Research on the Application of BOM in Modular Partition

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Abstract. In this paper, the criterions of module division are established, and the calculation formula of the number of modules partitioning schemes under two conditions is given, and the logic relation between modules is analyzed. On the basis of the research, a product structure attribute mapping method applied to the module division of products based on the bill of materials (BOM) is proposed. Finally, the feasibility and effectiveness of the method are verified by taking the wheel loader cab as an example.

Introduction

BOM mainly includes: Design BOM (EBOM), Manufacturing BOM (MBOM), Production BOM (PBOM)[1-2].EBOM mainly reflects the structure and function of the product, hierarchical relationship, quantitative relation, assembly relation. MBOM on the basis of EBOM, is from the manufacturing and processing aspects to describe product, containing manufacturing processes and other content, used to guide the production of products. PBOM is mainly from the perspective of production to describe the product, including the producers, funds, materials and other resources arrangements.

To some extent, bill of Material (BOM), as a set of material configuration information in manufacturing, can reflect the product configuration hierarchical relation. Therefore, BOM can be utilized to divide the module.

Module Division Method based on BOM

Establish Criteria for Module Partitioning

Module division is one of the most fundamental and key technologies of product modularization design. The result of partitioning will directly affect the success of modular design[3-5]. From different point of view, different division can be got, but in general, the division process, must comply with the following main criteria:

Function Structure Independence

The partition module must be simple in structure, independent in function, and independent of physical structure, which is beneficial to improve the reuse degree of the module, simplify the module structure, reduce the manufacturing cost, and assemble and disassemble easily.

Easy to Assemble and Disassemble

Module combination and split are two important relative processes about how to quickly combine the module into a product, and how to achieve efficient product maintenance and upgrade. Rational division of the module is often less time-consuming assembly and disassembly, and has a variety of forms of combination.

Moderately Partition

Modules have hierarchical relationships, the process of division has to avoid two extremes. Firstly, the degree of division is too small, will cause excessive number of modules, complex correlation between modules, which is not conducive to the scale of production and management of modules. The opposite extreme is that the degree of division is too rough, which makes the modules internal

structure complex and poor flexibility; so the moderate division means that product is divided into modules function can be achieved with a simple structure.

Reusability

Modular design is the pursuit of a small number of modules combined into as many products as possible, so the division of the module can not only meet the assembly of a product, and should have a relatively strong versatility that achieve the reuse for same series or even cross-series product.

Strong and Weak Coupling

"Strong coupling among the internal parts of the module, weak coupling between modules" on the one hand is to ensure that the internal parts of the module is closely correlated, the structure is as compact as possible, on the other hand to ensure that the modules is in the "loose coupling" for facilitating the demolition and combination.

Establish BOM Structure Attribute Map

There are different types of BOM, but they mainly reflect the hierarchy of products, components and parts, assembly relations and the quantitative relation from different points of view, including information about product materials, size, quality, production and other types of property. The parent-child hierarchical relationship in the BOM is the most valuable reference for module partitioning[6], because it is possible to know the structural relationship of the product by BOM analysis. For complex mechanical and electrical products, BOM sometimes up to ten layers, and each material has its own code and content, which make it as much as hundreds of thousands of item. However, some of the information is not significant for the partition, it is necessary to extract the main properties of BOM, and expressed it as a distinct graphical style.

In the study, the main attribute of BOM is defined as set $^{Q(A,B,C,D)}$, where A is the layer number, the product layer is the first layer, the system level is the second layer, and the component level is the third layer, in a addition, the component can be further divided into structure level and part level. The layer number is made up of code of product and hierarchy, for example, Code 001.02.03 represents a component located on the third layer is under system component 02 of product 001, encoded as 03; B represents the quantity of the material; C represents the name of the material; D on behalf of the type of material production that can be divided into home-made pieces, purchased parts, standard parts. After defining the focal properties of BOM, the structure attribute mapping relationship (see Figure 1) based on BOM can be obtained. Then, the correlation analysis of components and the division of function modules are carried out.

