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Digital Twin: Applications, Implementation and ROI In Printing Industry

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Abstract: ***It is expected that the global value across all print and printed packaging will reach $843 billion in 2026. This is increasing after the pandemic-induced negative disruption in 2020. The packaging market has a growing share in it [1]. In Industry 4.0; the manpower, machinery, and printing processes are in the network digitally [2]. Accurate and precise data is controlling the production and digital twins are an important tool for increased overall efficiency and sustainability. Digital twins are connected from the sensors to the cloud-based software which can be accessed by all the stakeholders such as manufacturers, intermediate supply chain managers, wholesale clients, and end-use customers. Therefore, digital twins are an important part of Industry 4.0. In the print & packaging industry, due to increased automation, the investments in plant and machinery are increasing but customers expect cost reductions with an emphasis on quality and sustainability measures. The order quantities are reducing and demand for short-run customized products is increasing. The customers expect the printing companies to follow international standards diligently. There are several benefits of digital twins in the printing and packaging industry which result in saving time, manpower, cost and thus reducing the adverse impact on the environment in terms of effluents, use of power etc. thus increasing overall equipment efficiency and sustainability.***

Keywords: Industry 4.0, Digital Twin, Types, Applications

I. INTRODUCTION

A digital twin is a replication of the physical asset in a virtual environment. This asset can be a process or complete production plant. Digital twins are considered as visualization and simulation tools which are mostly useful to designers and engineers however digital twin is a combination of simulations. Digital twins use continuously generated data in the production set up to analyze and come out with new approaches for the supply chain optimization, restructured flow and sequence of operations. It uses real-time data, simulation, and machine learning for making decisions. The process or object to be studied is fitted with various sensors related to important areas of functionality. These sensors produce data about different parameters of the performance of the physical object or process. The data is processed using special customizable software and its output is applied to the digital twin.

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If this data is accurate and relevant, then the digital twin can carry out various simulations, analyze performance and recommend necessary adjustments. The foremost objective of the digital twin is to get the information for improving the original physical asset [3]. A digital twin is a virtual representation of a physical product, process, person, or space that can represent a physical asset and can measure various parameters of it. A simulation can represent the physical object digitally at exactly one moment in time whereas digital twins are a constant exchange of data between the real and the virtual worlds [4].

Figure 1. Digital Twin Vs Simulation [4]

A. Applications of the Digital Twin in the Printing Industry

Following are a few application areas related to the printing industry for the deployment of digital twin-

1. A newspaper printing company continuously balances between publishing the latest news in the newspaper as well as making the copy available to the end user at the earliest. Here the supply chain with optimizing service, and consistency with cost management are required. It involves major factors such as inventory planning, product flow, and logistic optimization. Using previous vast data available with the company, it is possible to create a digital twin of its production and logistic operations which will contain input from the editorial section, printing operations, finished product handling for transport route-wise packing as per daily changing quantity, third-party transport contractors, and newspaper distribution centers to vendors; all this within a short period of 3 to 4 hours. The digital twin will allow the company to test different combinations within a day, assessing the probable results for different large and small choices such as planning of machine, inventory, waiting period for plates, etc. along the transport management. Since everything will be carried out in a virtual environment, there will be no real physical losses. An optimization algorithm in the digital twin will indicate informed recommendations.

The company may make decisions based on these recommendations to reduce the time between the dispatch from the press to the delivery to the end user.

2. Traceability in the printing of cartons for pharmaceutical and food industries -

QR (Quick Response) codes are printed on cartons and packing cases to track the inside material throughout the supply chain. It is in congruence with the regulations of local and international governments, and safety protocols by the food and drugs authorities. The QR codes are generated by using variable data and printed on cartons and cases. By scanning these QR codes, even the end user can verify the authenticity of the product. The manufacturing company can track the journey from the dispatch to the market. If conducted physically, these trials can be cumbersome, costly, and time-consuming involving multiple resources whereas the digital twin can make it easier by digitally conducting the trials and sharing the data with all the stakeholders in real-time.

