

# An innovative methodology for the characteristic mining on the conceptual mechanism design

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**Abstract** – In the conceptual design of mechanisms, the consideration of functional requirements is usually put off after the enumeration of kinematic structures. This design process can thus easily perform the enumeration of kinematic structures in an exhaustive manner. The degree of ingenuity involved can be greatly reduced. However, exactly since functional requirements are not taken into consideration during the enumeration process, numerous infeasible mechanisms are subsumed. It is necessary to evaluate each kinematic structure enumerated and screen out infeasible ones so that an inefficient procedure is yielded. In this paper, an efficient and systematic methodology for the conceptual design of mechanisms will be presented. It will be shown that functional requirements of mechanisms can be embodied as different categories of functional characteristics. Different aspects of functional characteristics can be systematic contrived from technical details from relevant patents. Through these functional characteristics, functional requirements can positively be utilized as the foundation of enumerating feasible mechanisms, instead of a negative use as the evaluation criteria for the enumerated kinematic structures. Hence, functional requirements can be brought into the enumeration process of kinematic structures to avoid creating numerous infeasible ones failed to satisfy functional requirements. The design efficiency can thus be greatly enhanced.

*Index Terms* - Conceptual design, Functional requirements, innovation design, Functional characteristics, Systematic methodology

## BACKGROUND

The traditional mechanisms design method needs abundant project experience and inspiration in good time, and then it could produce the new design. So designers know the mechanisms' practicability until at the entity stage. Unable to estimate that resources are consumed, will cause the cost to increase, lack efficiency and unable to accumulate. But systematized organization design method can make an systematized analysis by using knowledge, technology, experience of development in the past.

The mechanisms designed entered new field since Buchsbaum and Freudenstein [1] moves with the graph expressing the structure of the mechanisms, the advantage of graph expression lies in it has neglected the size but can keep the spirit which the organization designs. A lot of researchers utilized graph to develop a series of systematized organization's innovative design methods successively too (Belfiore and Tsai, [2]; Datsersis and Palm, [3]; Erdman and Bowen, [4]; Freudenstein and Maki, [5]; Freudenstein and Maki, [6]; Freudenstein and Maki, [7]). But when the designer unable to master the intention concept of technology effectively, it will let the design be confined to the trace of functional design.

The spirit of mechanisms conceptual designed lies in that mechanisms synthesis. The design condition narrates mechanisms' function and characteristic.

Freudenstein and Maki [7] sets up the systematized mechanisms conceptual design procedure taking organization's demand as starting point. But it only set the structure requirement in this procedure of mechanisms enumeration, while screening the feasible mechanisms, it still need to join the function requirement in succeeding in producing the new mechanisms. Because produce too much schemes not feasible in the mechanisms of enumeration, this lacks efficiency.

This research will revise a design method, and utilize mechanisms characteristic mining, it makes the design method of the concept more efficient to hope for.

## PATENT ANALYSIS AND CHARACTERISTIC MINING

Analyzing the relevant mechanisms in existence can help the designer to understand technological one's own concept and advantage. This can help the designer to set up the direction of studying, mine mechanisms characteristic effectively.

Master technological concept can make designer's knowledge of mechanisms reach to know why from know how, so the importance that the characteristic mining lies in the designer can have understanding totally to the relevant mechanisms.

### 1. Search Prior Art

Enter informational and knowledge management era, offer a designer to get a large amount of prior arts with the tools,

such as patent database ,etc. There are 90~95% of the research results in the world in the patent specification, utilize can collect and master the technological overview fast properly.

The spirit of this research is different from trace design, the systematized mechanisms design method is to regard a large number of relevant mechanisms information as the foundation of studying, to Fully grasp and apply the project to the technological concept.

