and only separate tasks are completed. Modern digital twin workshops need to realize unified management of workshop information and data, not only including order production process information, equipment operating status information, but also all information such as production environment testing parameters must be managed through the same decision-making system.

3.2. Digital twin system of flexible packaging production workshop

Digital twins are usually divided into three components: physical products in physical space, virtual products in virtual space, and data and information interaction interfaces between physical space and virtual space. Tao Fei et al. proposed a five-dimensional digital twin model[9] like Formula 1. The relationship of the five-dimensional model is shown in Figure 1.

\[ M_{DT} = (PE, VE, Ss, DD, CN) \]  

(1)

Among them, MDT stands for reference architecture; PE stands for physical entity; VE stands for virtual entity; Ss stands for service; DD stands for twin data; CN stands for connection between components.

![Digital twin five-dimensional model relationship](image)

Figure 1. Digital twin five-dimensional model relationship

The physical entity is the basis of the digital twin system, the source of virtual entity simulation data, and the prerequisite for accurate analysis. The physical entity model can be divided according to the level. For example, the layout of the flexible packaging production workshop can be divided into a space-level model; the space in the workshop can be divided into a space-level model. The equipment can be divided into the first-level model of workshop equipment according to the workshop; the equipment group in the workshop is divided into the second-level model; the individual production equipment in the equipment group is divided into the third-level model; the auxiliary production equipment is divided into the fourth-level model. The whole production process model is divided into the first-level production model; the second-level sub-link production process model is divided into the second-level production model. According to the process and procedures of flexible packaging production, production equipment, auxiliary equipment and production environment constitute production elements to realize complex physical entities to complete production. According to different monitoring requirements and production management requirements, the lowest-level physical unit is installed with sensors to monitor, so as to achieve data acquisition of complex physical entities.

Constructing virtual entities is the basis for realizing online and remote monitoring. The process of constructing a virtual entity must take the physical entity as a reference to fully restore the authenticity of the entire production process[10]. Virtual entities not only include geometric models, but also physical models, behavioral models, and rule models[11]. The virtual flexible packaging production
workshop not only simulates the space and equipment dimensions of the production workshop, but also simulates the spatial parameters, such as temperature and humidity distribution diffusion model, production exhaust gas diffusion model.

Ss service refers to the general term for various data applications in the digital twin application layer. It mainly includes two aspects. The first is facing the digital twin system:

1. The VE service that manages virtual entities can realize the modification and adjustment of virtual entities.
2. The data processing DD twin data service for data management can realize functions such as data storage, processing, and transmission.
3. The management of the connection function can realize the communication of data collection, the transmission of issued commands and other functions.

Then it is facing the outside of the digital twin system:
1. Management services for managers, such as data analysis, production evaluation.
2. Technical management services for enterprise technical personnel, such as dynamic adjustment of production, real-time adjustment of equipment operation pace.
3. Operational services for operators. As an industry with obvious discrete production methods, necessary operators need to know detailed information about equipment status, order status and production pace.
4. Order services for corporate customers, such as online order placement, order progress, quality inspection results.

Data is the basis for enterprises to manage and adjust production[12]. The twin data of the digital twin flexible packaging production workshop includes all real-time collected data and historical data of physical entities and even expected data generated based on analysis and decision-making, machine learning, etc. Real-time data can realize real-time detection of production conditions, historical data can provide practical guidance for analyzing production, and expected data can provide theoretical support for enterprises to adjust production.

CN represents the connection between various components, mainly the exchange of information, that is, the transmission of various types of data.

Based on the above content, the digital twin system of the flexible packaging production workshop is drawn as shown in Figure 2.

3.3. Advantages of digital twins in flexible packaging production workshops
Applying the concept of digital twins to management can improve the decision-making capabilities of operation and maintenance solutions[13]. Digital twin technology can provide 3D visualization solutions. Through the "mirror world", the virtual world can be seamlessly connected with real production, and the entire production process can be simulated and all-rounded to reduce out-of-production due to factors such as geographic location and time. Monitor production risks and realize "unbounded work and remote collaboration". Digital
Figure 2 Digital twin system of flexible packaging production workshop

Digital twin technology provides enterprises with database technical support, has more comprehensive analysis and forecasting capabilities, and provides historical data guidance and development direction forecasts for the development and decision-making of enterprises. Use historical data to predict production and ultimately achieve better production.

4. Conclusion
Digital twin technology has very attractive development prospects and is an effective means to realize Industry 4.0 and improve industrial productivity[14]. At present, the flexible packaging production industry, as one of the typical discrete manufacturing industries, has a longer way to go before the full realization of digital twins to guide production. Chu Leyang[15] proposed that the development of digital twin technology can be divided into three stages: virtual-real connection, virtual-real fusion, and virtual-real symbiosis according to the technological integration level. Similarly, flexible
packaging printing companies can also implement the digital twin technology application in multiple stages. The first stage realizes highly automated production and adjustment, the second stage realizes real-time monitoring and control of production, the third stage realizes virtual simulation monitoring and control of production, and finally realizes the perfect application of digital twin technology. However, the digital twin technology is a perfect fusion of multiple complex technologies. There are still many obstacles in the process of practice, and it needs to be explored continuously. The application of digital twin technology is a long-term research, which requires continuous refinement of the model and continuous optimization in combination with practice.

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