A Conflict Analysis and Resolution Method Based on Integrating the Extension and TRIZ Methods

Zhao Yanwei, Lou Jiongjiong, Ren Shedong, He Lu and Gui Fangzhi

Abstract To address the issue that traditional and single design methods cannot resolve modern conflict problems quickly and effectively, which have become increasingly complex, we propose a new method for analysis and resolution of conflict based on integrating the extension and TRIZ methods. First, we summarize research on integrating the extension and TRIZ methods and then we analyze and build models for their transformation. In this way we can unite the strict reasoning ability of the extension method with the abundant practical experience of TRIZ to resolve conflict problems. To verify the correctness and feasibility of the proposed method, we apply it to the problem of reducing the noise of a screw compressor.

Keywords Extension · TRIZ · Design method of integration · Conflict analysis · Conflict resolution

1 Introduction

The extension method [1] and the TRIZ method [2] are two methods to resolve contradictions problems. The extension method offers qualitative and quantitative analysis but lacks practical experience; and the TRIZ method makes use of abundant practical experience and is supported by a numerous outstanding patents but lacks a model. Integrating the extension and TRIZ methods can solve some of their problems.

Qiu et al. [3] researched the similarities and differences between the extension and TRIZ methods and concluded that they are different in terms of contradiction

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classifications, theoretical basis, and researching objects and method systems, but they are similar with respect to the philosophical thought in solving problems. Zhou and Chen [4] researched the essence of the 40 invention principles of TRIZ and described them by extension transformations item by item. Li et al. [5] and Zhao et al. [6] compared the difference of their objectives, analyzed the difference of programs, and analyzed the differences in definitions and classification on conflict problems. They noted the need for further discovery on how to integrate these two methods. Zhao et al. [6] reviewed the application of extension and TRIZ methods and compared them based on their principles and applications and proposed integrating the two methods.

To extend this previous research, in this paper we propose a new method for analyzing and resolving confliction problems based on integrating the extension and TRIZ methods. First we express engineering parameters by using extension basic-element theory and integrate extension reasoning method and the TRIZ substance-field model and contradiction matrix, enabling us to develop a concept design program. As an application to verify the correctness and feasibility of the new method, we use it to design a lower noise screw compressor.

2 Transforming the Modeling of Extension and TRIZ Methods

The common central core of extension and TRIZ methods is to solve conflict problems, so their models can transform between each other, and it is the base of researching their integration.

2.1 Transforming Engineering Parameters of TRIZ to Extension Method

Transforming the engineering parameters of TRIZ [2] to extension basic-element theory is useful for not only expressing the engineering parameters in more detail but also expanding them to adapt to more questions. Engineering parameters can be classified into static engineering parameters and dynamic engineering parameters.

A static engineering parameter can be expressed by a matter element or multiple elements of the extension quantitatively. Taking engineering parameter 1 for example, the moving objects can be expressed by a matter element M = (Om, Cm, Vm) = (Om, speed, Vm), so all engineering parameter can be expressed by multiple element M1 = (M, C0, V0) = ((Om, speed, Vm), quality, V0).

A dynamic engineering parameter can be expressed qualitatively by an affair element, a relation element, or multiple elements. Taking the engineering parameter 14 (speed), for example, we can express this by the affair-element M1 = (Om, Cm, Vm) = (Om, speed, Vm), and gathering the affair-element and matter-element

A14 = (enlarge, control object, (Om, speed, Vm)) = (enlarge, control object, M1). After that, we can expand them by using the divergence method in the extension and get element sets for solving conflict problems.

2.2 Transforming TRIZ Inventive Principle to Extension Method

By combining it with extension method, TRIZ inventive principle [2] can be expressed quantitatively and its key information can be displayed, making it more comprehensible and formal and simplifying its implementation. The TRIZ inventive principle can be classified into an incompatible problem solving principle and an opposite problem solving principle based on the thought of invention principle solving problems.

For the incompatible problem, we express the conflict problem corresponding to the inventive principle, by using the extension model and then transform the model by the way of TRIZ method using the extension transformation method. For example, when someone falls onto a table, how to protect that person from becoming hurt? We can use the 14th inventive principle: surface. We can build extension model $P_{I14} = G_{I14} * L_{I14}$. G is the goal of the product, L is the condition. We can use transform tool T_{I14} replacement to change the right to rounded corners.

