Replacing the BOM by Manifestation of Product and Production*

Dr Zhao Xinli\textsuperscript{a}, Dr Jurgen Bode\textsuperscript{b}, Gu Ming\textsuperscript{c} and Prof Ren Shouju\textsuperscript{d}

\textsuperscript{a}Postdoctoral Research Associate, \textsuperscript{b}Senior Lecturer and \textsuperscript{d}Vice-director of CIMS-ERC, National CIMS-ERC, Dept of Automation, Tsinghua University, Beijing, 100084, P R C, Fax (+86)81-2568184, E-mail GAOSK%BEPC2@SCS SLAC STANFORD EDU

\textsuperscript{c}Associate Researcher, National CAD Laboratory, Dept of Computer Science and Technology, Tsinghua University, Beijing, 100084, P R China

Abstract

A more accurate definition of BOM is described in the first part of this paper. Then discussed in detail is a more powerful and more useful method called MOPP (Manifestation of Product and Production) in comparison with BOM. It is more suitable to build global information models in CIMS concurrent engineering environments with MOPP. MOPP should be included in STEP.

Keyword Codes H 5 3, I 6 3, J 1, J 6

Keywords Information Interfaces and Presentations, Group and Organization Interfaces, Simulation and Modeling, Applications, Administrative Data Processing, Computer-Aided Engineering, CAD/CAPP/CAM, Concurrent Engineering, CIM, Industrial Engineering, Production Management

I. INTRODUCTION

For almost as long as there is manufacturing, BOM has served as an important document for communication between the corporate functions of management, design, manufacturing, etc. Today computerized BOMs are still used to transfer data between CAD, CAPP, CAM and MIS or in CIMS. According to the Dictionary of CAD/CAM, BOM (called traditional BOM in this paper) is "a listing of all the subassemblies, parts, materials, and quantities required to manufacture one assembled product or part." However, traditional BOM lacks information (e.g., information about blanks and technical equipment as well as their respective materials and quantities). To avoid the shortcomings of traditional BOM, there are improved ones in use.

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Even the improved BOM could not represent the production information and it is difficult to integrate it within the global information model in an enterprise. In this paper, a more powerful and more useful method called MOPP (Manifestation of Product and Production) is proposed. MOPP can easily represent the design and manufacturing information of a product, especially the hierarchical information. The production information is also included in MOPP. Therefore, it is more suitable to build global information models in CIM environments with MOPP.

A more accurate definition of BOM is described in the first part of this paper. Then MOPP is detailed in comparison with BOM. Some conclusions and results are also given in the last part of this paper.

2. DISCUSSION ABOUT BOM

Although BOM has been used for a long time, some mistakes about what is BOM and how to use BOM in CIM environments usually happen, especially in China, because of a lack of experience about building global information models.

2.1 What is BOM?

BOM is defined as an ordered triple set, i.e., \( BOM = \langle S, P, M, Q \rangle \), where:

- \( S \) is a purchased part or assembly or subassembly, or repeatedly used TE (technical equipment).
- \( P \) is a manufactured part including the part in technical equipment that could not be used repeatedly.
- \( M \) is the type(s) and dimensions of the materials needed to produce \( S \) or \( P \).
- \( Q \) is the required quantities of the \( S \) or \( P \).

![Diagram](image)

Fig 1 The partial IDEF0 diagram in traditional engineering.
To get a clear and correct understanding and use of BOM, BOM-I and BOM-II (Fig 1) should be introduced. BOM-I is a listing, generated by product designers, of all the purchased assemblies or subassemblies, parts with the exception of those in the purchased assemblies and subassemblies, and their materials and quantities to manufacture a product. BOM-II is a listing, enriched by the designers of process planning and technical equipment, of all the purchased assemblies or subassemblies, parts with the exception of those in the purchased assemblies and subassemblies, technical equipment, and their materials and quantities to manufacture a product.

BOM-II includes more information than BOM-I, e.g., geometry information about blanks, technical equipment (jigs, tools, and measuring tools as well as their respective materials and quantities). It seems that BOM-I ⊆ BOM-II, but it is not true. For instance, the materials(M) in BOM-I are the exact material type(s) and dimensions of S or P in the finished product. However, the materials(M) in BOM-II are the total material type(s) and dimensions of S or that needed to manufacture P (including one time used TE part).