### II. Effective Classification Analysis

The stage following collection and confirmation of related patent information is to correlate the content, itemize each design including details of effect, and record the number of the related patent of each effect, building a effective, “fishbone-like” figure. By completing this analysis, in this format, we obtain the general architect of the effects of all existing designs, making it easy to identify the most significant and least significant effects. Evaluation of expenses and time required for the designs of the least significant effects set a standard of evaluation so each effects can be accepted or rejected. On the other hand, by observing all types of effects, imperfection can be found rendering a new era where designs can be begun at a higher stage which makes the forthcoming design effects more complete. In Figure 1, an effective, fishbone-like figure analysis of correlated patent information is shown to describe the latch mechanism of a wafer container.

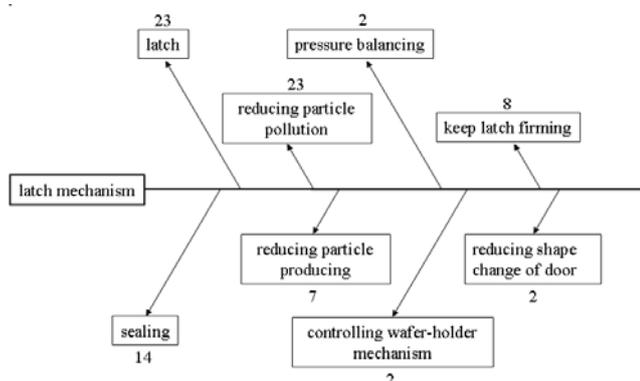


FIGURE 1

ANALYSIS OF EFFECTIVE CLASSIFICATION AND NUMBER OF PATENTS

By analyzing 23 patents, eight effects of the figure’s analysis were sorted out and the relation between assorted effects of all the patents, including effects such as latch design and reducing particle pollution. The numbers above or below boxes are patents that relate to the effect in the boxes. Over half of the patents contained sealable effects showing that latch design, reduction of particle pollution and sealing mechanisms were the three most consequential effects, the rest being considered as minor.

### III. Function-Effect Analysis

All types of effects were divided and sorted so the functions could be applied to the effects with each type of effect achieved by one or more types of technical concepts. For this reason, analysis of function offers a clear understanding of previous creative concepts, by different designers with a

variety of perspectives, and encourages broader visions with more concrete concepts or theories.

According to previous effect classification analysis one can match each effect to its applied technical concept; this then becomes the “Function-Effect Analysis” figure. By using this analysis, we can have a complete understanding of the general effects and the creative concept that the applied functions of existing patents can achieve. This analysis assists the designers to understand the creative concept of the existing functions and to evaluate its pros and cons; it can also help them to improve the imperfections of the existing functions and to stimulate new creative concepts efficiently from the hyper-level of concept. Furthermore, the function-effect analysis can precisely highlight function lacking positions; by judging the effects, the question of whether there are still unknown areas where functions have not yet been efficiently applied, thereby, providing the designers with a design focus.

In Figure 2, a function-effect analysis figure is shown to describe the effect of the latch mechanism of the wafer container. The central axis shows the eight effects of the latch mechanism, where the upward and downward arrows are connected lays the description of the function being used for achieving the effect. As the figure shows, each effect can be achieved by numerous kinds of functions. The two major effects among those: latching and sealing effects in the patent can be achieved by one function.

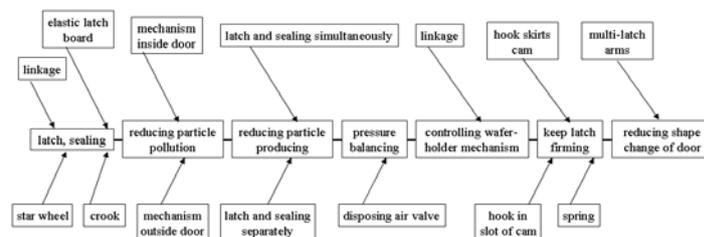


FIGURE 2

FUNCTION-EFFECT ANALYSIS OF LATCH MECHANISM

### IV. Function-Effect Correspondence Matrix

As we thoroughly read and digested each technically related patent, and more clearly understand what effects and functions patent technology may increases, we can then make a series of figures about the related patent; this is called a patent-summary table. In this table, basic patent information such as the patent assignee, patent number, USPC, the year as well as the title, major functions and effects are being marked, just as what table 1 has shown. Please notice that table 1 is only part of the series of the related patents.

