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The Structural Improvement Design for Gear Pump Based on Triz

Zheng Qingchun and Tang Zhiduo+

College of Mechanical Engineering, Tianjin University of Technology

Tianjin, 300384, P.R.China

Abstract—The article introduced the TRIZ theory and CATIA product function optimization, expounded the flow of solving the problems with product function optimization. Taking the structure improvement design of high-pressured great displacement gear pump as an application example, the article elaborated how to use CATIA to establish the product functional model and how to analyze and solve the problems based on the product functional model, finally obtained a feasible design proposal.

Keywords-TRIZ; technical contradictions; engineering effects; Product Function Optimization; gear pump

1. Introduction

TRIZ (Theory of Inventive Problem Solving) is the Latin abbreviation of Russian theory of inventive problem solving, which is known as Cuizhi theory in China. Since 1946, G.S. Altshuller, the Patent Office expert of the Navy Department in former Soviet Union, leading a group of scholars, reviewed and studied nearly 2.5 million patents all over the world. They summarized the laws of evolution of various technology development and innovative principles and rules to solve the contraindications, established a theoretical system—TRIZ, which is composed of a variety of innovative algorithms and methods of resolving technical conflicts and integrates plenty of principles and rules in multi-disciplinary fields. TRIZ mainly includes laws of evolution systems, 40 invention principles, 39 general engineering parameters, the contradiction matrix, material - field analysis, 76 standardized solutions for inventive problem, Algorithm for Inventive-Problem Solving (ARIZ), and engineering effects database[1].

In the product innovation process, the contradiction is the most difficult problems to solve. In TRIZ, Altshuller thought that contradictions can be divided into three categories: technical contradictions, physical contradictions and management contradictions, but TRIZ only studies the first two ones. The core of TRIZ to solve problems is to study the technical contradictions of problems and search the methods to resolve the technical contradictions. So-called technical contradictions, mean that a function in the same system leads to both beneficial and harmful effects to the system, which also means the introduction of a beneficial action or eliminating of a harmful action results in one or more subsystems or system deterioration[2].

Altshuller proposed to use 39 general engineering parameters to describe the technical contradictions, and applied 40 invention principles to guide the designers to innovate designs; they established a correspondence between the 39 engineering parameters and the 40 inventive principles, which is called contradiction matrix. The lines in the contradiction matrix show the deterioration of parameters, which need to be improved; and the columns show the optimization of parameters, which cause deterioration. In the contradiction matrix, the intersection of each row and column shows the recommended inventive principles. When facing practical

+ Corresponding author.
E-mail address: tangzhiduo1003@126.com

problems, confirm the conflict parameters of the system, and find the intersection point of them in the contradiction matrix, people will obtain the recommended inventive principles[3].

In TRIZ, IM-Effects is one of the most commonly used tools. This tool allows you to find numerous alternative ways to optimize and realize a required function by using physical and scientific effects. IM-Effects provides you with access to over 7,500 engineering and scientific effects and examples. Effects can convert and achieve the desired function[4]. It not only reflects the innovation of TRIZ, but also reflects the multi-disciplinary nature and complexity of the methods and tools.

In January 1997, Invention Machine published TechOptimizer 2.0, it succeeded in integrating the theory of Value Engineering and TRIZ in the computer environment. In November 2000, Dassault Systems released CATIA V5R5, successfully integrated the functions of TechOptimizer into Knowledgeware of CATIA. They are Product Function Definition and Product Function Optimization[5]. Conceptual design is to develop the best product concept to meet design specifications and customer needs. In the stage of product conceptual design, Product Function Optimization makes users digitally diagnose the system and find the engineering problems through creating the functional system, and provides strategies to modify. Users identify the functional problems of the system and classify, search solutions through the knowledge database.

2. The flow of Product Function Optimization

In CATIA, product analysis breaks the engineering system into parts that can be analyzed for improvement. Fig. 1 illustrates that the analysis is performed in 4 main stages. The first three stages (Functional Model, Analyzing, Trimming) identify the problems that need to be solved. The

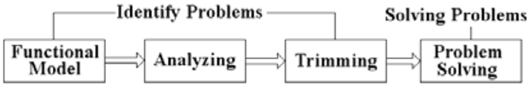


Fig. 1: The flow of Product Function Optimization

fourth stage (Problem Solving) provides solutions through the use of principles, effects and predictions of TRIZ.

2.1. Functional Model

The functional model describes the interactions between parts of the system and other elements. Objects in the functional model are divided into three categories: system purpose, system components and super system. Each system will provide one or more functions, and system purpose is the main target, which the system functions shall be imposed on. A system component is a process, substance, field, or a substance-field combination that is a part of the system under analysis. A supersystem is an element of the system but it does not belong to the system. It affects it but cannot be changed or included in the analysis, for example: the atmosphere, the working environment, locating facilities, maintenance facilities etc.