In mathematical way, the relationship between M in BOM-I and M in BOM-II is defined as follows:

\[ M = \{ <T, D> | T \leq \{t\}, D \leq \{d\} \} \]

where \{t\} set of material types, \{d\} the dimension or volume set of the materials

\[ M_{BOM-I} = \{ <T_{BOM-I}, D_{BOM-I}> | T_{BOM-I} \leq \{t\}_{BOM-I} \leq \{t\}, D_{BOM-I} \leq \{d\}_{BOM-I} \} \]

Here it should be mentioned that BOM-I does not equal BOM and BOM-II is the exact one needed by management and scheduling systems like MRP II.

2.2 Is BOM suitable for the coming CIMS environment?

There is no doubt that BOM will still play a useful role in the transfer of information in CIMS. However, along with the rapid and vigorous development of computer science (e.g., object-oriented techniques), CIMS, and modern innovation issues (e.g., concurrent engineering), the disadvantages of BOM have been exposed more and more. Some of them are:

(a) lack of management information for product and production (e.g., cost, time, space requirements)
(b) a BOM listing does not represent the originally hierarchical structure of product and production information
(c) difficulties to integrate BOM into a global product and production model
(d) even minor changes by non-designers eventually result in inconsistency, which conflicts with the principles of concurrent engineering
(e) no access to assembling information on subassembly level that is below the product and above the parts level
(f) a single BOM does not allow the representation of minor product or production variations (options), thus hiding flexible short-term adaptations, e.g., on workshop level.

3. MANIFESTATION OF PRODUCT AND PRODUCTION

To overcome those shortcomings of BOM a new way manifesting product and production has been developed by the authors. To distinguish it from BOM mentioned above a term MOPP is introduced.
3.1 What is MOPP?
MOPP (Manifestation of Product and Production) is defined based on Object-Oriented techniques as follows (Fig. 2 and Fig. 3)

Fig. 2 The schematic hierarchical structure of MOPP

(a) A 3 dimension tree represents the product and production information with object-oriented techniques. Objects and classes are structured according to the sequence of the operations comprising assembling, part manufacturing, and technical equipment manufacturing operations. Since there is an 1:1 relationship between assembling operations and product configuration, every MOPP contains the respective BOM.

(b) Each node in the MOPP tree represents a class and subclasses of objects which in turn have sub-objects. The objects in a class are operations having the same objective(function), are ordered based on some priority, and have the XOR relationship between each other. For every class of objects (node) its subclasses (lower nodes) are connected by the AND relationship.

(c) An 8-tuple \(<P, C, M_e, M, T, S, Q, F>\) is used to define the attributes of each object (node) in the hierarchical structure, where

- \(P\) man power needed by the object,
- \(C\) cost needed by the object, i.e., the variable cost corresponding to the object,
- \(M_e\) machine(s) used by the object, e.g., FMC, MC, etc.,
- \(M\) the geometry, dimensions, quantities, tolerances and the type(s) of material(s) of the work piece or blank manufactured by the object,
.Te: technical equipment including cutter(s), jig(s), and measuring tools used by the object,
.T: the time from the end of last operation (last lower node) to the end of the operation related to this object,
.S: the space requirement from the end of last operation (last lower node) to the end of the operation related to this object,
.QF: the quality objectives and function objectives of the product and production added by this object,

Each element of the 8-tuple may be represented with an order triple <a, b, c>, where
a: accumulated from the leaf nodes to this node in the hierarchical MOPP,
b: added, needed or modified by this object,
c: accumulated from the leaf nodes to this node in the hierarchical MOPP for users to use, maintain and scrap the product. This element is very important to evaluate the product quality in concurrent engineering[3]

(d) Just like BOM, MOPP can be divided into MOPP-I (Manifestation of Product) and MOPP-II (Manifestation of Product and Production). The structure of MOPP-I is based on the assembling operations of the product. Each leaf of MOPP-I is a purchased subassembly, a purchased part, or a manufactured part. Each leaf of MOPP-II is a purchased subassembly, a purchased part, or a purchased blank (material). The latter is the starting point for a manufactured part that itself is positioned above leaf level. Additionally, the technical equipment, which is necessary to carry out the operations for each part or subassembly, is itself in turn regarded as a part or subassembly in MOPP-tree.

The main work in each block has been changed to optimum design selection of existing objects and definition of new objects.

Fig 3. The partial IDEF0 diagram based on MOPP.
MOPP-II contains MOPP-I, i.e. MOPP-I is a subset of MOPP-II. If a 9-tuple \(<P, C, Me, M, Te, T, S, QF, R>\) is used to represent it, MOPP can be mapped onto a relational database, where \(R\) represents the relationship between this object and parent object and the relationship between this object and child object(s).

Actually, MOPP represents the product and production solution space upon the resources and constraints of an enterprise. Each node (object) of MOPP corresponds with several satisfactory solutions. In this way, MOPP is quite different from the traditional BOM where the design results must be unique.

