20th ISPE International Conference on Concurrent Engineering
C. Bil et al. (Eds.)

doi:10.3233/978-1-61499-302-5-353

DMU Management – Product Structure and Master Geometry Correlation

Gülden ŞENALTUN [a] and Can CANGELİR [b]
[a] *gsenaltun@tai.com.tr, Turkish Aerospace Industries Inc., Ankara, Turkey 06980*
[b] *ccangelir@tai.com.tr, Turkish Aerospace Industries Inc., Ankara, Turkey 06980*

Abstract. One of the main principles of Concurrent Engineering is accessing the up to date design information at any moment. 3D models are the basic design information for today's industry. To work with 3D models by different departments concurrently, every model should be managed as positioned in 3D space relative to other models. This brings the term of Digital Mock-Up (DMU), digital design of the product to be developed. In order to use DMU effectively, design data should be managed in Product Lifecycle Management (PLM) tools by the help of Product Structure. In addition to that, 3D modeling rules are also important parameters to have effective DMU. Therefore, these rules should be set and every model should be created according to these rules.

In this paper, definition and management of DMU in aerospace industry are explained. Relation between Product Structure and DMU is detailed considering different DMU management methods such as "Bottom-Up Method", "Top-Down Method" and "Hybrid Method". These methods are also explained in this paper. Moreover, definition of Master Geometry is done and the role of Master Geometry in DMU creation is explained by using specific design examples from industry.

Keywords. Digital Mock-Up, DMU, Concurrent Engineering, CE, Bottom-Up Method, Top-Down Method, Hybrid Method, Product Structure, Master Geometry

Introduction

Today's economic environment needs the high quality products with lower costs and in a shorter time according to the conventional methods. In order to have this type of production environment, Concurrent Engineering approach should be adapted to organizations since "*Concurrent Engineering aims reducing the total effort in bringing the product from concept to deliver, while meeting the needs of both the consumers and industrial customers*" [1].

According to Prasad, "*Concurrent Engineering replaces the traditional sequential "over the wall" approach to a simultaneous design and manufacture spectrum with parallel, less interrelated process.*"[1].

For aerospace industry, development of aircraft has a very complex work from concept to deliver. All disciplines should work in a harmony and there should be continues and up-to-date information flows between departments. A main principle of

Concurrent Engineering, working with up-to-date data in the same database by all departments in the organization, meets this collaborative work requirement. This is done with the help of Product Lifecycle Management (PLM) tools the digital environment keeps all design data and provides collaborative work between all related departments. All related departments reach the design data via PLM tools at any time of the product lifecycle, give comments about design or make their own works such as fatigue analysis of design.

For the complex product (e.g. aircraft), design group has plenty of outputs, mainly 3D models and other meta data such as part numbers, material information, version, etc. All this information should be kept in the PLM tools in an organizational way. This is done with the help of product structure. Moreover, 3D models bring together via product structure and Digital Mock-Up (DMU), digital representation of the product is created.

In the following sections of this paper, since DMU evolves during aircraft development design evolution methods namely bottom-up, top-down and hybrid methods and their effect the product lifecycle are explained. Additionally, product structure and master geometry are defined to explain their correlation with DMU.

1. DMU Management

As mentioned above, DMU is the virtual representation of the product. Figure 1 represents the example of DMU.

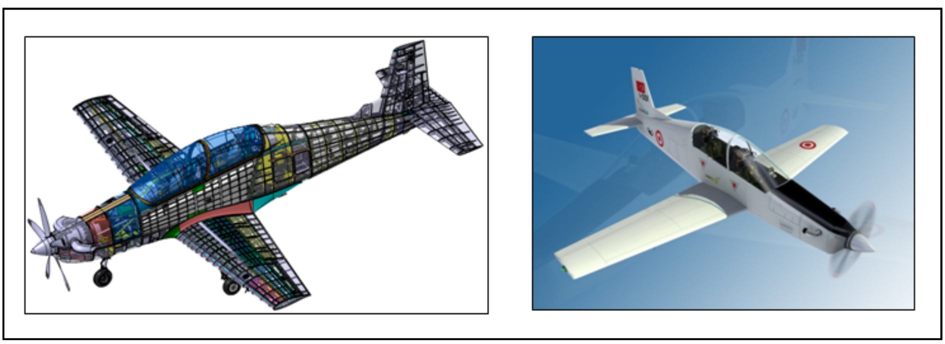

Figure 1. DMU Example

DMU provides main information of departments other than design to make their analysis such as maintainability, producibility, etc. analyses. Song states that "Digital mock-up (DMU) is used widely to prevent the interferences and mismatches during precision design and assembly processes without physical mock-ups" [2].

