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Manufacturing Execution Through e-FACTORY System

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Abstract

This paper presents a Manufacturing Execution System (e-Factory) developed to integrate manufacturing engineering, procurement, production planning, manufacturing and quality functions. e-Factory System supports the production preparation process. The main input of this process is data related with the three dimensions of Production. “Product Data”, “Project Parameters” and “Plant Data”. The outputs of the production preparation

1. Introduction

The regulations of the aerospace industry necessitates that the production process of an aircraft and the manufacturing process of each part of the aircraft must be documented in detail. This documentation must proof that the aircraft is produced as designed with full traceability. Accountability, traceability and documentation are of critical importance [1]. However, functional requirements and Project requirements such as cost and schedule targets must be fulfilled in order to sustain an aerospace program [2].

In order to fulfill these requirements, installation operations, assemblies and detail part manufacturing processes should be planned as steps. Material, tools and NC programs required should be defined. The activities performed to fulfill these production requirements are a part of the production preparation process. The output of this process will be valid process plans, tool orders, NC program orders and material requirements.

After the plans and definitions are completed, ordering starts. Purchase orders are issued, Subcontracting starts and shop orders and installation orders are issued. Production of an aircraft starts.

The changes initiated by engineering, will be incorporated to process plans and the parts, assemblies which are being manufactured and the components which are still being installed at the shop floor [3].

Traceability is a major requirement for aerospace industry. Configuration and material are two important dimensions of traceability. Configuration of the product should be tracked from the requirements to the end product Material used to produce the aircraft should be tracked from the detail part manufactured and hardware procured to the end product.

Customer requirements will be incorporated to the design of the product through models and drawings and to the procurement through MBOM and to shop floor through process plans, shop floor manufacturing instructions and quality assurance records [4]. This traceability will assure that the specific requirements are incorporated to end product.

This paper is prepared to describe an information system developed to support production preparation, detail part manufacturing, assembly and installation processes of an aerospace factory.

Fig. 1. Production Preparation and Product Realization Processes
2. e-Factory System

2.1. General Definition

e-Factory is an information system developed to support production preparation and product realization processes. The system utilizes Product Design Data and manages Process Planning, Material Data, Tool and NC Program Orders, Engineering Changes, Production Data, Traceability and As-Built Data of the completed products.

The Product Design Data is transferred from PDM System as single level EBOMs when the design of an assembly is completed. If the design of a product is provided by another company, a group of part lists can be imported to the system.

Installation, Assembly and Detail Part Process Plans are prepared and validated. Orders for the required tools and NC Programs can be issued when needed. Material requirements are defined in parallel with process planning. Material Catalogs and Alternate Part Lists are utilized during MBOM transfer to ERP.

ERP System manages the dates and quantities for purchasing, subcontracting or manufacturing. MBOM relations, lead times of parts, master production schedules for end items and on hand inventory quantities are used in calculation of the replenishment schedules for the parts and assemblies. Purchase Orders, Installation and Shop Orders to be given to factory or “Statement of Works” to be given to subcontractors are managed at ERP System.

The Installation and Shop Orders or Statement of Works issued at ERP System are accessed through e-Factory System and their process plans are prepared as PDF documents to be printed and in parallel, digital data is recorded in e-Factory database to be accessed from shop floor or subcontractor facilities. e-SOIR module of e-Factory System is used during execution of Detail Part Manufacturing and Sub-Assembly Processes. Material definition, valid documents, tools to be used and work instructions are accessed through e-SOIR system and any significant parameter (i.e. producer’s lot number or serial numbers) during manufacturing process is recorded by shop order number on the e-SOIR. Shop Order package which includes a printed page (traveler) and material is moved in the factory task center by task center. At every task center, e-SOIR data is accessed and digitally signed by technicians. At the end of the process, quality inspects the part digitally signs e-SOIR. In parallel, subcontractors access their material, document, tool data and work instructions through e-SOW module of e-Factory System at the execution phase. They also digitally sign for their operations. Installation operations are grouped by SWBS and issued to shop floor as an Operation Inspection Log (OIL) for each aircraft. During the execution phase, e-OIL/e-Operation module of e-Factory is used to access material data, valid documents, tools used and work instructions. Engineering changes are incorporated to master process plans to be used for future orders. For the orders on the shop floor, either rework operations are issued on e-SOIR, e-SOW, e-Operation or the open shop orders are updated digitally depending on the status of the parts/assemblies at the shop floor.

