Title:
Innovative Product Design Based on General Theory of Powerful Thinking

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Introduction:
Innovation is a key for enterprises to be competitiveness in the market. The innovation lies mainly in the product design stage. Design is a process of transforming user needs into concrete structures. It is inefficient for designers to rely on experience in design on the basis of trial and error. It is an inevitable trend to systematize the theory of product innovation. Invention Problem Solving Theory or TRIZ in Russian is an innovative design theory [4]. Based on analyzing a large number of high-level patents around the world, it was firmly believed that contradictions in product design are fundamental reasons leading to failure of the product to meet users' needs. Therefore, in the process of product design and improvement, contradictions must be found and solved, rather than using compromise methods to ease contradictions.

Classical TRIZ methods can help design of new products, but they can no longer meet needs of solving multi-contradiction problems in complex systems. In recent years, multi-contradictions have become one of the urgent problems in the field of product innovation. For this reason, some scholars proposed a general theory of powerful thinking, or OTSM in Russian [2]. This paper introduces a product innovation method based on the OTSM theory for solving multi-contradiction problems. This method deeply excavates internal relations of contradictions in a product to improve shortcomings of the classical TRIZ method in analyzing multi-contradiction problems, and thus enhances reliability of design solutions. A design process of the tire breaker is presented with a prototype verified by the manufacturer.

Main Idea:
ENV model
The element-name-value (ENV) model is proposed to represent bottleneck problems of a design process in the form of contradictions. The control parameter (CP) in the model is controlled by designers, and its changes will affect the product in some way, while the evaluation parameter (EP) represents the measure of a variable in the product [3]. Using these two parameters, design requirements and physical attributes can be correlated. Contradictions can be described intuitively and systematically, which builds a link between the concrete structure of a product and description of abstract design problems. For example, if element A is a battery, the control parameter is volume. At the current level of technology, the volume is proportional to electricity. Evaluation parameter 1 is

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standby time and evaluation parameter 2 is portability. Then the corresponding element B is a cell phone, and element C is the user. The bigger the volume, the longer the standby time, but the worse the portability. The relationship between control parameter and evaluation parameters affects the direction of arrows shown in Fig. 1.

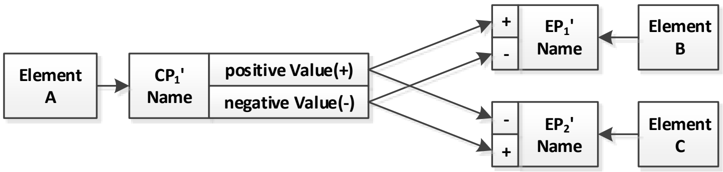

Fig. 1: Relations of control parameters and evaluation parameters.

Contradiction network

It is observed that different contradictions often share one evaluation parameter, or one contradiction evaluation parameter is another contradiction control parameter. According to the relation between two kinds of parameters, all contradictions can be integrated into a contradiction network [1]. Taking Fig. 2 as an example, nodes in the figure represent contradictions, and direct lines represent the relation between contradictions. Where C1, C2, and C3 form the ring contradiction, and three contradictions must be solved at the same time. C2 is a multi-output contradiction, and its change will affect five contradictions, while the multi-input contradiction C4 will be affected by the change of the other three contradiction parameters. C7, C8 and C9 form a contradiction chain with a causal relation. To solve this problem, we must start at C7. There may be independent contradiction C10, which cannot be included in the contradiction network. Contradictions with three or more input-output relationships can be identified as core contradictions, which has a greater impact on the product innovation design process. After the core contradiction is solved, the less-importance contradictions associated with it can be solved easily.

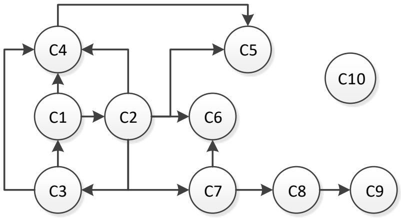

Fig. 2: A general form of contradiction network.

