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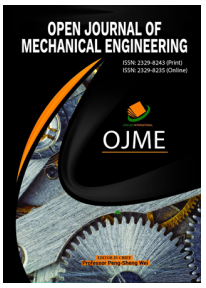

THE STRATEGY OF PROCESS INNOVATION BASED ON AHP AND TRIZ

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ABSTRACT

Theory of the Solution of Inventive Problems (TRIZ) is an effective tool to solve the conflict in process system. Consequently, it is very important to find the key conflict in process innovation. This paper presents a new strategy of process innovation that integrates the analytical hierarchy process (AHP) and TRIZ to assist engineers in identifying and solving the key conflict. The proposed approach starts with analyzing requirements and constraints in the process system, and the AHP method is employed to investigate the most important conflict by evaluating overall criterions of the conflicts, and then TRIZ is used to solve the key conflict. Finally, the performance of the proposed approach is illustrated and validated with the case of machining blade.

KEYWORDS

Process innovation, Process conflict, AHP, TRIZ.

1. INTRODUCTION

Process is the bridge of design and production. According to the U.S. National Productivity Survey Committee, process technology contributed 57% to the productivity in the last century [1]. However, previous research on process innovation design was not enough [2]. Therefore, it is crucial to focus on the research of process innovation.

Based on a study, process innovation means the change of technology, which involves new design, new process technology, new equipment and new management model [3]. Recently, some researchers have already applied innovation methods to process design [4]. In China, Scholars of Sichuan University proposed a strategy of process innovation design: Combining with process elements, process engineers use the TRIZ method to guide process innovation, and solve the conflicts of the process system [5].

TRIZ is a innovation theory which can effectively solves technological conflict with creative ideas3. So it is appropriate to apply TRIZ into process innovation. Process engineers need to establish a conflict model of process system, in order to make use of TRIZ. However, There are lots of conflicts in a process system. And building a conflict model accurately often turns out to be very difficult, because numerous factors which interact with each other all have an impact on the conflict model. If process engineers could find the key conflict with the assist of AHP, they could building a conflict model accurately and then use TRIZ to solve this process conflict efficiently. Consequently, analyzing process requirements and constraints, which are the source of the process conflicts, is inevitable [6].

2. ACQUIRING PROCESS REQUIREMENTS

Generally, drawings convey lots of information such as header information (e.g. name, number, materials, etc.), structure, size, tolerance, surface roughness, heat treatment and other technical requirements. But, the above information is not enough for process engineers. They need to obtain more information about process requirements with the assistance of QFD (Quality Function Deployment). According to a research, QFD can turn the customer and market demands into product design specifications, components/semi-finished products characteristics, and process requirements, by establishing the relation matrixes about them [7].

Process requirements mainly include: T (time), Q (quality), C (cost), R (resource consumption) and E (environmental impact), etc. In order to acquire the comprehensive process requirements, process engineers should consider market, technology and the source of process requirements, for example, product, external user and internal user (Figure1).

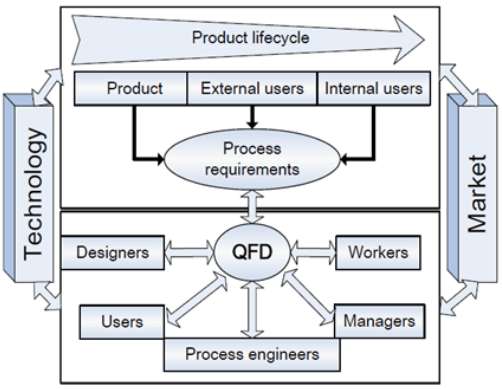

Figure 1: The Model of Acquiring Process Requirements

(1) Process requirements based on the information of product.

Drawing Sheet of product can reflect lots of process requirements, so comprehensively analyzing the information of drawings is very important. In cooperative atmosphere, process engineers engage in the whole cycle of product development, and can capture the process information comprehensively.

(2) Process requirements based on the external users.

The ultimate goal of process innovation is to fulfill the requirements of external users. External users are seriously concerned with quality, function, price, environmental protection, energy saving, service and man-machine engineering, etc.

(3) Process requirements based on the internal users.

Process engineers also need to consider the process demands of internal users such as workers and production department, etc. Workers want the low intensity labor and a comfortable working environment, on the other hand, production department demands short time, low cost, less consumption and easy management, etc.

3. ACQUIRING PROCESS CONSTRAINTS

Process constraints have a negative effect on productivity. Process constraints involve economic constraints, manufacturing constraints, production pattern constraints, technical constraints and so on. For each product, process constraints play different roles.