Actions describe the interaction between of objects. To more accurately describe and analyze the problems, actions are divided into useful actions and harmful actions in Product Function Optimization. A useful action is an action that satisfies and/or improves the capabilities of the system under analysis. A harmful action is one that worsens the parameters and/or performance of a component.

In order to create a functional model, users need to identify the relations between system purpose, super system and system components, as well the useful actions and the harmful actions, and break down the system in the case permitted.

Select the icon , and , create system components, system purpose and super system, double click the objects to change their names. And then select the icon and , link the objects of the system, double click the actions, modify their names.

2.2. Analyzing

Click the icon , enter the Matrix Browser. The Browser contains a step-by-step analysis mode that uses a chart form to show the purpose, components, and super systems that are parts of the system under consideration. The Product Function Optimization Browser provides 3 ways to access information concerning the system: Interaction Matrix, Function Table, Notes. The Interaction Matrix shows every object and action in the Functional Model. Each object is listed across the top and along the left side. Each action in the Functional Model is represented by a colored dot at the row and column intersection of the acting object of the model and receiving object. The color of each dot indicates the type of action, and the number of dots shows the number of actions associated with the two objects. The acting object is the part that performs the action. The receiving object is the part that receives the action. The Function Table lists the objects and actions in the Functional Model, the rank of each function (its useful/harmful status and the distance from the System Purpose), the parameters associated with it, and the performance level of each parameter. The Notes window lists information about the various components of the system. Any notes related to these elements can be entered in this window. The notes that you enter are directly associated with the element, or action that was highlighted when the note was entered.

2.3. Trimming

The Trimming tool is a tool designed to analyze all the information about the object and gives recommendations. These recommendations are for components that can be simplified or trimmed, along with their trimming conditions. As a result of trimming, the user can get one or more ideal trimming models and a series of new problems. These new problems in the new models must be effectively resolved.

Trimming includes adding values to the Problem rank, Function rank, and Cost values for all objects, setting the Harmful and Useful status for each action, and assigning values for each action using the slider bar.

Click the icon, start a new trimming process. Click the icon, continue the process. Click the icon, view the trimmed functional model for different trimming variants.

The function model after trimming is often on behalf of a less number of components, problems, low cost, and performance similar (or better) system.

2.4. Problem Solving

Begin working with Problem Manager after performing the Trimming Process for Functional System. Problem solving mainly relys on Problem Manager to find a solution. The Problem Manager is a tool that helps user browse through the list of problems, create concepts for their solution, and access a database of Effects and Examples for ideas for solutions from the Effects and Examples in the Knowledge and Innovation Server (KnIS). The Problem Manager uses two strategies. One is to examine the problems remained after the Trimming Process is completed, the other is to work with the Problem Solving tool to find a possible solution to the problem.

Click the icon in the tool bar to start the Problem Manager. Problem Manager contains three solving tools: Principles Database, Effects Database and Predictions database. Click the problem you want to analyze and select one of the solving modules(Principles, Effects, Predictions) to solve your problem.

Invention Principles are often recommended to solve the problems on technical contradictions. Click the icon, enter the principles window. When you have selected the improving feature and the worsening feature, information appears in the Principles and Examples section of the window. At the bottom of the Principles section are listed, by name and number, some of the 40 Inventive Principles that are relevant to your selected feature. Above the Inventive Principles list is an animated example of the current principle and a bulleted list of its features.

Refer to Principles, Effects and Predictions and ultimately determine the appropriate solution.

3. A Case for Using Product Function Optimization

3.1. The problems about the original gear pump

Fig. 2 illustrates the schematic diagram of the original gear pump. The pump is 3-piece structure[6](front cover, pump body, back cover). It uses roller bearing and floating sides, and set two sealing rings , building a secondary seal cavity. Therefore, it can effectively turn leak oil into high-pressure oil, which greatly improved the volumetric efficiency of gear pumps. Because this pump only set two rings on the bearing ends of the driving gear, both of the bearing seal cavities become high-pressure oil chamber and the other place is low-pressure oil chamber, while both of the bearing seal cavities of the driven gear were high-pressure oil chamber. So the holes of the driven gear in both front cover and back cover endured high pressure. When it needs to bore two oil holes on the back cover according to the structure requirement, which makes a higher demand about intensity, it means to increase the thickness of the back cover wall. This inevitably leads to the cost and shape increase of the pump. While the shape increase is not conducive to install and use on the host.