In order to create DMU, all design should be done in 3D design environment with CAD tools and design should be managed with product structure which is the basis of DMU. Moreover, master geometry should be used and design should be related with master geometry.

1.1. Design Evolution Methods

Using appropriate methods during design is important decision since design method affects time, costs and the quality. In this chapter, 3 different design methods and their effects to product lifecycle are explained.

Method 1-Bottom-Up Method.

As seen in Figure 2, the evolution of design starts from detail parts through assemblies. The individual detail parts of the assembly are first designed in great detail. These elements are then linked together to form larger sub-assemblies. This work is done in some cases in many level, until a complete top assembly is formed.

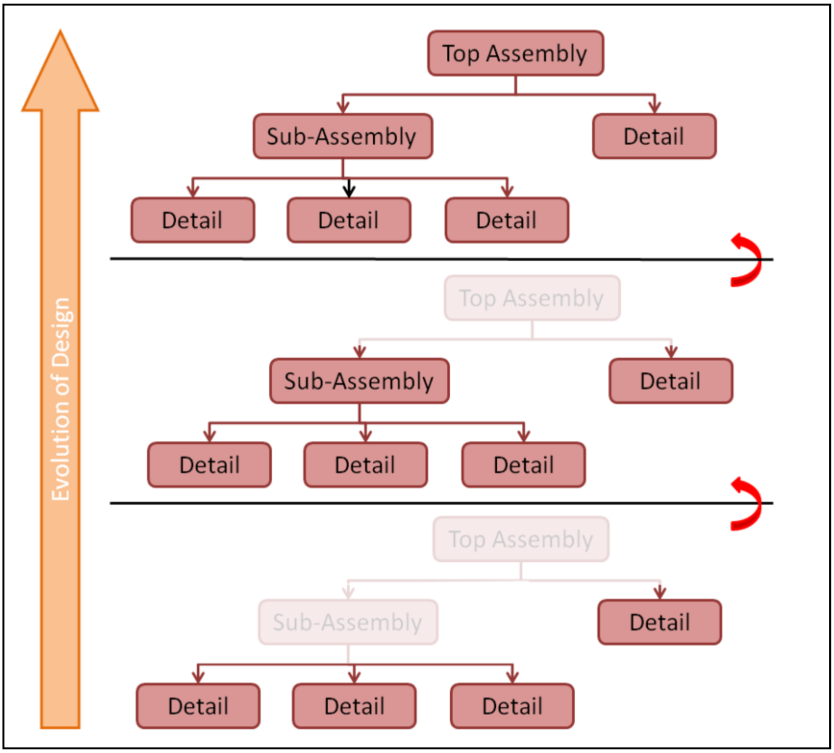

Fig. 2. Bottom-Up Design Method

This method brings the easy manufacturing of product and meeting the physically requirements properly. However, functional requirements should be transferred from assembly to detail parts. Bottom-up method could not guarantee that the functional requirements are not met by top assembly.

According to Terpenny "*Bottom- Up design method is the characteristic of traditional engineering and designs are built from known components in anticipation of satisfying functional requirements. In this scenario, physical realizability is guaranteed, but there is no immediate assurance that functional requirements are met*" [3].

In this method, since satisfying functional requirements are not guaranteed, there will be a large number of design change during verification of the product. Moreover, starting the design from detail parts brings the assembly design problems. There may be inconsistency in assembly's 3D model and detail parts should be redesigned. Bottom-up design is described as a highly iterative method by Terpenny [3]. As a result of these, bottom-up design is a time consuming process and it causes the long product lifecycle.

Method 2-Top-Down Method.