3. The original machine manufacturers (OEM) should be able to identify the trouble related to the machine without visiting the site physically and send the correct expert along with the machine parts of accurate dimensions. Frontline.io [5] & [6] offer a digital twin technology that is helping international hardware manufacturers with technical training and support services. The digital twins assist in increasing overall equipment efficiencies and training. The engineers need not travel to the actual site locations for problem identification resulting in optimum utilization of resources. This technology is used by HP (xRServices), Landa Digital Printing, and Bobst to create digital twins of their products. These leading print machine manufacturing companies using frontline.io digital twins have witnessed a 70% improvement in their efficiency of support services. In turn, the production time of its customers has increased. OEMs using frontline.io have seen about 50% savings in training costs and their customers have seen a 15% increase in productivity [5]. Customers can have cross-platform communication (IOS, Android, Windows, etc), and cross-reality experiences (AR, VR, or MR) with one integrated solution [5] & [6].
4. The customers demand strict adherence to the Delta E (color difference) below 2. It involves all the prepress, press, and post-press operations to be calibrated. The machines and systems from different OEMs can communicate with international standards - Open Platform Communications Unified Architecture (OPC UA). It results in an OEE increase and a WIP decrease. The sensors along the process chain continuously collect machine and production data in the background. The data stored on the cloud helps in improving decision-making for future jobs as well as material saving and logistics optimization, thus helping sustainability efforts [7].
5. Modern printing machines have sensors to record parameters such as viscosity, web tension, pH of chemicals, splicing trigger, vibration, torque, relative humidity, temperature, etc. The data received from these sensors can be studied in real-time and come out with solutions for the improved efficiency of the physical asset. In digital twins, it can be integrated into ERP and SCADA systems to optimize supply chain management. This data can be used in cloud-based IIoT software for real-time inspection to schedule the correct type of maintenance and change of parts and machines [8].
6. BST [9], a company for quality assurance systems for web converting processes has developed a digital network connectable, quality improving web reel guiding and register control, web reel monitoring and inspection systems which increase the overall equipment efficiency of the printing machines, reduce waste and make the process sustainable. For example, in the SMARTData software by BST, the data feeding is centralized from any ERP system. With the help of RESTful API, the data can be synchronized in the form of digital twins with multiple production processes. BST's register control systems, with the assistance of sensors, can adjust the printing register in vertical and horizontal directions. The web guiding system by BST also checks that the processed web is at an accurate position. These systems can exchange the data using SMARTData. By connecting the web viewing systems and SMARTData, register inspection and web reel checking can be done using an interface to minimize the incorrect entries logged in job settings. The TUBEScan print inspection system with SMARTData QLink can automate the printing by minimizing job setup time because of centralized data entries. TUBEScan can verify the new job and get the matching data from the old job in real time for comparison during quality checks. This saves time and reduces waste. The rewinder can be controlled with QLink Rewinder for error detection. The machines handling the finished web reels can be programmed to identify the correct reels to be dispatched. The Quality Management data can modify the QLink data through cloud software.
7. Digimarc Corporation, a product digitization company uses the EVRYTHNG Product Cloud to integrate its identification technologies. Digimarc's Brand Integrity solution assigns a digital QR code to every product for track and trace. Hence, all the stakeholders can track and trace the journey of the product throughout the supply chain. Due to the unique and complex QR code for every product, it is difficult to produce counterfeits and recycling can also be managed [10].
8. Change in the market dynamics is presenting many printing companies with challenges in production, supply chain management, etc. The production runs are getting shorter and the lead time from the order to the delivery produces cost challenges, hence automation is essential. Flexible innovative solutions are used by B&R in its latest modular printing press. which has OPC UA integrated into it. Any B&R controller can be used as an OPC UA server or client to communicate with SCADA, MES, and ERP systems as well as vendor-independent communication from PLC to PLC [8].
9. Smart sensors are major components of Industry 4.0 and the Industrial Internet of Things (IIoT). Standard non-smart sensors can accumulate data but can not analyze it.

