Research and Application of Mechanical Product Design Process Based on QFD and TRIZ Integration

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Abstract. with the Increasingly Fierce Competition in Science and Technology, the Competitiveness of Enterprises Depends on the Level of Products, and the Level of Products Depends on the Design of Products. Therefore, the Design Quality of Products Will Directly Affect Product Performance, Product Development Cycle and Economic Benefits, and Even the Development of National Economy, in Order to Achieve Product Innovation and Meet the Needs of Customers, This Paper Studies How to Integrate QFD and TRIZ to Achieve Mechanical Product Innovation Design. through the Research, It is Found That QFD Can Only Obtain Customer Demand, Not Create Demand, Only Find Conflict, Not Solve Conflict, and TRIZ Can Solve These Two Problems Well. Therefore, This Paper Takes HoQ as the Skeleton Framework, Integrates QFD and TRIZ in the Demand side of HoQ and the Roof to Guide the Product Design Process in Reality, Which Can Realize the Complementary Advantages, Overcome the Shortcomings of Only Relying on a Single Design Theory to Guide the Design Process, and Has Practical Significance.

1. Introduction
Modern product design puts forward higher and higher requirements for designers. Engineers urgently need design theories that can guide them to improve design quality, shorten design time, inspire and operate easily. And will be integrated organically, which will provide a powerful integrated support tool for product design. According to the different emphases of QFD and the two in product design, the biggest function of QFD is to determine the most important problems and parameters in product design, clarify the priority of each design element, and the relationship between each design parameter and the final target value of the product, and convert it into design and manufacturing information. The house of quality (HoQ) is usually constructed in a specific form to represent user needs, product functions and their interrelations. Product is the manifestation of function, that is to say, any product must complete certain function, so it is an effective method to design from function analysis[1]. In the design of new products, before establishing the relationship between what and how in QFD matrix, the functions of products must be decomposed into basic functional units. Every what item in the matrix should have an existing product structure function unit corresponding to it. Through the function decomposition and QFD method, we can understand the user's needs and clear the objective conditions of product design. However, due to the interference of many factors such as the complexity of information and the fuzziness of the problem, it is difficult to clear the nature of the problem and find a practical solution quickly[2]. Therefore, it is necessary to combine the thoughts and tools of TRIZ theory and method to seek solutions to the technical and physical conflicts in the design process. Most
of the tools in TRIZ can be applied to different stages of QFD, which undoubtedly enhances the practicability and effectiveness of QFD design methods.

2. Related Works
The development of quality function originated in Japan in 1966 and developed publicly by Mitsubishi in 1972. It mainly transforms the user's product requirements through multi-level deductive analysis into the quality management technology for product design, component characteristics, process design and production requirements[3, 4]. In other words, QFD is used to describe the functions and engineering specifications of the products to be developed. It is a systematic method that pays attention to the needs of users and breaks through the traditional enterprises only focusing on product functions and production specifications. Now, QFD has been successfully used in various industries, including AT&T, HP, Ford and GM in the United States. In the process of transforming customer demand into product quality design, it is necessary to integrate and coordinate with relevant departments such as marketing, product development, quality design, production and manufacturing[5]. QFD can improve the performance of communication, interaction and information sharing among departments. House of quality (HoQ), proposed by John R. Hauser and don clausing in 1988, is the core tool of quality function deployment, as shown in Figure 1.

![Figure 1 Structure of HoQ](image)

The steps of filling in the house of quality are as follows: user demand (VOC), user demand evaluation, engineering demand (VOE), relationship matrix between user demand and engineering demand, engineering demand evaluation, contradiction check of engineering demand, selection of key quality characteristics. The user requirements are regarded as the input of QFD, and the evaluation results of quality characteristics are regarded as the output of QFD. Through the process of quality function deployment, the user demand (VOC) is transformed into engineering demand (VOE). After the evaluation and statistical analysis of correlation analysis, the weighted importance weight of VOE is obtained, and then combined with the analysis of VOE contradiction at the top of the house of quality, the key quality characteristics are selected. In this way, the importance weight obtained through user demand analysis can make the established key quality characteristics more accurate and close to the user's ideas.