For the opposite problem, we can use the primitive theory of the extension method to express the target and the condition. And then we build a model of the extension problem. Finally, we transform the conditions by using the extension solution to obtain the final solution. For example, we desire a tank to have suitable armor while also having good maneuverability. We can use the 40th invention principle: composite materials to analyze. The final tank goal can be expressed as $G_{I40} = M_1 \wedge M_2$, where M_1 and M_2 are two ways to achieve the goal, increasing the thickness of the armor to increase damage resistance, and reducing the thickness to increase maneuverability. Based on this, the model of the extension problem is $P = G_{I40} * L_{I40}$. Then we do the extension transforming on the tank armor. $M//\{M_{01}, M_{02}, M_{03}\}$ = {Main armor, Inner fold, Backplane}, we replacing the inner fold material by composite materials.

2.3 Transforming Factors of Conflict of the Extension Method to TRIZ

Based on the number of characteristics that cannot meet the need, we can classify the conflict into two parts: single-factor conflict and multiple-facto conflict.

For a single-factor conflict problem, we can express the need characteristic by the tool of the extension to target G = (optimize, technical parameters, xin → xjm) and the objective conditions to L. Then we expand the structural parameters and get the detailed and base parameter characteristics of the problem.

Multiple-factors conflict problems can be classified into two types: those in which conflict parameters are independent and parameters are conflicting with each other. For the first type, we can use the single-factor conflict method to build the model. For the second type, we first need to build the parametric mater-element model of the design characteristic, then, by extension analysis of the parameters model, get the base characteristic parameters.

Finally, we match the parameters to the engineering parameters of the TRIZ to get the corresponding engineering parameters Ypi1 and Ypi2.

3 Analyzing and Resolving Conflicts Based on Integrating the Extension and TRIZ Methods

We have learned that conflict problems based on the extension and TRIZ methods can be classified into two types: single-factor conflict and multiple-factor conflict. Consequently, when we analyze and resolve the conflict problems, we can also classify them into two parts.

3.1 Analyzing and Resolving Single-Factor Conflict Problems

According to the definition of the extension, single-factor conflict problem belong to the incompatible problem. The analysis and resolution process is shown in Fig. 1.

According to TRIZ theory, one can use the substance-field model or separation principle to analyze the single-design-factor conflict problem. According to the engineer parameters, for the design requirement performance for two opposite states, when one requirement is met, the other will cease to be satisfied. We can use the separation principle to analyze and resolve the problem. It is the dependent contradiction problem in the extension, so we can use compatibility strategy to analyze it.

An affair element model of the extension based on the spatial separation principle can be built such that

$$A= (O_A, c, v)\|\left\{(s_i)(O_A, Y_{PRir}, v_i);\ \left(s_j\right)\left(O_A, Y_{PRjr}, v_j\right)\right\} \tag{1}$$

where A = (OA, c, v) is an affair-element model, si and sj refer to different space conditions, respectively, vi is the value of YPKir in condition si. The other separation principles [2] offers a similar way to build the affair element model of the extension. Then the confliction problem can be solved by the appropriate inventive

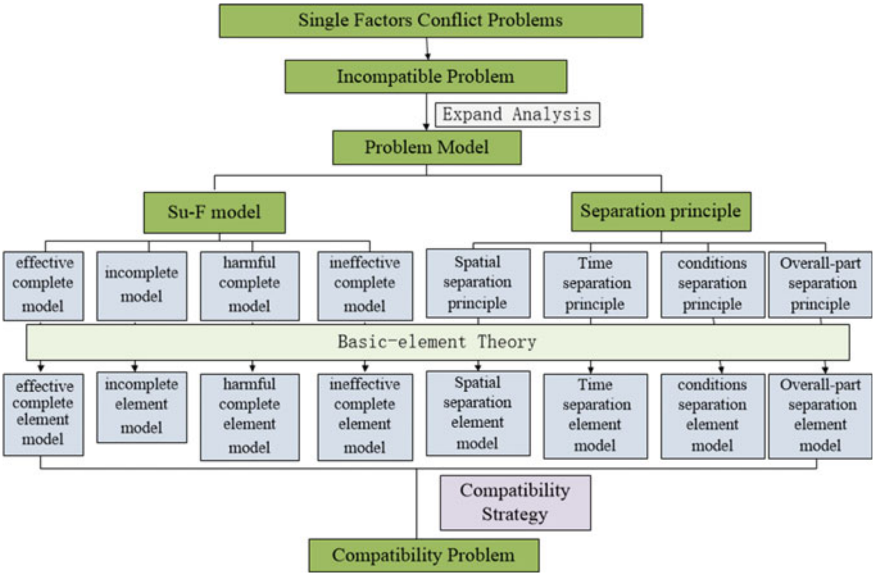

Fig. 1 Analyzing and resolving the single-factor conflict process based on integrating the extension and TRIZ methods

principle, which is strong to operate and give details of the conflict coordination strategy.

