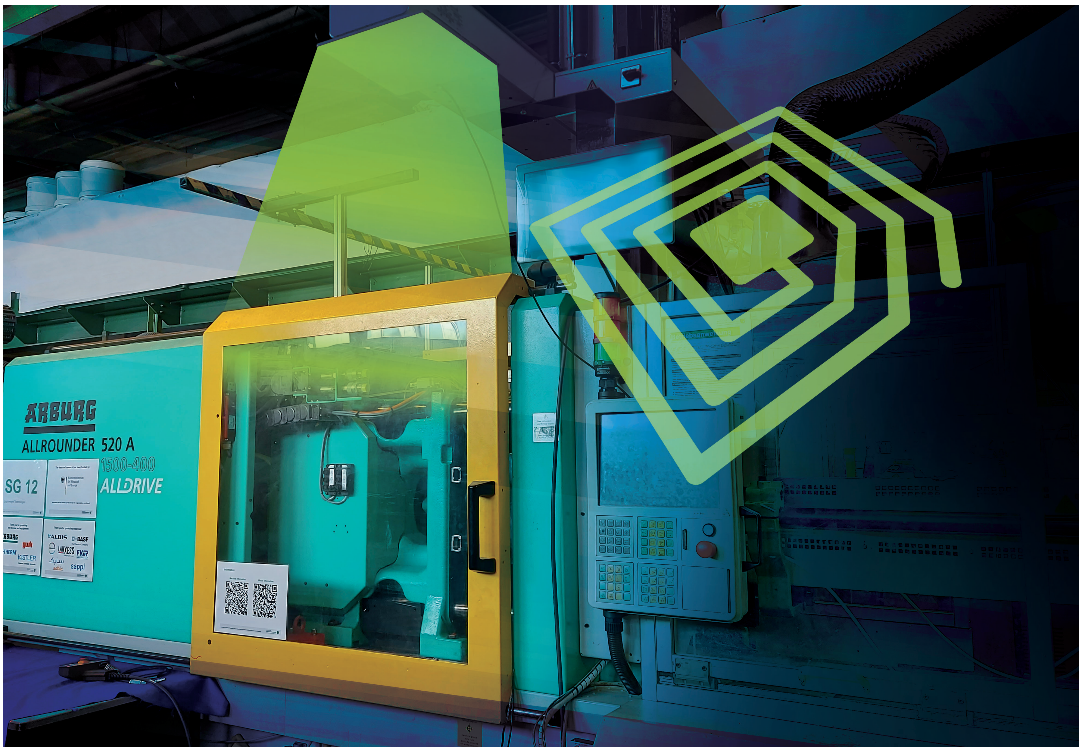
The Digital Mold Twin

How Track-and-Trace Technologies Can Support Mold Management

Industry 4.0 is characterized by autonomous production systems in which the "things", so-called assets, communicate with each other and decide independently. This can be achieved through digital twins as a virtual representation of these assets and digital shadows as decision supporters. The following article demonstrates the use of digital twins for molds in injection molding through the integration of track-and-trace technologies for data collection.



An RFID reader records whether a mold is ready for the setup process © IKV

Industry 4.0 technologies aim to secure the international competitiveness of high-wage countries. This is assisted by the merging of the physical world with the digital world to create so-called cyber-physical systems, in which the separate components (assets) communicate autonomously [1]. Digital twins represent the image of the real assets in the virtual world in order to use the advantages of Industry 4.0 [2]. Characteristic for the digital twin is the ability to influence real systems and interact with them. The digital shadow, on the other hand, exists only for a specific purpose. Therefore, the digital shadow just extracts and processes the data that are relevant to fulfil the purpose. The digital shadow furthermore cannot exert any influence on the real system and therefore serves primarily as data context and not as an active, interacting system component [3].

There are a number of advantages of establishing digital twins of molds. Employees can focus on value-adding operations [4] because time-consuming manual bookings of molds can be reduced or mold data can be automatically passed on [5, 6]. The current state in the production can be transparently observed at any time by molds transmitting their status to a higher-level control system [7], for example information about the current location or the setup status of the mold. Apart from that, information about the mold itself is available, e.g. the number of completed injection cycles, in order to initiate maintenance based on this at the right time [8].

