The Function Model For Existing Product Using Reverse Fishbone Diagram

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Abstract: The substance-field model for a function in TRIZ is simplified first and two elements and an action as a function model is given. The process of reverse fishbone diagram existed is improved, by which the diagram is suitable for the determination of the functional elements for an existing product. A new process for the development of a function model using reverse fishbone diagram is developed. This process can determine the mini-problems for an existing product. The function model obtained can be used as an input model for the software TechOptimizer 3.5 or be used in the problem analysis directly. An engineering example shows the application.

Key words: reverse fishbone diagram, product design, mini-problems, function model

1 Introduction

The problems in engineering design are distinguished into three categories, which are maxi, middle and mini-problem[1]. The mini-problems are the problems with which a subsystem in a product should be changed. The core of a mini-problem solving is that a contradiction is solved. Theory of inventive problem solving (TRIZ)[1-2] has given some tools, such as 40 principles for technical contradictions and 4 principles for physical contradictions to solve them.

The determination of the mini-problems for an existing product is the first step to apply the tools of TRIZ. ARIZ (Algorithm for Inventive Problem Solving)[1-2] in TRIZ deals with the determination of a mini-problem for an existing product. But it depends on the experience and familiarity of TRIZ for designers. The improvement of subsystems in existing products is important task for designers in manufacturing firms. A systematic procedure to determine mini-problem is needed for them.

System analysis, a module in TechOptimizer 3.5[3], uses a function model as an input model at the beginning when someone uses the software. In that function model, the elements, materials, signals in the existing product are connected by actions. The mini-problems can be determined easily by using this function model. This model has been used in the analysis of a heat exchanger[4], a motor cycle [5]. But systematic

method to develop the function model for a complex existing product has not been given.

The reverse fishbone diagram existing[6-8] is modified in this paper in order to make it to be suitable to develop that function model. A systematic procedure will be given.

2 Function and Functional Elements

A product is an implementation of one or more functions. Functions describe what to do for a product. There are three approaches in representing function in design[9]:

1) In the form of verb-noun pairs;
2) Input-output flow transformations, where the inputs and outputs can be energy materials, or information;
3) Transformation between input-output situations and states.

In the conceptual design process, the overall function is decomposed into sub-functions. And each sub-function is divided to low-level functions. When the decomposition is reaches supported functions it is ended[10]. The supported functions are generic models for well-known components, processes. The decomposition is suitable for the solving of the maxi-problems but not for finding the mini-problems for an existing product.

In TRIZ, all functions can be decomposed into three basic elements, which are two substances and a field. Substance is defined as something generally considered being a thing or an entity. A field is defined as a source and type of energy. According to Altshuller[2], the right combination of two substances and a field "coming together" to form a triad - called a "Substance-Field," or "S-Field" - creates a function. This triad-like arrangement manifests itself as an action, operation or capability. An S-Field is a function shown as Figure 1.

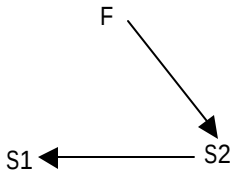

Fig.1 A function in TRIZ

Terninko changes the Fig.1 to Fig. 2 to show a function graphically[11]. In this figure, the Field is the name of the field in this function.

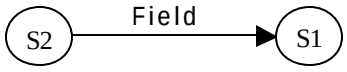

Fig. 2 A function in TRIZ (Terninko)

The function in one module of TechOptimizer[5] is similar to Fig.2. The difference is that an action is applied instead of Field. The diagram of a function in Tech Optimizer is simplified and a simple diagram shown in Fig.3 is obtained. In this

figure, functional elements S2 is active and S1 is passive. The action is a verb to show the relationship between S2 and S1. The line and the arrowhead show from S2 to S1. The line has different type shown in Fig. 4.

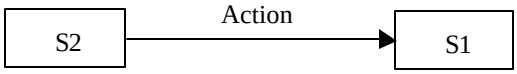

Fig.3 The diagram of a function

Fig.4 The lines of action

The desired action means that the function meets the technical needs of the product. The insufficient and excessive actions mean that the action is less or more than that of desired action. The harmful action is negative action for the product and should be deleted. The insufficient, excessive and harmful actions are all mini-problems in an existing product and the reasons for redesign or improvement.

Cascini[6]? Slocum[12] develop the function models for a heat exchanger and a nuclear reactor terminal gland. Cascini makes a simple analysis for the process of modeling and Slocum only gave the final result of the function model. A general method or process is needed for the modeling of complex systems.