If the design demand can be expressed by a homogenous change, we can use the material field model [2] to resolve the conflicts. First, we build the extension model to describe the problem that can specify the function of a single design need:

$$\begin{aligned} P = G_{PRi} \rightarrow L_{PCi} &= M_1 * (M_2 v M_3) \\ &= (O_{M1}, c_{M1}, v_{M1}) * [(O_{M2}, c_{M2}, v_{M2}) v (O_{M3}, c_{M3}, v_{M3})] \end{aligned} \tag{2}$$

With the thought of extension method to resolve the conflict problem, we use extension transform and extension reasoning, combined with the standard solution Vi, i = 1, 2, 3, …76 which is corresponding to material field model to analyze and give the final solution.

3.2 *Analyzing and Resolving Multiple-Factor Conflict Problems*

The process to analyze and solve the multiple-factor conflict problem is shown in Fig. 2.

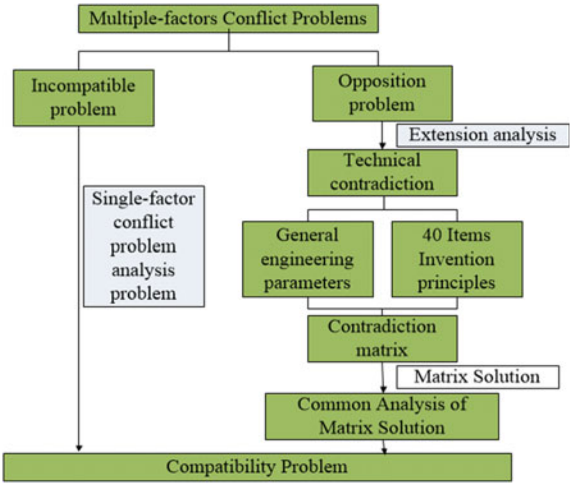

Fig. 2 Analyzing and resolving the multiple-factor conflict process

According to the previous discussion, we can see that we mainly need to solve the second type problem. First we need to extract the two opposite design parameters PRia and PRib from the design element of conflict and build the matching extension model

$$P = \left(GPR_i^a \wedge GPR_j^b\right) \uparrow L \quad (a < b, a, b = 1, 2, \ldots, l, 1 < l < n) \tag{3}$$

(where the symbol ↑ indicates that it cannot meet the need). Then we transform the contradictions in the process of real design to standard technical contradictions of the TRIZ and then match the GPRia and the GPRjb with the 48 general engineering parameter, obtaining the matching engineering parameters YPRia and YPRib. According to the technical contradiction matrix, which is built from the improved engineering parameters and the other parameters that may cause deterioration, we determine the corresponding matrix elements Mpri-prj, where the numbers i, j specify the number of the invention principle, and we identify the detailed invention principle according to those numbers. Finally, with reference to the method of coordinating the conflict problem of the extension, we build up a co-existence strategy based on the invention principle to resolve the multiple-factor conflict problem.

4 Example Verification

The main parameters of a screw air compressor are displacement, exhaust pressure, noise, volume, weight, rated power, and cost. First we retrieve information from the instance library [7] and get the incompatible problem. Second, we analyze and resolve the problem according the method of integrating the extension and the TRIZ methods. Finally, we construct a satisfactory plan.

We assume that the following performance requirements: *DP* (displacement) is medium, *EP* (exhaust pressure) is about 1.1 Mpa, the *NS* (noise) has no obvious impact upon nearby persons, *VM* (volume) is about 2300 dm^3 and the *RP* (rated power) is about 40 kW. According these performance requirements, we can transform them to the extension element model

$$PR_i = \begin{bmatrix} \text{screw air compressor} & EP & [0.9,1.3]\,\text{Mpa} \\ & DP & [5,7]\,\text{m}^3/\text{min} \\ & RP & [35,45]\ \text{kw} \\ & NS & [60,70]\,\text{dB} \\ & WH & [1000,1400]\,\text{kg} \\ & VM & [2000,3000]\,\text{dm}^3 \end{bmatrix} = \begin{bmatrix} PR_i^1 \\ PR_i^2 \\ PR_i^3 \\ PR_i^4 \\ PR_i^5 \\ PR_i^6 \end{bmatrix} \tag{4}$$

Because of the different dimensions for different data parameters, we need to normalize [8] the original data in the instance library. For some product characteristic parameters, such as the noise of the screw air compressor, it is customary to minimize their value. Thus we make the extension domain range [60,72] dB, with the optimum value being 60 dB. For other product characteristic parameters, such as the displacement, higher values are better. Thus the extension domain range for displacement is set to [4,8] m^3/min, with the optimum value being 8 m^3/min. By substituting the extension domain range and the optimal value into the multidimensional correlation functions and the similarity calculation formula, we can obtain the corresponding similarity value and the demand characteristic parameter number.

