Siemens Digital Industries Software

Opcenter Execution Discrete

Executive summary

In a scenario in which business is more and more impacted by the internet and end customers are increasingly able to tell manufacturers directly exactly what they want and when, manufacturers must respond quickly with improved flexibility to enable individualized mass production, and with the efficiency to reduce energy and resource consumption. Merely focusing on the automation of manufacturing processes or on the cost and efficiency of individual production operations is no longer enough to compete in the global marketplace and to meet these requirements. A holistic approach, spanning the entire value chain and including suppliers, is necessary.

Siemens now offers a holistic automation solution covering all major Industry 4.0 requirements: the Digital Enterprise Software Suite. Manufacturers are better equipped to initiate or respond to disruptive innovation trends when their processes are fully digitalized.

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1 Introduction

1.1 A holistic approach to optimize the entire value chain

Siemens Digital Industries Software solutions smoothly connect major parts of the product and production lifecycle. Powerful product lifecycle management (PLM) software enables the development and optimization of new products on an entirely virtual basis.

To digitally transform the realization phase, Siemens provides a complete portfolio of solutions for manufacturing operations management (MOM), bridging PLM and automation domains and enabling customers to implement strategies for the complete digitalization and integration of their product and production lifecycles.

The Siemens portfolio for manufacturing operations management enables the digitalization of a broad spectrum of production-related functions, including advanced planning and scheduling, manufacturing execution, quality management and manufacturing intelligence. Working together, these solutions optimize production processes and drive operational excellence, with a focus on steadily improving production efficiency, flexibility and time-to-market.

Improved efficiency. The Siemens MOM portfolio provides end-to-end visibility into production operations and quality management, connecting the automated operations equipment and systems on the shop floor to the decision makers in product development, manufacturing engineering, production and enterprise management. With full visibility into production, decision makers can readily identify areas to be improved within both the product design and associated manufacturing processes, and make the necessary operational adjustments for smoother and more efficient production.

Improved flexibility and time-to-market. Using the Siemens MOM portfolio, our customers are able to model, visualize, optimize, update, and harmonize production processes globally, and have the ability to collect, plan and schedule, aggregate, analyze and respond to real-time manufacturing events. The integration with PLM, enterprise resource planning (ERP) and automation provides the flexibility and scalability of production processes required to maximize responsiveness. With a fully optimized Digital Enterprise, manufacturers are better equipped to rapidly respond to market changes and realize the innovation that customers demand today.

2 Why focus on manufacturing operations management?

On a daily basis, a variety of people in charge of different activities face problems that involve manufacturing systems. Implementing MOM and deploying the right production model can provide a solution to many of these issues. In broad outline, the problems encountered concern:

- Business
- Production
- Information technology (IT)

2.1 Business issues

Increase the overall efficiency of your supply chain

Supply-chain efficiency is strongly affected by how the business level (ERP) and the shop floor (control) interact. MOM represents the go-between that, when streamlined and efficient, contributes to a better supply chain.

React quickly to new conditions and new market requirements

In manufacturing, the ability to adapt to new operational requirements (for example, changes in product specifications or quality procedures) and environmental conditions (for example, introduction of new standards) is paramount to success. If your system is ready to meet these challenges, the reward may be a significant increase in your competitiveness, as well as significant cost savings.

Standardize production process across all plants

Guaranteeing uniform, consistent production procedures is a key issue. If this is lacking, then the result may be uneven quality of your product from one facility to another. Control systems and business systems cannot solve the problem; a structured and modeled environment is required to coordinate the production process seamlessly, and in different contexts (for example, different hardware and software installation bases).

Comply with new regulations

Established standards and regulations such as ISO or VDA already exist to guarantee high-quality products. However, new regulations, as well as the need for exhaustive material traceability, are affecting manufacturing procedures substantially. MOM can help you achieve compliance with these regulations and maintain full accountability of materials.

Make your business more customer-oriented

Standard monolithic applications often represent a barrier to implementing an efficient system that can adapt and satisfy ever-changing requirements from both the customer and the market. In view of the growing demands posed by customers, MOM can make your system much more flexible and adaptable.

With a fully optimized Digital Enterprise, manufacturers are better equipped to rapidly respond to market changes and realize the innovation that customers demand today.

2.2 Production issues

Rework, scrap and materials management

Typically, rework and scrap cannot be handled by control systems. Without appropriate management, excessive waste or uncontrolled material tracking can also affect the quality of your final product. In addition, overall material tracking throughout the production process is now a crucial factor for both accounting and the correct evaluation of production costs.

Increase visibility with production-related KPIs and advanced reporting

To comprehend fully how your plant is performing, you need a system that can generate production reporting correlating process control-specific data with production-related data (order number, lots, personnel, materials, etc.) to facilitate troubleshooting and analyze performance problems. MOM can increase visibility into the production process, creating the right conditions to promote improvement and increase your manufacturing system's efficiency.

Improve quality, pinpoint defects

Without tools to accurately identify defective lots and backtrack production, you may be unable to address specific issues regarding the quality of your product. You may also be unable to respond to customer complaints appropriately or organize product recalls promptly. An efficient MOM system can provide complete genealogy to track materials throughout the entire production process. It also follows all material transformations with precision until the final product is produced and delivered to the end customer.

React efficiently to production problems, reduce downtime

What if something goes wrong on the shop floor? Efficient management of failures and downtimes is a must. Often, several systems need to be involved in solving the problem (maintenance must be informed, rescheduling is required, personnel must be notified as soon as possible). Poor coordination leads to using resources ineffectively, ultimately raising your production costs.

2.3 IT issues

Integrate and synchronize systems, reduce maintenance costs

A myriad of links between your software solutions greatly increases the complexity of the manufacturing system. In turn, costs for IT maintenance and program modification become staggering. This is mainly due to the lack of coordination and flexibility of the majority of manufacturing applications. The modeling approach can effectively simplify integration and actively coordinate the interaction and the flow of information between different applications on site.

Reduce implementation costs and risks

Employing re-usable solutions creates the conditions for streamlining and accelerating project implementations. Total ownership costs can be cut dramatically, thanks to efficient software re-usability.

Share and re-use know-how and expertise

Efficient re-use of software is key to effective cost saving. Being able to "code" the expertise permits the rapid transfer of know-how between users, which is usually not feasible with standard applications. Without a modeling environment to help you define business procedures, focusing on the production process rather than specific IT issues, it is difficult to understand complex manufacturing applications, making it virtually impossible to modify or reutilize code.

Streamline monitoring and troubleshooting

Typically, a production system is a complex integration of software applications and physical devices. Pinpointing problems and debugging are serious issues that require a great deal of effort and ultimately cost money. If you are able to model and run programs and business procedures from a single environment involving several systems, then extended monitoring and troubleshooting become more than just a possibility.

Maintain your team's technological skills, reduce training costs

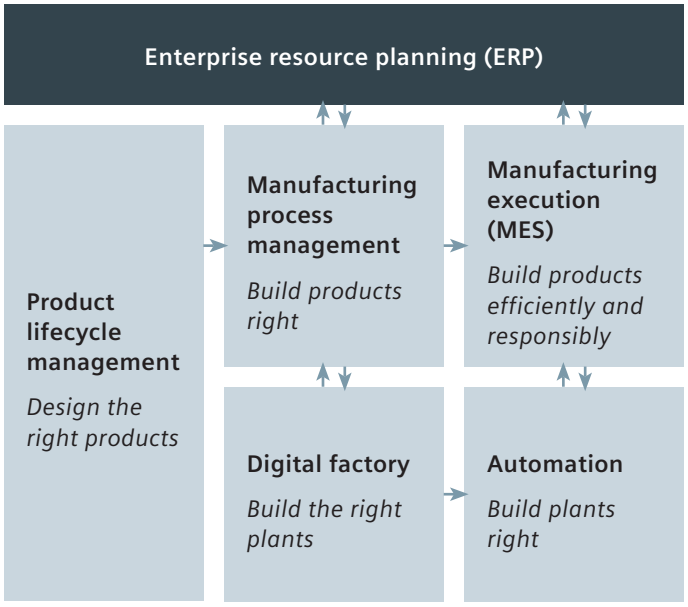
Applications are very often numerous and customized to satisfy specific needs. As a result, the person with the most thorough know-how is frequently used to develop and maintain these applications. Such competence is very difficult to maintain, and very expensive. By adopting a solution that covers all functionalities in an integrated and homogenous environment, complex manufacturing systems can be implemented with ease, making the tasks involved viable even for those users with mainstream skills.

