Study on Application of Model Based 3D Process Planning System

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Abstract. based on the study on existing status of MBD technology applied in design and manufacturing aspects, this article analyzes the importance of model-based 3D process planning system utilized in manufacturing sector, puts forward a package of MBPP application proposal and describes the application objectives, application structure, implementation process and major functions. The model based MBPP system is developed based on process planning proposal, and has been validated by its application in the development and manufacturing of model X aircraft.

1. Introduction
Currently, as CAD technology develops, the mature application of MBD (Model Based Definition) technology in aircraft product design aspect leads to the realization of “3D mocked-up, information parameterized, and parameters correlated” design, supports the rapid R&D and manufacturing of aircraft products, and improves the design efficiency and design quality of aircraft products. In production shops, as digitalization engineering projects are implemented and NC equipment are popularly introduced in production lines, NC machining and NC forming technology have been utilized extensively, which impels the fast improvement of processing capabilities in other specialties of manufacturing aspects; while at production shops, CAPP technology as a pivot and bridge to connect product design and product manufacturing sees no evolutionary changes, and 2D CAPP is still playing a leading role in process planning, with no full play given to the process realization efficiency of 3D models. This has become the technical bottleneck for design-manufacturing process, and has restrained the improvement of overall manufacturing level in manufacturing aspect. Therefore, it has become an urgent need for aircraft manufacturers engaged in the new generation aircraft R&D to develop a model-based process planning system so as to bring the technical advantage of MBD models into play, and to establish a model-based process planning production line.

Figure 1  Current Situation of 3D Process Application
2. Study objectives
MBD, as a methodology to demonstrate complete product definition information with an integrated 3D solid mockup, is to add various manufacturing semantic information of product dimension, tolerance and technical requirement, etc. in 3D solid mockup. It can make full use of 3D mockup capabilities, and is an understandable and more efficient method for product information definition [1-2].

Conventional CAPP system, which is to make process planning in 2D CAD environment with 2D graphic information [3], cannot satisfy the fast R&D and production requirements of enterprises. This article intends to study the method of model-based 3D process system establishment, the model-based BOM reconstruction, detail/assembly 3D Planning Sheet planning and visualization demonstration technology, so as to establish a model-based 3D process planning system platform and provide solutions for key technologies in the conversion from design model to process model and manufacturing model, such as dynamic evolution of EBOM, PBOM and MBOM, and planning and visualization demonstration of detail/assembly 3D Planning Sheets.

3. Planning of 3D process system
3D process planning system, as a model-based process planning system, uses 3D models as process information carrier and information integration source [4], and demonstrates all geometrical information and non-geometrical information of products in 3D models so as to generate a full-information-related model, and to drive process planning process and on-site production process on the basis of models.

3.1. Overall Structuring Concept
3D process planning is intended to link engineering and manufacturing. Based on enterprises’ existing resources and conditions, the technology to establish a model-driving 3D process planning system is studied in depth, and a 3D process planning system supporting the integration of design and manufacturing is developed independently, so as to achieve a model-driving visual production process, in which:

(1) information are synchronized and unified between design and manufacturing with 3D models at the core;
(2) design, Methods, manufacturing and inspection activates sharing the same information source are concurrently synchronized;
(3) full 3D model based information is organized, correlated, transferred and published;
(4) model-based BOM reconstruction, 3D process planning and on-site visualization technology are realized with 3D BOM as the single data source, which leads to the realization of 3D digitalized process planning in the entire business flow;
(5) multiple specialties are simulated on the basis of full 3D model.

3.2. Requirements for Overall Function Structuring
(1) Packaging and integration of software tools and systems
With CATIA software tools selected and under ENOVIA VPM environment, software tools and management environment are seamlessly integrated.
(2) Economical and practical
With customized development of system and CATIA software, to realize product structure classification and simulation function with DELMIA software.

3.3. Analysis on Business Demands
(1) Model-based
Process planning results in a full-information-related model which inherits design data, simultaneously demonstrate process manufacturing data, with 3D models as the unique reference for manufacturing process;
(2) Data reference and extraction
Design dimension, tolerance, notes and attached data, etc. used in process planning shall be referenced or extracted from the original model data instead of manual entry, which can ensure the correlation and consistence of upstream and downstream data and the correctness of changes.