In top-down method, the evolution of design starts from assemblies through detail parts. First top assembly is designed and its components are decided. Then components after then sub-components up to detail parts are design. Systems engineering approach is adapted to this method. The design evolution of top-down method is represented in Figure 3.

Top-down method explained as "*top-down assembly design process is refined from the traditional product design process to better exhibit the recursive-execution and structure-evolvement characteristics of product design*" by Chen [4].

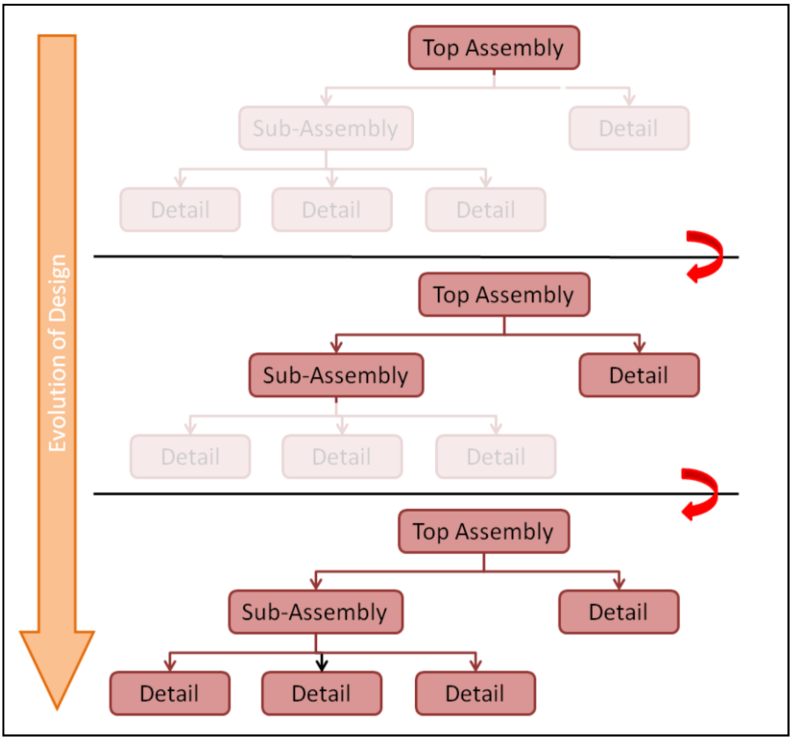

Fig. 3. Top-Down Design

Functional requirements are transferred from top assembly through detail parts during design process. However, manufacturing concept is not considered during these process.

According to Terpenny "*In the top-down method, design is driven from functional requirements toward solution alternatives. While design solutions using this approach are likely to meet functional requirements, there is no guarantee that solutions are realizable in terms of physical manifestations*" [3].

Starting from top assembly brings the full consistency of interface between detail parts and/or sub-assemblies. Hence, there is no extra time spent to assemble detail parts to get the top assembly. This brings the shorter design time compared to bottom-up method. On the other hand, top-down method does not guarantee of meeting physical requirements, thus manufacturing process could be long and complex process. Moreover, there could be change of design because of physical constraints and long production time means long product lifecycle.

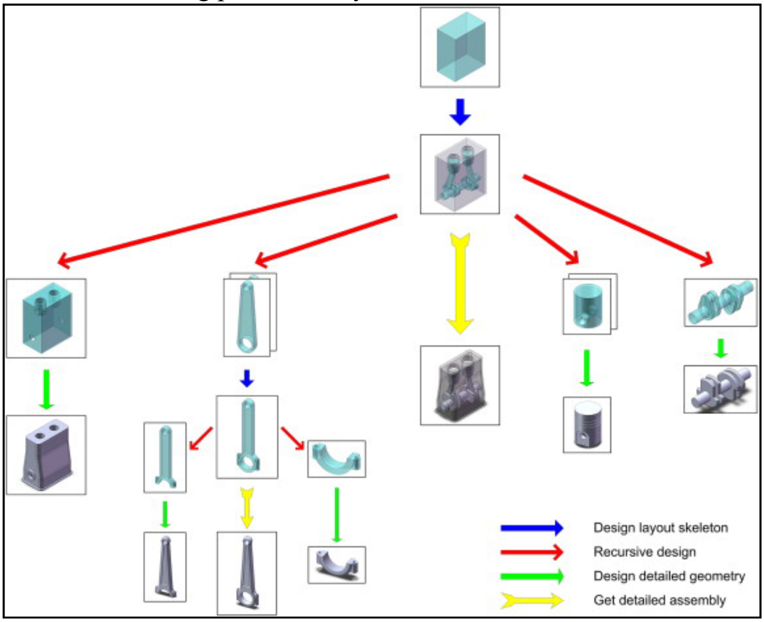

Fig. 4. Example of Top-Down Method [4]

