FORCAM™ FORCE

Version 5.10

Track & Trace

Product Description

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Product Description

FORCAM FORCE™ Track & Trace can be used to track and trace transport containers/production batches as well as individual parts.

Scanning the identification numbers of (transport) containers such as boxes, product carriers or crates enables tracing back components to their manufacturers, for example. In this process, the itinerary of the individual part between the input and output containers is recorded accurately.

It is also possible to integrate a quality management (QM) system to ensure optimum quality for the parts produced. In addition, it is possible to use a compliance batch (comprising parts referred to as retain parts) to demonstrate appropriate quality or for analysing the material manufactured at each stage of the production process in retrospect in case of a complaint.

Track & Trace can be used for tracking and tracing across several workplaces and operations. Whereby the additional data generated at each workplace are included in the course of the process.

Moreover, Track & Trace can be used to manage an assembly plan and make it available to the worker using the Shop Floor Terminal. The predefined assembly plan is displayed when an operation starts at a workplace and provides instructions for assembling the components. Reading and confirming defined individual steps of this assembly plan is mandatory for the worker. For example, important documents must be read and confirmed and components to be assembled must be identified by specifying their serial/batch number.

FORCAM FORCE™ Track & Trace offers various options for analysing the data acquired. Data can be displayed in a trace tree format and in table/list format.
For visualization in the form of trend lines, graphics and relationships between values/elements, FORCAM FORCE™ uses professional graphic systems and data analysis tools of cooperation partners and third-party providers.

Track & Trace may involve large data volumes ("big data"). For this reason, FORCAM FORCE™ uses a document-based NoSQL database and the JSON data interchange standard for Track & Trace. The document-based management of trace data offers significant performance advantages in comparison with traditional relational database management, particularly regarding data analysis. In addition, the NoSQL database features replication and scaling mechanisms.

Process Data Acquisition

Selected signals from a machine are recorded based on values and directly written to a time series database, independent on a reference to processes, orders or serial/batch number. In most cases, this is triggered when a signal value has changed. Alternatively, signals can also be written to the time series database at certain intervals (e.g. every 5 seconds).

In addition, the data can also be displayed directly in a visualization. The display is dynamic and changes depending on the corresponding signal.
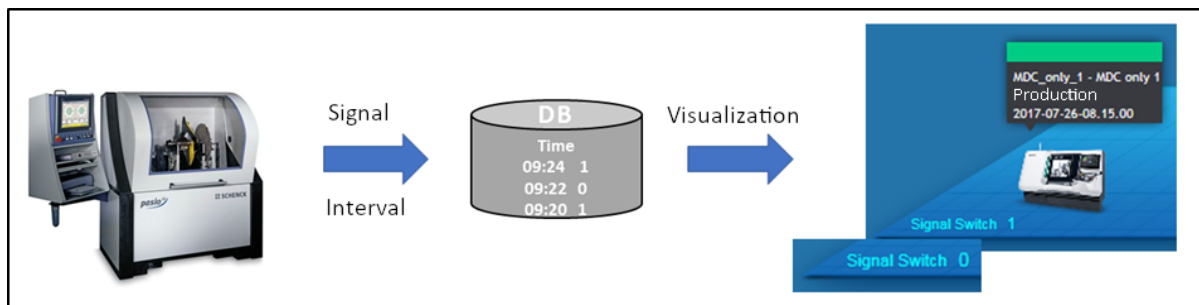

Fig. 1: Data from the PLC are written to a time series database and visualized

FORCAM FORCE™ Track & Trace can process very large amounts of data, such as those that result from measuring a very precise curve, for example. If a curve is sampled approximately every 1000ms, the corresponding value is recorded every second, which can result in a massive amount of data. If signal values are acquired from the FORCAM FORCE™ Bridge, the maximum sampling rate depends, among other things, on the number of signals to be collected. As a rule, sampling every second is not a problem. If higher sampling rates are required, the curve may have to be sampled in blocks in the machine control and transferred to FORCAM FORCE™ Track & Trace as a whole.

Track & Trace is also suitable for machines and systems that cannot be connected via a classic machine control. For example, a system uses a measuring machine to read in a part and starts the measuring process. This measuring process, for instance, determines twenty different values such as diameter, pressure, temperature, etc. The measuring machine writes all results into a CSV file. FORCAM FORCE™ can use Track & Trace to read out this CSV file and assign all determined process values to this part. Ideally, the CSV file should contain the serial or container number to which the data is to be assigned.

Track & Trace also enables third-party systems to transfer process data to FORCAM FORCE™ Track & Trace via a database interface. In addition to an arbitrary list of process parameters, the serial or container number to which the process data is to be assigned is transferred. The interface dynamically adds further process parameters, which means that it is not necessary to manually adjust the configuration of FORCAM FORCE™ Track & Trace.

Data Input for Track & Trace

Process data for FORCAM FORCE™ Track & Trace can be made available either automatically or manually.