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Smart sensors can analyze the data and initiate certain actions to save time and resources on the production line. For example, a sensor may indicate to a press operator the pH, conductivity, and surface tension of the dampening solution in the offset printing machine or the precise value of viscosity of gravure printing ink or optimum temperature and relative humidity in the pressroom. It will result in breakdown prevention actions. Sensors can communicate across the platforms (iOS, Android, Windows, etc.) with the help of OPC UA standards to give more understanding of the overall equipment efficiency of the production line. It helps in sustainability by saving energy and materials [11].

B. Advantages of using Digital Twin in a Printing Industry

1. Increased efficiency of the production system

   With a Digital Twin, it is possible to replicate the parameters of a physical asset in real-time. It can identify troubles in particular printing units such as imbalanced cylinders, improper printing pressure, dryer temperature, and relative print width (fan-out). This in turn helps in reducing work in process inventory and improving overall efficiency. The company can turn out more jobs at the same time after the deployment of the Digital Twins. The modifications are done in the digital twin before being implemented in a physical asset model which saves several resources such as men, materials, time, machines, and cost thereby increasing sustainability [12].

2. Predictive maintenance

   With real-time data and cloud-supported machine learning, digital twins can predict the potential failures of a system such as web breaks, poor drying, mis-registration, plate blinding, etc. This can prevent downtime and reduce costs. It prevents costly breakdowns. Digital twins can judge the health of the physical asset and inform about the potential need for maintenance or change of parts or machines. A simple bearing failure can cause the machine downtime. Based on past data, the digital twin can predict the time duration up to which the bearing will last [13].

3. Improved product development

   With a digital twin, the end product can be simulated for its performance in various situations. A carton can be viewed for its shape, design, and stacking on shelves in the shop. Thus modifications in the product design can be carried out to avoid shortcomings before actual production. The digital twins can put the operations in proper sequence and minimize the bottlenecks. During this stage, the workflow can be modified without the use of resource-consuming physical assets. For example, the shape and design of the cartons, boxes, and pouches can be simulated, their placement on the shelves and response of customers can be studied and any shortcomings can be overcome.

4. Sustainability

   Digital twins can help in sustainable operations by reducing waste of substrates, ink, chemicals, and machine time thus reducing energy requirements. The planned maintenance schedules and increased overall equipment efficiency can save costs in the long term. Digital twins assist in deciding the proper material and operation to save costs and other resources.

5. Ease of testing

   Eliminating the use of physical assets in testing can save costs. For example, it can inform about the need to use special inks instead of process inks. With the comparison of old data and simulations, digital twins give a base for decisions. This reduces the possibility of human errors such as wrong punches, plates without register marks, imposition on the printing substrate, etc.

II. DIGITAL TWIN ARCHITECTURE

It involves three main components [12] -

A. Physical Product

The physical product is the real-world process which is virtually mirrored by the digital twin. It can be an individual printing machine or production workflow such as carton production for the food industry which requires following stringent laws and regulations as well as traceability.

B. Virtual Product

The virtual product is a digital replica of the physical product. This is typically a high-fidelity 3D model that replicates the parameters of the physical product in a virtual environment. As per the above example of carton manufacturing, a virtual workflow can be generated starting from design to dispatch. It can inform about bottlenecks in production, supply chain, the location of products on the shop shelves, and customer reactions.

C. Data Linkages

The data linkages connect the physical product and the virtual product. They are sensors used for accumulating real-time data from the physical product and forwarding it to the virtual model. It helps the virtual model to replicate the physical product in real-time. Sensors on physical objects such as printing machines or shop floors will gather data such as machine stoppages, substrate properties and their performance, human errors, color values for deviation, stacking of the product time and space occupied, etc. This data gets fed to the digital twin in real time and corrective actions can be carried out.