Product innovation is the key for manufacturing industry to win in the market competition. How to produce a competitive new concept quickly in the conceptual design stage, and how to realize the rapid innovation of products are the cutting-edge issues in the field of design, and also the results that the industry hopes to use as soon as possible. Recent studies have shown that the theory of problem-solving of invention originated from the former Soviet Union should be one of the important theories guiding innovation for both academic and industrial circles. The core of the invention
problem solving principle (TRIZ) is how to determine the conflict in the design faster and more accurately, and how to solve the conflict in a standardized way[6, 7]. The process is shown in Figure 2. These standardization methods include invention principle, invention problem solving algorithm and standard solution. Standardized solutions do not depend on specific problems, so they are easy to learn and master. Although TRIZ was introduced to the West in the mid-1980s, it has become popular in the field of design theory, and has been adopted by many companies in the United States, such as general motors and Ford, and has created considerable benefits.

![Figure 2 Basic Processing Of Triz](image)

In the process of product innovation, conflict is the most difficult problem to solve. In many cases, designers know how to improve the performance of their products, but they don't know how to improve the level of their products. When there are conflicts in the design process, the traditional design method is to use a compromise solution, but the compromise solution is often not an innovative solution. The key to this result is that the designer does not master the solution which satisfies both sides of the conflict at the same time. The core of TRIZ is conflict resolution. There are two requirements for the new solution in conceptual design: “that is, while improving one component or performance in the system, it can not have a negative impact on other components or performance in the system or adjacent systems.”. TRIZ provides a set of knowledge-based technology to solve such problems. The application of TRIZ can naturally generate new concepts in the process of eliminating conflicts. Innovation is different from design, engineering or technical problems in the usual sense. Innovation is to solve problems by eliminating conflicts, while those problems that do not have conflicts or adopt compromise methods to solve problems are not innovation.

3. Integrated Model Design of QFD and TRIZ

The integrated information system of product design enables the personnel of all departments of product design to share all relevant design information in the same database through an information platform. Based on the four stage model of quality function deployment, TRIZ is integrated into the relevant stages of product design. The input data of the integrated information system is user requirements (user requirements classification, user requirements importance, design quality characteristics, etc.), and the output data is user requirements competitive analysis. The information expansion of QFD and TRIZ information integration model is shown in Figure 3, which shows that QFD runs through the whole process of product development. In the whole design process, when it is necessary to solve technical conflict, physical conflict, functional decomposition, determination of ideal solution and other issues, with the help of TRIZ theoretical tools, it can achieve complementary advantages in the design process.
QFD collects technical information, price market information, cost material information and user's perceptual demand information for products, takes them as the input information of product planning house of quality, and maps them to product technical demand information, and then relies on this product technical demand information for product parts planning, process planning and manufacturing planning. TRIZ combines the products to be designed, collects and analyses the relevant information of the existing products or patents (mainly the information at the technical level), transforms the conflicts or contradictions in product design into the general engineering parameter information of TRIZ by using the idea and method of analogy, and determines the specific scheme of product design according to the corresponding invention principle provided by TRIZ conflict resolution matrix. In the specific application of QFD and TRIZ theory, information collection, transformation and mapping play an important role, which usually has an important impact on the success or failure of product design. And, in the process of information processing, there are many intersections, which are the performance of information integration between the two. TRIZ can be used to help determine the product planning information, user demand information, concept selection information, parts selection information and production planning information of QFD, and QFD just points out the direction for the specific application of TRIZ. The important feature of QFD and TRIZ information integration is the smooth sharing and transmission of product design information. Collects the design information of QFD and TRIZ in a product design quality information database, then invokes the relevant information in the database during the product design process, and applies them to the design, production and other practical processes of the product. Finally, the finished product is provided to the user to verify, rely on the feedback information from users, and combine the information database to design the final product. Finalized and put on the market.