As the data is accumulated on e-SOIR, e-SOW, e-Operation modules, the status at the shop floor can be monitored through other modules of e-Factory system. When the installation operations of an aircraft are completed, delivery reports generated and “As-Built Bill Of Material” for a specific aircraft is maintained.

Fig. 2. Block Diagram of e-Factory System
2.2. EBOM – MBOM Relations in e-Factory

After the transfer of EBOM to e-Factory System, SWBS (Schedule Work Breakdown Structure), IGN (Installation Group Number), Installation Operation, Assembly and Detail Parts Planning are defined in e-Planning (TVPS-TAI Visual Planning System) Module of e-Factory System.

MBOM is constructed during this process by attaching MGNs to SWBS, Installation Planning to IGNs and the Subassemblies, Detail Parts and hardware (Standard Parts) to the Installation / Subassembly Plan and Raw Material to the Detail Part Plan.

In the process of MBOM construction, the EBOM parent relations of the assemblies, details and hardware are kept linked in parallel of the MBOM relations in e-Factory Database.

The EBOM link to MBOM, helps to find affected parts when an engineering change issued. The EBOM Assemblies affected by the change is accessed on the Material tab of e-Planning Module of e-Factory. The Part List of the engineering assembly is listed on the “Engineering PL” table. The changes within this Part List are indicated through different colors; red for unchanged, white for added/changed and blue for deleted.

By clicking the ‘Apply Changes’ button, the newly added parts are transferred to Manufacturing Part List without an MBOM relation. The deleted parts are transferred with minus quantity. If the effectivity of a part is limited, the change in the effectivity is considered as deleted and a new record is added with minus quantity. If the effectivity expands then the difference is added as a new relation. After this transfer, MBOM is maintained through establishment of MBOM relations.

In the Manufacturing Part List, Under one MBOM Parent, a subpart no may exist several times with different EBOM parents. However, EBOM relations are not transferred to MBOM. These parts are transferred without EBOM relations and consolidated as one MBOM record.

2.3. Process Planning with e-Factory

Process Plans are prepared through e-Planning (TVPS) Module of e-Factory System. There are three types of process plans defined at e-Planning. These are Installation Operations, Assemblies and Detail Parts.

Basically these three types of Plans are similar. However, there are some differences in their natures.

Installation Operations are those production activities which are performed at the last parts of the product realization process. Through these operations, the parts of the final product (i.e. aircraft) are installed and left on the product. When Installation Operations are completed, the product is being built gradually. They are grouped under SWBSs/IGNs in order to facilitate scheduling efforts.

Assemblies are produced and stored in the warehouse. They are planned to produce parts which are composed by several parts. When an assembly is completed, it is another part number and called with this part number. Structural subassemblies, harness assemblies, composite assemblies are some samples for assembly type.

Detail Parts are manufactured parts. Raw materials are processed to get the planned features. When a detail part is completed, it will get its part number and stored in the warehouse.

Planning Header

The header of a plan keeps the identification data. Number, description, revision and current status of the plan are standard for all three kinds of plans. Other attributes may be different for different types.

Cure Cycles are maintained for composite assemblies. However, Finish Codes are maintained for detail parts only.
Material

Material relations are established on this tab. For installation and assembly plan, MBOM is maintained through this tab. The EBOM Parent is accessed and active plan Number is saved as MBOM parent for the records of EBOM without an MBOM parent.

If a part or material is not shown on EBOM, it can be created as a header and be related to the active plan as a record of “Manufacturing PL”. These parts can be synthetic parts or chemicals which are shown on the drawings only. Synthetic parts are created to stock semi-finished parts. Sometimes, installation or assembly of a part requires very close tolerance that finishing the part during installation or assembly is better than having risk of unfitted parts. For this reason, semi-finished parts are given synthetic part numbers and they are stocked and planned to be called in the next assembly.

The material information for the detail part plan is maintained differently. Firstly, the material code for the raw material is defined. For each material code, different attributes are required to be filled. The material catalog is searched with defined material information.

Material catalog keeps the material information defined for purchasing. The appropriate catalog item is selected. Through this relation, a quantity is calculated as a percentage of the catalog item and is used when MBOM relation established between Detail Part and Raw Material. Sometimes, a detail part is manufactured from another detail or standard part. In this case, a Make From relation is established between two parts.

Steps

Manufacturing process plans consists of steps to instruct work to be performed. The steps of assembly and detail part manufacturing are defined for the operations performed at specific task centres. Installation operation steps do not refer to a task centre. The steps of Installation operations and assemblies can be performed as parallel steps. However, the steps of detail parts should be sequential.