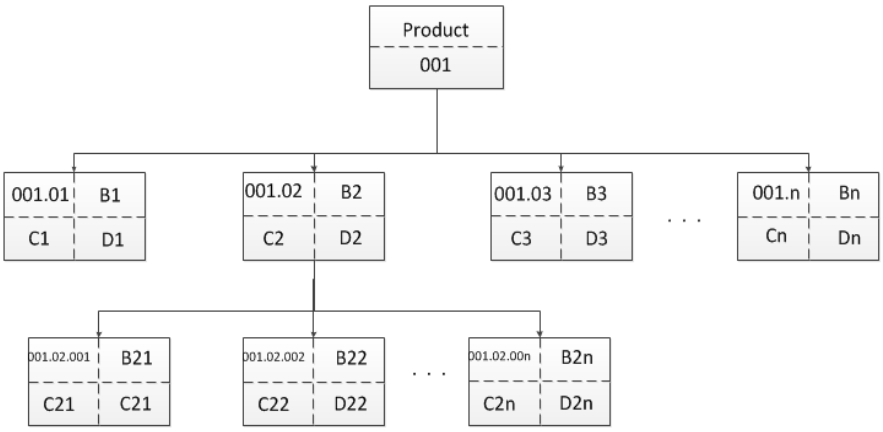

Figure 1. Structure attribute map based on BOM

Calculation of the Number of Module Partition Schemes

As showed in Figure 1, the parent item M is composed of components (m_1, m_2 ... m_n).By definition 1 and 2, the number of module divisions under two different conditions can be calculated.

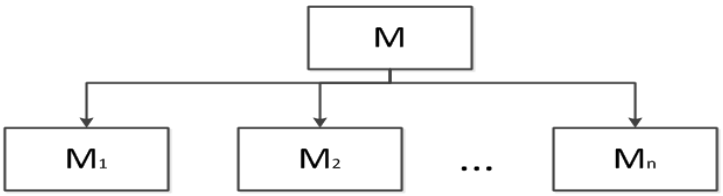

Figure 2. The composition of module M

Definition 1 If the parent item M consists of components m_1, m_2 ... m_n, is divided into P modules (n ≥ P≥ 1), and the division of the module can be arbitrarily achieved , then the total number of division methods is: C_{n-1}^{p-1} .

Definition 2 If the parent item M consists of components m_1, m_2 ... m_n, it is divided into P modules (n≥P≥1), and the division process of the module requires that components m_{n_1}, m_{n_2} ... m_{n_p} (n-p+1≥q≥2) must be divided into one module, Then the total number of division methods is: C_{n-q}^{p-1}.

The Main Logical Relationship between Modules

Each module comprises of a number of sub-components with shape, size, structure, occupying space. It is also provided with a variety of other attributes, such as a hierarchies, coding information, materials, processing technologies, product types. In order to complete the overall function of the system, the modules need to contact in terms of energy, information, material, which mainly contains the following logical relationship.

Equivalence Relation (Figure 3)

When the structure and function of two modules are identical, then the two modules can be judged as equivalent. In the module library management, the module equivalent relationship should be avoided, because it will make different names corresponding to the same module, leading to confusion in the module management, hinder the development of modular design.

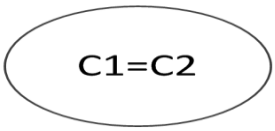

Figure 3. Equivalence relation

Intersection Relationship (Figure 4)

Intersection refers to the function and structure of the modules that have the exact same parts. In Fig. 4, the modules C1, C2, C3 have the same portions A, B, C, D. For modules with intersecting relations, it is appropriate to divide the same part into a module for specialized and large-scale manufacturing, and to increase the module's reuse rate.