3 How you can succeed

3.1 Opcenter Execution Discrete

The challenges in current manufacturing environments are becoming more and more exacting, and manufacturers need solutions from their suppliers that provide tangible benefits with quantifiable and quick return on investment. To increase competitiveness, manufacturers must simultaneously reduce time-to-market and cope with shorter product lifecycles, increase visibility and comply with regulatory demands, optimize forecasting and scheduling, and reduce scrap, stock levels and downtimes – all while ensuring optimal quality and production efficiency across all global facilities.

In an enterprise IT architecture, this means enabling communication and integration between the key components that are contributing to bringing products successfully to the market.



MOM architectural model.

In order to rationalize and speed up processes, product design/ideation data needs to be transferred seamlessly to the engineering environment, where the manufacturing process and test/inspection points are defined.

The engineering process is the critical link between product ideation and manufacturing. It is where ideas become industrialized reality. Greater speed can be realized when this data is transferred seamlessly to the manufacturing floor for actual execution. Real-time capabilities and supply chain efficiency come from interoperability with the financial/administration software, managing customer orders and transferring them to the manufacturing level.

In parallel, the production floor also needs to be ideally equipped and organized to produce efficiently, avoiding unforeseen problems with equipment capacity, energy use, etc. Therefore, the digital factory/plant lifecycle management part of the Siemens portfolio enables virtual testing and commissioning of plants and their equipment, delivering up front the required configurations for the automation layer, which in turn communicates with the manufacturing execution level.

All these interactions, managed by the Siemens industrial software portfolio, enable integration of the product and production lifecycles – resulting in faster time-to-market.

Opcenter Execution Foundation is the innovative MES from Siemens, and it supports manufacturers by enhancing productivity and flexibility through technological leadership combined with industry-specific features.

Opcenter Execution Discrete is the specialized product addressing the needs of the discrete industry market, focusing on job-shop part manufacturing and complex manual assembly.

The Siemens Closed-Loop Manufacturing (CLM) solution provides a way to bring together product engineering and process planning with production execution and automation: both engineering and runtime data is exchanged circularly (that is, in a closed loop), accelerating the adoption of any changes or corrective measures necessary for improving quality and lead time. The Siemens CLM solution is based on the integration between Teamcenter® Manufacturing and Opcenter Execution Discrete.

3.2 Business benefits

Opcenter Execution Foundation fills the gap between business level systems (typically PLM, ERP, SCM, etc.) and control systems, providing the conditions for increasing overall supply chain efficiency. The unique approach of Opcenter Execution Foundation allows manufacturing systems to have a native flexibility that gives users the possibility to easily adapt and modify the business process to new requirements and business drivers.

- Opcenter Execution Foundation enables manufacturers to model their businesses to be much more customer-oriented and ready to satisfy any on-the-fly requirements from the market
- Opcenter Execution Foundation supports a flexible scalability concept by design, allowing customers to scale and distribute their system as required in a very cost-effective way
- As a verticalization focusing on a specific market, Opcenter Execution Discrete comes off the shelf with implemented industry-specific manufacturing processes
- Opcenter Execution Discrete effectively helps users to comply with existing regulations

3.3 Production benefits

Opcenter Execution Discrete offers a set of modules able to cover the MOM core requirements in the context of job-shop part manufacturing and complex manual assembly. By modeling and defining production procedures, Opcenter Execution Discrete effectively increases visibility of the entire production process:

- Close alignment and synchronization between product design and production environments
- Ability to introduce product design changes while production has started already
- Operator guidance to ensure timely and correct execution
- Traceability, genealogy and visibility of work-in progress (WIP) are essential to understand current production status and support decision-making.
- Deviations and nonconformances can be managed most effectively, tying into customizable sentencing and rework processes.
- Support for mobility, as a wide range of devices may be used as clients

3.4 IT benefits

The Opcenter Execution Foundation product family combines the benefits of a platform for developing and orchestrating custom use cases with predefined industry-specific, off-the-shelf functionality, as is the case with Opcenter Execution Discrete:

- Standard industry-specific functionality immediately available
- Ability to modify existing features and to develop new functionality
- Built-in scalability allows tailoring investment and maintenance according to case-by-case requirements
- Ability to connect and interact with external and legacy IT systems

4 Opcenter Execution Discrete

4.1 General overview

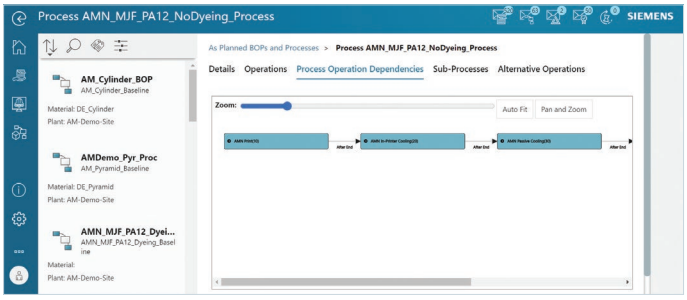
Manufacturing of high-technology special devices needs to manage production complexity, improve quality, reduce costs and shorten the time-to-market of new products. Opcenter Execution Discrete (Opcenter EX DS) implements a tailored MES for complex job-shop organized factories and provides the following functions:

- Production process and flow control
- MOM integrated with product lifecycle management
- Production route enforcement
- Execution management
- Tracking and tracing
- Defect tracking and nonconformance management
- Paperless manufacturing and reporting
- Electronic data collection
- Additive manufacturing support

Opcenter EX DS is a software product specifically designed and developed by Siemens by leveraging the Opcenter Execution Foundation technology.

Production process and flow control

- Allocate operator activity to production operations, steps, material items and resources
- Accurate work-in-progress management of orders, operations, batches and serial numbers
- Distribute workload among operators at shift start, taking their skills into account; ability to define teams of operators working on the same operations



Dependencies among process operations.

MOM integrated with PLM

- Ability to receive production processes – plain or nested – ready to be executed from a PLM system (specialized features are available in the case of Teamcenter Manufacturing in the context of the CLM solution)
- Ability to create configuration-specific work orders based on variant processes
- Ability to analyze the impact of changes on planned and running work orders
- Nonconformance feedback to PLM (specialized features are available in the case of Teamcenter Manufacturing in the context of the CLM solution)
- Ability to expose plant resources from MOM to PLM to enable manufacturing engineers to address correct data
- Ability to define Human Resources with related skills needed to perform specific Operations and ensure that these constraints are followed during the production

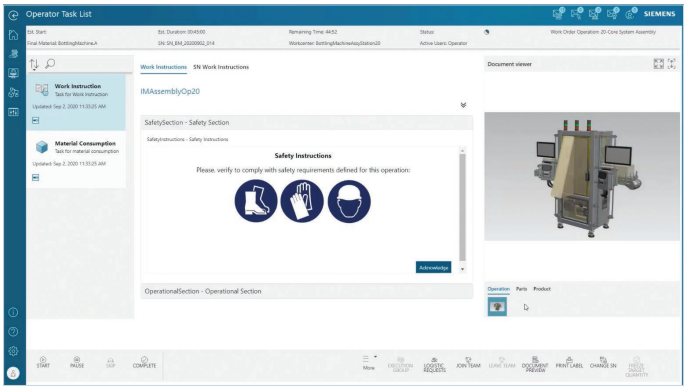
Production route enforcement

- List operations on screen based on certified operator skills (required certificates, skills and skill level are defined at operation level, typically in Teamcenter Manufacturing)
- Operator punch in/out on operations, with time logging
- Check correctness of process steps execution
- Production scheduling through Preactor AS

Execution management

- Display details of activities to be performed
- Part assembly declaration and tracking
- Tool usage declaration
- Check for part/tool correctness

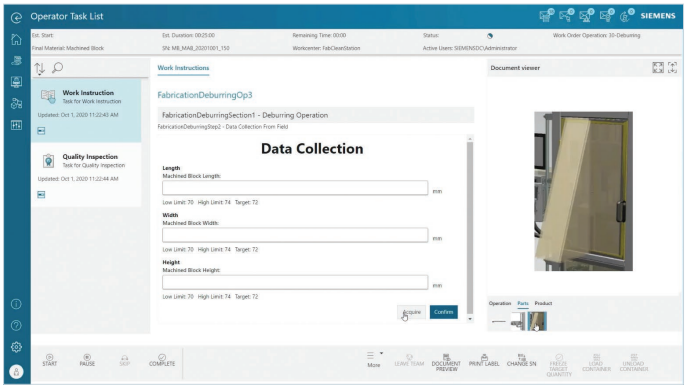
- Ability to interact with external DNC system for CNC part program transfer
- Separate labor tracking on non-productive activities



Details of activity to be performed.

