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STUDY ON GROUP TECHNOLOGY EFFICIENCY GAINS FOR SOLID WOOD SEATING FURNITURE

C. ZHOU[1] J. KANER[2] F. IORAS[2] Z. WU[1]

Abstract: *Group Technology (GT) a concept started in the 1920s to reduce transportation by standardising products in machine manufacturers is used here in the production technology of manufacturing furniture. The similarity in structural shape and technology of parts are classified arranging product parts into groups in order to organise and manage multiple varieties, small and medium-sized batches. This article aims to resolve the polarity between the demand for mass production of solid wood chairs & stools and the market demands for small batches and multiple varieties of seating furniture.. The study classifies and organises the wooden components according to the managed data. Following analysis the results are used to gain efficiencies of manufacturing by adopting the GT method.*

Key words: *Seating furniture, Group Technology (GT), Part classification, Standardisation, Design Specification.*

1. Research Purpose

This research involves seating furniture (chairs & stools) made from solid wood. It analyses the application of GT to seating furniture in order to establish a number of improvements for manufacturing furniture. This includes optimum methods for manufacturing GT, to confirm the group design method of furniture parts. This establishes an embryonic form of group organisation for wooden seating components, to illustrate a compelling case for adoption of GT by solid wood furniture enterprises to apply GT into the design, production and management of furniture [5].

The secondary purpose of the study is to allow quality to be achieved by solid wood furniture manufacturers. The study attempts through investigation, classification and summarisation of seating furniture to standardise the GT method. This is presented through parts standardisation and design specification documents. The standardization of parts made of solid wood suggests an extension from this study from seating furniture to provide a hypothesis that GT may be applied to other types of solid wood furniture (tables and cabinets).

[1] College of Industrial and Furniture Design, Nanjing Forestry University.
[2] Faculty of Design, Media & Management, Buckinghamshire New University.

2. Research Concept

The basic concept of this research is to find an approach to standardise and simplify the design of furniture through the adoption of the GT process with the primary aim of benefitting the furniture industry.

The study attempts to establish rigorous standardised specifications for group design of seating furniture using the categories of name, shape and size of parts respectively.

Chairs & stools solid wood furniture GT is mainly geared to the needs of production, processing and management. Here the similarity principle can be used to simplify and classify components. Tables are constructed to classify parts followed by data analysis. For instance, the thickness of a part shall be simplified and standardised: tabulation treatment can be done first according to the data collected, comparing the main distribution of thickness size, attempting to adopt the same thickness size for the parts with the same function. According to the experience of industrial production the employment of GT is not viable when the operating frequency of parts is less than five percent [8].

For this study eight variations of seating furniture were observed. This included four chairs and four stools (see Fig.1 below).

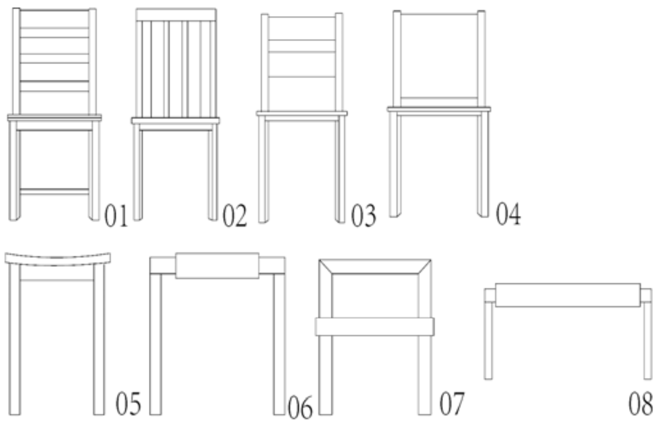

Fig.1. *CAD of Solid Wood Chairs and Stools*

GT design is a gradual process and also a process of standardisation. Its most important principle is to define the essential design characteristics as variable parameters. The method adopted is the analysis and study of the established replaceable variants. For example, in the cross sectional dimensions of parts, those that have no direct impact on furniture functions are definable parameters and those that have important design characteristics can be defined as invariables. Following this, intuitive analysis should be conducted on the data and charts. At this stage any additional shape requirements, such as decorative elements, can also be defined.

3. Object of Study

3.1. Analysis on parts of solid wood chairs & stools

The seating furniture studied in this article refers to a series of modern simple solid wood chairs and stools which have similarity amongst components. Table 1 is a Dimensional Data for the eight selected examples.