Figure 4 represents the cylindrical piston system design using top-down method. As seen in the figure, design starts from assembly and going through the detail parts. After all detail parts are designed, assembly's 3D model is completed.

Method 3-Hybrid Method.

Hybrid method is the combination of bottom-up and top-down methods. It brings together advantages of top-down and bottom-up methods.

Physical design starts from detailed parts through top assembly and during physical design; functional requirements are transmitted from top assembly through detail parts. This makes the product lifecycle shorter compared to other two methods.

In this method, both physical and functional requirements are considered during design phase means meeting all requirements is guaranteed. Moreover, this brings the less number of changes in design and manufacturing process.

During aircraft design, top level analyses are done and in the same time detail parts are designed. For example, for aerodynamic analysis frame locations, landing gear systems locations are designed. Concurrently, landing gear and frames are designed in details. This detail design gives input to aerodynamic analysis. This means design is done both top-down and bottom up means hybrid.

1.2. Product Structure Correlation

Product structure, defined in EIA-649-B, represents the composition, relationships and quantities of a product and its components and it is determined from product configuration information [5]. According to Military Handbook (MIL-HDBK) 61B; *"Product structure derived from the functional analysis and allocation process of system engineering, may be depicted graphically as a tree structure or as an indentured listing"* [6].

Dolezal states that product structure is composed of main and sub-components in a hierarchical way. It refers to system architecture, internal structure, relationship of system components and associated configuration documentation [7].

According to all these references, it can be easily said that product structure is the base for all design information management including 3D models, material information, change information, etc. Product structure is also base for DMU creation and management. 3D models are kept up-to-date and in an organizational way with the help of product structure. DMU is created and managed with design information through product structure.

Moreover, there are different types of parts in aerospace industry such as structural parts, systems, equipments, harness, softwares, etc. Product structure brings all different kinds of parts and this is an important information for DMU. Analysis done with DMU differs with the part types and this information is kept on DMU via product structure.

Simplest product structure of aircraft is seen in Figure 5.

Product structure construction process is also important for DMU management. All related departments should be involving this process and product structure should be constructed according to their needs. For example, for some analysis fuselage and wing models should be reached separately via PLM tools. In this case, product structure should be constructed according to this requirement.

Additionally, DMU and analysis done by using DMU should be done for one product. This is controlled by the effectivity information which is the manufacturing serial number of the product. Parts could be filtered according to effectivity information via product structure and this is the significant feature of product structure in DMU management.

1.3. Master Geometry Correlation

To manage DMU, all parts should be located on their exact location on the product in top assembly model. This could be done by two ways:

- Design all detail part in their exact locations by using only product axis system.
  This is suitable for bottom-up method since detail parts are designed first.
- Keep location information in the assembly models.
  This is suitable for top-down method since assemblies are designed first.