3 Reverse Fishbone Diagram

For mechanical products, assembly and disassembly are reverse actions. A fishbone diagram is a kind of diagram to show the assembly sequence of components[6]. A reverse fishbone diagram is the reverse application of a fishbone diagram, which is used for analyzing the recyclability of products. Kevin et al[7] apply this tool to determine existing modular of a product and Tan et al[8] apply the tool to determine the support functions of a product. Here, the method in [8] is modified to be suitable for determining the function elements for an existing product. The new process is as following:

1) Select an existing product.
2) Disassembly original modules in consequence.
3) Write the names of modules in consequence at the right side of the fishbone.
4) Write the names of functional elements at the left side of the fishbone by the following conditions:

   If an original module is a functional element write it in left side directly.

   If an original module can be divided into a few functional elements write them at a same level in the left side of the bone.

Figure 5 shows a typical reverse fishbone diagram. There are four original modules. The first and the third module are divided into two and three functional elements respectively and written to the same level on the left side of the bone. The

second and the fourth are one functional element and write directly in the left side of the bone.

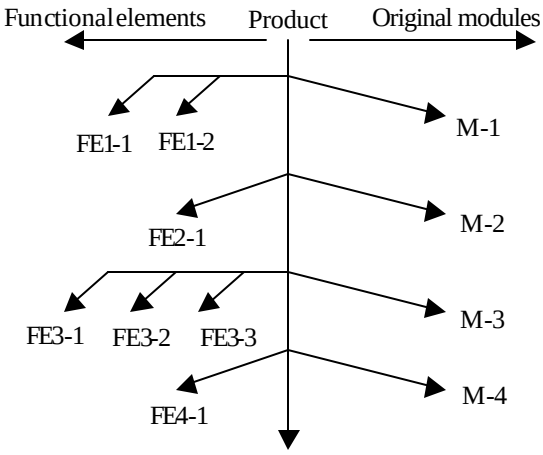

Fig.5 Reverse fishbone diagram

4 Function Model For Existing Products

The product or system selected is in the environment and exchanges energy, materials and information as shown in Figure 6. Generally speaking there are several systems in the environment. The systems in the environment are called super-systems, which are difference from the system to be studied. The outputs of the system selected are called artificial objects, which are the ultimate of the existing system. Several functional elements and actions in the system selected and the super-systems together form a functional model of the system to be studied, which is shown in Figure 7.

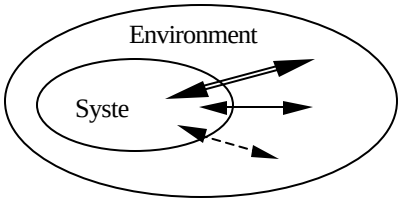

Fig. 6 System and its environment

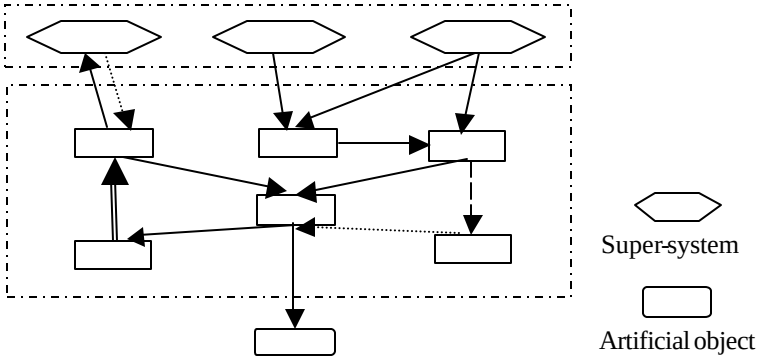

Fig.7 Functional model of a product

The process of functional modeling can determine insufficient, excessive and harmful functions, which are mini-problems of the system. After that the inventive principles, separation heuristics, standard solution in TRIZ can be used to solve them. The solutions will push the process of the product evolution.

The process of functional modeling is divided into six steps shown as following:

Step 1: Select an existing product and determine its super-systems;

Step 2: Determine the input/output and artificial objects between the existing product and the super-systems;

Step 3: Develop the reverse fishbone diagram and determine all the functional elements;

Step 4: Determine all actions and the types;

Step 5: Develop the functional model by connecting actins and functional elements;

Step 6: Determine all the mini-problems.