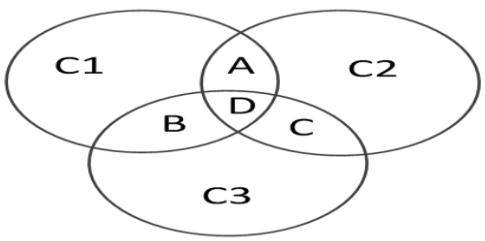

Figure 4. Intersection relationship

Inclusion Relationship (Figure 5)

Inclusion relationship exists in the product family, and configuration examples. For instance, loader bucket module contains 3-square bucket, 5-square bucket, 8-square bucket module, while engine module includes Yuchai engine, Weichai engine, and Cummins engine.

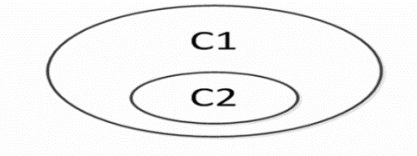

Figure 5. Inclusion relationship

Decomposition and Combination Relationship (Figure 6)

Decomposition and combination relationship different from inclusion relation is mainly related to the hierarchical relationship between the modules, for example the parent module and the sub-module are the decomposition and combination relation rather than inclusion relation. such as loader and the power system is the decomposition and combination relationship, and the relationship between Loader and A-type loader, B-type loader is included.

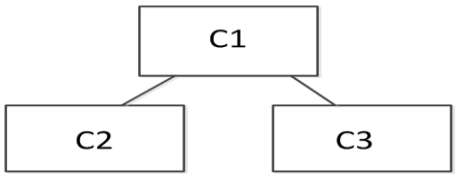

Figure 6. Decomposition and combination relationship

Parallel Relationship (Figure 7)

The parallel relationship mainly represents the horizontal relationship among the modules in the same system. In Figure.7, C2, C3 are in the same system C1, and the relationship between them is parallel. For example, in a wheel loader, the power system, braking system, working device is a parallel relationship.

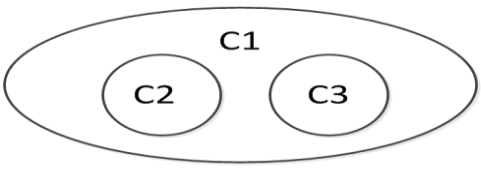

Figure 7. Parallel relationship

Application of BOM in Module Division of Cab

Figure 8 is a loader cab BOM that includes components as follows: 1 Cab frame, 2 Front window glass, 3 Front window seal, 4 Rear window glass, 5 Rear window seal, 6 Control platform frame, 7 Instrument panel shell, 8 Instrument panel, 9 Steering wheel base, 10 Right door, 11 Right side window glass, 12 Right side window strip, 13 Right door lock, 14 Right door seal tape, 15 Left door,16 Left side window glass, 17 Left side window strip, 18 Left door lock, 19 Left door seal tape, 20 Wiper assembly, 21 Driver chair, 22 Car Mirrors.

According to the method proposed in Section 2.2, the structural attribute map(shown in Figure.9)can be obtained.