(1) Economic constraints. Low cost creates more profits. It is worth noting that economic constraints include not only short-term profits, but also strategic enterprise development.

(2) Manufacturing constraints. Manufacturing environment imposes restrictions on component's attribute, such as structure, size, precision, etc. Constraints involve four categories: (A) Blank constraint. The blank is the prototype of product, and has a great effect on manufacturing cost and productivity of component. (B) Resource constraint. The equipments used to manufacture products include machine tools, cutting tools and fixtures, etc. (C) Machining constraint. This kind of constraints includes cutting, cooling, scraps discharge and adjacent Machining method, etc. (D) Testing restriction. When machining components with complex geometry or high precision, process engineer should consider the constraints of measuring and testing method.

(3) Constraints of the mode of production. The mode of production of each product is different from one another. There are also several feasible processing methods for choice, according to production batch, part feature and process requirements.

(4) Constraints of technology. Technical engineers are important resources for enterprise. The technological capability largely depends on its process engineers.

4. PROCESS CONFLICTS BASED ON PROCESS REQUIREMENTS AND CONSTRAINTS

(1) Process requirements and constraints lead to process conflicts. Process requirements and constraints can generate lots of process conflicts, for example, the contradiction between precision and cost, and the contradiction between heat dissipation and system complexity, etc. Above all, the key conflict has greater negative effects on the process system than other conflicts. In order to improve the efficiency of the process system, engineers need to find the key process conflict.

(2) Find the key process conflict with the assist of AHP According to a researcher Analytical Hierarchy Process (AHP) can be used to analyze the factors of the process system qualitatively and quantitatively [8]. Using the AHP method involves mathematical synthesis of the judgments about problem, which could help engineers to find the most critical one among many process conflicts. The procedure of applying the AHP method can be summarized as:

Step 1. Decomposing.

Based on a study, engineers need to model the problem as a hierarchical structure which contains the decision goal, the alternatives for reaching it, and the criteria for evaluating the alternatives [9] (Figure 2). For example, the goal is to find the key process conflict in alternative process conflicts. The criteria for evaluating process conflict contains time, cost, quality, resource and environment.

Step 2. Weighing.

In order to calculate the weight number of each element in the hierarchy, Engineers need to make a series of judgments based on the comparative matrix pairs of criteria, and synthesize these judgments to yield a set of overall priorities for the hierarchy.

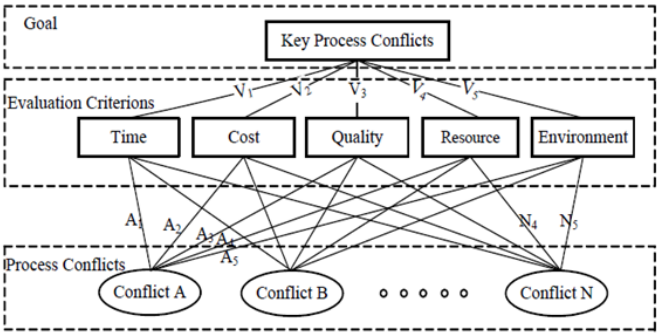

Figure 2: The Hierarchical Structure of Process Conflicts

Then check the consistency of the judgments. For example, when calculating the weight number of each element in the hierarchy, engineers might think low cost take precedence over short time, short time take precedence over environmental protection, and so on. Then if we set V_m represent the weight number of criterion to goal: short time (V_1), low cost (V_2), good quality (V_3), low consumption (V_4), environmental friendly (V_5). Then we would have A_m, B_m... N_m represent the weight number of process conflict to criterion (Table 1). Note: The sum of the weight number is 1. For example: $\sum V_m = 1$.

Table 1: Weight

	1	2	3	4	5	∑
V_m	V_1	V_2	V_3	V_4	V_5	1
A_m	A_1	A_2	A_3	A_4	A_5	1
…	…	…	…	…	…	1
N_m	N_1	N_2	N_3	N_4	N_5	1

Step 3. Evaluating.
Calculate the conflict index: SA, SB....

$$S_A=\sum A_m \cdot V_m ,$$

$$S_B=\sum B_m \cdot V_m ,$$

……

$$S_N=\sum N_m \cdot V_m .$$

Step 4. Selecting.
Then we can draw a conclusion on the problem based on the conflict indexes. Comparing the "conflict index" SA, SB..... SN, and the key process conflict is the one with the largest index.