4.1 Analyzing Conflict Problem

According to the similarity value and the demand characteristic parameter number of the screw air compressor calculated, we can divide the instances that meet the condition Kn-9(PR) < 0 into a single-factor conflict problem and multiple-factor conflict problem. Such as 9#SAL37, which satisfies Kn-9(PR) < 0, Kn-8(PR) > 0, Knoise(PR) < 0. It is the single-factor conflict problem. Such as 13#SBL37, which satisfies Kn-9(PR) < 0, Kn-7(PR) > 0, Knoise(PR) < 0, Kdisplacement(PR) < 0, it is the multi-factors conflict problem.

4.2 Resolving the Conflict in the Large Screw Air Compressor Based on Integrating the Extension and TRIZ Methods

According to the analysis in Sects. 4.1 and 4.2, we obtain a single-factor conflict problem and a multiple-factors conflict problem. We choose the noise as the object of interest, with the help of PRO/INNOVATOR to analyze what causes the noise, and then give the solution.

Firstly we build the component model to the noise problem, as shown in Fig. 3. And the parts function model figure of the screw air compressor system will generate a set of "how to" transformation problem models to coordinate the problem of noise not meeting the requirement. The set of "how to" models is shown in Fig. 4.

According to the set of "how to" models, we can clearly discern which parts of the system cause the noise and then find the potential reasons through analysis of the original problem. In this section we will analyze the original problem of axial flow fan components (Fig. 5).

As an example problem model we consider the following: "How to decrease noise of axial flow fan?" The matching general engineering parameter is 31,