Layer	Part Number	Version	Name	Serial number	Material	Code	Quantity	Type
2	47C0017	006	Cab	1.14	assembly		1	Self-made
3	23D0043	001	Cab frame	1.14.1	Welding part		1	Self-made
3	87A0011	000	Front window glass	1.14.26	Toughened glass	ZL40B.17-	1	Self-made
3	84A0053	000	Front window seal	1.14.27	Rubber V-2	ZL40B.17-	1	Self-made
3	87A0012	000	Rear window glass	1.14.28	Toughened glass	ZL40B.17-	1	Self-made
3	84A0054	000	Rear window seal	1.14.29	Rubber V-2	ZL40B.17-	1	Self-made
3	23D0059	000	Control platform frame	1.13.1	Welding part	ZL50G.16.	1	Self-made
3	86A0013	001	Instrument panel shell	1.13.5	ABS		1	Self-made
3	86A0014	000	Instrument panel	1.13.7	ABS	ZL40B.16(	1	Self-made
3	72A0068	000	Steering wheel base	1.13.22	ZG270-500	ZL40B.16-	1	Self-made
3	47C0040	000	Right door	1.14.15	assembly	ZL40B.17.	1	Self-made
3	87A0020	000	Right side window glass	1.14.4	Toughened glass	ZL40B.17-	1	Self-made
3	84A0055	000	Right side window strip	1.14.6	Rubber V-2	ZL40B.17-	1	Self-made
3	47C0031	000	Right door lock	1.14.13	assembly	ZL40B.17.	1	Self-made
3	84A0513	000	Right door seal tape	1.14.30	assembly	HM006	1	Purchased
3	47C0041	000	Left door	1.14.15	assembly	ZL40B.17.	1	Self-made
3	87A0021	000	Left side window glass	1.14.4	Toughened glass	ZL40B.17-	1	Self-made
3	84A0105	000	Left side window strip	1.14.5	Rubber V-2	ZL40B.17-	1	Self-made
3	47C0032	000	Left door lock	1.14.13	assembly	ZL40B.17.	1	Self-made
3	84A0512	000	Left door seal tape	1.14.30	assembly	HM006	1	Purchased
3	47C0080	000	Wiper assembly	1.14.25	assembly	STZL40B.1	1	Purchased
3	47C0078	000	Driver chair	1.15	assembly	LT01	1	Purchased
3	47C0069	000	Car Mirrors	1.14.8	assembly	SK649	2	Purchased

Figure 8. BOM of loader Cab

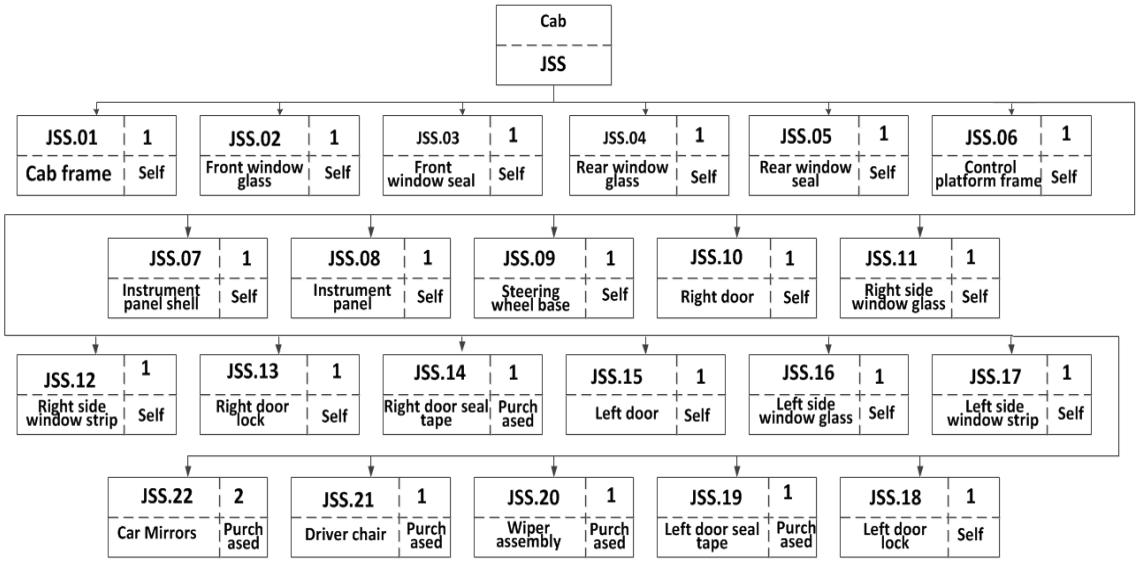

Figure 9. Structure attribute map of cab

From the map, there are 22 components of the cab, according to the formula in Definition 1 of Section 2.3, the number of some partition cases can be calculated in Table 1.