A step consists of work instructions to be performed, materials to be consumed, documents and tools to be used. Material defined in manufacturing part list is distributed to steps. By this way, material to be used in a step can be listed with work instructions. Work instructions may refer to some parts which are already installed or assembled as a reference for another part to be used. These parts are shown as “Reference”. In some cases, if a part will be removed from assembly, then these parts are shown as “Removed”.

If the plan is prepared for a harness, Reference Designations Table can be constructed for the parts distributed to steps. The content of Reference Designations Table is listed on plan as “In Process Inspection” table.

Tools and documents defined to be used for operation, assembly or detail parts are related to their process plan. Tools related to process plan can also be distributed to steps.

Steps can have effectivities if required. Effectivity is defined with Type Version (TV) of the aircraft and starting unit (From) and ending unit (To). If effectivity is defined for a step, this step is printed on work instructions for the aircrafts which the plan is effective according to the production order effectivity data.

Notes

Process Plan Notes are used to get attention for an issue before an operation starts (Before Steps) or after it is completed (After Steps). Notes are constructed like steps. They have paragraphs which can be free text or standard manufacturing work instruction. Notes can also have effectivities.

Statement of Work (SOW)

For any reason, manufacturing of subassemblies or detail parts can be subcontracted. The SOW information is maintained for subcontracting. Scope of Work, type of contracting and other specific notes are all included in SOW data.

If a part will be subcontracted, there should be some instructions in SOW document. These instructions are added to steps of the plan with “SUB” task center. When a part is subcontracted, SOW document can be generated with the steps with “SUB” Task Center and SOW information provided on SOW tab of e-Planning.

Create Same As

“Create Same As” function is used for copying a prepared plan to other plan(s). This function helps save time in preparation of plans with similar tasks.

Preview

This function helps manufacturing engineer in Plan preparations. It helps to see the gross (engineer’s copy) or net (shop copy) before validation of plan.

This tab also shows the revision history of plan. When a plan is validated, gross print is constructed and saved as a history record of the plan. If required, the PDF files of previous revisions are put together.

Validation and Revisions

When a process plan is completed, it is validated. A validated plan is ready to be used for production. During validation, the task center routing is transferred to ERP system to be utilized in calculating lead times for the parts/operations. Gross Plan for the validated revision of the plan is generated as PDF document and saved at the database.
2.4. Material Definition in e-Factory

Materials to be used in producing parts are defined in catalogues of e-Factory. These catalogues keep parametric information related with material. Three different kinds of catalogues exist in the system. Raw Material Catalogue, Chemical Material Catalogue, Standard Part Catalogue.

**Raw Material Catalogue**
This catalogue keeps parametric data for the raw material stock sizes. There are 18 parameters to define a material.

Raw Material Catalogue is continuously updated. New material definitions are added to catalogue when new parts are planned. There is a seamless integration between detail part plan material definition function and raw material catalogue maintenance function.

**Chemical Material Catalogue**
This catalogue keeps parametric data for the chemical material. There are 17 parameters to define a material. Chemicals are defined during preparation of process plan. They are included in the manufacturing part lists of installations and assemblies. The chemicals applied to detail parts are defined depending on the finish codes of the detail parts. Through this way, chemical material requirements are estimated using the dimensions of the detail parts.

**Standard Part Catalogue**
Parts which are used in production as they are purchased are standard parts. There are many categories of Standard parts. Nuts and bolts, electronic parts such as connectors, cables and many other types of parts are all defined in this catalogue. Catalogue entries are also related with the specifications describing the parts. The catalogue definitions are used during BOM transfer to ERP from e-Factory.

2.5. Process Plans at Shop Floor

**Detail Parts and Assemblies**
The orders for producing a detail part or assembly are issued through ERP System. After a Shop Order is issued, this order is accessed from e-Factory System’s Net Print Process. The Shop Orders issued in ERP are accessed through this screen and a unique process plan with the Shop Order Number printed on it is prepared as a PDF document. This document is printed and given to shop as authorized work instructions.

**Installation Operations**
Even Installation Operations do not represent a part, they are a part of the MBOM and they need to have an order to be worked on. Installation Orders are issued in ERP and they are accessed from e-Factory OIL Process function.

Process plans of Installation Operations are transferred to shop floor as a bundle of SWBS and TV-SHIP (Tail Number). This is called as OIL (Operation Inspection Log) package. This package includes all the process plan of an individual aircraft’s installation operations under an SWBS.