The core of this process is the third step. For a simple system it is easy to determine all functional elements. But for a complex system the process above should be easier to develop the functional model by the application of the reverse fishbone diagram.

5 Case Study

In order to use excessive blast furnace gas a kind of equipment called TRT is developed. By application of the equipment and the pressure drop of the gas electricity is generated and the gas with low pressure is also applied as a kind of resource. A butterfly valve is included in the TRT, which cuts the gas in the pipe connected with the valve rapidly when something wrong is happen in order to protect the whole system. The opening and closing actions of the valve are controlled by a hydraulic system. The butterfly valve and its control system together is named speedy cutting off valve, as shown in Figure 8. The hydraulic system used now can make a rapid response to cut off the pipe but there are some problems, such as complex structure of the control system, big volume in dimension, high cost. System analysis for this control system is needed in order to find mini-problems and to solve them.

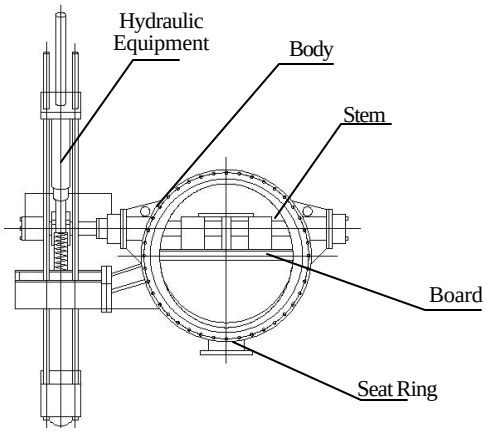

Fig.8 Structure of the speedy cutting off valve

Step 1: The speedy cutting off valve is the existing product selected. The base to support the valve, the pipes to connected to the valve and electricity supply are super-systems;

Step 2: The gas to be controlled is the artificial object;

Step 3: Disassembly the module one by one from the existing product and determine the functional elements as shown in Fig. 9;

Step 4: Determine all actions and the types;

Step 5: Develop the functional model by connecting actins and functional elements as shown in Fig. 10;

Step 6: Determine all the mini-problems as shown in Table 1.

Table 1 is the summarization of all the functions in Fig. 9. Some functions which should be improved are marked by symbol "v" . These functions are called problematic functions here. The Table 1 shows that No.6, 11, 13, 17, 20, 31 functions are problematic functions, which are mini-problems to be improved. Functions No.6 belong to excessive function because of vast energy consumption of electromotor. Redesigning the hydraulic system can solve these problems. Functions No.11, 13, 17 belong to harmful functions because of counteracts of filter and pipeline on the oil and hydraulic cylinder on piston, and it's difficult to solving these problems thoroughly so it can be solved partly. No.31 function belongs to harmful function because of dust pollution in the oil, and this problem can be solved completely. No.20 function belongs to insufficient function because dynamical spring lacks enough power to drive the piston at the end of road, and this problem can be solved completely by improved design.