Generally, this kind of seating has the following characteristics:

(1) Overall modeling is simple with minimal decoration;

(2) The frames are constructed of solid wood; seat surface and backrest employ board materials or soft package (upholstery);

(3) Specifications, dimensions and structural styles are similar among parts; the cross section of the components is rectangular or approximately rectangular;

(4) Part processing technology is suitable for modern industrial production.

Dimensional Data of Linear Parts of 8 Types of Chairs & Stools Table 1

Serial number of furniture	Part name	L (mm)	W (mm)	Thickness (mm)	Quantity.	Remarks
01	Front leg	450	30	40	2	
	Front rail	340	20	40	1	
	Back rail	340	20	40	1	
	Front and back stretcher	420	20	20	2	
	Side stretcher	420	20	20	2	
	Side rail	340	20	40	2	
02	Front leg	430	30	25	2	
	Front rail	335	65	18	1	
	Back rail	295	65	18	1	
	Side rail	310	65	18	2	
	Backrest mullion	295	30	18	4	
03	Front leg	435	30	26	2	
	Front rail	360	64	20	1	
	Back rail	290	64	20	1	
	Side rail	340	64	20	2	
04	Front leg	440	35	35	2	
	Front rail	340	60	16	1	
	Back rail	265	60	16	1	
	Side rail	330	60	16	2	
05	Front rail	290	40	20	1	
	Back rail	290	40	20	1	
	Side rail	200	40	20	2	
06	Front leg	370	260	40	2	
	Rear leg	370	260	40	1	
	Side rail	280	60	10	2	
07	Front leg	240	30	30	2	
	Rear leg	400	30	30	2	
	Side stretcher	300	42	18	2	

Serial number of furniture	Part name	L (mm)	W (mm)	Thickness (mm)	Quantity.	Remarks
08	Front leg	350	380	60	1	
	Rear leg	350	380	60	1	
	Front rail	1300	80	20	1	
	Back rail	1300	80	20	1	

This kind of simple solid wood chairs and stools includes such parts as front leg, rear leg, front rail, back rail, side rail, top rail of backrest, middle rail of backrest, backrest mullion, seat surface, seat surface support bar, corner block, front stretcher, back stretcher, side stretcher and backrest, etc. respectively in sequence). Not every type of chair has the same number or type of parts. However, in this set of examples there are only minor differences evident between the cross rails and backrests of the different types of chairs.

Structural components are the main parts for the production of chair furniture. The processing and manufacturing technologies and equipment are relatively complicated for chair parts, especially the processing of profiles of support parts.

4. Confirmation of group standardisation and design specifications for parts of solid wood seating

The group standardisation of parts is to arrange the parts, process and production according to their features. Organising mass production of the parts with similar machining features will produce a scale effect, thus improving productivity [4]. recognized that there are structural and functional similarities among 70% of functional components of products in the mechanical industry, thus GT may be adopted to improve production efficiency [4].

Group standardisation of parts means part universalisation, serialisation, modularisation, normalisation and standardisation. If a part can be used repeatedly, it shows that it's design has inheritance [1].

Part standardisation involves the following fields: part name, part size, part material grade, machining accuracy, part code, part processing technology and the corresponding name, cutting tool and mould needed as well as equipment name [2]. The standardisation of all the contents can achieve the purpose of being helpful to retrieval and convenient for design in future models. This article employs standardisation fields of mainly part name, part size and part code.

The standardisation of part name is also beneficial to part code, because general codes need to be classified according to the part name. An additional benefit of standardisation is that consumers can replace/interchange some parts for the furniture they purchase and enterprises can produce flexibility or mass customisation of furniture production. Here an objective of the furniture is flexibility in order to provide a product that can be customised to meet the requirements of the consumer. These requirements may be complex. This requires flexibility in furniture design and production. R&D designers rely on their own sensibility to constantly invent "new" parts, regardless of the slight difference between these "new" parts and original parts, which will lead to unlimited increase in the quantity of parts and part codes related to orders as well as increased fixed cost. Fixed cost will not only affect the delivery time and quality of product, but also increase the difficulty in production management. Standardisation of parts enables production to produce flexibility and to meet the needs of consumers.

4.1. Specification and dimension analysis of parts

Furniture products consist of various parts, different part specifications and dimensions directly affect the production efficiency and cost of furniture. This article conducts statistics and analysis on dimensions of parts of simple solid wood chairs to seek the similarities between parts and puts forward a dimensional optimisation scheme.