4. Application of Mechanical Product Design Process Based on QFD and TRIZ Integration

Based on the research of QFD and TRIZ information integration, this paper integrates QFD and TRIZ in the process of mechanical product development from the perspective of application. The application integration of QFD and TRIZ in the design process of modern mechanical products is shown in Figure 4. In the product planning stage, the integrated model completes the investigation and determination of product market demand, determines the feasibility of development plan, customer demand analysis and verification, commodity advantages, selling point determination, technology embodiment analysis, object selection, intelligence collection, function analysis and function evaluation, qualitative description, classification and sorting of functions, finds redundant, surplus and insufficient functions, and reflects. In the stage of technical design, complete the establishment of detailed product development and promotion plan, complete the preparation work of design and production products, development scheme conception, creation and evaluation, target material cost analysis, propose the maximized design conception, design conception evaluation, development embodiment analysis; in the stage of process planning and production planning, complete the process formulation, Evaluation
and inspection of mass production, and how to ensure the quality of production products, etc., complete the preparation of mass production, specific development plan, sample research and detailed evaluation, etc.; finally, comprehensive evaluation of user satisfaction. Product design is a complex process, involving many aspects of work, so the risk of product design is large.

Figure 4 Application Integration of QFD and TRIZ in Modern Mechanical Product Design

The integrated application of QFD and TRIZ is to reduce this risk and improve the effectiveness and success rate of mechanical product design. However, in the actual product development process, a method that can link the interaction between engineering measures and the conflict matrix in TRIZ is also needed to solve the contradictions and conflicts between engineering measures and get the innovative design scheme to meet the needs of customers. The basic standard to measure the success of a product innovation design is whether the technical or physical conflicts in the design process have been well resolved. A powerful tool in TRIZ theory is conflict matrix and the corresponding invention principle of conflict resolution. In the QFD four stage development of the house of quality, the roof points out the conflict between the design parameters for the design process. Therefore, the established conflict relationship can be used to establish the relationship between them and TRIZ technology conflict matrix. In the problem definition stage, the house of quality in QFD is used instead of the “material field” model. In the problem solving stage, the conflict matrix searching principle in TRIZ is used to solve technical or physical conflicts. Because the roof of HOQ represents the relationship between design variables. When the relationship is negative, there are design conflicts (physical conflicts or technical conflicts) between design variables. These conflicts are described by general engineering parameters in TRIZ. Finally, according to the conflict resolution matrix in TRIZ, appropriate invention principles can be selected. Using the method of house of quality to determine design conflicts, the analysis process can be quantified, and the priority of multiple conflicts in the same design can be determined. It has been known that the beginning of QFD is user requirements, that is, the quality function deployment in the four stages of QFD is based on user requirements. Through QFD, the designer understands the design task. As for some key technologies or some design bottleneck technologies in the design, they must be solved by TRIZ theory.

5. Conclusion

In the increasingly competitive international market environment, continuous innovation of products and technologies is an important means for manufacturing enterprises to succeed and survive. In other words, product and technology innovation has become the core of national or regional competitiveness. Mechanical product design is a very complex process, including demand analysis, conceptual design, technical design and detailed design. The traditional product design method is trial and error method, which is similar to the artist's artistic creation, without a complete set of theoretical guidance. The design mainly depends on the inspiration and experience of people, thus affecting the market
competitiveness of products. In this context, it is of great practical significance to promote and apply more mature innovative design theory and improve the innovative design ability of products for the industrial adjustment and product development and upgrading in China. QFD and TRIZ can't complete all problems of product design alone. QFD indicates what to do and TRIZ indicates how to do it. In this paper, the methods and ideas of QFD and TRIZ integration are given, and their integration is studied from two aspects of information integration and application integration, and their information integration model and application integration model are established. Information integration gives full play to the role of both in product design and achieves the purpose of information resource sharing in product design. Application integration organically integrates the application of QFD and TRIZ in mechanical product design, so that they can participate in the whole process of product design in a way of collaborative work, so as to learn from each other's strengths and make full use of the advantages of integrated application.

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