TABLE I  
PATENT-SUMMARY TABLE

NO.	assignee	patent number	Title	USPC	year
10	Kabushiki Kaisha Toshiba	US5780320	Method of manufacturing a semiconductor laser including two sets of dicing grooves	438/33	1998
major function			major effect		
scribing both upon and below and make the scribing line perpendicular before cutting			avoiding residual stress		

## V. Conceptual mechanism Design and Topological Analysis

After understand technology in depth, designer can mine mechanisms characteristic and form the concrete condition, so analyze that the design concept in the existing relevant mechanisms is a foundation of mining mechanisms characteristic.

After mastering the intention concept of technology, designers can analyze in depth the function caused of mechanisms movement structure. This stage is analyzing know why, and Here can be channeling into the abstract structure that mechanisms graph express the mechanisms. Use graph to simplify the complicated size in the mechanisms into link and kinematics' pair, but can keep spirit that the mechanisms design. This kind of method can also pick and choose the meaning designed to do the basis designed newly effectively, the expression method of graph has already become the language applicable to all in the mechanisms research.

Kinematics' topological analysis, to various kinds of design parameters which the mechanisms construct mainly, such like degree of freedom, number of links, number of independent loops and feasible kinematics' pair, Define these parameters in the kinematics, and then get the relevant design of the sport structure.

Functional topological analysis is disposed to the relation of movement of functioning link. Functioning link accords with kinematics' demand and function, It is usually defined as input link output link and structure.

Through analyzing that functioning link can understand how the kinematics reaches the function, so designers can mine for the condition and characteristic which accord with kinematics' function. Analyzing some special design condition can mine for the special structure condition. These will become standards of feasible screening.

## VI. Utilizing Mechanisms' Characteristic to Set Up Design Condition

Setting up the direction and design object of designing can further investigate the characteristic of the existing mechanisms. Utilizing mechanisms' characteristic to set up the design condition for structure. This research divides design condition into three following big classes: functional requirement, structural requirement and design constraint.

Topological analyzing and can set up mechanisms' characteristic then set up characteristic demand. The function characteristic analysis can receive the function demand, and put the following design conditions: 1).the neighboring relations among functioning link, the permutation associations of input link, output link and structure; 2).adjacency of functioning link and number of adjacency links with special link; 3). type and direction of kinematics' pair.

And the special design constraint usually includes the following two 1). Limit in the position of specific link, such like: input link, output link and structure, 2).limit of kinematics' pair.

Above-mentioned three kinds of design specifications will be channeled into the conceptual design procedure that

this research institute mention, can consider the structure condition of the mechanisms and give consideration to the functionality at the same time, this one that will design the procedure than the tradition is more efficiently and more systematic.

Regard designing latch of wafer container as the example. In order to master existing technology and assessment pluses and minuses before the procedure of designing begins, utilize the patent database to search the relevant patent at first, and a large amount of latch information that the interconnected system exactly appears.

Then analyzes with mechanisms' conceptual design that helps to redefine the question , promote the information of the income from know how to know why, sort out latch according to different movement ways, then study the pluses and minuses of different kinds of technology. Receive the design object as follows: low number of link, have no rub and two stage mechanisms.

Continue mining mechanisms' characteristic after setting up the direction and goal designed, Use the characteristic received to set up design conditions. Taking two stage latch as an example, it is analyzed that the organization of existing tow stage can know that rotates the input kinematics driving latch to produce two directions motion, firs, letch is put out in x direction, locks and shuts the function of the door and container in production, and then letch is exposed to the displacement that another link produces y direction and sealing the container, this is two stage kinematical structure.