The continuous information on the mold status also influences the behavior of other system components. For example, if a mold is set up on one machine, other machines cannot request it for immediate use. On the other hand, if this data is automatically recorded, potential input errors by employees can also be avoided and consistent data records can be generated [9]. High data consistency ensures, for example, the quality of planning simulation [5] for production control and con-

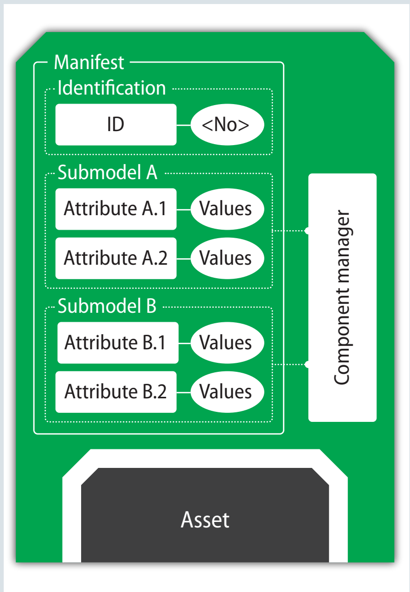


Fig. 1. Basic structure of the asset administration shell, consisting of the manifest and the components manager Source: IKV, based on [2]; graphic: © Hanser

sequently improves decision-making [4], e.g. for optimal scheduling as regards minimizing mold setups or changeover times. Digital shadows support this by extracting the data needed for the decision-making from the entirety of data and consolidating the data into planning-relevant information [10].

The Asset Administration Shell as Digital Twin

Besides data acquisition, data structuring of the digital twin is essential. To this end, the concept of "asset administration shells" has been established for the implementation of the digital twin [11]. The asset administration shell consists of two main building blocks: the manifest and the component manager (**Fig. 1**). The manifest is comparable to an identity card. On the one hand, it clearly identifies the asset and, on the other, it describes the attributes of the asset based on previously defined features. Moreover, the asset administration shell allows the encapsulation of relevant attributes in submodels for a specific application case.

The component manager specifies interfaces for communication between the outside world and the asset, e.g. by the listing of endpoints and permissible communication protocols. The boxing of asset administration shells is also permissible [2]. Both the implementation and the access to the asset administration shell is technology-independent [12, 13]. Therefore, track-and-trace technologies generally are suitable for manipulating the attribute values of asset administration shells. This is shown below using a practical application example for mold management using RFID technology.

Classification of RFID Compared to Other Tracking Technologies

Within the last few decades, different tracking technologies for a variety of applications have achieved industrial maturity. Many of them were fundamentally developed as early as the 1990s. Besides optically identifiable barcode variants (classic barcode, QR codes, 3D and 4D codes), transmitter/receiver-based systems (RFID, NFC) for discreet tracking were also used. Real Time Location Systems (RTLS) like GPS, cellular or also Bluetooth Low Energy (BLE) and ultra-bandwidth technology are suitable for continuous tracking. The appropriate technology must be selected depending on the particular application. The criteria may be e.g. the technology maturity, the costs, the susceptibility to failure, the information content and the automatability. Extensive technology comparisons already exist regarding various criteria [14].

There is no need for continuous recording of tracking molds, therefore the choice must be made between optical identifiable markings (QR codes) and transmitter/receiver-based systems. Optical markings must be reliably visible for the reader and, because of that, have limited suitability for the tracking of molds. Based on its good scalability, RFID as a transmitter/receiver-based system offers itself for automated applications [15]. Both transponders and corresponding readers are, unlike other transmitter/receiver-based systems, cost-efficient and very flexible in terms of the range, the demarcation of the area to be recorded and the modularity.

Some applications in the industry, e.g. moldmaking from Phoenix Contact [16], have already made use of RFID technology. For these reasons, the application described below uses RFID systems.

Greater Transparency in Production

In the demonstrated application, molds are equipped with RFID transponders and specific storage positions and »