Tracking and tracing

- Serial numbers of assembled materials
- Batch identifiers of transformed materials
- Measurement data collection
- Co-product tracking
- As-built report
- Genealogy report



Details of data acquisition for tracking and tracing.

Defect tracking and nonconformance

- Failure tracking
- Nonconformance management based on problem catalog
- Nonconformance lifecycle management
- Manage and execute rework processes
- Leverage the integration with Teamcenter Quality to perform planned quality inspections including visual inspections

Paperless manufacturing and reporting

- Electronic work instructions
- Data collection points
- Barcode reading support

Additive manufacturing support

- Ability to interact with CAM systems to inject serial numbers in print job files; ability to interact with 3D-printers to transfer print job files
- Track and display the genealogy of powder material batches
- Track and display the lifecycle of substrates

4.2 Opcenter Execution Discrete licenses

Opcenter Execution Discrete is composed of different licenses oriented to cover specific key functionalities.

This modular approach yields benefits including:

- Tailoring the solution closely to customer requirements
- Improving competitiveness by reducing price
- Scalability

Opcenter EX DS modules:

- Standard (mandatory)
- Operator Management
- EWI and DC
- DM Additive Manufacturing

4.3 Opcenter Execution Discrete standard

4.3.1 User management

The adoption of user management is fundamental to any system, as it permits restricting access to sensitive data, while ensuring that only individuals with the appropriate know-how and position within the organizational hierarchy of the business perform certain tasks.

In Opcenter Execution Discrete, the basic entities involved in user management are:

- Users and groups
- Roles
- Certifications (refer to "Certifications" chapter)

Users and groups

In Opcenter Execution Discrete, a user is defined as a person who can access the application. Each user has a login and a password.

The list of Opcenter Execution Discrete users is logically separate from the list of Windows users on the machine where Opcenter Execution Discrete is installed. During installation, a dedicated user (who assumes the Super User role and has administrative rights) is created from a Windows user. Additional users can be created later.

A group represents a set of users who have been categorized according to specific rules. In a Windows operating system, users can be grouped; Opcenter Execution Discrete can use these Windows groups, as well as create new groups.

Roles

Roles define which operations a user is authorized to perform; every Opcenter Execution Discrete user has a role.

Opcenter Execution Discrete comes with predefined roles for access control. In addition, you can create custom roles to satisfy specific needs, and assign a role to a single user or to a group of users.

4.3.2 Operation work booking

A common requirement during production is to collect all the possible information regarding execution time and location of orders; this information is very useful when compared with estimated time in order to improve order planning and engineering, but it is also useful in tracking the labor time of operators and allocating resources (both human and machine).

To satisfy this requirement, Opcenter Execution Discrete provides these capabilities:

- Track work order execution start/end time
- Track work order due time
- Track execution equipment

This set of information is tracked automatically by the system: the operator simply clicks the "Start" button.

When an operator stops working for any reason (for example, during lunch break), he/she must interrupt the execution of the operation by clicking the "Pause" button: the system then stops tracking work time and can provide the actual execution and labor time during subsequent analysis (as-built, genealogy).

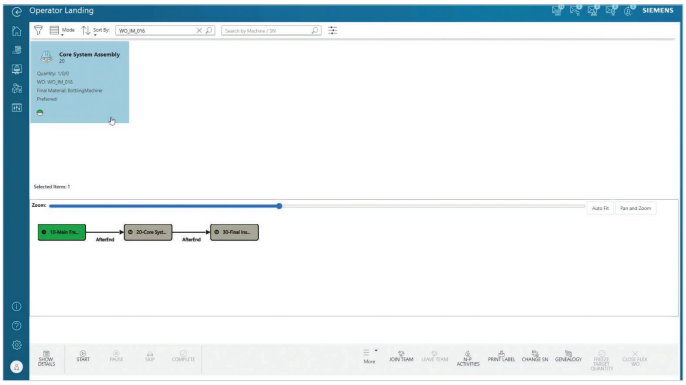
Operators can resume work at any time by again clicking the "Start" button: the system will restart tracking working time and location. Operators click the "Complete" button when they complete operation execution: the working time counter is stopped and the operation is declared as completed.

Information collected during this process is typically presented as:

- Genealogy report
- As-built report
- Custom reports

To maximize productivity and minimize equipment downtime, thereby allowing machines to work at full capacity, operations (associated to the same or to different work orders) can be grouped in execution groups.

They are executed together at runtime on the same equipment.



Select and start work order operations from the operator landing page; other commands are available.

4.3.3 Process management

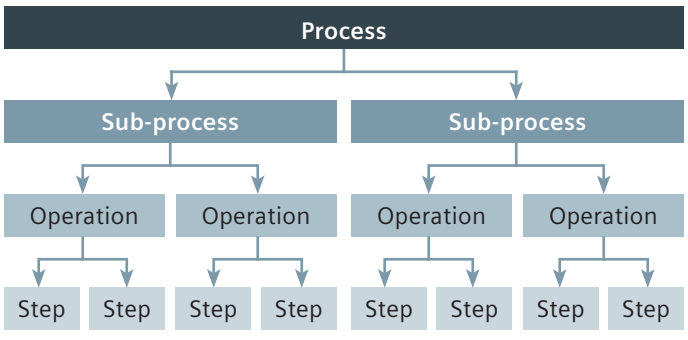
The framework for all production engineering is based on processes and how they are sequenced. A process is an abstract representation of the sequence of operations and steps involved in producing a specific product. Processes are high-level outlines that illustrate how to proceed in order to execute a specific manufacturing activity. A process represents all operations, tools and machines to be used, and materials to be consumed to achieve a particular goal in a production activity that will be executed. Each instance of a process is referred to as a work order.

Processes can be defined directly for a specific product, or they can be generic production route templates that apply to a number of different products; in the latter case, product-specific properties will be defined in the production orders derived from generic processes.

The following elements contribute to forming a single process and are listed hierarchically (top-down):

- Subprocesses
  (optional; multiple subprocess levels are supported)
- Process operations
- Process steps (optional)

All processes involved in a production activity are contained in what is known as an as-planned bill of process (BOP); its contents are whatever concurs to manufacturing the product to which the processes refer. In detail, all processes and their sub-elements, all the tools and machines to be used, as well as the materials to be consumed in the specific production activity to be executed are contained in the as-planned BOP.



Process hierarchical structure model.

Through the use of dedicated catalogs (for example: libraries containing all the available processes, operations and steps in your system), it is possible to reutilize processes, operations and/or steps when configuring your production activity in different contexts within the same production plant.

It is possible to modify a process, making changes as needed; the end result is a revision of the original process. Likewise, revisions can also be made for:

- Subprocesses
- Process operations
- Process steps

All processes have a status that is tracked and managed. For example, they can be active, obsolete, etc.

Subprocesses

In the case of complex production activities, it may be necessary to break down a process into a number of subprocesses. Subprocesses are made up of process operations, which, in turn and depending on their complexity, may be formed by a series of process steps.

Process operations and process steps

Process operations are the main building blocks of an abstract process: during engineering, a series of process operations are linked to form the backbone of a generic process. Each process operation can exist as the result of linking of various process steps, which are optional. Process operations can be linked to different parent processes or parent subprocesses.

The concepts described in this section apply both in the context of the CLM solution and when processes are defined directly in Opcenter Execution Discrete. In the former case, Teamcenter Manufacturing is the master of process information and no changes are applied at Opcenter Execution Discrete level.