(3) Explicitness

Implied information (such as dimensions) in design model shall be explicit as much as possible, rather than re-indicating dimensions and tolerances, etc. after projection. Automatic conversion by means of system functions shall be used as much as possible so as to reduce manual writing and notes.

3.4. System Realization and Function

3.4.1. System Realization

Targeting the current application status of CATIA system and CAPP system, this system which is further developed in CAA environment and with VPM system as the design platform, generates a model-based working environment which supports overall process planning and detailed process planning, creates a B/S-structured 3D process planning system consists of basic platform of process information, functional components of process planning management, integration & management service of process planning, and customer end, etc.

The system is mainly constructed of three levels, namely data level, business logics level and user level.

Data level mainly provides data support and data access for business logics level, and the basis to support the entire system operation. Multi-site replication technology is adopted to copy the data from source database server (VPM server) at design institutes to the VPM database at manufacturing end. The VPM database list at manufacturing end is consistent with the VPM database list at design institutes. The process database used for business processing is a self-designed multiple-instance based process database by reference to the mature PDM system design concepts and satisfying management requirements of new aircraft model configuration. It is correlated to the VPM database at manufacturing end, and can meet the demands of current business processing mode.

Business logics level is mainly responsible for the realization of system logics, including verification of system users, and limitation of logon users’ authorization. Function allocation, to support assemblies for system application, and to interface with the system compatible with other systems, etc. are all realized at this level. And it is the support for user level to process business.

User level mainly provides an operation interface for system users to process businesses. Users can operate with the functions provided on the interface to complete relevant business processing.

![Figure 2 Overall Structure of System](image-url)
3.4.2. System Functions

In general, the system can realize the three primary BOM management, process planning management and on-site visualization management. From perspective of business function, process planning consists of four tasks: (1) synchronized generation of factory EBOM from design data source; (2) creation of PBOM with process routes and process assemblies added in EBOM; (3) formation of MBOM according to assembly workstations and hierarchical AOs on the basis of PBOM, and (4) development of corresponding Planning Sheets.

Among the four tasks above, task (1) is, by means of multi-site replication technology, to extract (export) EBOM data of the aircraft from PDM system database at design institutes, transmit it to database servers at manufacturing end, and import the extracted design data to the 3D process system of local database. It has to be guaranteed that the PDM system data at design end and the data in 3D process system must be updated periodically.

3.4.2.1 Model-based BOM planning

The system is capable of model-based EBOM-to-PBOM planning and construction, PBOM-to-MBOM construction and workstation planning, shipset-based process effectivity management, associated design change and reminding, etc. During the lower-level BOM planning based on higher-level BOM, information can be correlated, and neglected part installation can be reminded in consumable part classification process.

(1) PBOM Construction

PBOM structure tree is created by means of “drag-and-drop” and attribute addition based on EBOM-model structure tree, which mainly includes the follow two tasks: (1) determination of process-required temporary assemblies and disassemblies, and (2) addition of process assignment attributes. In the above process, the key technical point is to realize model-based consumable classification of parts, i.e. parts already assigned are colored on EBOM for reminding purpose and to avoid re-classification. The classified tubing parts in LCA system are displayed explicitly in PBOM. Classified and allocated hardware in NOTE file will be automatically replicated at the symmetrical side of aircraft. 2D Process Schedule and other relevant documents can be generated for production PBOM if necessary.
(2) MBOM and AO Top Schedule

MBOM structure tree is generated on the basis of PBOM-model structure tree by means of “drag-and-drop” and attribute addition, which mainly includes MBOM top-level workstation, detail parts and hardware classification from PBOM to MBOM workstation and AO location, so as to create AO Kitting List and prepare for Planning Sheet development. In this process, the key technical point is to realize the downward consumable classification of parts from the top, accurate inheritance and correlation of PBOM data, as well as the check for neglected part installation.