3.2 A real-life example

MOPP has been put into use partially in a rock bit factory. It is a hard work to establish complete information models based on MOPP. Even though it is still the initial work on MOPP, it is believed that "MOPP is easy to understand and manipulate", "covers most of the information in an enterprise and is quite consistent".

### Accumulated Information of a Tungsten Carbide Bit with MOPP

<table>
<thead>
<tr>
<th>TUNGSTEN CARBIDE BIT</th>
<th>P</th>
<th>C</th>
<th>Me</th>
<th>M</th>
<th>Te</th>
<th>T</th>
<th>S</th>
<th>QF</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLT LEGS</td>
<td>34.25</td>
<td>113,900.00</td>
<td>BL Me</td>
<td>3</td>
<td>BL Te</td>
<td>68.90</td>
<td>2</td>
<td>BL OF</td>
</tr>
<tr>
<td>CONES</td>
<td>890.00</td>
<td>119,964.00</td>
<td>C Me</td>
<td>297</td>
<td>C Te</td>
<td>68.90</td>
<td>2</td>
<td>C OF</td>
</tr>
<tr>
<td>Compact Land</td>
<td>20.00</td>
<td>6,400.00</td>
<td>CL Me</td>
<td>3</td>
<td>CL Te</td>
<td>24.00</td>
<td>2</td>
<td>CL OF</td>
</tr>
<tr>
<td>Carbide Teeth</td>
<td>60.00</td>
<td>8,560.00</td>
<td>CT Me</td>
<td>204</td>
<td>CT Te</td>
<td>64.00</td>
<td>4</td>
<td>CT OF</td>
</tr>
<tr>
<td><strong>Ovoid</strong></td>
<td>15.00</td>
<td>1,680.00</td>
<td>OV Me</td>
<td>42</td>
<td>OV Te</td>
<td>16.00</td>
<td>2</td>
<td>OV OF</td>
</tr>
<tr>
<td><strong>Ogee</strong></td>
<td>15.00</td>
<td>4,800.00</td>
<td>OG Me</td>
<td>110</td>
<td>OG Te</td>
<td>16.00</td>
<td>2</td>
<td>OG OF</td>
</tr>
<tr>
<td><strong>Scout Ogee</strong></td>
<td>15.00</td>
<td>2,000.00</td>
<td>SO Me</td>
<td>50</td>
<td>SO Te</td>
<td>16.00</td>
<td>1</td>
<td>SO OF</td>
</tr>
<tr>
<td><strong>Coneal</strong></td>
<td>15.00</td>
<td>584.00</td>
<td>CON Me</td>
<td>2</td>
<td>CON Te</td>
<td>16.00</td>
<td>1</td>
<td>CON OF</td>
</tr>
<tr>
<td>BOZZLES</td>
<td>15.00</td>
<td>945.00</td>
<td>B Me</td>
<td>3</td>
<td>B Te</td>
<td>19.00</td>
<td>0.21</td>
<td>B OF</td>
</tr>
<tr>
<td>Jet Nozzles</td>
<td>15.00</td>
<td>540.00</td>
<td>RN</td>
<td>3</td>
<td>RN Te</td>
<td>16.00</td>
<td>0.05</td>
<td>RN OF</td>
</tr>
<tr>
<td>&quot;O&quot; Rings</td>
<td>0.10</td>
<td>180.00</td>
<td>OR Me</td>
<td>3</td>
<td>OR Te</td>
<td>0.50</td>
<td>0.03</td>
<td>OR OF</td>
</tr>
<tr>
<td>Retaining Rings</td>
<td>0.10</td>
<td>150.00</td>
<td>RR Me</td>
<td>3</td>
<td>RR Te</td>
<td>0.50</td>
<td>0.03</td>
<td>RR OF</td>
</tr>
<tr>
<td>Nozzle Boss</td>
<td>2.33</td>
<td>75.00</td>
<td>NB Me</td>
<td>3</td>
<td>NB Te</td>
<td>2.36</td>
<td>0.41</td>
<td>NB OF</td>
</tr>
<tr>
<td>LUBRICATORS</td>
<td>20.32</td>
<td>555.00</td>
<td>L Me</td>
<td>3</td>
<td>L Te</td>
<td>30.00</td>
<td>0.45</td>
<td>L OF</td>
</tr>
<tr>
<td>Reservoir Cap</td>
<td>1.20</td>
<td>75.00</td>
<td>RC Me</td>
<td>3</td>
<td>RC Te</td>
<td>16.00</td>
<td>0.1</td>
<td>RC OF</td>
</tr>
<tr>
<td>Protector</td>
<td>3.33</td>
<td>120.00</td>
<td>P ME</td>
<td>3</td>
<td>P Te</td>
<td>6.40</td>
<td>0.1</td>
<td>P OF</td>
</tr>
<tr>
<td>Compensator</td>
<td>3.69</td>
<td>180.00</td>
<td>COMP Me</td>
<td>3</td>
<td>COMP T</td>
<td>6.40</td>
<td>0.15</td>
<td>COMP OF</td>
</tr>
<tr>
<td>O-ring Seal</td>
<td>0.10</td>
<td>180.00</td>
<td>LORS Me</td>
<td>3</td>
<td>LORS Te</td>
<td>0.00</td>
<td>0.1</td>
<td>LORS OF</td>
</tr>
<tr>
<td>BEARINGS</td>
<td>6.30</td>
<td>1,176.00</td>
<td>BRG Me</td>
<td>6</td>
<td>BRG Te</td>
<td>2.00</td>
<td>0.35</td>
<td>BRG OF</td>
</tr>
<tr>
<td>Roller Bearings</td>
<td>0.10</td>
<td>540.00</td>
<td>RB Me</td>
<td>3</td>
<td>RB Te</td>
<td>0.80</td>
<td>0.15</td>
<td>RB OF</td>
</tr>
<tr>
<td>Ball Bearings</td>
<td>0.10</td>
<td>426.00</td>
<td>BB Me</td>
<td>3</td>
<td>BB Te</td>
<td>0.80</td>
<td>0.1</td>
<td>BB OF</td>
</tr>
<tr>
<td>O-ring Seals</td>
<td>0.10</td>
<td>210.00</td>
<td>BORS Me</td>
<td>3</td>
<td>BORS Te</td>
<td>0.50</td>
<td>0.1</td>
<td>BORS OF</td>
</tr>
</tbody>
</table>