4.3.4 Change management

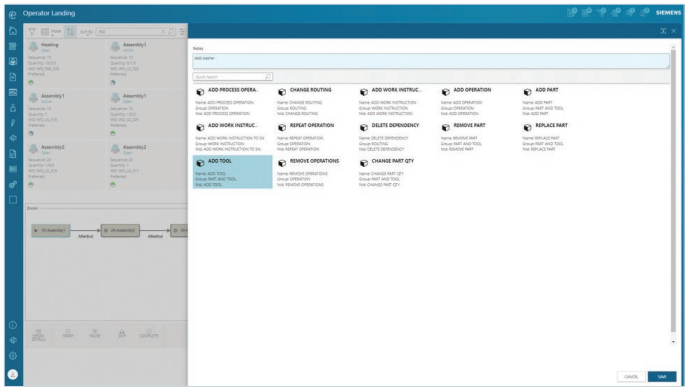
Operators can request changes to a specific work order; the change can affect the BOP or the part list of a specific work order. Exceptional changes affect all processes in the system; changes performed using Opcenter Execution Discrete change management affect only selected work orders.

Possible changes include:

- Add data collection to an operation
- Add operation to a work order
- Repeat a work order operation
- Add part/material to the part list
- Remove part from the part list

- Replace part/material in the part list
- Change part/material quantity in the part list
- Change routing (sequence of operations)
- Delete dependency between operations

Changes can be applied both to scheduled work orders and to in-progress work orders: the changes are totally managed by Opcenter Execution Discrete, so there is no constraint in applying changes at any time (after approval by a production supervisor or quality manager).



Requesting a change.

If changes are made at the PLM level resulting in a new process revision, a production supervisor at Opcenter Execution Discrete level can decide whether to adopt the new revision, based on the actual status of production. The cross-collaboration between PLM and MOM is delivered out-of-the-box in the case of an end-to-end solution with Teamcenter Manufacturing (CLM solution).

4.3.5 Note exchange

Opcenter Execution Discrete provides the capability to exchange notes among operators. Any operator can write free text notations that are accessible to other users working on the same operation. This feature is very useful for leaving notes across shifts.

4.3.6 Order splitting

Opcenter Execution Discrete allows splitting of work orders, both when the order is going to be released for production and when it is already in production.

Splitting during the release phase

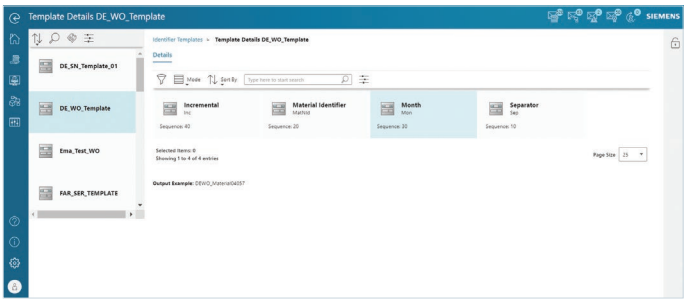
To execute a work order, it is necessary to release it for production inside Opcenter Execution Discrete. During the release phase, it is possible to split a work order applying a predefined template. A system administrator can create different templates according to the work order type and/or the material that is produced; then the production coordinator can split the work order accordingly into suborders following the template quantity.

Templates are created by defining the following information:

- Quantity
- Prefix
- Index (incremental number)
- Suffix

Each suborder that is created has a new quantity to be produced equal to the quantity defined in the template. The name of each new suborder is created merging the prefix, index and suffix defined in the template.

Templates can be defined for an entire plant (to be applied to all the released orders) or to specific part numbers (to be applied only to orders that produce that part number).

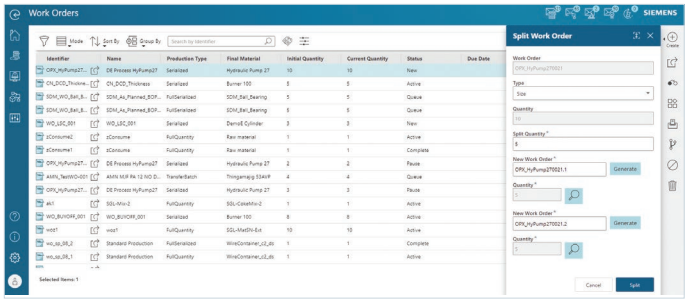


Example of an ID template for work orders.

Splitting a released order

When required, a manager can split an already released work order into several suborders. To do this, Opcenter Execution Discrete provides a split functionality; this functionality can split a work order according to the following criteria:

- By size, to split an order into *n* orders of the specified size
- By number, to split an order into the specified number of orders
- By copy, to split the order into two orders: one of a specified size, and the remaining size assigned to the original order



Splitting a work order.

4.3.7 Material consumption

Opcenter Execution Discrete displays the list of material components assigned to each operation, regardless of whether the process was defined in Opcenter Execution Discrete or transferred from the PLM system. Basically, material components are displayed as instruction information about what is to be consumed.

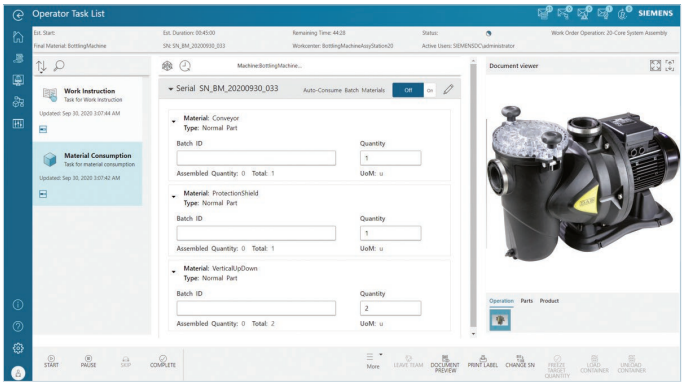
The system allows operators to collect material usage information. Reasons to request operators to declare material usage include:

- Material usage as checklist
- Material usage declaration as error-proofing
- Accurate as-built data collection

Opcenter Execution Discrete can manage several material types. The most relevant for production are:

- Serialized – operators are required to insert the serial numbers (S/Ns) of the part to uniquely identify it. The S/N can be inserted using a keyboard or barcode scanner, or selected from a list of available numbers. S/N information is available at any time in genealogy and in as-built reporting.
- Not serialized – operators are required only to insert the used quantity; this kind applies especially when there is no need to track the used part identifier (bolts, for example).
- Batch managed – operators are required to insert the identifier of the batch that the used parts are taken from. The identifier can be inserted using a keyboard or a barcode scanner, or selected from a list of available identifiers. Batch ID information is available at any time in genealogy and in as-built reporting.

Every time an operator consumes a material inserting a S/N or batch ID, Opcenter Execution Discrete checks whether the specific part is available, whether the S/N is unique, and whether it is not already used or reserved for another work order. It is also possible to define barcode rules for each material: at runtime the system will validate the scanned barcodes with the pre-defined rules preventing the Operator of assemblying the wrong material.



Collecting material consumption data.

It is also possible to define ‚Co-product' materials, secondary goods that are generated during the manufacturing process.

4.3.8 Material pre-kitting

Material pre-kitting is a functionality provided by Opcenter Execution Discrete to assign parts to be used during production to each operation. Production supervisors can pre-assign S/Ns or batch IDs to an operation; in such cases, during production the operator is not required to enter the used part, but must confirm the use of the one already assigned. For high regulated environment it is also possible to configure the system in order to ask the operator to insert again the SN and let the system to validate if this corresponds with the pre-kitted one.

4.3.9 Tool usage

The usage of tools is often required during operation execution; sometimes knowing exactly which tool has been used is irrelevant, but in other instances, it is mandatory information. Opcenter Execution Discrete displays the required tool type in the operation details: Operators can view the list of required tools and may be required to enter the ID of the tool used. To enter the tool ID, operators can use the keyboard or a barcode scanner or select it from a list of available tool IDs.

4.3.10 Interlocking checks

The start and completion of an operation's (or step's) execution can be governed by the outcome of the interlocking checks enabled for it.

Interlocking checks verify whether one or more conditions have been satisfied in full in relation to the operation or step in question: if the outcome of all these checks is successful, the execution of the operation or step will either be started (inbound interlocking checks satisfied) or completed (outbound interlocking checks satisfied).