- Master Data
Order, Operation, Workplace, Worker, …
- IDs
DataMatrix-Code, Mat. IDs, Components
- Process Data
Temperature, Diameter, Pressure, Torque, …
- Trigger
Start of record, save at the end

Automatic trace

Process data can be acquired automatically from the production/assembly process from a PLC, from CSV files or via a database interchange interface.

Manual trace

Every data acquisition point that can be provided with process data automatically from the production/assembly process by a machine control, for example, can also be set and entered manually by a worker in a dialog on the terminal.

In addition, it is possible to perform assembly operations guided by dialogs on the terminal. In addition to the serial/batch numbers of the components to be assembled, additional parameters describing the assembly status of the component can be input manually (e.g. protrusion of the cylinder on the engine block).
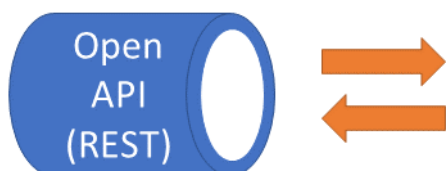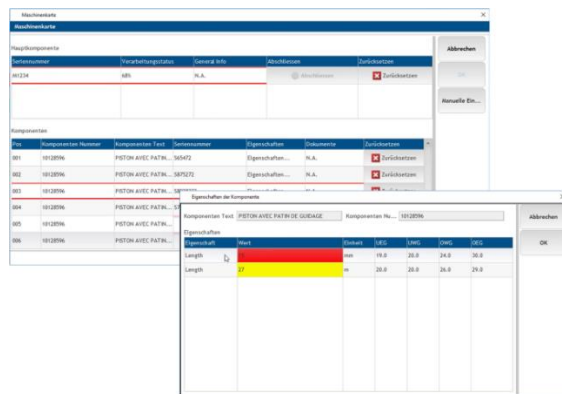
Open API

Track & Trace can integrate third-party QM systems (usually CAQ systems) via a web service interface. CAQ systems measure a part produced or a subset of parts (crate) against a quality control plan and send a message to FORCAM FORCE™ Track & Trace, communicating the measurement parameters to be input and the quality of the parts determined.

The open API makes it possible to read in measurement parameters that had not yet been defined. These are automatically added to the FORCAM FORCE™ Track & Trace configuration and the associated data are saved (self-learning feature).

Components

FORCAM FORCE™ Track & Trace can process data about components used so that these can be traced back, for example, to know the respective supplier.

Example:
An operation starts on a workplace using a specific bill of materials (BOM). According to the BOM, the components C1, C2 and C3 are required to produce the material/product.

Component C1 is administrated in the ERP system as a storage unit. This storage unit has a unique storage unit number which can be used to register it on the terminal in FORCAM FORCE™ Track & Trace. FORCAM FORCE™ Track & Trace will then retrieve other properties of the storage unit directly from the ERP system via a web service interface, e.g. supplier, batch number, storage location, etc. Component C2 was produced as a production batch in FORCAM FORCE™ Track & Trace on a previous workplace or in an upstream production process. This production batch is located in a container (e.g. crate) and can be identified by the corresponding unique container number.
Component C3 is an individual part (single piece) with a unique ID that had been registered in FOR-CAM FORCE™ Track & Trace in an upstream production/assembly process.

The worker scans both the output box (container) and the storage unit for C1, the container for C2 and the single piece for C3. Whereby FORCAM FORCE™ Track & Trace verifies the plausibility of the component bookings. Subsequently, all the components are processed on the workplace. The data saved enables tracing back to the specific supplier, for example. When a production cycle has been processed on the machine, a tree structure (trace tree) is created for each individual part, showing how the product has been composed. As a prerequisite, the machine must communicate the serial number of the individual part produced in addition to the process data. In the case of a batch trace (see next section), the flow of materials between the input components/containers and the output container is recorded.
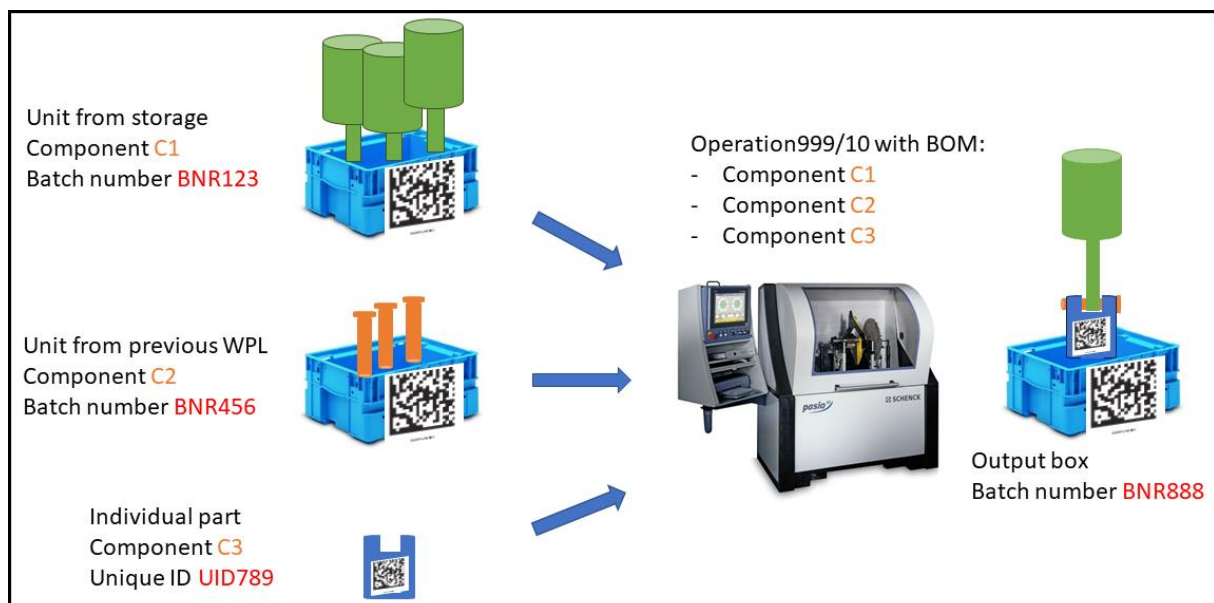