4.2. Similarity analysis of parts

The **analysis** of the similarity of parts mainly includes the external dimension and specification of components, connection method and processing technology. Different size and appearance of parts result in different processing technologies of those components. Here, the simple solid wooden chairs are divided into two categories: one is the linear type, including front rail, cross rail, front leg and seat surface support rail. The other is the curved type which includes the rear leg and backrest. Because the shapes and specifications differ considerably for the rear leg, backrest and seat surface, this article focuses on linear type parts [9].

4.2.1. Product interior

Figure 2 shows the distribution diagram of part dimensions for Chair 01. The broken line graph shows that:

(1) On the whole, the width and thickness dimensions of parts are similar and its dimensions are far less than the length;
(2) in the parts selected, the similarity of dimensions in comparable parts is high. There is high similarity among internal parts for this kind of simple solid wooden chair providing an opportunity for the implementation of GT; therefore, this article chooses this kind of simple solid wood chairs as its samples and applies the GT principle to conduct analysis and research.

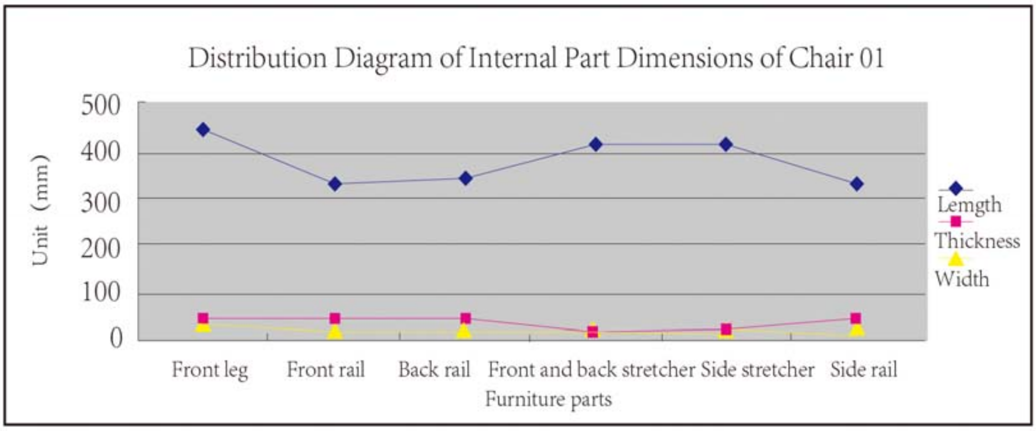

Fig.2. *Distribution Diagram of Internal Part Dimensions of Chair 01*

4.2.2. Product exterior

External analysis of products for linear type parts allows statistical analysis on the category and quantity of dimensions of parts.

Thickness dimension analysis

Linear type parts were selected from eight types of seating for analysis; only the length, width and thickness dimensions of parts were completely the same, they were the same kind of parts; the following lists 10 kinds of different thickness dimensions and the corresponding category and quantity of parts in eight types of seating furniture; the quantity of parts refers to each chair for each type (the same below).

We can see from Table 2 that there are a total of 51 linear type parts with 10 varieties of thickness. If we classify the thickness dimensions with the same part category in Table 2 using statistics, as shown in Table 3; there are four groups of thickness dimensions whose number of part categories is 1. We can also see that the thickness dimensions are relatively numerous but the standardisation degree is low.

Table 2

Category and Quantity Table of Linear Type Parts with Different Thickness Dimensions

No.	1	2	3	4	5	6	7	8	9	10	Total
(mm) Thickness dimension (mm)	10	16	18	20	25	26	30	35	40	60	
Part category	1	3	5	13	1	1	3	1	2	2	32
Quantity of parts	2	4	10	18	2	2	6	2	3	2	51

Table 3

Corresponding Table of Thickness Dimension Quantity and Part Category

No.	1	2	3	4	5	Total
Part category	1	2	3	5	13	
Quantity of thickness dimensions	8	5	10	10	18	51

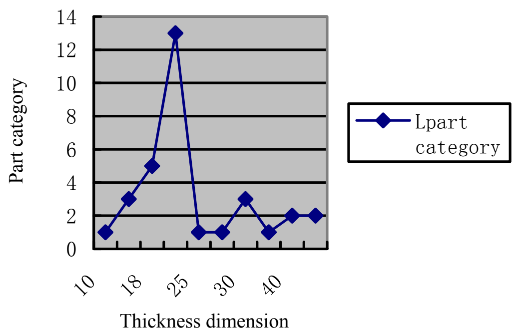

Fig. 3. *Category and Quantity Distribution Diagram of Linear Type Parts with Different Thickness Dimensions*