By a large number of mechanisms' information and SEMI norm, we can put the functional requirements out : 1). latch needs the displacement of x direction to structure for locking container, and the displacement of y direction for sealing, 2). to structure, input link needs to rely on the rotating of y direction to urge (SEMI [8] and [9]), This is the design condition.

## INNOVATIVE METHODOLOGY FOR MECHANISM DESIGN

Making use of and analyzing the relevant mechanisms' characteristic systematically, and bring the mechanisms characteristic specified into the conceptual design procedure, can create the new design which accords with the function efficiently. The design procedure put forward of Freudenstein and Maki [5] is only channeled into the structural requirement at the beginning, so produced too many unfeasible mechanisms in the course of enumeration.

This research is based on design procedure of Freudenstein, revise it's procedure like Figure. 3.

### 1. Classify The Design Conditions

Design conditions is narrated with divide into three kinds according to the content, for function requirement, structural requirement and design constrain, In the new design procedure, regard functional requirement and structural requirement as and design the starting point, and join design constrain as judging and screening the basis. It can reduce unfeasibly mechanisms and improve design efficiency to do so.

In the design specification, functional requirement can construct out functioning kinematic chain. The functioning

kinematic chain is made up of functioning link. The same functioning kinematic chain has the same functions. Traditional design procedure is going without functioning kinematic chain.

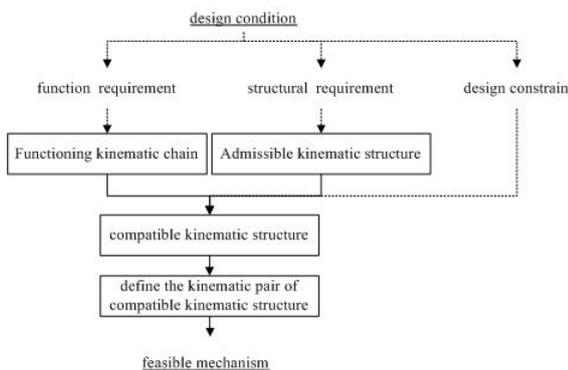


FIGURE 3  
THE DESIGN PROCESS OF THIS RESEARCH

Structure requirement produced admissible kinematic structure, Freudenstein's conceptual design procedure relies mainly on structure requirement, but it is very time-consuming to screen in graph of the huge quantity.

In the conceptual design procedure of Freudenstein, just channel into and design exercising restraint in judging after disposing kinematic pair, but this research is channeling into in good time during the course, so can not reduce unfeasibly mechanisms.

## II. Feasible Mechanism Enumeration

The design procedure of this research has the design specification classification, it can analyze functional requirement and structure requirement and produce functioning kinematic chain and admissible kinematic structure, the functioning kinematic chain will Screen tentatively in the course. Screen out what the mechanisms that can't place functioning kinematic chain, and produce compatible kinematic structure which satisfies functional requirement and structure requirement.

When find out compatible kinematic structure, it can get topological structure to and then utilize kinematic pair and axial that design constrain defines the mechanisms. In the procedure of this research, the last work of enumeration stage is a disposition of kinematic pair, all because the stage will take so much time. It can save time to do it in this way.

The advantage of this research lies in regarding structure synthesis as the foundation of enumeration, the unfeasible structure has already been deleted in the course of enumeration, and all the ones are compatible kinematic structure finally. It improves quality of designing and shortening designing time.