Fig. 2: Production of an output product from individual components

Batch Trace

FORCAM FORCE™ Track & Trace lets you track production batches by batch numbers. A production batch is located in an identifiable container (e.g. crate) at a defined point of time. It is also possible to integrate a quality management system to ensure optimum quality for the quantities/parts produced. In addition, it is possible to use a compliance batch to demonstrate appropriate quality or for analysing the material manufactured at each stage of the production process in retrospect in case of a complaint.

Movements between Boxes

The movements of materials between input and output boxes are managed in the Shop Floor Terminal. A dialog in the Shop Floor Terminal prompts the worker to register an input box for the workplace/operation. Another dialog prompts the worker to register an output box. The material is taken from the input box, machined (e.g. cut) and placed into the output box.

When an output box is full, it can be deregistered automatically and forwarded to the next workplace or the QM process. The worker now scans another output box and starts filling it. Quantities and movements are accurately recorded in this process. It is also possible to distribute the quantities to several transport boxes/containers.

A production batch is linked to a box/container at a specific point in time. The production batch has a quantity model which precisely distinguishes the materials contained in the box for each order and operation (= production stage). Process data such as temperature or pressure are associated with the production batch.

A production batch may also contain identifiable single pieces in addition to the anonymous batch quantities. In this case, process data are usually assigned to each single piece. Single pieces can be moved between boxes/containers.
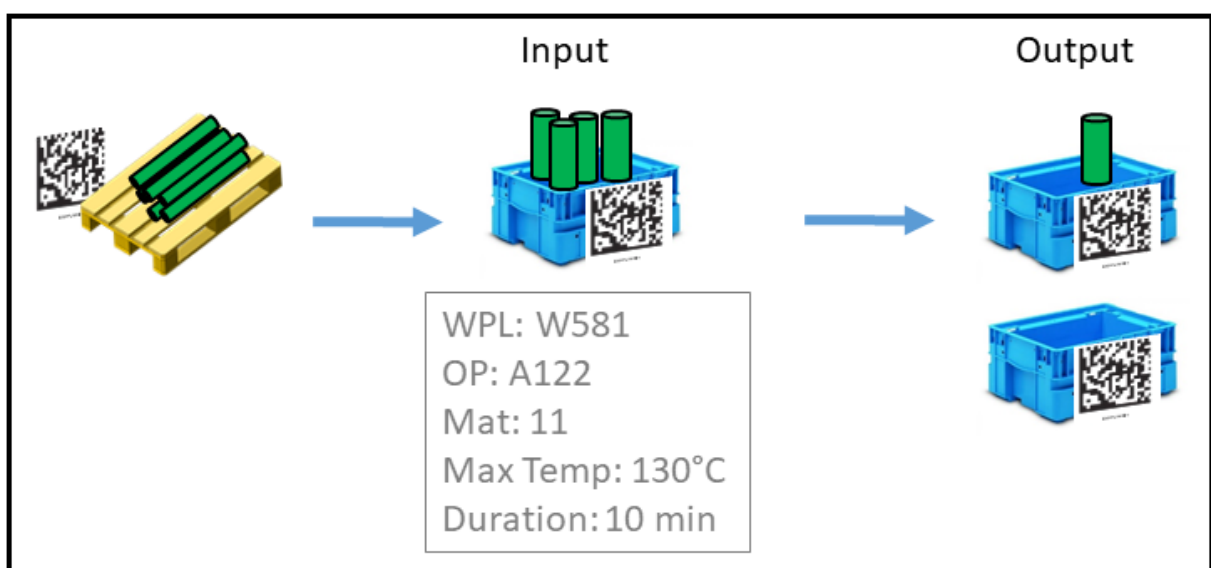