Concept Solution Evaluation

There are usually more than one concept solution (CS) for a product. All concept solutions need to be evaluated. A concept scoring matrix [5] is introduced into the design process as follows. Firstly, the evaluation criteria are determined based on the problem network. Comparing these criteria in pairs, the weight of each criterion is obtained. Secondly, conceptual solutions are analyzed for the performance related to criteria. Since it has not yet entered the detail design stage, the conceptual performance here is compared to the existing products. Finally, the total score of each CS is calculated for concept ranking.

For example, an enterprise needs to choose a best design from four concepts of Ⅰ, Ⅱ, Ⅲ and Ⅳ. Criteria extracted from the problem network are A, B, C, D, E, F and G. Results of criteria comparison and each criterion weight are shown in Tab. 1. Based on the existing products, the comparison of the four conceptual solutions is shown in the right half of Tab. 3. The relative performance score is

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multiplied by the criterion weights, and then scores of the seven criteria are summed. As shown in Tab. 3, CS 1 is scored the highest.

Criteria	*A*	*B*	*C*	*D*	*E*	*F*	*G*
A		B	C	D	E	F	A
B			B	D	B	F	G
C				D	C	F	C
D					D	F	D
E						E	E
F							G
G							
Total hits	1	3	2	5	3	4	2
Weights	0.05	0.15	0.10	0.25	0.15	0.20	0.10

Tab. 1: Criteria comparison results and weight.

Level	*Meaning*
1	50% to 75% performance of existing products
3	75% to 100% performance of existing products
5	same performance as the existing products
7	100% to 125% performance of existing products
9	125% to 150% performance of existing products

Tab. 2: Relative performance level.

Criteria	*Weights*	*Design I*	*Design II*	*Design III*	*Design IV*
A	0.05	5	7	5	9
B	0.15	7	5	3	5
C	0.10	7	7	5	5
D	0.25	5	9	5	5
E	0.15	3	7	7	5
F	0.20	5	7	9	7
G	0.10	3	5	7	7
Total score		5	7	6	5.8
Rank		4	1	2	3

Tab. 3: Concept scoring matrix.

Case study

Tire breaker is a kind of security device to prevent illegal activities. It is found that users' dissatisfaction with the existing tire breakers mainly lies in following areas: the short product life (Pb1), poor use effect (Pb2), affecting driving (Pb3), ugly appearance (Pb4), and hidden danger (Pb5). In a further analysis of the main causes of the above problems using the decomposition of the problems, sub-problems and partial solutions (PS) are summarized in Tab.4. Its problem network is shown in Fig. 3 according to the internal relations of the problems.

No	*Problem description*	*No*	*Problem description*
Pb1.1	Rolling of Vehicles under Driving	Pb2.12	Large power consumption

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Pb1.2	Malicious destruction	Pb3.1	Low Chassis Vehicle Bottom
…	…	…	…
PS2.11	Electric lifting	Pb5.7	Signals are easily disturbed

Tab. 4: Sub-problems and partial solutions

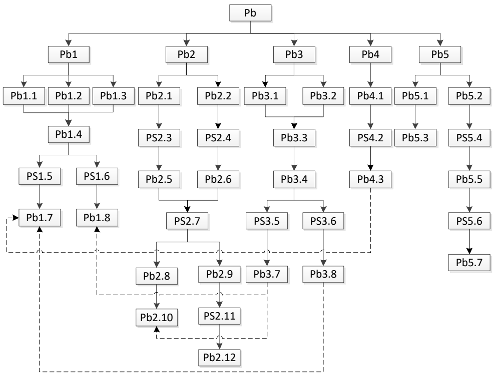

Fig. 3: Problem network of a tire breaker.

All the sub-problems in the problem network are evaluated based on criteria. 8 bottlenecks are obtained as Pb1.3, Pb1.4, Pb2.1, Pb2.2, Pb2.7, Pb 3.3, Pb4.3 and Pb5.6. Contradictions contained in bottleneck problems are represented by the ENV model, and contradictions C1 to C8 are obtained. Taking Pb5.6 as an example, the control mode of a tire breaker includes the wired and remote control. The wired mode has a high reliability, but users need to close the tire breaker for operation. By contrast, the remote control is safer for the operator but lower reliable, which results in contradiction C8 as shown in Fig.4.