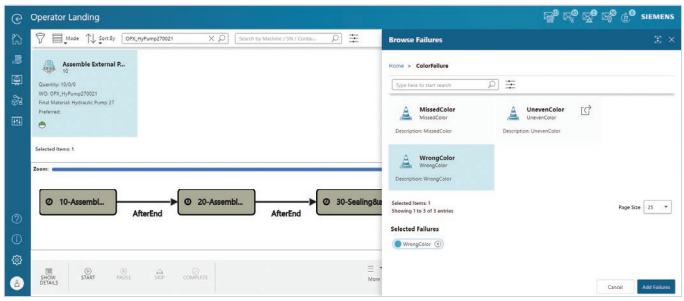
If more interlocking checks have been defined, they are executed in parallel. The system provides some OOTB interlocking checks, but it is also possible to create custom ones.

4.3.11 Nonconformance declaration

Opcenter Execution Discrete provides runtime quality-related functions that allow tracking of nonconformances and defects and management of their lifecycles through a complete approval process.

Nonconformances are used to determine whether the production in progress needs to be adjusted to achieve better performance levels and better end results. The production coordinator has the task of evaluating (or sentencing) a nonconformance to decide what to do to rectify the situation. There are two types of nonconformance:

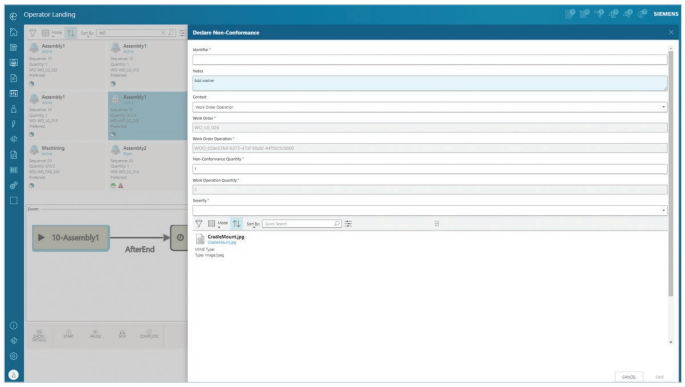
- Quality nonconformance – declared when failures are found in the product that is being manufactured or in the entities involved in the production (machines, material items or tools). These entity types have an associated lifecycle (that is, a set of rules used to specify what happens and which states the entities assume when a nonconformance is declared on them)
- Change nonconformance (also called Change Request) – declared when something needs to be changed in the production workflow



Browsing the failure catalog.

Nonconformances include information about:

- Operation
- Material/tool
- Operator who declared the nonconformance
- Declaration time
- Failure reason
- Severity
- Description
- Status
- Quantity
- Work center



Declaring a nonconformance.

4.3.12 Nonconformance management

In order to close a nonconformance, a quality manager can make decisions according to a specific lifecycle: this lifecycle can be configured according to customer needs. By default, Opcenter Execution Discrete already provides a lifecycle with the following actions:

- Return to work – defect is tracked in MOM and the operator can return to working on the work order
- Scrap – the defect cannot be solved and the part must be scrapped
- Rework – applying a rework operation will solve the problem (see Rework process section for more information)
- Change – apply a change to the work order BOP or bill of materials (BOM) to solve the issue
- Concession – leave the nonconformance pending, awaiting decision

- Hold work center – prevent executing any operation in the specified working area
- Send to engineering – in the case of integration with Teamcenter Manufacturing, this choice will feed back the details to engineering, with the link to the relevant genealogy

4.3.13 Rework process

One of the possible options to fix a failure is to apply a rework process. When a quality manager decides to apply a rework on a specific defect, the system displays a list of possible rework processes according to the defect that was declared. The list of rework processes must be configured in advance in Opcenter Execution Discrete; rework processes can be created manually at the MOM level or downloaded from the PLM system.

Opcenter Execution Discrete can associate specific rework processes with each defect configured in the system; once the quality manager selects the correct rework process, the system creates a rework order based on that process and the operator can view the rework operations to be executed in order to fix the problem.

A rework order is identical to a work order from the point of view of Opcenter Execution Discrete, in that it includes the following information:

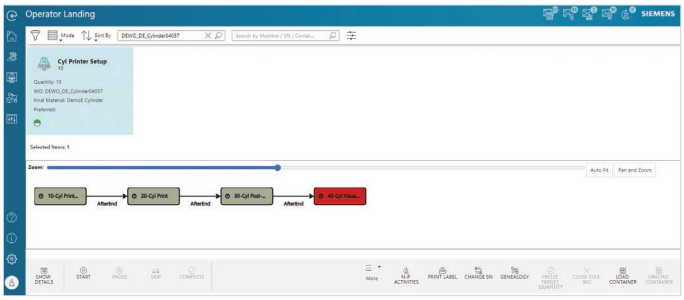
- Working area
- Electronic work instructions
- Date/time information
- Materials
- Tools
- Part number
- Serial number

All information about a rework order is visible both in the genealogy report and in the as-built report.

4.3.14 Preventing operation work booking

There can be situations when it is necessary to prevent working on specific work orders or workcenters (quality audits, equipment maintenance and equipment problems, for example). To accommodate these situations, Opcenter Execution Discrete provides the ability to set work orders and workcenters on “Hold”; this means that it will not be possible to work on the held-up item until a production coordinator removes the hold.

Setting status to “Hold” is an action that can be performed both by operators and by production coordinators.



Future hold set on a work order operation.

4.3.15 Order work-in-progress (WIP) monitoring

Production coordinators and operators need an accurate view of what is actually taking place on the shop floor, so that they can make the right decisions to streamline production. Examples include:

- Which work orders are currently being processed
- Which plant is involved
- How much of a work order has been completed
- The outcome regarding the production of a certain product (that is, the quantities of what has been produced and what has been scrapped)

To satisfy your customers with the best possible product in the briefest time, it is essential that you have maximum visibility regarding work in progress. Opcenter Execution Discrete offers a dedicated WIP screen for viewing how the work orders are progressing in their execution. The screen displays all work orders, with an indication of the final product being produced and the current percentage of completion, as well as the plant of execution.

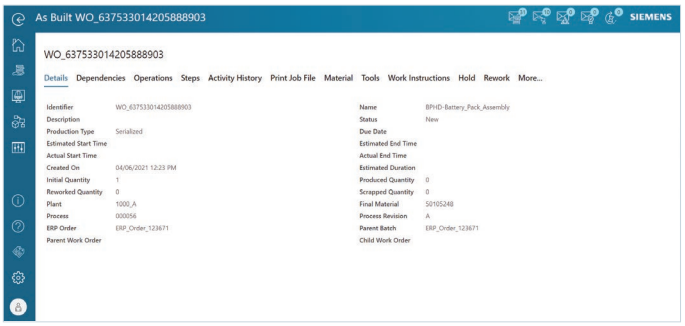
By selecting a specific work order, you can view information related to its operations (status, as well as produced and scrapped quantities).

4.3.16 As-built

The standard as-built report page of Opcenter Execution Discrete contains information related to a specific work order. Work order data is displayed in a flat way; as-built does not contain information related to suborders.

The following information is displayed:

- List of operations, with status, estimated/actual start and end date, quantity
- List of steps
- List of materials that have been assembled with their quantities and/or serial numbers
- List of Co-products materials with their quantities and/or serial numbers
- List of notes that have been opened and closed by operators
- Personnel log related to an operation
- Data collection values
- List of tools
- List of transferred CNC part programs or AM print job files
- List of associated rework orders
- List of changes



As-built report retrieved starting from a work order.

4.3.17 Genealogy

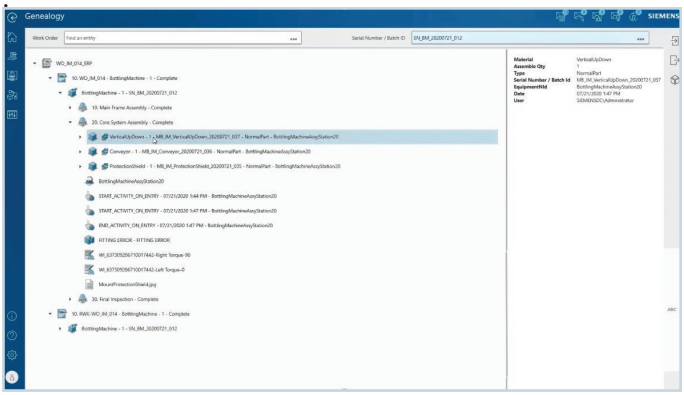
Opcenter Execution Discrete tracks information related to material consumption/assembly/disassembly. The genealogy report screen displays data related to a batch, serial number or work order in a tree view.