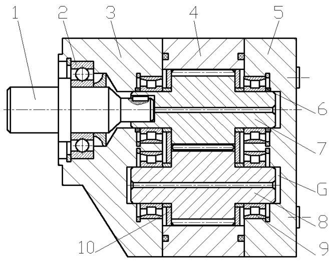
There were mainly two problems: the two floating sides were not balanceable and the back cover could not meet intensity requirement when bored oil holes on it.

3.2. Do the improvement design

1) Functional Model

According to the schematic diagram of the gear pump, affirms the system components. They are front cover, pump body, back cover, drive shaft, driving gear, driven gear, ball bearing, roller bearing, sealing ring , floating side and oil. To better express the function relations between oil and other components, high-pressure oil and film are isolated from oil.

Click the icon, create components and name them. Click the Icon and , link the objects of the system and name these actions. Fig.3 is the completed functional model.



1.drive shaft 2.ball bearing 3.front cover
4.pump body 5.back cover 6.sealing ring
7.driving gear 8.driven gear 9.roller bearing
10.floating side G.high-pressure oil chamber

Fig. 2: The schematic diagram of the original gear pump

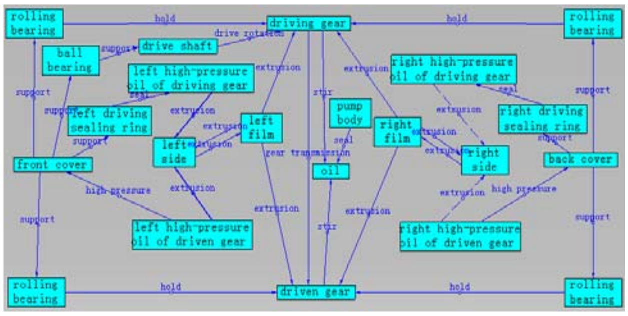


Fig. 3:The functional model of the original gear pump

2) Analyzing

Click the icon, enter the Matrix Browser, as shown in Fig.4. There are 22 system components, and no super system and system purpose. The model has 33 useful actions (contains two non-effective useful actions and two surplus useful actions).

In turn make notes to the system elements and the actions.

3) Trimming

This system mainly trims the problem components and actions. Therefore only carries on the rang assignment to the related components and actions, the system already automatically assigned the rank value on other components and actions. Fig.5 and Fig.6 show two of the reset objects and actions.

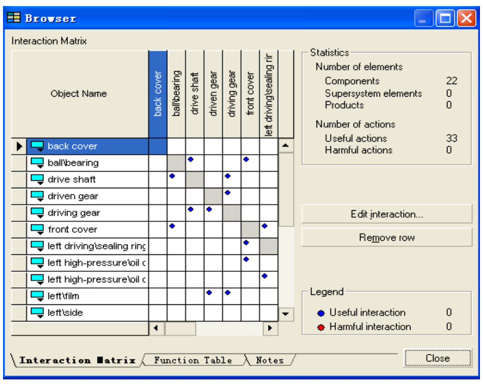


Fig. 4:Matrix Browser

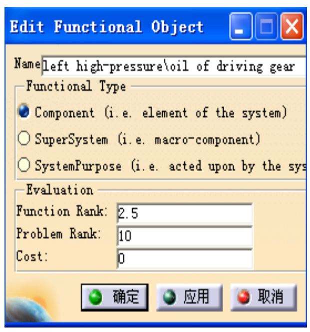
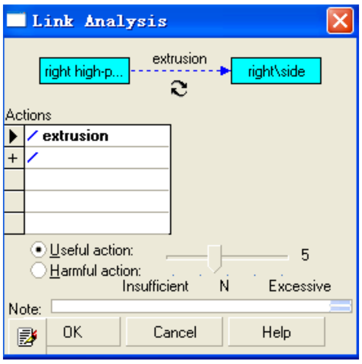


Fig. 5:The function rank of left high-pressure oil of driving gear.



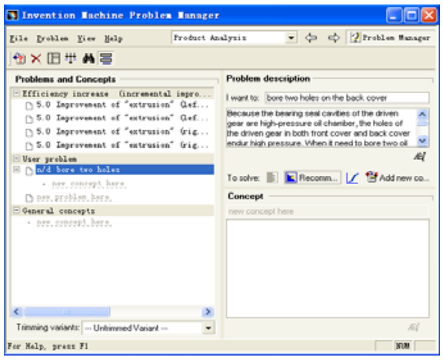


Fig. 7:Problem Manager

Fig. 6:The action rank of the extrusion

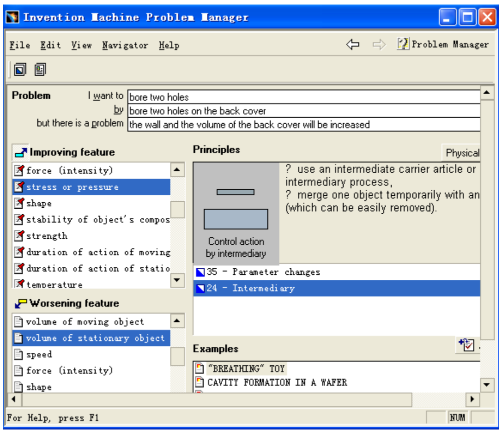
4) *Problem Solving*

Click the icon, enter the Problem Manager. There are 4 efficiency increase problems. Add a new problem in the User problem column and describe the problem in the Problem description column, as shown in Fig.7.

