Research on the Optimization of the Structure Design of Functional Sofa Based on Modular Technology

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Abstract: This paper is based on the sofa as a modular research object, and analyzed the current situation of the sofa modularization. In view of the function sofa included in sofa, this paper puts forward the optimization method of the structure modularization of the function sofa. Combined with concrete examples, modularization technology is used to analyze the structure of existing functional sofas, and the methods of modular classification and structural design optimization are proposed.

1 INTRODUCTION

Nowadays, the furniture market is developing rapidly, there are countless brands and many varieties, what is dazzling. The designer's imaginative imagination makes the various furniture shape different, that causes the consumer to choose the furniture which he is interested in to be more difficult. In particular, the large role of the living room--sofa, which is a difficult problem that people choose. How to quickly choose, design, produce sofa product are customers, designers, production personnel who are expected. So the modular design of the sofa is put on the agenda.

Based on furniture function, habit, human body mechanics and so on, the furniture is decomposed rationally, the furniture is decomposed into standard unit, and the function of these standard cells is summarized and simplified, and merged into modules. Different modules have their own independent functions, with similar or similar functions, merged into a common module; there are some modules to meet the special functions of the furniture, merged design for the dedicated module. If a module is not satisfied the rule in the future, a new modular design is proposed, which is added into the module library.

In the current sofa module, the module may be a combination relation. Module is the most basic unit of furniture, multiple modules can be composed of one or several new two-level modules, two-level modules can and other two-level modules or even a class of modules into a three-level module, and so on. Until the composition of the customer needs of the furniture combination. The furniture not only changeable, but also diverse functions, at the same time to meet customer requirements, to encounter interchangeability, universality and other design principles.

Analysing to the sofa structure, function, characteristics， we can draw the following four kinds of modular sofa: ① suspension module, ② load module, ③ splicing module, ④ hybrid module. The existing modularity advantage is that they are based on the basic form of “functional form” which can stand in the angle of function, promote the designer to produce new idea, and also conducive to customer and designer choice. The disadvantage is that it cannot be accurately divided into similar modules, which according to the overall furniture function of the division module. Instead of dividing the module according to the structure and function of the parts, so we need a new modular sofa design.

2 MODULAR

2.1 Basic Ideas

The structural design of functional sofas optimizes its structure and parameters by means of modularization, its main contents are:

1) Accurate division of modules. The module needs the accurate division, guarantees its structure function does not overlap.

2) The structure inside the module is optimized. Existing product structure is various, it is need to think that the similar structure how to optimize it.

3) Determination of key parameters. The serialization standardization of parameters is the most intuitive point to improve the efficiency.

3 FUNCTION SOFA MODULARIZATION

3.1 Module Division

The most basic principle of module division is (1) functional Independence principle, (2) structure independence principle, (3) serialization, standardization, generalization three principles.

Functional sofa module division is aimed at the specific functions of furniture, the same or similar units split, with modular design principles for induction and unification. The process of division as shown in Figure 1, after the survey of specific structural data, performing functional analysis and module division, if not satisfied with the module results, then continue to these two steps until determined the module.

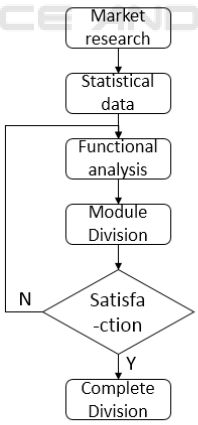

Figure 1: Module partitioning process.

3.1.1 Function Analysis

Functional sofa structural design of the module division is focused on design-oriented, analysis the total function of the product, decomposed into a series of basic functions. As shown in Figure 2, according to different levels of division, can criteria the total function is divided into the smallest functional unit.

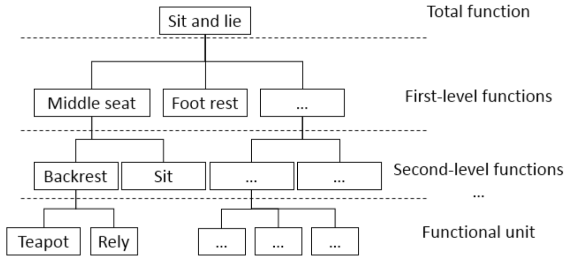

Figure 2: The function decomposition process of the product.