For each identified material that is produced the system displays:

- Operations performed to produce the material
- Consumed materials
  - Quantity
  - Material definition
  - Batch ID or serial number
- Used workcenter
- Acquired data collection
- Tools used
  - Tool definition
  - Quantity
- Nonconformances
- Operators involved
  - Role
  - Start/end activity time

If a work order consumes materials produced by other orders (subassembly), all the order information is shown in the main work order genealogy tree.

Opcenter Execution Discrete provides both forward and backward genealogy: a production coordinator or operator enters the desired serial number or batch ID, and the genealogy report shows how it has been produced and/or where it has been consumed.



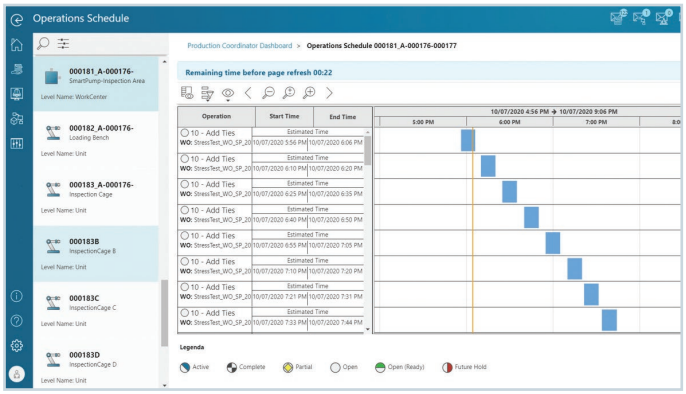
Genealogy report retrieved starting from a work order.

4.4 Operator management

4.4.1 Workload distribution

At shift start, production coordinators or team leaders can check the work schedule assigned to the job shop area they are responsible for, rearrange it as appropriate and distribute operations among their team members based on skills and availability.

This is most effective when operations modeled in the processes have specific minimum operator skill requirements for their execution.



When such association is performed, operators logging into Opcenter Execution Discrete will find operations directly assigned to them. Of course, it is possible to assign the same operation to any number of operators.

4.4.2 Labor tracking

Opcenter Execution Discrete enables production coordinators to monitor work booking times related to operations.

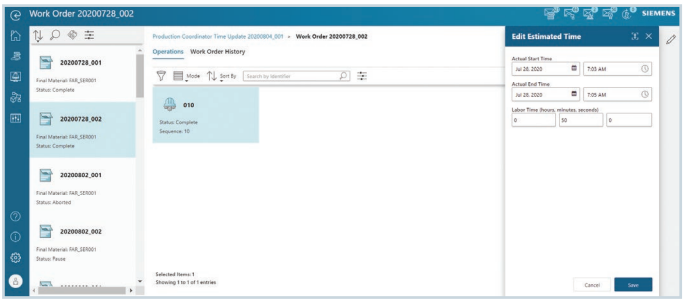
For each work order operation, Opcenter Execution Discrete displays:

- Status
- Estimated start/end time
- Actual start/end time
- Labor duration

For each work order operation, production coordinators can view time details for each operator. For each operator, Opcenter Execution Discrete provides:

- User identity
- Activity (start, pause and complete)
- Timestamps

Production coordinators can amend collected data for completed operations both at work order operation and at operator level.



Activity track record on a work order.

4.4.3 Team work

Teams are groups of users that can be formed for the purpose of performing production operations together.

While roles represent a more permanent way to group individuals according to their know-how or position within the business hierarchy, teams are flexible and designed to be created “on the fly” and disbanded when no longer necessary (for example, when two or more operators are needed to perform an assembly operation because the part is too large to be assembled by one person).

A single team member can start/pause/complete work order operations on behalf of the entire team. Each individual of the group takes responsibility of actions of the other team members as a collective responsibility.

4.4.4 Non-productive activities

A non-productive activity is an activity performed in a workcenter that is not directly related to a production cycle and/or to a specific work order, but that still needs to be tracked and recorded.

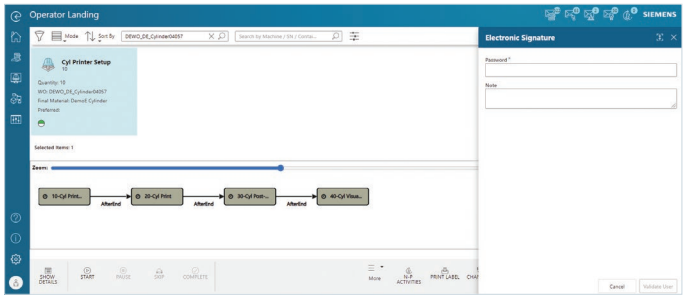
Some non-productive activities may be totally unrelated to production entities, while others may be related to them. Examples of non-productive activities include, for instance, cleaning of machines and tools, general maintenance, training, mentoring, assistance, meetings, administrative activities.

4.4.5 Electronic signature and buy-off

Opcenter Execution Discrete implements electronic signatures during operation work booking (see Operation Workbooking section for more details) to represent validation and buy-off; only certified users can execute and complete an operation and sign it.

The operator or supervisor who has the appropriate authorization is in charge of signing the whole operation data, regardless of the users who actually worked on the operation and filled in checklists or declared tool and material consumption.

For each operation, more than one person can be required to provide electronic signature. The buy-off is recorded in the as-built summary.



Electronic signature required upon material consumption.

4.4.6 Certifications

A certification represents an authorization that is created ad hoc with particular characteristics and then assigned to a user or role, and defines the sphere of action within which he/she can operate. Users and roles can be certified to:

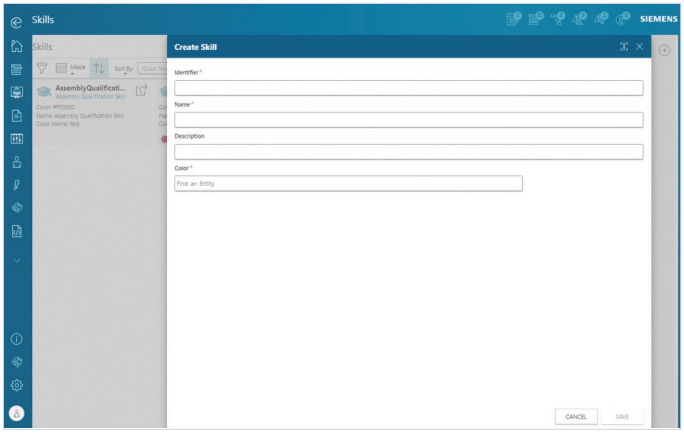
- Perform a certain task (that is, start, pause or complete a specific operation)
- View the details of a specified operation
- Operate in a specific location (workcenter)
- Use a specified machine
- Use and/or produce a specified material

The definition of a certification may include:

- One or more material definitions
- One or more machine definitions
- One or more locations (workcenters)
- One or more skills, optionally with their levels
- Any combination of the above

Opcenter Execution Discrete adopts access control through certifications to simplify the task of tracking “where” within a production plant “who” can perform “what” to produce “which” materials using “which” machinery owning “which” skills.

Possessing a certification that is currently valid is essential for a user/role to perform runtime operations; whenever a certification is assigned to a user or role, an expiration date is required. The validity of a certificate is not indefinite.



Certifications details.

4.4.7 Result management

Shop-floor operators can declare a result upon operation completion of each serial number or batch, so that the execution of the failed activities can be reiterated (either immediately or at a later time) until their outcome is positive (that is, “as expected”). This is the default strategy followed by the system when result declaration is adopted.

In addition to the native result types provided in Opcenter EX DS to declare positive and negative results, it is possible to configure custom result types that may better satisfy specific needs. After a result has been declared, if necessary, authorized users who possess the appropriate user rights can override its value by performing an amend operation.