Table 1. Number of division schemes

The number of modules	5	6	7	8
The number of cases	5985	20349	54264	116280

It can be seen from Table 1 that if there is no constraint on the division of the cab, there will be a huge number of division schemes in the cab. Therefore, it is necessary to analyze structure and function of cab (see Fig.10) according to the division principles established in Section 2.1 and the logical relationship proposed in Section 2.4 after obtaining information of assembly relationship, the number of materials, production type from BOM. Finally, the results of the wheel loader cab division are given in Table 2.

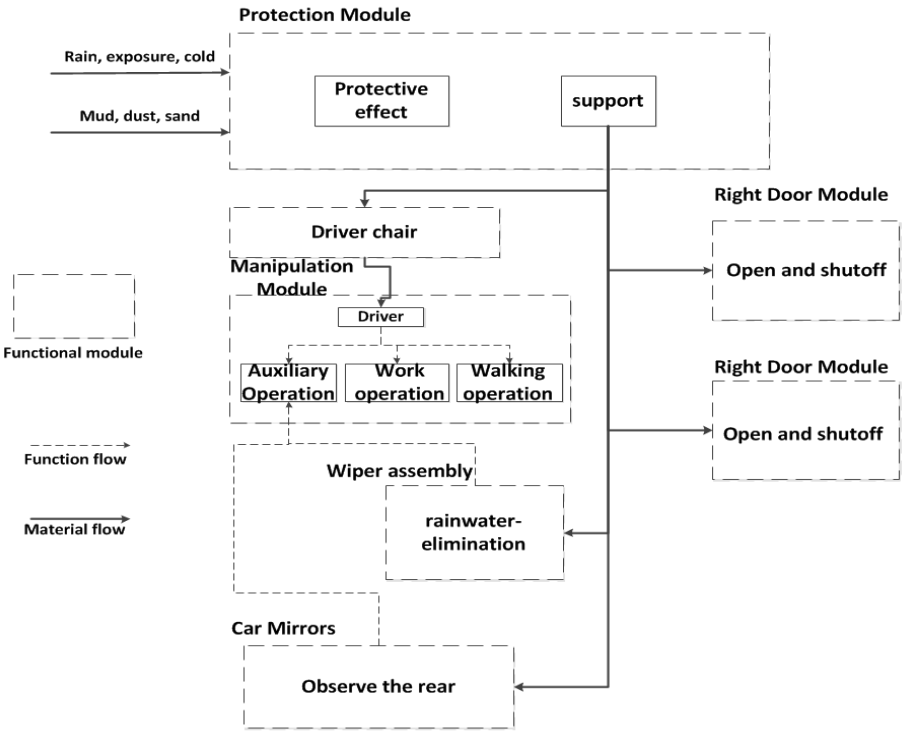

Figure 10. Analysis of cab function

Table 2. Results of module division in cab

The main functional modules	The main components
M_1 Protection Module	1 Cab frame, 2 Front window glass, 3 Front window seal, 4 Rear window glass, 5 Rear window seal
M_2 Manipulation Module	6 Control platform frame, 7 Instrument panel shell, 8 instrument panel, 9 Steering wheel base
M_3 Right Door Module	10 Right door, 11 Right side window glass, 12 Right side window strip, 13 Right door lock, 14 Right door seal tape
M_4 Left Door Module	15 Left door ,16 Left side window glass, 17 Left side window strip, 18 Left door lock, 19 Left door seal tape
M_5 Auxiliary Operation Module	20 Wiper assembly, 21 Driver chair, 22 Car Mirrors.

Conclusion

In this paper, the principles of module division are established, the concept of logic relation of the module is put forward, and the calculation formula of number of division modules is given. By analyzing the BOM, the main attribute set of BOM is defined, the structural attribute map is constructed. Finally, the method is applied to the division of the loader cab, and the results matching engineering application are obtained

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