D. Steps for Digital Twin Implementation

A. Clarity about purpose such as improving efficiency, reducing downtime, or increasing quality.
B. Readiness for the initial investments in information technology and manpower resources.
C. Sources and types of data and its accumulation as required by the digital twin.
D. Connection between the physical and virtual worlds.
E. Building the digital twin of the physical entity using the collected data and special software.

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F. Test whether the digital twin accurately represents the physical asset and provide information received from the sensors and other IIoT software.
G. Put the digital twins into operation. Regular update of the digital twin is required for continuous improvement.
H. Define key performance indicators (KPIs) to assess the performance of the digital twin implementation. For example, more impressions per shift per machine, material saving, making the assets debt-free in less time duration.

E. Factors to be Considered Before Implementing Digital Twins in the Printing Industry

1. Heavy capital cost - Digital twins building involves trained manpower, money, and other elements, therefore, their deployment is justifiable where capital extensive machinery and operations such as packaging printing where deadlines are important and further logistics are dependent upon the precise packaging and timely delivery of the packaging material [19] [20].
2. Complicated workflow - In printing, each product is unique. There are several variables such as pressroom atmospheric conditions, substrate properties, finishing operations, designs of punches, time factor, etc. In such cases, digital twins are beneficial.
3. Requirement of reliable data - For an accurate virtual image of physical assets, the digital twins have to be input with high-quality data. The data set should be consistent, measurable, and reliable across all the parameters of the physical assets. In printing the mixture of solvents, the viscosity of ink, pH, hardness of dampening solution, mis-registration, and fan out are peculiar problems where precise data is required to initiate the corrective action.
4. Multiple variables in the physical assets - Digital twins are designed for repeated use to solve real-world problems that contain multiple variables. For example, a company may not know the overall equipment efficiency (O.E.E.) of its plant accurately due to inefficient production workflow, and too much material in process inventory which do not have mathematical solutions. For such problems digital twins are suitable. Digital proofing, the output rate of finishing machines concerning printing machines, customer-acceptable quality, and rework for rejected production are a few examples [14] [16] [17] [18].

F. Interoperability

Interoperability between different systems and devices can be challenging when integrating data into the digital twin. OPC (Open Platform Communications) [15] is the interoperability standard for the secure and reliable exchange of data in the industrial automation space. The OPC standard is a platform-independent series of specifications developed by industry vendors, end-users, and software developers which decide the interface between all the stakeholders in real-time.

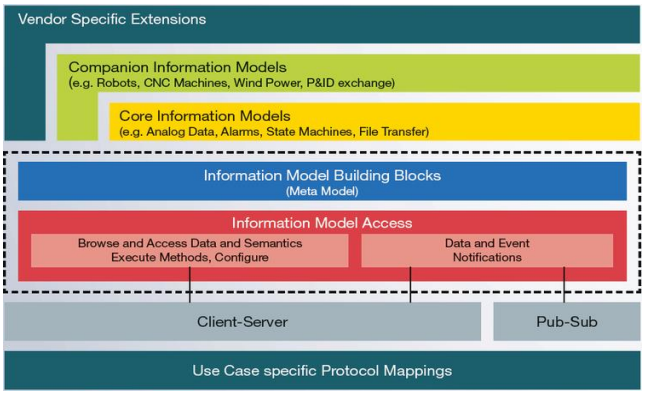

Figure 2. The Multi-Layered Architecture of OPC UA Source - Opcfoundation.Org

III. CONCLUSION

The ROI of the implementation of the digital twin can be measured by comparing pre-digital twin and post-digital twin costs. The digital twin use which is capital intensive should be based on the type of market, future orders, and their nature. Currently, it is viable for only the bigger organizations where supply chains are long and the stakeholders are more such as book production and delivery across the world for international customers or pharmaceutical label production. However, if the product is going to remain similar over a longer period such as newspaper or carton colors and design for the food chain then it is better to use simple planning tools instead of the digital twins. Secondly, the data collection and transmission have to be reliable, measurable, and consistent. With the ever-changing nature of digital file formats, constant updates of the digital twin are required, the cost of which has to be considered during the planning.

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