It is also possible to amend a result’s strategy. For example, let’s say that the corrective action initially associated to a result becomes unnecessary or is no longer valid. In this case, depending on the situation, the user can choose to amend the result’s strategy by either:

- Removing it: in this case, no corrective measure will be adopted
- Switching to a different corrective action

4.4.8 Work order operation execution using the high automation user interface

Opcenter Execution Discrete uses the high automation user interface to monitor and control the production and delivery of products and services. The high automation user interface allows the user to select a machine instance so that the high automation details user interface will show the details of the work order operation active on the selected machine. Once the machine is selected, the information is saved on the database and re-used after the next login of that user.

The high automation user interface uses the signals about the operations performed on the machine, such as start, complete and assemble and displays the correct corresponding data in real-time. The user can perform standard functions of the operations details user Interface such as adding a note, defect, among others. The high automation user interface contains all the documents and material to be consumed associated with the active work order operation on the selected machine.

While configuring the system, the default layout of the high automation landing page can be changed to enable the display of runtime tasks, similarly to what is done in the standard operator landing page.

4.4.9 Production execution in offline mode

Opcenter EX DS comes provided with the capability to execute production in offline mode (that environments without connectivity to the Opcenter EX DS server.).

In such cases, if a dedicated app is installed on mobile devices, shop floor operators can manage operations directly from their mobile devices.

Once selected for offline execution, and their content is downloaded on the mobile device, operations remain visible in the operator landing page. However no actions are permitted: operations remain locked until they are checked in again.

The following actions can be performed while working offline:

- Starting work order operations and steps
- Pausing work order operations
- Completing work order operations and steps
- Consuming materials
- Using tools
- Displaying documents
- Collecting data
- Uploading documents
- Creating quality non-conformances

As an operator, you can:

- Perform the check-out of work order operations on the mobile device and thus implicitly start offline sessions
- See the content of the related offline session (in terms of involved work order operations) from the offline Sessions page
- Upload production execution data from the mobile device to Opcenter Execution Discrete once the work order operations are completed, or in case you want to proceed with execution in online mode
- Amend the content of uploaded offline actions, in case of failures
- Perform the check-in of offline actions and offline sessions to conclude production execution in offline mode

4.5 Electronic work instructions

4.5.1 Electronic work instructions

The work instruction (WI) is a technical package of information defined within the authoring environment and consists of all associated data required within the MOM system to perform the necessary manufacturing, assembly or test activities.

In a paper-based environment, operators can spend hours looking for the correct WI to be used for a specific operation; moreover, the document can be damaged or illegible. Opcenter Execution Discrete provides the operator with only the electronic work instruction (EWI) related to the specific task at hand; moreover, the document is always in an electronic format that guarantees the usability of the instructions.

It is possible to specify EWIs at different levels in the manufacturing process, which is typically defined hierarchically with two nested levels: operations and steps.

The following types of data are included as part of the EWI and are displayed within the MOM system at the appropriate point of operation:

- Operation or step text – instructional text can be authored to guide operators at runtime to perform the right operations in the right sequence. It is also possible to define special notes, warnings and cautions

- Parts to be used at operation/step level – a list of items required at each operation/step with appropriate attributes (part number, description, quantity, classification, type, location, etc.). Part images such as 2D drawings can also be attached
- Resource (tooling) to be used at operation/step level – a list of tools required at each operation/step with appropriate attributes (tool type, description, quantity, classification, location, etc.). Tool images such as 2D drawings can also be attached
- Images (2D drawings, photos, etc.) – various media types can be attached at operation/activity level and can be displayed with the appropriate viewer in the MOM system
- Documents (Word documents; Excel sheets, PowerPoint slides and PDF reports/specifications) – various datasets can be attached at operation/step level and can be displayed with the appropriate viewer in the MOM system

The association between an operation and the EWIs to be displayed can be performed manually in the dedicated Opcenter Execution Discrete screen or by downloading the information directly from the PLM system.

4.5.2 Data collection

During production, it is often required to collect various manufacturing data manually (for example dimensions, process parameters, etc.). This information can differ for each work order and work order operation. Opcenter Execution Discrete offers the ability to collect data during the execution of specific operations. Operators on the shop floor execute the required activity and fill in dedicated forms with the required data. All of the entered data is visible in the as-built report screen and genealogy report screen.

Data collection values can be also acquired directly from the automation layer at runtime. You can achieve this by either integrating the Opcenter Execution Foundation Automation Gateway linking machines/data collections to automation node instance parameters, or by leveraging Opcenter Connect MOM to read datagrams. A data collection form may be associated with a work order operation or step in its entirety, or to individual serial numbers.

To enable manufacturing data collection, Opcenter EX DS provides an engineering environment for creating forms with fields for specified information; these forms can be linked to operations manually and displayed for operators during production activities; operators are always asked to collect the right set of information for each operation.

When creating forms, it is possible to define:

- Sets of data to be collected
- Type of data to be collected (number, text, etc.)
- Range and limits (if the collected value is out of range, Opcenter EX DS will notify the operator)
- Mandatory values (if mandatory values are not collected, it is not possible to complete the operation and proceed with the next one)

4.6 Additive manufacturing

Additive manufacturing is an industrial process used to create a three-dimensional object in which successive layers of material (typically metal powders, plastic, concrete) are formed under computer control. Opcenter Execution Discrete supports additive manufacturing through the following functions.

- "Print job files" management – it is a file that contains information used by a 3D printer to create products by means of additive manufacturing processes. Through custom plugins, Opcenter Execution Discrete can retrieve the file from a print job file repository, present the print job file to the shop floor operator during operation execution and download it on the correct 3D printer

  Print job files can be associated with a single work order operation or with an execution group – their contents can be subsequently transferred as needed to the machine associated to the execution group. Thanks to this possibility, you can launch production as specified in the print job files for all the work order operations making up the execution group in a homogeneous manner
- Track and display the genealogy of powder material batches – additive manufacturing material is available as powder material batches. Each batch represents the container that holds the powder material item. A powder material batch is thus raw material for a 3D printing operation. Opcenter Execution Discrete supports the capability of reusing powder material from multiple batches. Powder material batches can also be split and mixed to form new batches. Powder material batches assume a status, and thus have lifecycles. The history of batches mixing is called powder material genealogy

- Track and display the lifecycle of substrates: a substrate is the build plate upon which 3D objects are printed by using a 3D printer. Since final items are developed upon substrates, Opcenter Execution Discrete treats substrates as specialized tools, which is why they are created as tool definitions, and instantiated as tool entities. Substrates are configured and associated with work order operations. The substrate lifecycle represents the states that a substrate assumes, and transitions to, because of the operations performed on it

4.7 Closed-loop manufacturing execution

Closed-loop manufacturing enables customers to seamlessly unite product engineering and process planning with production execution; this is a key differentiator of the Siemens Digital Enterprise portfolio.

Opcenter Execution Discrete works in conjunction with Teamcenter Manufacturing and Teamcenter Quality to deliver a holistic vision through superior information access across different business domains. A tight relationship between the two products manages engineering changes most efficiently: any change defined at the manufacturing planning level can be taken into account and implemented quickly and properly at the shop floor level by means of accurate and repeatable communication.

Downstream from PLM to MOM, Opcenter Execution Discrete foresees:

- A consistent view of manufacturing technical information authored in Teamcenter Manufacturing including Failure Catalog and Quality Characteristics authored in Teamcenter Quality
- Real-time data views in Teamcenter Manufacturing as rationale for manufacturing engineers before releasing changes to execution
- A structured model of the manufacturing plant in Teamcenter Manufacturing, enabling manufacturing engineers to better detail the content of the bill of process

Upstream from MOM to PLM, Opcenter Execution Discrete provides out-of-the-box capabilities to create issue reports in Teamcenter Manufacturing (Teamcenter Issue Management) and to enrich them with relevant content.

The integration between Opcenter Execution Discrete and Teamcenter Manufacturing is available only for selected product versions; please refer to specific documentation.

More information is available in the *Closed-Loop Manufacturing (CLM) – Implementation Guide*.

5 Integration

5.1 Opcenter Scheduling integration

As Opcenter Execution Discrete is focused on operations and the workcenters where such operations are executed, the ability to schedule operations based on constraints provides a powerful tool to optimize activities and fulfill planned delivery time.