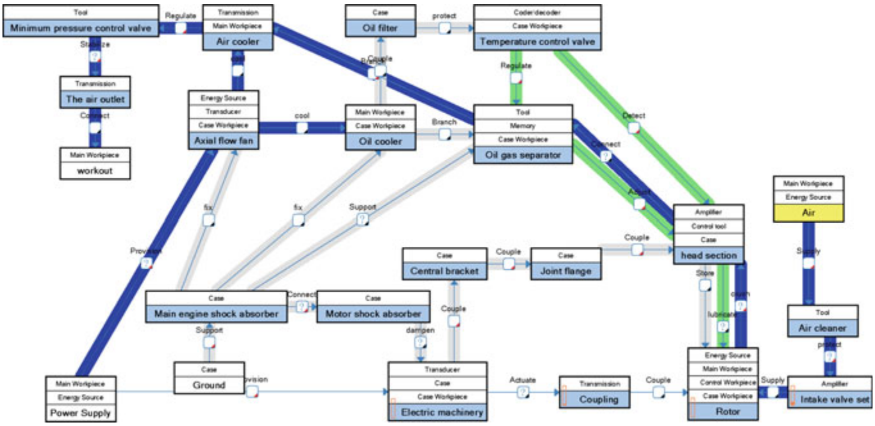

Fig. 3 Component model of the screw air compressor

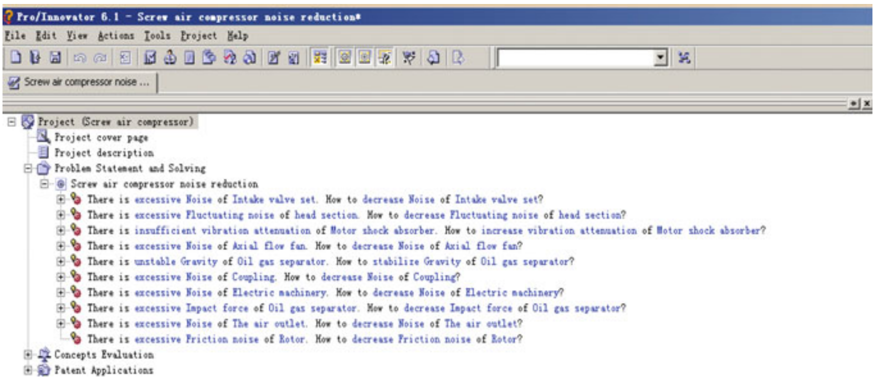

Fig. 4 Transformation problem models

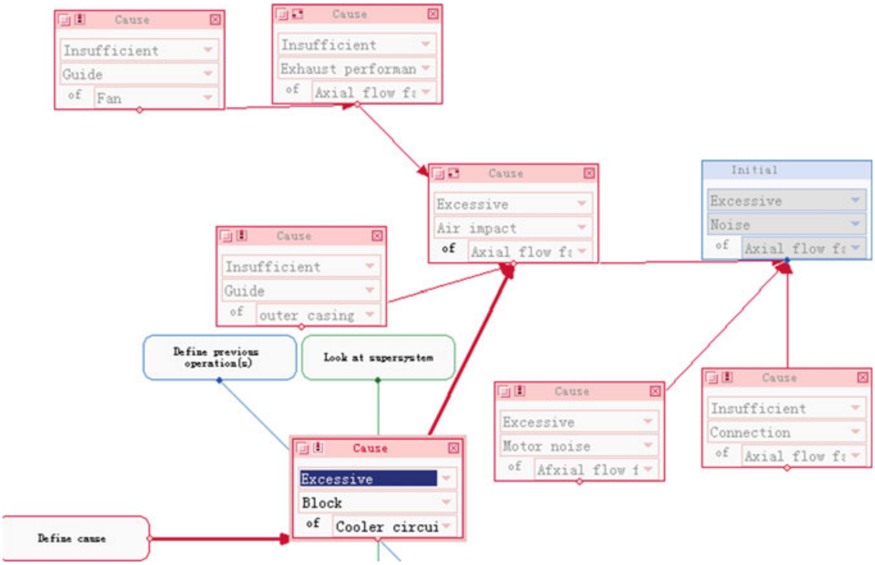

Fig. 5 Analysis of the noise of axial flow fan parts

object-generated harmful factors. Reducing the noise leads to an increase in the complexity of the equipment, so the general engineering parameter is 36, the device complexity. In PRO/INNOVATOR, the innovation principles given by contradiction matrix are 1, 19, and 31. According to PRO/INNOVATOR, we find the reference solution for the model of "there is excessive noise of axial flow fan. How to decrease noise of axial flow fan?," as shown in Fig. 6.

Fig. 6 Solutions for the noise of axial flow fan parts

#	preliminary idea	N,%	C,RMB	D,YEAR	Valuation		
1	Concept plan 3: Fan additional pits reduce air resistance	86. 00	800. 00	10. 00	100		
2	Concept plan 4: Improve the speed of the air in the fan by i mproved radial rib	88. 00	50. 00	12. 00	98		
3	Concept scheme 5: cooling pipe is designed to have the shape of the diversion capacity	84. 00	500. 00	12. 00	97		

Fig. 7 The first three results

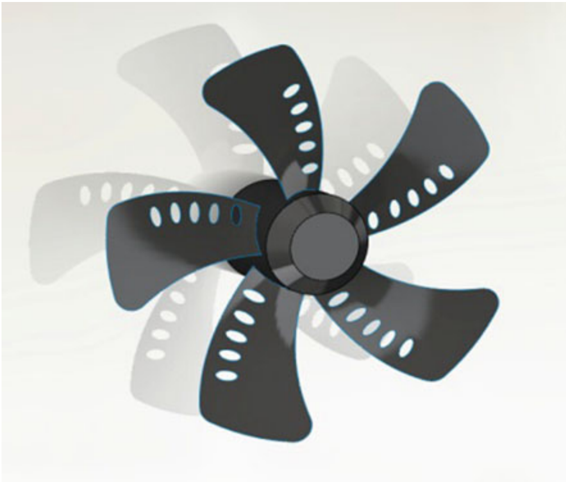

Fig. 8 Improved axial flow fan

Fourthly we choose three parameters (noise, cost, and use time) as the evaluation indices, and set the weights as 80, 15, and 5 %. Then we invited the experts to evaluate every solution. The first three results are shown in Fig. 7.

Fifthly we find that conceptual scheme 3, increasing the pits in the axial flow fan to reduce air resistance is the best solution. So we punch some holes in the blades of the axial flow fan which is shown in Fig. 8.

5 Conclusion

To address the limitations of current single innovation methods to solve the contradiction problem in complex product design, in this paper we researched the integration of the extension and TRIZ methods and built a model to resolve the conflict. Application of the model in a large screw air compressor verified that the method is correct and feasible. However, in this paper we only combined the general engineering parameters of TRIZ, the innovation principle, and the substance-field model with the extension element method; there are additional TRIZ tools that can be used.

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