Regarding the 4 efficiency increase questions, puts forward the concept. According to the project effects (physical effects), apply the U-tube connected vessels principle, open two channels on the pump body, the front cover and the back cover. One connects the high-pressure oil chambers of the driving gear, the other connects the high-pressure oil chambers of the driven gear.

Regarding the user problem, confirm that it's technical contradiction. The system recommends invention principle. Click the icon, enter the invention principle database. Select the deterioration of parameter 11 stress or pressure and the optimization of parameter 8 volume of stationary object, as shown in Fig.8. The recommended invention principles are 35 Parameter changes and 24 Intermediary.

Because the back cover usually is cast, it's not easy to change the physical and chemistry parameter. Refer to Principle 24, and Fig.9 is one of the cases of application of Principle 24.



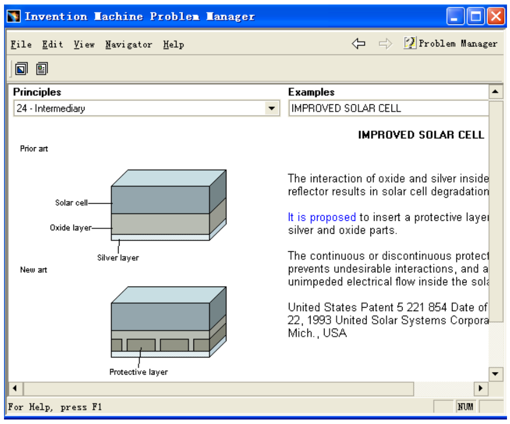


Fig. 9:An application case of Principle 24

Fig. 8:Inventive principles

3.3. The improved gear pump

Fig. 10 illustrates the functional model of the improved gear pump. The new additional components are lightened. The channels make the outside pressure of the two floating sides equal, so the two floating side are balanceable. The new sealing rings debase the pressure of the bearing seal cavities of the driven gear, accordingly the back cover can meet its intensity requirement. Fig.11 shows the schematic diagram of the improved gear pump.

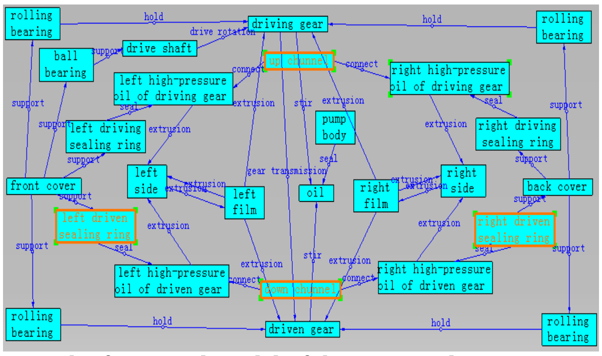


Fig. 10: The functional model of the improved gear pump

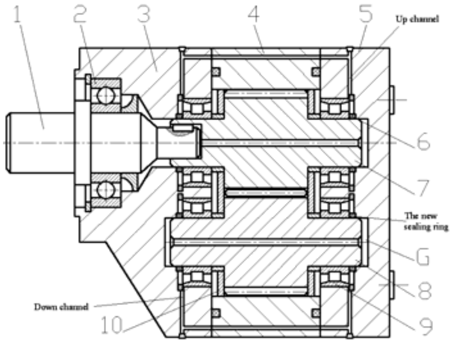


Fig. 11:The schematic diagram of the improved gear pump

4. Conclusions

TRIZ is an effective tool for product innovation, which provides a very unique innovative knowledge base and technology knowledge base, as well as the systematic problem-solving steps, guiding engineers to solve thorny design problems. The application of TRIZ in the engineering products innovative design can effectively provide designers with the right direction to solve the problem, resulting in novel and groundbreaking design concepts. Product function optimization is one of the successful softwares applying TRIZ. The structure improvement design of high-pressured great displacement gear pump has applied the product function optimization module, and has obtained the feasible design proposal, proving the effectiveness and usability of product function optimization. Product function optimization can aid designers in proposing creative design proposal, which therefore has a good application prospect.

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