More research are with function analysis as the main factor, while considering other factors of the modular design method.

3.1.2 Determination Module

Functional analysis gets a variety of functional factors, some can be referred to as a separate module, some need to be based on the basic features of functional sofa modules and correlation analysis, the combination of different functions into a new module. The modules conform to the principle of functional independence and structural independence. The internal classification of modules is taken the standard of the structure of small differences for the classification, divided into modules within the first class to the Nth class.

3.2 Structural Optimization

Optimal design is the best optimal design scheme under the condition of satisfying the given constraints. Functional sofa design options can be optimized in any way, such as size, shape, installation location, manufacturing costs, material types, etc. The purpose of structural optimization design is to realize the innovation of product function and morphological structure on the basis of saving material and simplifying technological process.

3.2.1 Optimized Design of Structural Strength

Function sofa optimized design of structural strength is to study the connection between the parts of the cross section size, so that its structure is the lightest or most economical, often known as size optimization, it is the lowest level of structural optimization design, but also the most widely used.

Size optimization is to reduce the cost of materials on the basis of ensuring the structural strength requirements.

3.2.2 Optimized Design of Structural Forms

Functional sofa structure optimization design, change the geometry of the structure, which is called structural shape optimization. Then allow the optimization of the structure layout and material distribution, i.e. topology optimization of the structure. The goal of topology optimization is to find the best material allocation scheme. Through the calculation of material cost and labor cost, found out the optimal material distribution and distribution scheme.

$$Q = \sum_{i=0}^{n} ci * mi + t * d \qquad (1)$$

Formula (1), ‘Q’ for the total price, ‘ci’ for material dosage, ‘mi’ for material price. According to the different types of materials are divided into ‘i’=1, 2, 3, 4 ..., different materials correspond to different prices, ‘t’ for product work, ‘d’ for labor cost. The product total price ‘Q’ can be calculated by formula (1).

3.3 Determination of Key Parameters

Parametric design is to achieve the entire product parameter definition by changing the size of a part or parts, or by modifying the parameters that have already been defined. The key dimensions are determined by various external constraints, including human mechanics, packing size, etc. The remaining parameters are solved by means of numerical method and symbolic calculation, and the remaining parameters are obtained by transforming the constraints into a series of algebraic equations.

4 EXAMPLES

Take a backrest of company's functional sofa as an example, make a set of modular analysis.

4.1 Function Sofa Module Split

According to the function analysis, the function sofa each structural part is different, each component realizes the function also to be different, will decompose the product to the smallest structure function. As shown in table 1, the last column is the smallest function unit. Third column is the secondary functional unit. Unit combination become Modules into third columns.

Table 1: Functional sofa module division.

Function Sofa	Backrest	—	—
	Handrails		
	Seat frame		
	Footrest		
	Middle	Middle backrest	Middle turned backrest
		Middle seat	Middle seat front board
	Tea table	Tea table backrest	Tea table turned backrest
		Tea table seat	—
	Sofa bed	Backrest, Handrails	Sofa bed front board
	Angle	Angle back	—
		Angle seat	

4.2 Backrest Module Classification

4.2.1 Preliminary Classification

Take the backrest as an example, referring to all the backrest types, all the back backs are as shown in Figure 3a, 3b, 3c, 3d, 3e, 3f, plus all the strange backrest, altogether seven categories.

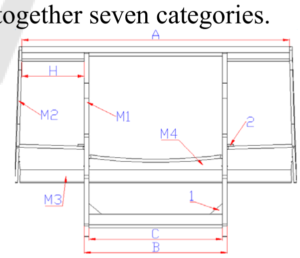

Figure 3a: Backrest first class.

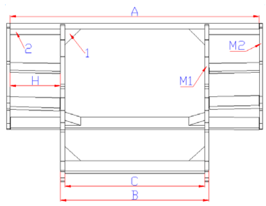

Figure 3b: Backrest second class.