In Figure 3, the horizontal axis represents the thickness dimensions of parts which range between 10~60mm, with ten kinds of specifications; the vertical axis represents the number of corresponding part categories for thickness dimensions. The data shows that the quantity of categories is the greatest for the parts with thickness dimensions between 10~30mm; of which, the categories reach thirteen for the parts with a thickness dimension of above 20mm, accounting for 40% of the total quantity.

Table 4

Statistical Table of Thickness Dimension Difference for Linear Type Parts

Part type	Dimension direction		Quantity statistics		
			Dimension category (groups)	Part category (kinds)	Quantity of parts (PCS)
Linear type	Thickness direction	The same	6	28	43
		Different	4	4	8
		Total	10	32	51

Table 4 analyzes linear type parts from the perspective of difference in thickness dimension; of which, there are six groups of parts with the same thickness dimension and four groups with different thickness directions, there is a total of 10 groups.

(2) Width dimension analysis

Table 5 lists eleven kinds of width dimensions and the category as well as quantity of corresponding linear type parts, there is a total of eleven kinds of width dimensions.

Statistical analysis is conducted for the width dimensions with the same category in Table 5. The width dimensions of parts are more and their distribution is relatively dispersed, with low similarity (Table 6).

Table 5

Category and Quantity Table of Linear Type Parts with Different width Dimensions

No.	1	2	3	4	5	6	7	8	9	10	11	Total
Width dimension (mm)	20	30	35	40	42	60	64	65	80	260	380	
Part category	5	6	1	3	1	4	3	3	2	2	2	32
Quantity of parts	8	10	2	8	2	6	4	4	2	3	2	51

Table 6

Corresponding Table of Width Dimension Quantity and Part Category

No.	1	2	3	4	5	6	Total
Part category	1	2	3	4	5	6	
Quantity of width dimensions	4	7	16	6	8	10	51

In Figure 4, the horizontal axis represents the width dimensions of the parts which range between 20~380mm with eleven types; the vertical axis represents the number of part categories with the corresponding width dimensions.

If we examine Figures 3 and 4, with a comparison of thickness dimensions this shows that the category and the quantity distribution of width dimensions are more dispersed and that the quantity is increased to eleven types These types mainly focuses on 20~65mm; of which, the former accounts for 80% of total quantity of width dimensions, and the most frequent width dimension is 40mm which accounts for 25% of the total number. The number of categories of parts fluctuates greatly with the change of width dimension and width dimensions are numerous and dispersed.

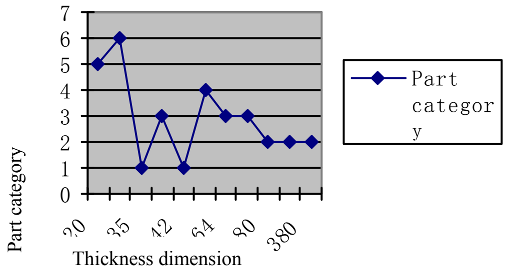

Fig. 4. *Category and Quantity Distribution Diagram of Linear Type Parts with Different Width Dimensions*

Table 7 analyses the linear type parts from the perspective of difference in width dimension; of which, there are nine groups of parts with the same width dimension and two groups of parts with different width dimensions, totally eleven groups. On the whole, part universality among products is very low.

Table 7

Statistical Table of Width Dimension Difference for Linear Type Parts

Part type	Dimension direction		Quantity statistics		
			Dimension category (groups)	Part category (kinds)	Quantity of parts (PCS)
Linear type	Width direction	The same	9	30	47
		Different	2	2	4
		Total	11	32	51

(3) Summary of similar parts

The higher the similarity of parts and the degree of standardization, the less the number of required specifications and dimensions of parts. This limits the frequency of processing preparations such as machine debugging and tool change, thus processing preparation time is considerably reduced allowing production efficiency to improve [6].

Table 8 observes the statistics for the differences of linear type parts as compared to the angles of thickness dimension, width dimension The data shows that there are a total of ten groups of linear type parts with different thickness dimensions, eleven groups with different dimensions of width and thickness and ten groups with the same width dimension.