(3) Hardware Classification

During the reconstruction of various-leveled BOMs, it is required to realize accurate assignment of hardware in NOTE file and to ensure the correlation of upstream and downstream data.

During BOM construction process, based on breakdown of design NOTE file, hardware noted in form of point, line and set are added with distribution route information and classified to PBOM and MBOM and further to different workstations and operations. It is required to have accurate work assignment information attribute for each piece of hardware.

For hardware classified to AO, automatic annotation and statistics of information, such as interval, margin, size and quantity, etc. can be realized in a quick way, and substantiation transformation can be achieved for simulation assembly of processes.

3.4.2.2 Planning of model-based processes

The development of Assembly and Detail Part Planning Sheet is to detail MBOM so as to create AO and FO. Finally, a model-based MBOM is created by piled-up AO and FO.

(1) AO/FO Development

Select AO or FO creation at location of assemblies or parts on MBOM, and then system will create assembly or part PPR file. AO/FO can be created on the basis of PPR file structure tree, and steps and operations can be described at PPR model structure tree or in man-machine dialog box, with tooling/tools and parts/hardware information automatically associated.

Automatic check is performed for any neglected part installation on aircraft, with kitting parts used in each operation step examined one by one, and with parts already used not highlighted in models. Part quantity is also automatically checked for EBOM-PBOM-MBOM consistency. Finally, a simulation file
is created based on edited AO/FO to verify manufacturability. And then, the edited AO/FO is transferred to Manufacturing Execution System for operations on shop floor.

During FO development, the process solution can be planned automatically by means of automatic identification of part features and based on process resources and knowledge pool, so as to create the decision-making model of machining process. In addition, rapid programming, manufacturing unit building, cutter and cutting parameter selection can be realized, which leads to the automation of the complete programming process.

2) Design Change Management
In case of any changes to EBOM, the EBOM in system is updated automatically with the changes reminded. Personnel engaged in PBOM and MBOM activities perform maintenance on BOM changes as per the reminder, and Methods personnel make modifications to AO/FO. Description of AO/FO modification shall be parameterizedly expressed on the basis of model-based structure tree, and change instructions shall be output in format of 2D Planning Sheet Change Note as required.

4. System application in practice
Based on the analysis on enterprises’ demands for 3D process planning, a model based process planning (MBPP) system is developed, with breakthrough made in key technologies, such as EBOM-to-PBOM reconstruction, model-correlated expression of process description information, rapid creation of feature-based operation models, which leads to the extensive application of MBD technology in process planning by means of product models. MBPP system, which has been applied in the entire process of research & development of certain new aircraft, can support process review in parallel with aircraft development, process planning, data release, visualized production at shop floor, etc. and has provided better technical support for satisfying “better, faster, and cost-reduced” development of aircrafts.
In aircraft development and manufacturing process, model-based AO/FO and PBOM/MBOM are created for all structural parts on the aircraft, and process data remains correlated with upstream data, which can be demonstrated in 3D or exported in form of 2D list. Finalized MBOM, AO/FO are respectively distributed to ERP System and Manufacturing Execution System for production direction. Tools demonstrating process documents on site based on original models, light models or 2D views are nested in MES System. After receiving assigned tasks in MES System, operators check corresponding 3D or 2D process documents, and with simulation process referenced, perform corresponding assembling and manufacturing operations.

Figure 9 AO Application at Shop Floor

5. Conclusion
3D CAD-based process planning is one of the hotspots in the study on advanced manufacturing technology[5] currently. 3D model-based process planning is a technological innovation in the background of globally collaborative research and development of large and complex mechanical products, and is of great significance to directly apply product 3D design outcome in product manufacturing phrase with product data source in 3D form throughout the entire research and development process and a large number of 2D manufacturing processes eliminated. With consideration given to aviation manufacturers’ actual demand for model-based product development and manufacturing, this article studies and develops the MBPP system of model-based process planning and process data integration, with which process planning and process collaboration mode based on full 3D information related models are realized, and efficiency of process planning is improved greatly. The outcome of this project has already been applied in the development and manufacturing processes of multiple new models of aircrafts, and of reference significance for 3D CAPP research and application.

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