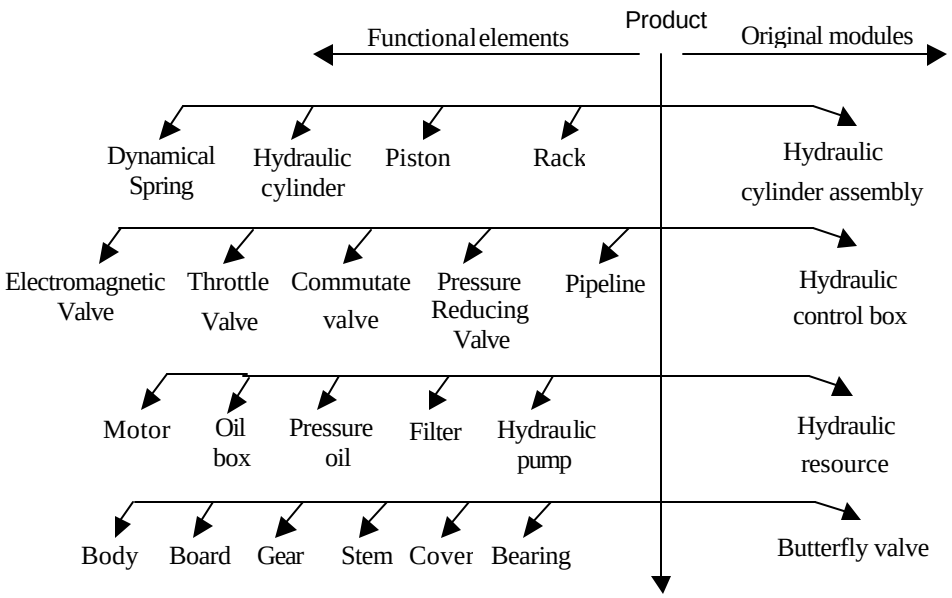

Fig.9 Reverse fishbone diagram for the speedy cutting off valve

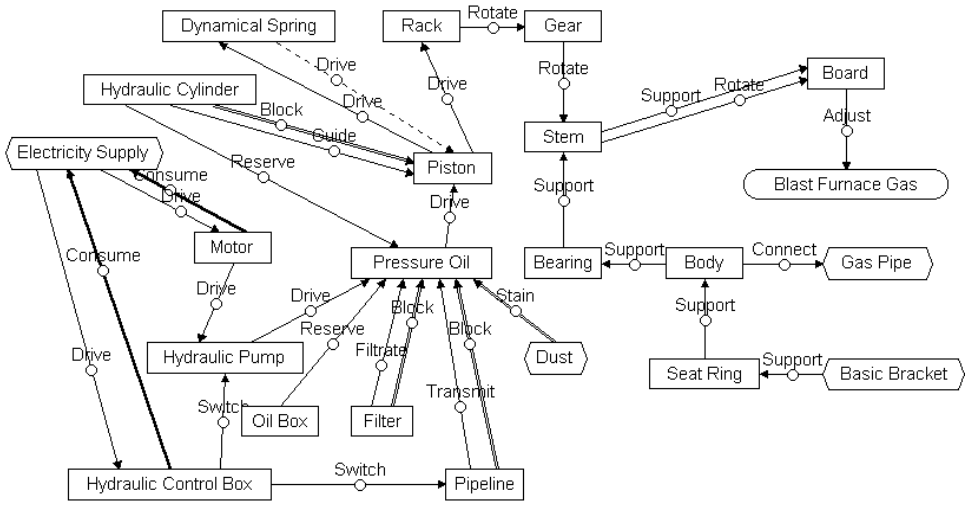

Fig.10 Function model of the speedy cutting off valve

Table 1 the summarization of functions

No.	Active element	Action	Passive element	Type	Problematic function
1	Electricity supply	Drive	Hydraulic control box	Standard	
2		Drive	Electromotor	Standard	
3	Hydraulic control box	Consume	Electricity supply	Excessive	
4		Switch	Pipeline	Standard	
5		Switch	Pump	Standard	
6	Motor	Consume	Electricity supply	Excessive	v
7		Drive	Hydraulic pump	Standard	
8	Hydraulic pump	Drive	Oil	Standard	
9	Oil box	Reserve	Oil	Standard	
10	Filter	Filtrate	Oil	Standard	
11		Block	Oil	Harmful	v
12	Pipeline	Transmit	Oil	Standard	
13		Block	Oil	Harmful	v
14	Oil	Drive	Piston	Standard	
15	Hydraulic cylinder	Reserve	Oil	Standard	
16		Guide	Piston	Standard	
17		Block	Piston	Harmful	v
18	Piston	Drive	Dynamical spring	Standard	
19		Drive	Rack	Standard	

20 21	Dynamical spring	Drive	Piston	Insufficient	V
22	Rack	Rotate	Gear	Standard	
23	Gear	Rotate	Stem	Standard	
24	Stem	Rotate	Board	Standard	
25		Support	Board	Standard	
26	Board	Adjust	Blast furnace gas	Standard	
27	Bearing	Support	Stem	Standard	
28	Body	Support	Bearing	Standard	
29		Connect	Gas pipe	Standard	
30	Seat ring	Support	Body	Standard	
31	Dust	Stain	Oil	Harmful	V
32	Basic bracket	Support	Seat ring	Standard	

6 Conclusion

The determination of the mini-problems for an existing product is the first step in redesign of a product. The process of improved symbol based on function symbol in TRIZ, functional elements confirmed by reverse fishbone diagram and function model for existing product established are put forward, and the mini-problems are ascertained by the function model established. That is a systematization method setting up the function model for an existing product.

The function model cannot only be used in the problem analysis directly but also be used as an input model for the software TechOptimizer 3.5.

The process of function model of the speedy cutting off valve proves that the process mentioned above is feasible.

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