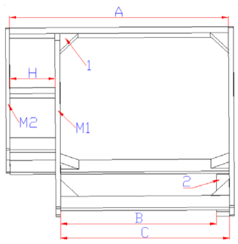

Figure 3c: Backrest third class.

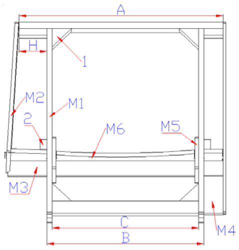

Figure 3d: Backrest fourth class.

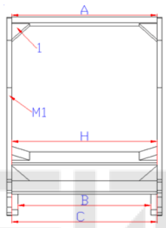

Figure 3e: Backrest fifth class.

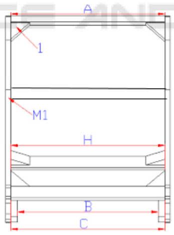

Figure 3f: Backrest sixth class.

This is based on the different structure of the backrest, summed up seven kinds of preliminary types. Because the principle of modularity is that the smaller the number of modules the better, so the structure of the backrest need to optimize the module.

4.2.2 Structure Optimization

Figure 3 the top wood of all backrest (called backrest top wood) has two kinds of specifications 20mm*40mm and 20mm*50mm. The use of testing found that 20mm*40mm can meet the strength requirements of the backrest top wood size optimization.

Backrest sixth analogy class fifth internal structure more than one wood side, the use of detection found to meet the strength requirements, you can delete the sixth class, backrest topology optimization.

The first type of backrest and the second type of backrest, the third type of backrest and the fourth type of backrest of external structure similar to the internal structure of some different, so the cost of accounting to eliminate the high cost of the structure. The comparison of figure 2, the first type of backrest and the second type of the backrest are shown difference as figure 4a; the third type of backrest and the fourth type of the backrest are shown difference as figure 4b.

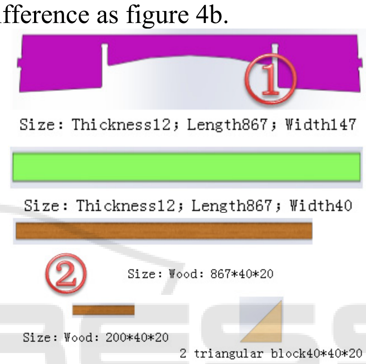

Figure 4a: A comparison between the first class and the second class.

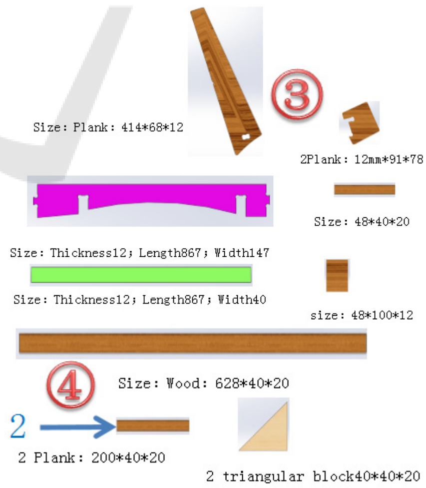

Figure 4b: A comparison between the third class and the fourth class.

According to table 2 cost table, using formula (1) to calculate the cost of their different structure, the results are shown in table 3.

Table 2: Cost table.

Labor costs (yuan/min)	0.3
12mm thick board (yuan/sqm)	20
40*20 wood square (yuan/m)	1.5
Average opening of laminated plate (sec)	20
Average wood opening (sec)	5

Table 3: Comparison of backrest cost.

Kinds	Manual work (minutes)	Plate dosage (sq. m)	Amount of wood (m)	The total length of the material (seconds)	Total Cost (yuan)
①	3.2	0.16	0.04	50	4.220
②	3.7	0	0.91	25	2.475
③	4.1	0.13	0.05	155	3.905
④	3.5	0	0.87	25	2.355

This shows that the backrest of the first category, the backrest of the third type of open materials longer and higher costs, so delete them, retain the second type of backrest, backrest to the fourth category. Optimized for backrest topology optimization.