Fig. 3: Movements of materials between input and output boxes

FORCAM FORCE™ can show the movements of anonymous quantities of materials between their input and output boxes. Such movements of materials/quantities are displayed in detail, i.e. indicating order and operation.
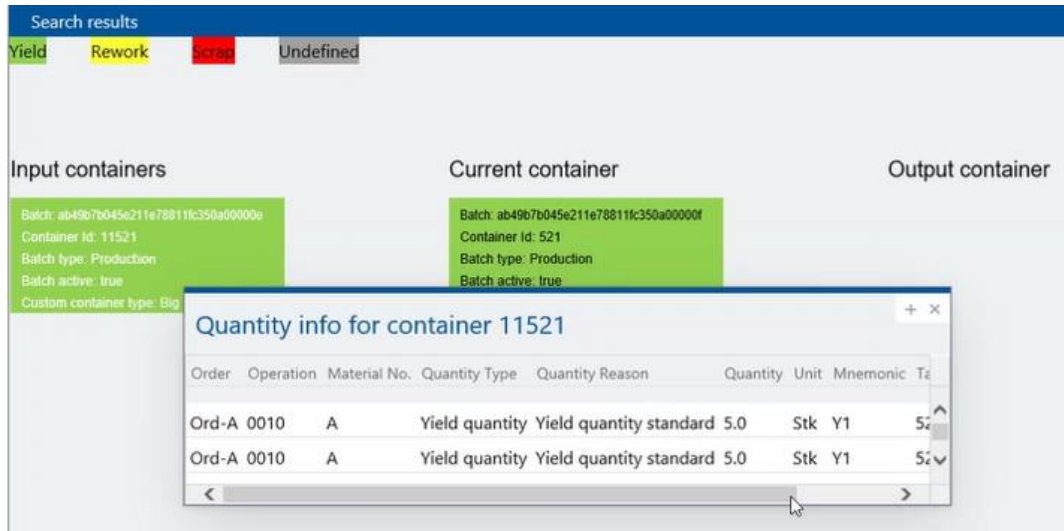

Fig. 4: Movements of quantities between boxes

The boxes relating to an operation are additionally displayed in the Shop Floor Terminal in a sub-screen of the operation screen. The unique batch number is indicated in addition to quantity and material number/production stage. The display shows the output box and all input boxes (components) registered.

Fig. 5: Box information in the Shop Floor Terminal

Quality Management

An existing quality management system can be integrated into the trace process via a defined web service interface to ensure efficient production without defects.

When starting an operation, the QM system (e.g. CAQ system) is informed via a web service about which order/operation was started in FORCAM FORCE™. The QM system can subsequently send (also via web service) the currently valid (sampling) interval for this operation to FORCAM FORCE™ Track & Trace. It is possible to dynamically adjust the (sampling) interval at any time via the web service interface.

At the end of each (sampling) interval, the worker is prompted to take a defined number of parts from the process (output box) and forward them to the QM system. The QM system will then verify the quality of the parts submitted against a defined quality control plan (which may also involve several inspection operations) and communicates the inspection result (including any measurements) to FORCAM FORCE™ Track & Trace. If the quality of the subset of parts is unsatisfactory (scrap), this is an indication of a potentially poor quality of the entire contents in the box. Track & Trace adjusts the quantity info and the quality/release status of the output box accordingly.
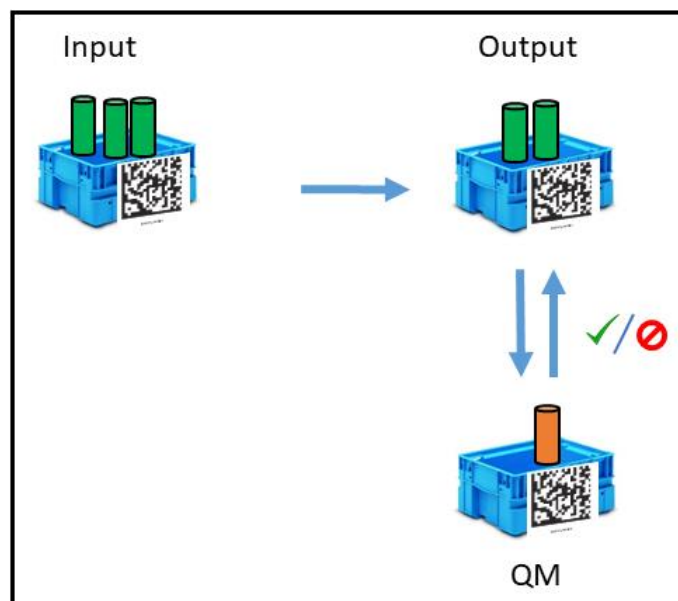

Fig. 6: Product sampling/inspection by QM to determine the quality

Compliance Batch

In addition to integrating a quality management system, it is also possible to use the compliance batch function to demonstrate quality and for analysing the products at each stage of the production process in retrospect in case of a complaint.