### DESIGN EXAMPLE

Here the latch mechanism of the wafer container is set as an example for the following explanation. The existing latch mechanism is presented as a graph and shown in Table 2 with the vortex representing the link, the edge representing

the joint. In Table 2 the double round spots represent the ground link, black spots represent the latch link, and the gray spots represent the input link. By analyzing those designing concepts, it shows that latch mechanism depends on the installation of the joint between the latch link and the ground link, in order to achieve the needs of latch and sealing effects. By confirming the installation of the joint between the input link and the ground link, it achieved the needs of the input setting of the SEMI standard (Book of SEMI standards). In Table 2, the parts marked with stars represent that they contain both the latching effect as well as the sealing effect, where no star is shown; the design contains only the latching effect but no sealing effect. By analyzing the designs marked with a star, we can conclude the characteristics as the following:

- 1. The kinematic pairing between the latch link and the ground link to achieve latching and sealing effects by a revolute joint ( $R_z$ ) about z axis, which is a one DOF joint or a cam pair ( $K_z$ ) about z axis, which is a two DOF joint.
- 2. In order to adopt the actuator, which is set by the book of SEMI standard, the kinematic pair between the output link and the ground link must be a revolute joint ( $R_y$ ) about y axis.

TABLE II  
GRAPH REPRESENTATION OF EXISTING LATCH MECHANISM

Planar case	Spatial case

Based on characteristics 1 and 2, which were previously offered, in order to make a latch mechanism achieve latching and sealing effects, the key links were the ground link, the latch link, and the input link which must exist as a functional kinematic chain form as shown in Figure 4.

Taking the functional kinematic chain KC1 and KC2 which conform to the characteristics of the mechanism in admissible mechanism topology (Mayourian and Freudenstein[10]) and center on a new innovation latch mechanism that is different from the past mechanism and can be efficiently gained.

Table 3 shows the innovation latch mechanisms which are one DOF, five links and up to six kinematic pairs.



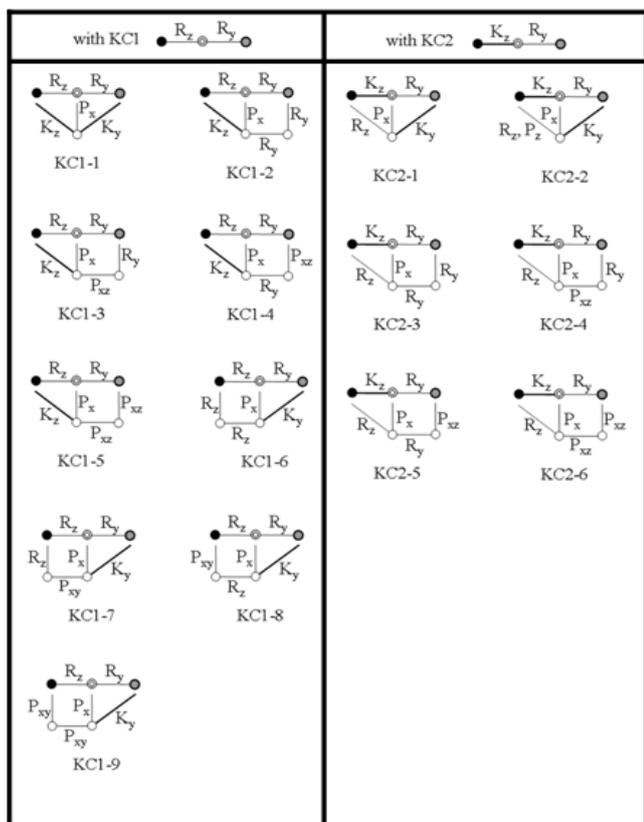
FIGURE 4  
THE FUNCTIONAL KINEMATIC CHAIN

### CONCLUSION

Traditional organization design method scarce to think , for utilizing existing mechanisms' information is comparatively weak, so utilize patent database a large number of organization information effectively , is analogous to the earth to help to designing.

This research is making collecting relevant information systematically, and mines mechanisms' characteristic and set up the norm from it, and put forward the procedure of designing concept, classify design condition, channel into the procedure of enumeration, and then get the feasible mechanic design. By mining mechanisms characteristic would help designer get the intention efficiently.

TABLE 3  
INNOVATIVE DESIGN OF LATCH MECHANISM



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