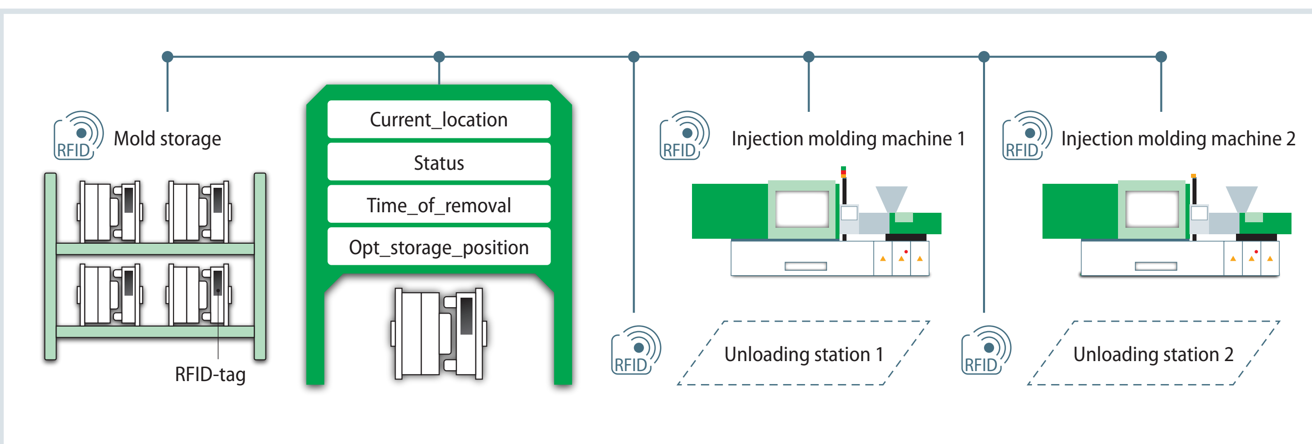


Fig. 2. Using the asset administration shell, the mold is represented as a digital twin and exchanges information via RFID with its environment, e.g. with the storage position, the injection molding machines and unloading stations Source: IKV; graphic: © Hanser

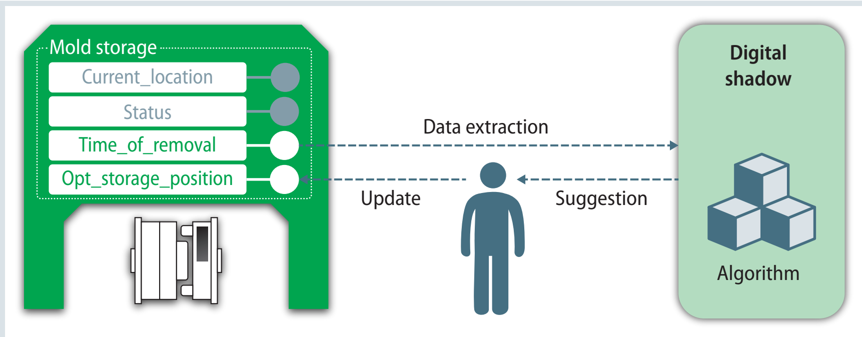


Fig. 3. The digital shadow uses the data recorded by RFID to suggest an optimum storage position for the mold and to carry this out if a staff member confirms it Source: IKV; graphic: © Hanser

current locations of the molds are continuously monitored by corresponding antennas. As a result, mold movements can be recorded at any time and relevant data can be transferred into the system.

To increase the transparency of the production, the digital mold twin should show the current location of the real mold in real time and without manual intervention. Apart from that, the storage position should be optimized based on the number of mold movements, whereby the position of frequently used molds is located near the base so that these molds are more easily and quickly accessible. For this purpose, the asset administration shell submodel "mold storage" will be modelled, which contains the relevant attributes plus possible characteristics (**Fig. 2**). Besides the attribute *Current_location* recorded via RFID, the submodel includes the attributes *Status*, *Opt_storage_position* (the optimal storage position) and *Time_of_removal*.

If the relevant attributes should change over time, the asset administration shells can be adapted easily. The structuring of the data took place in the JSON format, which is a versatile exchange format that can be easily integrated into many software applications.

Optimization through the Digital Shadow

The digital shadow should support logistics staff with the determination of a suitable mold storage position in the form of an assistance system. Relevant for that are the attributes *Opt_storage_position* and *Time_of_removal*, the attributes *Current_location* and *Status* are not addressed by the digital shadow. Through this automatic logging, a history of moving times is created, which is saved in the attribute *Time_of_removal*.

The digital shadow takes this history for every mold and combines it into a data trace. Using an algorithm, it establishes a ranking in which the molds are sorted by their number of movements and assigned to a corresponding storage place. The updated storage position is automatically logged into the attribute *Opt_storage_position* after confirmation by a logistic staff member (**Fig. 3**). If necessary, the algorithm could be expanded by any additional conditions, e.g. by taking into account the size and weight of the mold for the selection of its storage position. The only requirements for this are corresponding attributes in the asset administration shell and the correct recording of relevant data.

One advantage of attribute-based asset administration shells is the standardized database, which can use different services. These services can be deployed modularly, so that, using an asset administration shell, a service-oriented architecture (SOA) can be realized. Also, the "Plug and Play" idea is practicable with asset administration shells that are structured in a standardized manner.

To illustrate the described application, the Institute for Plastics Processing (IKV) in Aachen, Germany, is working on a demonstrator. On the one hand, the data structure of the digital shadow will be developed and, on the other, an exemplary recording of molds using RFID will be implemented in the technical center.

Outlook

The concept of digital twins and digital shadows can be applied to the management of molds. Through the standardized asset administration shells, which include all relevant attributes, digital twins can be implemented for the virtual mapping of molds. Track- and-trace technologies like RFID are suitable for manipulating attributes. All in all, the digital twin can increase the transparency of production. In addition, the digital shadow can be used as a service module, as this article shows, based on the optimization of the storage position of molds.

Further studies are dealing with the creation of other asset administration shells and submodels for other assets, so that all relevant assets of injection molding production are transferred to the virtual world and supported by the digital shadow. ■

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