Similar to the quality inspection, a sampling of good quality is taken from the production and placed into a separate container. The container can be of any type, for example, a box, product carrier or plastic bag.

The container is provided with a label that basically indicates the compliance batch number and is then stored. If any quality issues should arise later in the context of a complaint, it will be possible to trace the corresponding compliance batch back to any stage of the production process.
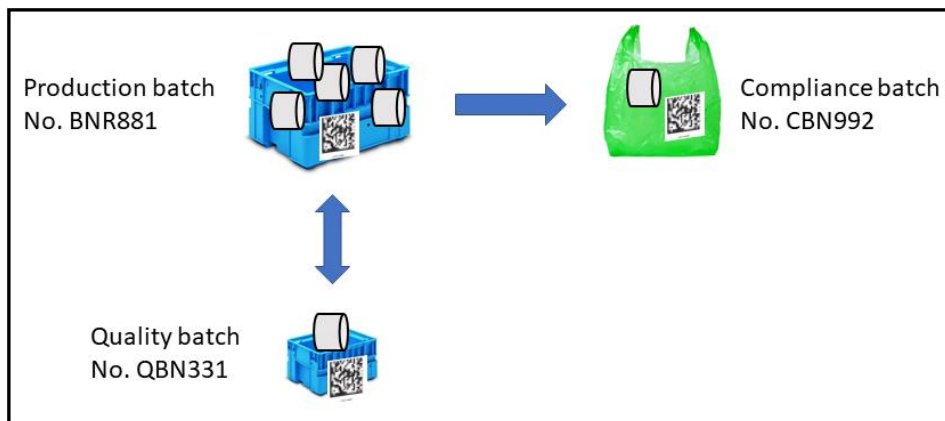

Fig. 7: Separation of a compliance batch (retain parts) from a production run

Serial Trace

FORCAM FORCE™ Track & Trace permits tracking a single piece with a unique identification across several workplaces and operations, including the data additionally generated at each workplace.

Example:
A part with a defined ID is conveyed into a furnace at a workplace. The furnace temperature is assigned to the part at this workplace. Holes are milled at the next workplace. The cutting speed and hole diameter are assigned to the part at this workplace. Other data generated on other workplaces are appended to the data previously recorded.
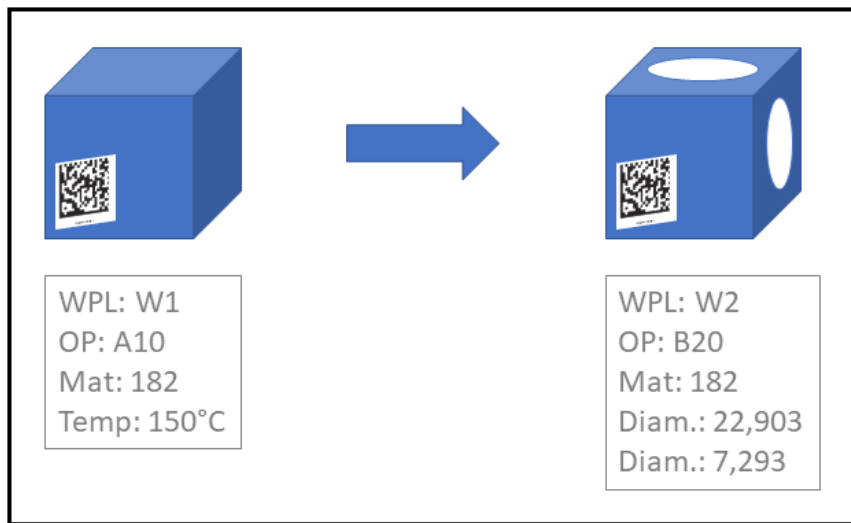

Fig. 8: Recording trace data for a single piece across several workplaces

Data acquisition begins according to the configuration of the data acquisition points defined in FOR-CAM FORCE™ Track & Trace. A data acquisition point describes all process parameters to be collected (e.g. pressure, temperature) and their source (e.g. signal X from machine controller Y).