4.2.3 Final Classification of Backrest Modules

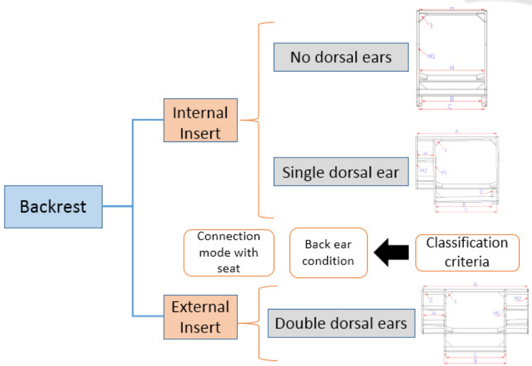

Figure 5: Final classification of backrest module.

After the end of the backrest category deletion, the final backrest module classification results are shown in figure 5.

4.3 Size Division

4.3.1 Points of Attention for Size Division

From the perspective of module division, each module has its own size series, the time of the module division to pay attention to 3 points: 1, the size division to notice the correlation between each module, such as the width of the iron frame and the width of the back and the width of the frame is consistent, so as to match. 2, the size is from the total data extracted from the summary, also need to find different products to verify the size of the design is consistent with the product. 3, the size of the division also needs to be noted is to meet the volume of the container.

4.3.2 Key Dimensions of Backrest

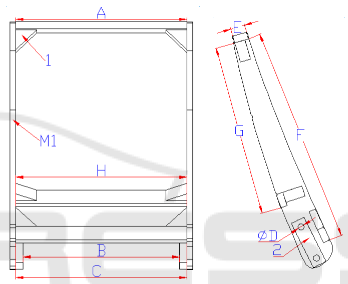

Figure 6: Key dimensions of backrest.

As shown in figure 6, the width ‘C’ between the two planks is determined according to the size of the iron frame. Because the iron frame is provided by the Iron stand factory, they have the specific data size, so the backrest width can be determined as a series.

4.3.3 Association of Dimensions

Figure 7 is the side view of the sofa, ‘a’ is the total depth of the sofa, ‘b’ is the function of the sofa without the angle of the total height, the size series of the seat frame deep ‘d’ determined by the packing size, the gagnier depth of the backrest is a fixed value ‘m’, the angle between the backrest and the seat frame ‘α’=106°, the angle between the ground and the frame 2°, and ‘a’, ‘b’, and ‘m’ are known, thus, the size series of the height ‘c’ of the backrest can be calculated according to the formula (2) and (3). And ‘e’ is the height of the seat, can be based on the formula (4) to calculate the size of the seat high ‘e’ parameters.

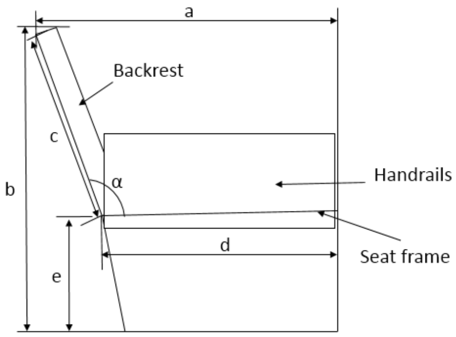

Figure 7: Sofa side view.

$$c = \frac{a-d}{\sin(\alpha - 90^\circ + 2^\circ)} \quad (2)$$

$$m=c+d \quad (3)$$

$$c = \frac{b-e}{\sin(180^\circ - \alpha - 2^\circ)} \quad (4)$$

5 CONCLUDING REMARKS

In this paper, on the basis of the current modular sofa, a new version of the sofa module is established, and this new type of sofa modularization is applied to the company example. Not only reform of the company's old style, but also for the design of new styles brought convenience. The next step is to sum up a set of sofa modular method, perfect sofa modular theory, then establish the relevant quotation system, it can be used by designers, sales, customers, to form a customized sofa and can offer independent pricing system.

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