Fig. 4 A simplified MOPP list of a living example

Fig. 4 is a simplified MOPP list from the rock bit factory. It corresponds to the accumulation element "a" in the tuple \(<a, b, c>\). The figure is not an original table. The configuration (hierarchical structure) of a rock bit is described by different text fonts in the first
column. The elements in columns $M_e$, $T_e$ and $Q_f$ are the corresponding file names. Some equations and constraints are defined in this table. For example, the total cost of Tungsten Carbide Bit is the sum of that of Bit Legs, Cones, Nozzles, Lubricators and Bearings. The numbers of Compact Land, Roller Bearings, Lubricators, Protector and so on must be same. The table is also supported by a synthesis information gathering system and an integrated database management system.

4. CONCLUSIONS

MOPP has many advantages, especially compared with BOM. Some of them are:

(a) MOPP is not a list, but a hierarchical structure similar to the product and production structure.

![INTEGRATED PRODUCT & PRODUCTION INFORMATION MODEL](image)

Fig. 5 Product & Production Information Model is the kernel in CIMS concurrent engineering environment
(b) MOPP represents perfectly and more precisely information than BOM does. BOM can only specify partial information at the leaves of MOPP and does not include further management information.

(c) MOPP can serve as an integrated object-oriented database for diverse applications such as MIS, CAD, CAPP, CAM, etc. (Fig 5) Therefore, enterprise-wide optimal product and production solutions instead of local application-wide solutions can be achieved.

(d) The resources and constraints of an enterprise are changing continuously so that MOPP is a function of time. It could realize the optimization on time domains to make decisions about a process just before it starts. This kind of work can be done upon MOPP. Therefore, the solutions upon MOPP are also the optimization on time domains.

(e) The STEP (Standard for the Transfer and Exchange of Product model data) is focusing on establishing an IPIM (Integrated Product Information Model) and we propose an IPPIM (Integrated Product and Production Information Model) written in STEP style based on MOPP(Fig 5).

(f) Instead of repetitive work, the main work of employees in an enterprise will be decision-making (i.e., selecting objects) and creating (i.e., defining new objects).

(g) MOPP supports the concurrent engineering process.

(h) Because of the object-oriented paradigm, MOPP has an open structure, can be enriched and modified easily.

Everything has two sides. It is more complicated and difficult to manage and maintain MOPP than BOM because the data based on MOPP are much more than that on BOM and needs updating opportunity.

Some of the further work for us to do is to finish the case study or application of MOPP in the oil field and to find out whether it is too complicated to manage and maintain MOPP in big manufacturing factories that produce much more complicated products with complicated processes.

REFERENCES