In addition, each data acquisition point includes a definition of the time when data acquisition will be triggered. The specific trigger can be defined flexibly, such as the change of a signal to a specific value (e.g. rising edge). The end of data acquisition is defined by the end of the trigger, e.g. falling signal edge.
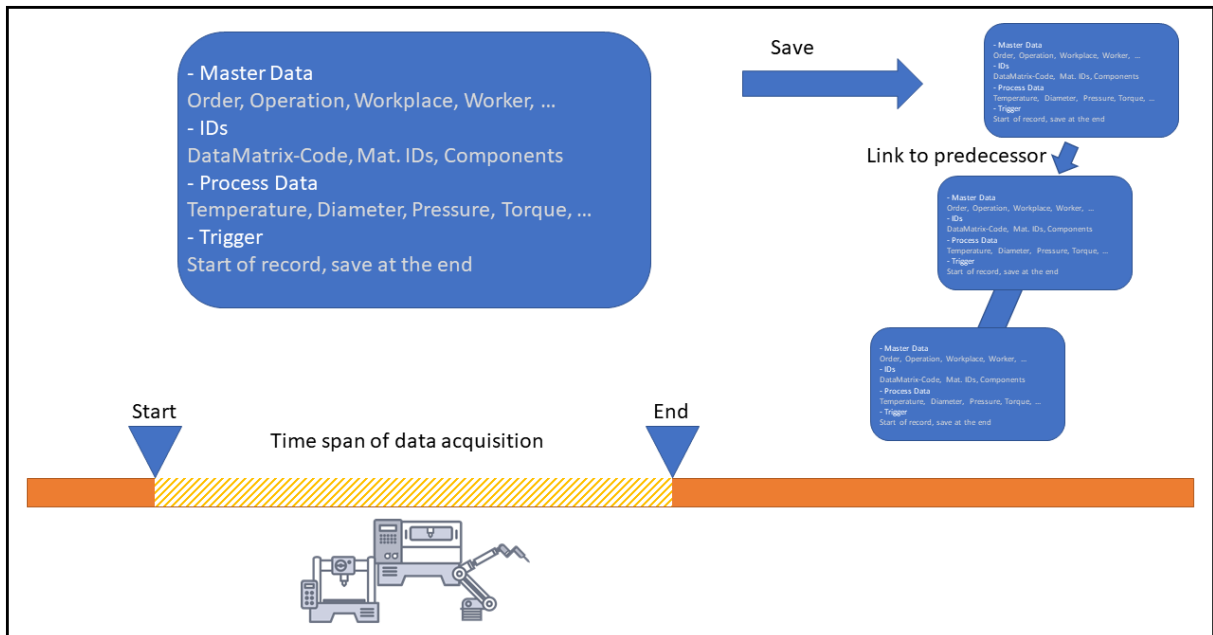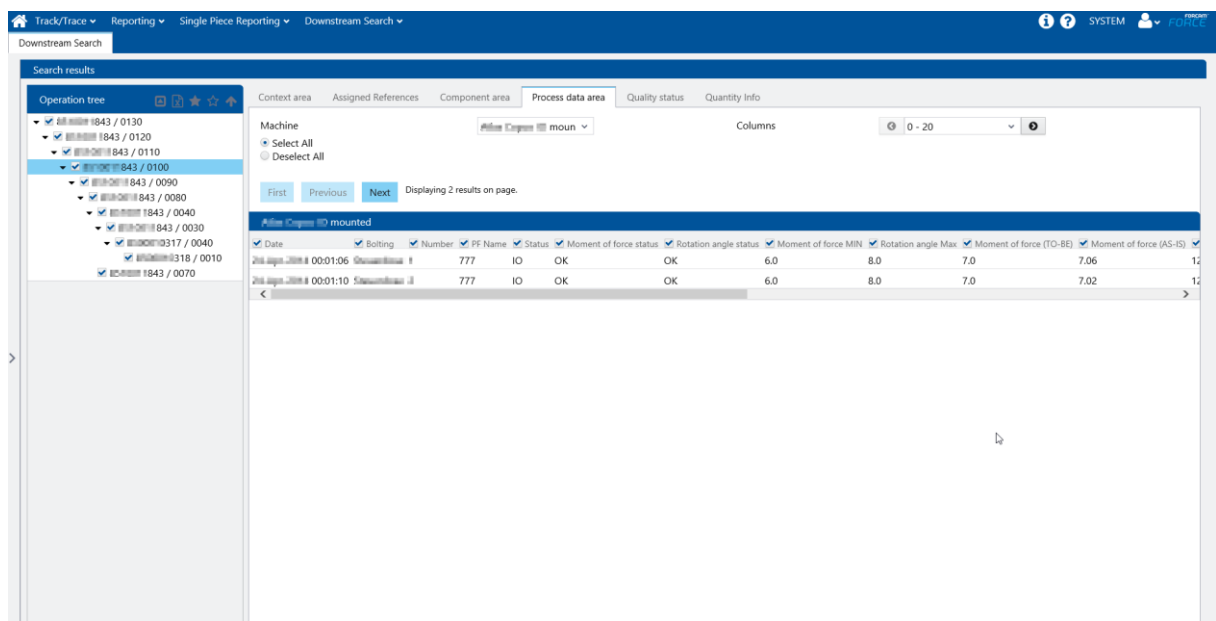
Fig. 9: Serial trace concept

When recording is finished, the process data are saved in a trace node together with their valid processing context. Here, the processing context is the order/operation executed.

The system uses the ID of the single piece to check whether it had already been processed in a previous workplace/operation. If this is true, the corresponding trace nodes are joined. Joining these nodes results in a trace tree precisely reflecting the structure and chronological sequence of the production/assembly operations. When searching FORCAM FORCE™ Track & Trace for an ID of a single piece, the corresponding trace tree is displayed.