In standard Opcenter Execution Discrete operation work booking functions, you can assign a workcenter to an operation based on manual evaluation. Production planners can retrieve the set of operations inside a predefined time interval using Opcenter Scheduling, and push back scheduling proposals to Opcenter Execution Discrete that the supervisor can adapt to specific, real-time needs.

Opcenter Execution Discrete supports two-way communication with Opcenter Scheduling:

1. The Opcenter Execution Discrete operator can access all planned operations available in the workcenter sorted by estimated start time. Operations will also have suggested equipment on which the operation should be started, so that the operator will have more information about when and where to start the operation.
2. Production planners have access to the list of operations, and according to the constraints can schedule them to streamline equipment utilization. Planners can also be informed of any order/operation in scheduling that has been modified at the shop floor.

The integration between Opcenter Execution Discrete and Opcenter Scheduling is available only for selected product versions; please refer to specific documentation.

6 Integration with automation, physical devices and third party system

6.1 CNC integration

Opcenter EX DS is frequently used to manage production steps that involve machining via CNC devices. The way such devices are operated may vary according to several factors including material, machine, tools and operation. The CNC part program is the element that drives a CNC device to work as requested by Opcenter Execution Discrete. In this context, it is essential to have an automatic transfer of the CNC part program to CNC devices.

Part program packages defined in an external DNC system can be imported into Opcenter Execution Discrete and associated with the defined machines. At runtime, the system prompts the operator for the correct program to download to the machine; upon operator confirmation, Opcenter Execution Discrete triggers the DNC system to download the correct part program to the correct CNC machine.

The DNC system is external to Opcenter Execution Discrete and includes the capability to write a custom connector to any DNC system available at the customer's site.

6.2 Setpoints

Setpoints are used to drive how a machine or a tool must behave at runtime, thereby eliminating the need for shopfloor operators to perform manual adjustments.

On their own, setpoints are merely empty containers: in order to function, they must be filled with one or more variables.

For example, if a certain machine must reach a certain temperature before it can be used in executing a work order operation, then the setpoint to be associated to that specific machine will contain variable "temperature", the value of which is equal to that specific temperature.

During runtime, the setpoint variable's value will be transferred to the machine: the machine, which is linked to the automation layer, must necessarily reach the temperature specified in the setpoint before it can be used.

Setpoints can be associated to the following items thus declaring their compatibility:

- Equipment types and equipment configurations
- Tool definitions and tools.

If you associate a setpoint to an equipment type or tool definition, the same setpoint will be inherited by all machines or tools generated from the equipment type or tool definition to which the setpoint was associated.

6.3 Structured-message exchange

Certain activities can be automated during production execution by adopting a "structured-message exchange" approach.

Through appropriate scenario configuration, in Opcenter Execution Discrete, this approach can be adopted to exchange messages between the MES layer and the shop floor, in order to:

- Automatically start and complete operations
- Automatically create and resolve non-conformances by machines or workcenters
- Automatically consume material during the execution of operations
- Automatically collect data and quality characteristics during the execution of operations
- Automatically use tools during the execution of operations

Opcenter EX DS is able to exchange messages through interaction with the Opcenter Connect MOM product.

6.4 Barcode management

Opcenter Execution Discrete provides the possibility of configuring barcode rules to validate a barcode string.

Once created, barcode rules are empty containers which can be associated with rule parts in any combination you deem necessary, each of them containing a regular expression which will be used to validate the barcode string.

Whenever a barcode string is received from a barcode reader, the system automatically retrieves the corresponding rule from the associated material. If the rule is not found, the system retrieves it from the functional code or, as a last option, from the default barcode rule that is provided out-of-the-box and can be set thanks to a dedicated configuration key.

As a product engineer or production coordinator, you can:

- Enable the dedicated configuration key for setting a default barcode rule
- Create a barcode rule
- Configure the rule parts
- Associate a material to the barcode rule
- Associate a functional code to the barcode rule

As an operator, you can scan the barcode to validate the material to be consumed. If it matches the barcode rule, its consumption can proceed.

6.5 Semi-automatic acquisition of values

If the system is properly configured and linked to the shop floor via the Opcenter Execution Foundation Automation Gateway App, it is possible to acquire values from the field.

The operator can acquire the values related todata collections, tools/substrates and material tracking units, without the need to insert them manually.

The semi-automatic acquisition is possible due to the mapping of parameters with the variables coming from the field, via the Opcenter Execution Foundation Automation Gateway App.

For data collections, the field values acquired are related to work instruction parameters.

For materials, the operator can acquire the serial number, batch ID or quantity to be consumed during an assembly operation, or enter them manually.

For tools/substrates, the operator can acquire the ID of the tool/substrate to be used, the usage counter and the time duration, or enter them manually.

Information related to the acquisition from the field is traced in both the as-built and genealogy pages.

6.6 Label printing

Opcenter Execution Discrete offers the possibility of printing labels containing barcodes, text or images for:

- Work orders
- Work order operations
- Material tracking units

7 Intra-plant logistic

7.1 Transportation management

All those activities regarding the transportation of items within the boundaries of a plant can be classified as related to transportation management, also referred to as intra-plant logistics (IPL).

Here are some examples of such activities:

- Raw materials are moved from a storage area to the machine that will process them
- Semi-finished products are transported from one machine to another so that they can undergo additional processing
- Final materials are moved to another storage area prior to being packaged and subsequently shipped out from the Plant
- A specific raw material is transported upon request from a storage area to a specific location inside the Plant so to permit the continuation of production activities
- A defective piece is pulled from the normal flow of activities and moved to a specific location so that it can be checked, reworked or scrapped

7.2 Containers and container types

Containers are entities configured to contain or hold and move semifinished products during the production process. Containers represent physical entities where the materials can be loaded and stored, temporarily, for the time between one operation and the next. Containers can be re-used.

It is possible to define templates (container types) from which many different containers can be defined inheriting the same configurations and associated documents.

7.3 Logistic classes

A logistic class groups together similar materials or tool definitions for transportation or packaging. For example, logistic class “burner pipes“ groups together all burner pipes that are produced in the same plant and need to be transported.

Opcenter EX DS comes with a predefined default logistic class, but it is possible to create custom logistic classes tailored to your needs.

7.4 Buffer definitions and buffers

Buffer definition

A buffer definition is an abstract representation of a specific area or accessory (for example, a wagon or cart) allocated to store items. The configuration of a buffer definition takes into account the maximum weight, maximum volume or maximum quantity, as well as the unit of measure to be used, when defining the overall capacity allowed. It is possible to configure a buffer definition so to allow the storage only of specific materials and/or logistic classes, specifying minimum and maximum quantities, as well as threshold and target quantities for automatic replenishment.

Buffer

A buffer is the runtime instantiation of a buffer definition, therefore it inherits its configuration: it represents the actual area or accessory for storing specific material to be used or consumed during production within the plant.

7.5 Logistic requests

Declaring a logistic request is essential to transportation management within your production plant, as it specifies which materials are required and where.

Automatic logistic request generation is the most common scenario. By importing a dedicated signal rule installed with Opcenter Execution Discrete, logistic requests are generated automatically by the system whenever the buffer level falls below a defined threshold.

However, it is also possible to declare logistic requests manually, if desired. A manual logistic request can consist in a single material request.

7.6 Handling units and transport operations

When a logistic request is declared, it can be accepted in order to actually initiate the movement of the required item, or rejected. When accepting a logistic request, it is mandatory that at least one source buffer be specified.

When a logistic request is accepted, a new transport operation to fulfill the request is automatically generated.

The various states of the transport operation specify the various phases of the transport operation's execution.

Once the transport operation has been released and appropriately configured, the transport operation will be started. The required item(s) will be pulled from a source buffer and then placed into a handling unit.

Handling units are designed specifically to identify a set of materials that must be moved together from source to destination. Handling units can start to proceed toward the destination buffer provided that they are in dispatchable status. Once the handling unit is set in motion, it is in onroute status: its contents are transported to the destination buffer. At this point, the transport operation has been completed and the contents of the handling unit can be unloaded.

The transport operation history is used to trace the details regarding the transport operation's execution, whereas the handling unit history traces the various phases of the handling unit's progression.

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