**Rework Operations**
If a change is required after physical production starts at shop floor, a special process plan is prepared for the incorporation of the change. These reworks are called as Rework Operation for Assembly and Detail Parts and Green Card for Installation Operations. These plans are also prepared through e-Factory and released to shop floor.

2.6 Electronic Data at Shop Floor

**e-OIL / e-Operation**
The process plans of Installation operations are tracked online through e-OIL and e-Operation screens. e-OIL screen is used to track the status of installation operations for an aircraft at an SWBS.

The content of an OIL is listed on the screen. At the right side of the screen, green cards are listed. Through clicking on installation operation, e-Operation screen opens. This screen lists the details of an installation operation. Operation steps are listed step by step. When a step is selected, work instructions are shown below of the screen. When a step is completed, Production and QA stamps the step separately.

If the step requires data to be recorded, the “Input List” tab is used. This input can be related to step or a specific part installed on this operation. Additionally, any other attachment can be uploaded to database.

The material installed on the selected step is listed on the “Material List”. The material planned to be installed or removed is listed on the left side of the table (planned Material List) and material installed or removed is listed on the right side of the table (Built Material List). On the “Built Material List”, problems related with material can also be recorded. Installed or removed material is also stamped by production or QA personnel.

**e-SOIR**
The need dates and start dates for the parts and assemblies below the installation operations are managed in ERP system. Material requirements are planned according to Master Production Schedule of the
end product and bill of material relations. A shop order is issued on the start dates of the parts. The shop orders are released to shop floor as an Shop Order and Inspection Record (SOIR) data package. The process plan of a part is accessed through e-SOIR screen.

**e-SOIR**

The e-SOIR screen lists the work list at a task centre. When a SOIR selected from the work list the steps are listed. When a step is selected, work instructions, visual aids, input lists, material list, document list and tool list are shown on screen. Production and QA personnel stamps materials used in a step and stamp the step when completed.

If a group of SOIRs will be processed in a task centre, they can be grouped with a group name. The grouped steps of different SOIRs can be stamped at once as a group.

**e-SOW**

Subcontracted works should also be tracked through e-Factory system. The outsourced work is ordered through Purchase Orders. A Statement of Work is generated for each item of a Purchase Order. The data for the outsourced work is accessed through e-SOW screen.

The Purchase Orders are listed for a specific subcontractor. The steps of a Statement of Work are shown on the screen. When a step is selected related work instructions and other information is listed on screen. The subcontractor stamps material and steps.

### 2.7 Change Management in e-Factory

Engineering changes affecting product or other changes affecting production process require to be incorporated to process planning and bill of materials for future orders and to the work in progress.

The process planning is changed through creating a new revision. The Bill of Material is updated and transferred to ERP System to be used for subsequent requirement planning.

**Green Card and Rework**

Work in progress orders are in the shop floor and there is a physical reality. Material is installed on an aircraft or some parts have been assembled in the assembly area. Metal is cut or a hole is open which requires additional work to be done to incorporate the change. This additional work should be planned for each specific order and issued to shop floor as an order.

The additional work for installation operation is planned as a “Green Card”. It is listed on the below part of the Installation Planning Screen and should have an effectivity and be transferred to ERP for ordering. After a green card gets and operation order in ERP, the process planning data package is prepared and issued to shop floor through e-factory/OIL Process.

The additional work for Assemblies and Detail part manufacturing is planned through “Rework Operation Sheet”. It is listed on the below part of the Assembly or Detail Part Planning Screen. They should have effectivity and be transferred to ERP for ordering also. A Rework is issued and process planning data package is prepared as an SOIR.

**Order Planning**

If a change affects the unprocessed steps of an Installation Operation, Assembly or Detail Part process planning, these steps can be modified through “Order Planning” facility of e-factory system. Through this facility, actual data is modified and transferred to shop floor as a new issue.

The changes performed through order planning are shown on the PDF of the Process Planning as showing the changed lines in strikethrough format.

### 2.8. Completed Product Data in e-Factory

The data accumulated with e-Operation, e-SOIR, e-SOW systems is processed to become “As Built Bill of Material” database. The delivery reports to be given to customers or co-producers are derived from this database. Additionally, this database is used in after sales support process.

### 3. Conclusion

E-Factory System is developed to support the manufacturing process of an aerospace company. It is helpful for the company in the fulfillment of EN/AS 9100 standard requirements. As-Built data can be managed through paperless shop suite of e-factory system. Changes can be transferred to procurement and shop floor immediately. Genealogy of the products and traceability of its components can be accessed whenever required.

### References