Fig. 10: Trace tree in FORCAM FORCE™ including all relevant information about a single piece

Information is available for each operation in the following tabs (see figure 10):

- Context area:
  Basic information about order, workplace, person logged in, etc.
- Component area:
  Information about components, such as component number, name, supplier, etc.
- Process data:
  Information about data collected at this workplace, such as torque, rotation angle, etc.
- Assigned references:
  The IDs assigned to the node (e.g. serial numbers)
- Quality status:
  The quality status indicates whether the part is OK or NOK at this stage of production.
- Quantity info:
  The quantity info describing the quantity acquired for this node. This also includes a qualified quantity reason (e.g. "Surface scratched").

Assembly Plan

FORCAM FORCE™ Track & Trace can be used to manage an assembly plan and make it available to the worker using the Shop Floor Terminal.

The assembly plan is based on the bill of materials of an operation and is displayed on the terminal when the operation is initiated. The assembly plan contains instructions for assembling the output product. The instructions include a list of the components to be assembled that must be identified by the worker during assembly by entering/scanning the serial or batch numbers.

In addition, document links can be specified for each component which the worker can access to obtain helpful or critical information (e.g. drawings, safety instructions). FORCAM FORCE™ Track & Trace also allows configuring other parameters for each item on the bill of materials that must be handled manually – including their limit values. These parameters are specified manually by the worker when assembling a component.

The operation is not completed until all mandatory steps have been performed. However, it is possible to interrupt the assembly process at any time and resume it later seamlessly with all data previously input.
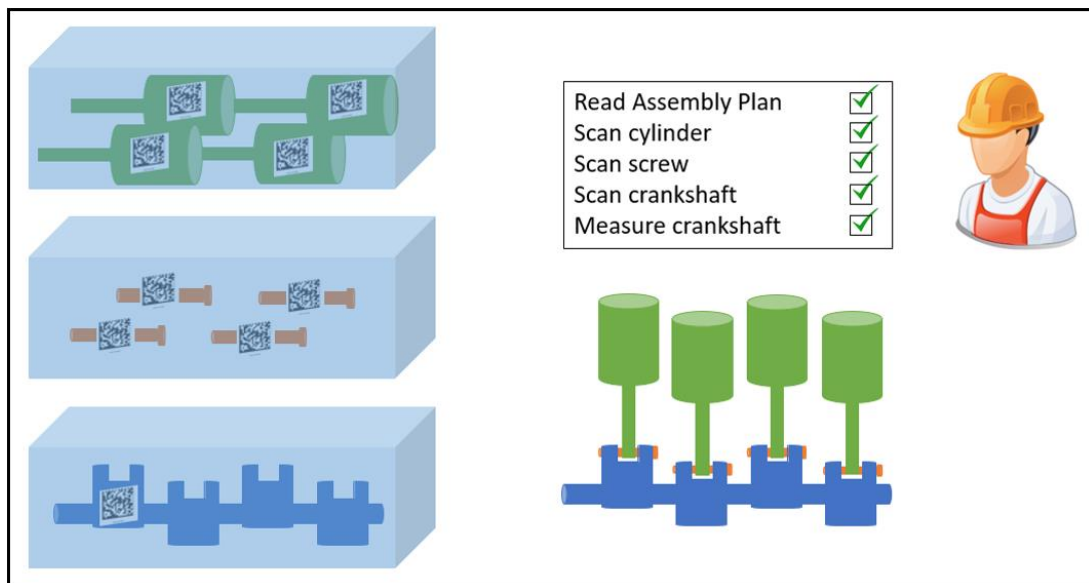
Fig. 11: Assembling an output product and confirming the components added, including measurement parameters and documents displayed

Track & Trace can specify and process the following actions in assembly instructions:
- Scanning of parts/components
- Measurements of parts/components (after identifying these by entering a serial or batch number)
- Opening document links and logging this activity
  (http links referring to documents stored, e.g. in Microsoft® SharePoint that are not managed within FORCAM FORCE™)

Intelligent Analysis

FORCAM FORCE™ Track & Trace offers various options for analysing the data acquired.