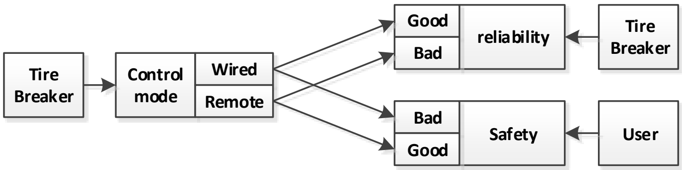

Fig. 4: Contradiction C8 extracted from Pb5.6.

Relations of control and evaluation parameters of these 8 ENV models are illustrated using C3 as an example. Because needles are mounted on the transmission shaft, the number of needles changes the weight of the pressure on the transmission shaft, leading to the change of reliability of evaluation parameter C3, therefore C4 affects C3. Similarly, the internal space of the tire breaker is to place parts such as the transmission shaft. The diameter of the transmission shaft changes the required space, which leads to the change of the thickness of control parameter C6, C3 also affects C6. Based on understanding of relations among the eight contradictions, a complete contradiction network can be formed as shown in Fig. 5, where the core contradictions are C3, C4, C5 and C7.

Design Result of Tire Breaker

The new design combines the advantages of some concept solutions. Comparing the new design with the existing products of the cooperative enterprise, it is found that the new design has a lower height

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and is very friendly to low chassis vehicles. Its structure is simple and compact for portability. At the same time, inner parts of the shell are equipped with a single chip computer and a Bluetooth transmitter module, which can be remotely controlled at any time if required. Fig. 6 shows the new design and prototype of the tire breaker.

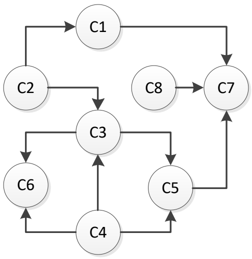

Fig. 5: Contradiction network of Tire breaker

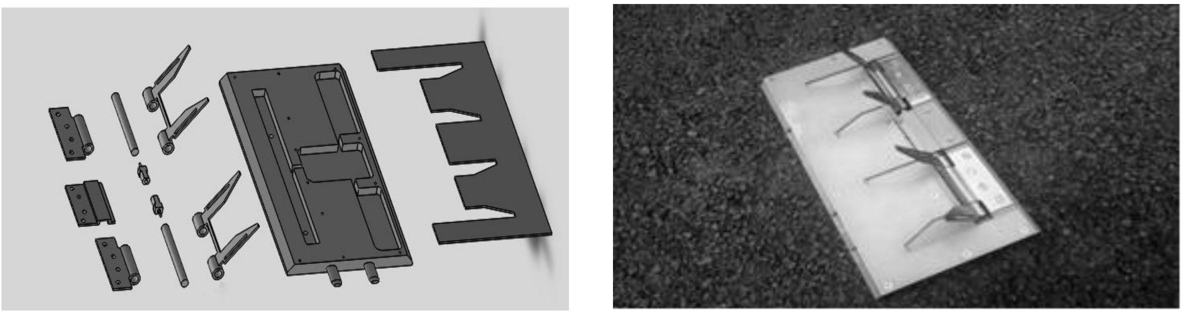

Fig. 6: New tire breaker: (a) The explosion figure, (b) The prototype.

Conclusions:

In order to solve multi-contradiction problems in product design, this paper proposed a new process of innovative product design inspired by the OTSM theory. Compared to the existing research, the process has following new features: (1) the problem network is formed based on the valuable patent document, rather than designers' personal experience. The relevance and integrity of the problem network are guaranteed. (2) Criteria are clarified for detecting bottleneck problems and core contradictions to reduce the redundant design. (3) The concept scoring matrix is introduced to reduce subjectivity in evaluating concept solutions. A new tire breaker is developed for a local manufacturer. The manufactured design prototype has verified the effectiveness of the proposed process for the innovation design.

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