Table 8

Summary Table of Width and Thickness Dimension Differences for Linear Type Parts

Part type	Dimension direction		Dimension category (groups)	Part category (kinds)	Quantity of parts (PCS)
Linear type	Thickness direction	The same	6	28	43
		Different	4	4	8
		Total	10	32	51
	Width direction	The same	9	30	47
		Different	2	2	4
		Total	11	32	51
	Width and thickness direction	The same	10	16	30
		Different	11	16	21
		Total	21	32	51

5. Standardised method for parts of chairs & stools constructed from solid wood furniture

Production efficiency is gained from the repetition rate of part dimensions; the higher the repetition rate , the higher the production efficiency because high repetition rates can greatly save tool change time, equipment adjustment time and quality control such as first article inspection time.

5.1. Thickness and width dimensions develop from decentralised to centralised for simplification

Thickness dimensions may be optimised without affecting furniture appearance and function using the GT production method. The specific GT production methods are: (1) adopting the same thickness dimensions for all of the parts that have the same functions; (2) using an advanced system for the thickness dimensions of parts.

In the examples used for this study method (1) employs thickness dimensions mainly to focus on 16mm, 18mm and 20mm components, and for the purposes of GT the thickness dimensions have been unified to 18mm; while there is little difference in 64mm and 65mm for width, we can unify the width to 65mm. Although this process will increase the workload for sanding, a lot of equipment adjustment and first article inspection time is saved so production efficiency is improved. Secondly, under the condition of the same thickness dimension, we can classify width dimensions into several different grades. For example, we can classify widths of 40mm, 64mm and 80mm into the grade of 65mm. The whole machining process is ongoing in the form of multiple blanks.

The simplification of thickness dimensions means the increased number of parts with the same specification of thickness dimension. This can create conditions for efficient production and directly reduce tool change time, equipment adjustment time and first article inspection time. Efficiencies are gained in the dressed timber machining process as it will decrease positioning adjustment time and mould change time. In short, the machining processes are greatly reduced.

To simplify width it is necessary to adopt the same width dimensions for the parts with the same functions., as well as selecting small-specification width dimensions based on meeting process and function requirements.

5.2. Part interchangeability design among a variety of furniture

Interchangeability is the core concept of Group Technology. If effective universality design can be conducted among the parts of furniture it will improve profit for the furniture industry. The so-called interchangeability improvement means one part or a component can be universally used by multi-group different types of furniture whilst retaining the uniqueness of individual furniture models. An example is seen with Chair No.2 and No.3 as the dimensions of their apron boards are extremely similar. If the design includes a universal dimension the machining process will be simplified and the number of tools required reduced making an economic efficiency gain.

5.3. Simplification display for thickness and width dimensions of parts

Figures 5 and 6 illustrate efficiency gains. The simplified thickness dimensions mainly focus on 18mm and 30mm, accounting for 86% from previous 31%. The simplified width dimensions mainly focus on 35mm and 60mm, accounting for 70% from previous 15.6%. This significant production efficiency shows reduction in the manufacturing process time and resource.

6. Conclusions

At present, the literature on the GT of solid wood furniture mainly focuses on research methods and the appearance of the modeling of furniture (Reference has to be included) and more discussions are given to board type furniture. This study discusses the GT of furniture from the perspective of solid wood seating furniture dimensions. It provides data on establishing the benefits of employing GT striving to improve the disparate approach to solid wood seating furniture manufacture and design [7].