Serial trace

- Trace tree for a part produced
- Search for all parts with specific properties (e.g. temperature > 100°C)
- Search for all parts with specific properties and display of correlated parameters (basis for correlation analysis)

Batch trace

- Trace tree for a production batch
- Search for production batches/containers with specific properties
- Visualization of movements of materials between containers

For visualization in the form of trend lines, graphics and relationships between values/elements, FORCAM FORCE™ relies on the experience and know-how of cooperation partners and third-party providers. Professional graphic systems and data analysis tools can present the data collected by Track & Trace in numerous different ways. Individual customer-owned tools may also be used.
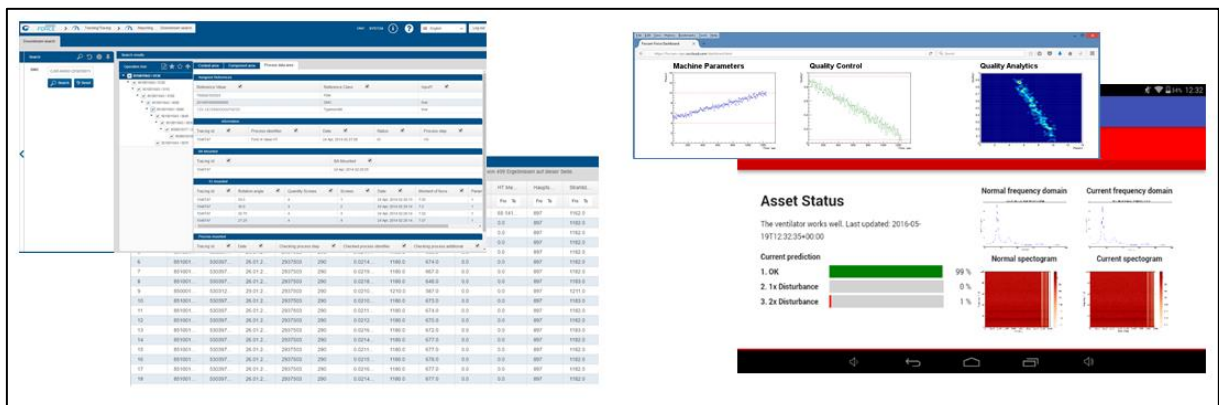

Fig. 12: Visualization of trace data using third-party applications

Data Storage

Track & Trace may involve large volumes of data ("big data"); for example, complete process data sets comprising 10 process values of 100 machines every 10 seconds. Conventional relational databases (e.g. Microsoft® SQL Server) are not suitable for this data processing situation for the following reasons:

- Fixed database structure.
- Lower analytical performance (see table 1).
- Horizontal scalability (e.g. distribution of the data to several computer nodes) is difficult and/or expensive.
- Redundancy mechanisms (for high availability) are difficult to implement.

For this reason, FORCAM FORCE™ uses a document-based NoSQL database and the JSON data interchange standard for Track & Trace. Table 1 illustrates the difference in analytical performance between a NoSQL database and a Microsoft® SQL Server. It is evident that the NoSQL database permits substantially faster analysis of the trace data.

Table 1: Difference in analytical performance between the NoSQL database used and a Microsoft® SQL Server (based on about 165,000 parts processed)

	NoSQL	SQL Server	Factor
Downstream analysis	0.08	9.2	115
Upstream	19.2	378.1	19.7
Upstream with parameters	15	875.5	58.4

Scope of Functions

FORCAM FORCE™ Track & Trace offers the following functions:

- Process data acquisition:
  Saves process data directly into a time series database without reference to serial number or batch number
- Data input:
  - Automatic acquisition from machine controller
  - Manual entry on the Shop Floor Terminal
  - Database-type exchange interface
  - Connection of third-party systems via suitable interfaces (e.g. for CAQ systems)
- Components:
  Tracking and tracing the components used, for example, with reference to the specific supplier
- Batch trace:
  - Movements between containers/boxes:
    Tracking the movements of quantities and parts between input and output boxes
  - Quality management:
    Integration of QM systems (e.g. CAQ system) via a web service interface
  - Compliance batch:
    Archiving of a reference sample (of each production stage) to be able to trace back / demonstrate the quality later
- Serial trace:
  Tracking a single piece across several workplaces and operations including the relevant process data added at each workplace
- Assembly plan:
  Predefined assembly instructions specifying requirements that a worker must fulfil to complete the operation
- Intelligent analysis:
  - Trace tree for a part produced
  - Search for all parts with specific properties (e.g. temperature > 100°C)
  - Search for production batches/containers with specific properties
  - Other analyses using graphic systems and data analysis tools of experienced cooperation partners
- Data storage:
  Data management using a document-based NoSQL database and the JSON data interchange standard, fulfilling the requirements of big data applications: Analytical performance, high availability and scalability.

Annex

Table 2: Abbreviations and terms used

Abbreviation/term	Description
API	Application Programming Interface
BOM	Bill of materials (list of components)
CSV	Comma-separated values file format
ID	Identification number
JSON	JavaScript Object Notation: A compact data format in an easily legible text format
Mat	Material
Max Temp	Maximum temperature
MB	Megabyte
MDC	Machine Data Collection
min	Minute
MongoDB	Document-based NoSQL database
ms	Milliseconds
NC program	A program designed to control NC equipment. An NC program is transferred on a data storage medium to the NC equipment for execution.
NOK	Not acceptable, incorrect
OK	Acceptable, correct
PLC	Programmable logical control
QM	Quality management
sec	Second
SQL	Standardized query language for databases
WPL (APL)	Workplace