5. THE STRATEGY OF PROCESS INNOVATION BASED ON AHP AND TRIZ

Process design is a highly empirical activity. In order to solve the process conflict effectively, It is necessary to establish a strategy of process innovation design, namely, acquiring the constraints and requirements of the process system, then analyzing the process conflicts combining with these requirements and constraints, and identifying the key process conflict with the AHP method, then solving this conflict with TRIZ, finally evaluating the solution (Figure 3).

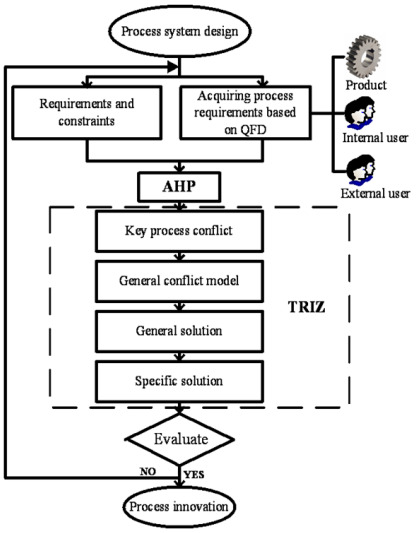

Figure 3: The Design Flow of Process Innovation

When engineers solve a conflict with TRIZ, they need to turn the specific process conflict to a general conflict model, and then obtain the general solution of this conflict model and turn it to a specific solution combined with practical conditions, and evaluate this creative concept in the end. The case of machining blade illustrates how TRIZ solves a process conflict. The blade surface has an important influence on the cutting tool's durability. In the finish machining process, workers need to grind the hardened blade of tool. And because of the complexity of blade and grinding system, dry grinding is widely used in traditional grinding process, instead of pouring cooling fluid (Figure 4).

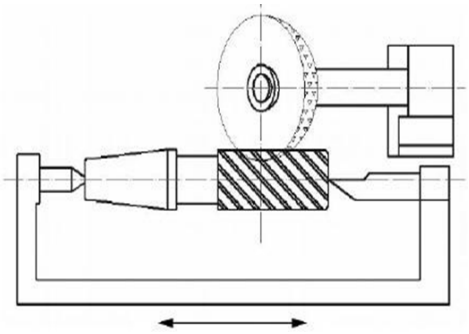

Figure 4: Traditional Grinding Process System

The quality of blade is instable, when machining the blade of tools in traditional way. In this system, high temperature, high speed, complexity and cost are all the Conflict elements of process system.

If pouring cooling fluid to the blade, the grinding process system might needs to upgrade control device and install additional isolation device and also recycle device. Engineers analyze many conflicts in the process system with the assistance of AHP method, and find that high temperature and complexity are the key process conflicts.

According to above analysis, in the finish machining process, what needed to be improved is the high temperature caused by the absence of cooling medium. However, pouring cooling medium will increase the complexity of the process system. Then applying TRIZ and combining the 39 parameters of contradiction table, process engineers can obtain a new description about this problem (Table 2).

Table 2: The New Description of Problem

Improved parameter: 31	Object-generated harmful factors
Deteriorated parameter: 36	Device complexity

Then engineers can obtain the corresponding innovation principles (01, 19, and 31) with the contradiction matrix and the 40 principles which are the innovation tools of TRIZ (Table 3). Study showed the final specific solution is that oil dilutes solid lubricant, and then infiltrates it into grinding wheel [10]. In practice, Cutting oil which evaporates easily acts as thinner, and graphite powder acts as lubricant, and then they seep into the grinding wheel. Lubricant can reduce the heat generated by the friction of grinding. At the same time the evaporating cutting oil takes away the heat in the grinding process. This solution creatively solves the problem of heat dissipation without increasing the complexity of grinding system.

Table 3: Principles and Meaning

Inventive Principles	Meaning
NO.01 Segmentation	Divide an object into independent parts.
NO.19 Periodic action	Instead of continuous action, use periodic or pulsating actions.
NO.31 Porous materials	Make an object porous or add porous elements (inserts, coatings, etc.)

6. CONCLUSIONS

Currently, process innovation design in most industries is still based on the experience of designers and engineers. In order to assist them in solving process problems effectively, a strategy is established. The research effort of this paper is to integrate AHP and TRIZ into the process innovation design. The strategy of process innovation can be summarized as follows: According to requirements and constraints, process engineers analyze the conflicts of the process system comprehensively, and identify the key process conflict with the assist of AHP, then solve the process problem efficiently with TRIZ, finally evaluate the solution. In this way, the maneuverability of applying TRIZ to solve process problems is improved. Future studies will focus on applying TRIZ to solve the process conflicts in different systems.

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