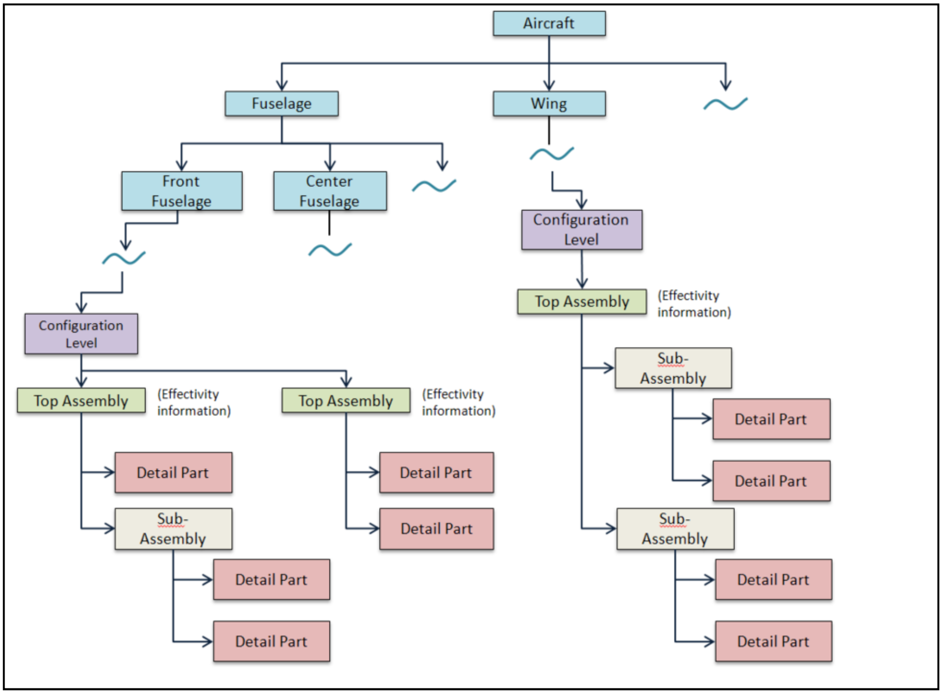

Fig. 5. Product Structure

In the hybrid method, both ways are used for creating DMU. For complex products, mostly, detail parts are designed on their exact locations and the parts used more than once are located in the assembly model.

For both ways, to locate parts in the 3D model, auxiliary products named as master geometry should be used.

Master Geometry could be defined as one of auxiliary products of DMU. Master Geometry is a 3D CAD model which presents the outer geometry and the elements forming the structure of the aircraft all together. This geometrical composition consists of surfaces, planes, lines and points which include all necessary geometrical dependencies and constraints required for design of the aircraft. Dolezal explains master geometry content like "*indications e.g. planes, coordinate systems of main structural components e.g. frames, ribs, spars, cut-outs like doors or windows and the positions of main sections*" [7].

During design process, parts locations should be linked to auxiliary geometries in the master geometry, such as frame positions. This brings the easy control of parts locations and changes of the location changes of critical components. Hence, if one frame location changes, parts' locations that are linked to the frame are changed automatically. This is the main advantage of using master geometry.

1.4. Conclusion

In this paper, 3D design evolution methods named bottom-up, top-down and hybrid for DMU creation are explained. Details of three design methods are given and their effects on product lifecycle are studied. If physical constraints are more important than functional constraints, bottom-up method is the suitable for design. However, top-down method should be used, if functional requirements are more important. Both two methods affect negatively product lifecycle time. Because of this effect, using these methods for complex products like aircraft is not suitable. Moreover, for aircraft all physical and functional requirements are important. In that case, hybrid method is the most suitable one.

In addition, DMU management and its relation with product structure and master geometry have been studied. Product structure keeps all design data up-to-date and in an organizational way. Furthermore, design data could be filtered according to effectivity information. Both these reasons state the importance of using product structure in DMU management. Master geometry is also as important as product structure. Parts are located in 3D environment on the product by using master geometry. This simplifies the design process and location changes could be controlled easily.

References

[1] Biren Prasad, *Concurrent Engineering Fundementals*, 1996

[2] In-Ho Song, Sung-Chong Chung, *Synthesis of the digital mock-up system for heterogeneous CAD assembly*

[3] Terpenny, Janis P., Nnaji, Bartholomew O, Bøhn, Jan Helge ,*Blending Top-Down and Bottom-Up Approaches in Conceptual Design*, May 1998

[4] X. Chen, S. Gao, Y. Yang, S. Zhang, *Multi-level assembly model for top-down design of mechanical products, Computer Aided Design*, In Press, Available online 24 December 2010.

[5] EIA-649-B, National Consensus Standard for Configuration Management Department of Defence

[6] Military handbook 61B, *Configuration Management Guidance*, 2002, page 5-5

[7] Dolezal, W., *Success Factors for DMU in Complex Aerospace Product Development*, Technische Universität München, s. , November 2007