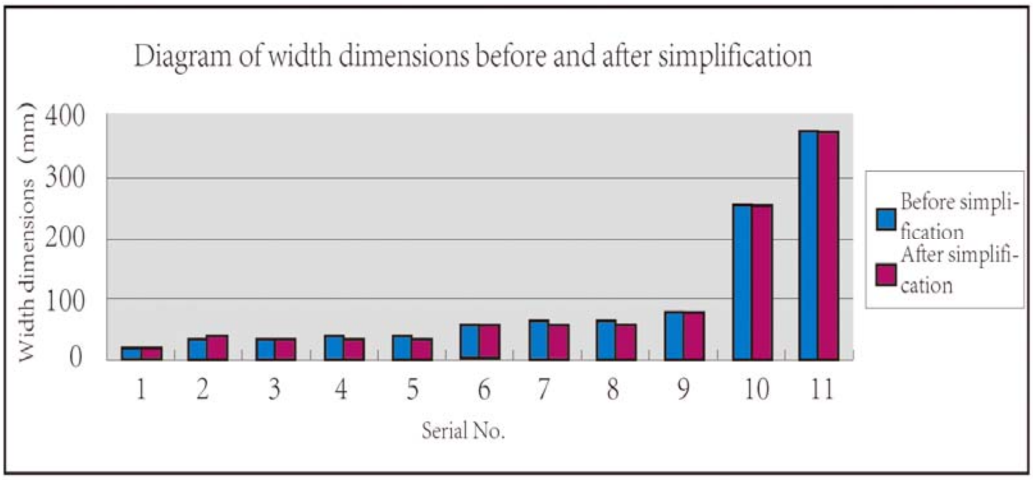

Fig. 5. *Diagram of Chair No.2 and No.3's Part Thickness Dimensions Before and After Simplification*

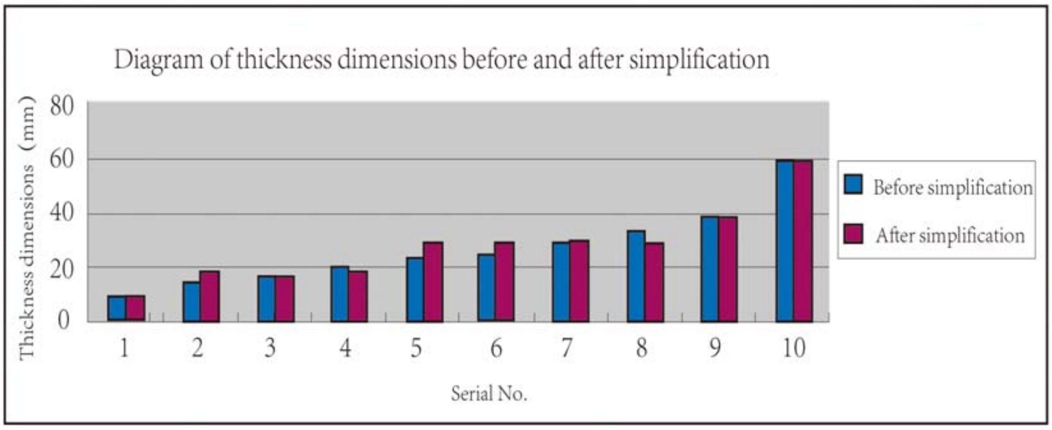

Fig.6. *Diagram of Chair No.2 and No.3's Part Width Dimensions before and after Simplification*

In the actual production process, the diversity and complexity of solid wood parts themselves often bring many inconveniences to production, whilst small-batch and the varieties of market demands also bring new challenges to furniture manufacturing where we witness that enterprise production efficiency is low and the cost is high [3]. Reviewing the dimensions of raw materials while considering the dimensions of parts, conducting comprehensive analysis on the dimensions and conducting comprehensive analysis on the proportion relations among different parts provides opportunity for the application of GT in solid wood furniture. This will ensure that production organisation will result in efficiency improvements such as cost reduction.

GT is conducted using a part dimensional coding system. When the design is completed, modifications to the application can be employed based on the parts of the furniture and these efficiencies can be exploited.

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References

1. Fu Y., 2007. Feasibility Study on Application of GT in Board Type Furniture Production. Furniture and Interior Decoration 1: 76-77.
2. Han W., Wu Z., 2007. Group Machining of Board-type Furniture Parts. Wood Industry, 03: 27-29.
3. Ishii K., 1998. Modularity. A key concept in product life-cycle Engineering. Handbook of Life-cycle Engineering. In: Molina, A., Sanchez, J.M., and Kusiak, A., (Eds.), Kluwer Academic Publishers.
4. Li G., 1997. Application of GT in Furniture Production. Furniture and Interior Decoration, 05: 12-13.
5. Li J., 2006. Research on Flexible Production of Furniture (Doctoral dissertation), Nanjing, Nanjing Forestry University
6. Li S., 2001. Agile Production Organization Based on GT. China Mechanical Engineering: 70-74.
7. Liker J.K., Kamath, R.R., Waatinagamachi M., 1995. Integrating suppliers into fast-cycle product development Engineered in Japan: organization and technology. New York: Oxford University Press, New York, 152-191.
8. Sun Z. and Yin G., 2006. Research on Application of GT in Modern Manufacturing Industry. Mechanical Research and Application 12: 4-7.
9. Xu Q., 2003. Assembly and Disassembly Design of Modern Furniture. Furniture 05: 30-33.