Title:
**An Attribute-based Method for Identifying Implicit Contradictions in Product Development**

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Introduction:
The evolution of a technology system or product is developed in a spiral way [1], accompanied by the resolution of contradictions [2]. Contradictions are ubiquitous, dynamic and obstruction in the product development. Contradictions mean that the change of a technical index can lead to both beneficial and harmful effects. There are technical and physical contradictions [3] of the technical system in the engineering field. Contradictions can be divided into explicit and implicit contradictions. The explicit contradiction refers to a kind of contradictions that are obviously to produce harmful results and can be solved immediately, otherwise the system cannot work normally. The implicit contradiction is one that does not have negative impacts on the system at present, but will gradually appear with the change of time, environment, or other factors. The classic TRIZ (Theory of Inventive Problem Solving) is widely used in analyzing and solving explicit contradictions, but it is not effective for implicit contradictions. The implicit contradiction in product, when it occurs, will cause great losses to users.

Because of characteristics of the strong concealment, long latency and large loss after emergence, the implicit contradiction has attracted a lot of research attentions. Some researchers used attributes of the material in identifying useful resources to improve products [4]. Attributes can produce not only useful product functions, but also harmful effects. This paper explores the implicit contradiction according to product attributes and their relations for objectivity and comprehensiveness of design solutions. Methods of Anticipatory Failure Determination (AFD) and Function/Behavior/Effect-Oriented Search (FBEOS) are used to find and solve implicit contradictions. A pipe cuter is developed as an example to illustrate feasibility of the proposed method.

Main Idea:
*Attributes*
Attributes are divided into essential and non-essential attributes. Essential attributes are the unique and important characteristics of something that is different from other things in a system or product. Functions of system components depend on the interaction of attributes, which is shown in the maintenance or change of attributes [4]. For example, the protection of a cell phone mainly uses physical attributes of the shell to maintain the function. However, attributes can also cause harmful effects between components. The function is the attribute effect of components in a product, according to user

expectations. However, with expected results there are unexpected results. Unexpected results are those where the attributes of the functional object are outside the normal range, so that the normal function becomes insufficient, excessive or harmful. For example, the inner side of automobile windshields are easy to be covered by fog in winter because the temperature attribute of glass changes the state attribute of water vapor from gaseous state to liquid. Theoretically, after determining attributes and correlations of a system and system components, potential problems or implicit contradictions can be identified in advance.

*Anticipatory Failure Determination*

Anticipatory Failure Determination (AFD) [5] was originally developed on the basis of Algorithm for Inventive-Problem Solving (ARIZ), a main method of analyzing and solving problems in the TRIZ theory. The idea of AFD enables designers to think reversely a product fail, and then find ways to avoid the failure. AFD can be used to mine the root causes of problems and predict undetected system problems, so it has advantages in assisting in mining implicit contradictions. As shown in Fig. 1, under normal circumstances, the system will develop over t(time) along the success mode $S_0$-curve. Each point in the curve represents the success mode at a certain time. In a specific context, combining with results of the attributes analysis, we can get "what will go wrong in this place?", that is, an initial event (IE) is obtained. If an IE occurs, a series of events from the IE can be expressed as a failure mode (Si). The cause of Si is the implicit contradiction in the system, which should be found and handled in advance.

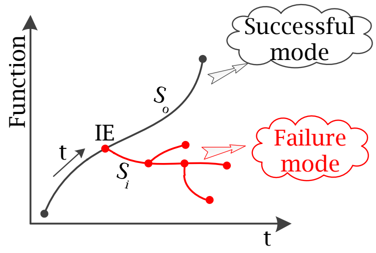


Fig. 1: Deviation of failure mode from success mode [6].

*Function/Behavior/Effect-Oriented Search*

Function/Behavior/Effect-Oriented Search (FBEOS) [7] is an effective method for searching innovative knowledge. This method, as shown in Fig. 2, first analyzes and summarizes functions of the research object, then expands behaviors and principles (effects) corresponding to the functions, and extracts keywords, finally, constructs patent search sentences according to the logical relationship of keywords, and filters valuable innovation knowledge from patents. It gradually concretizes the abstract function concept and obtains multiple possible function implementation paths to find appropriate knowledge for innovative design. In the subsequent design process, we can use the knowledge to gain design solutions.

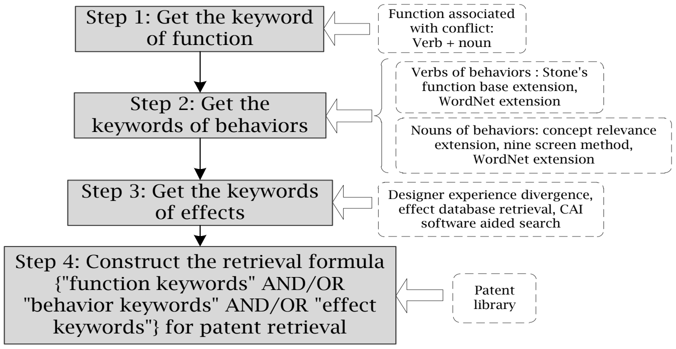


Fig. 2: Process of FBEOS.

*Theory process overview*

According to the failure modes obtained from AFD, summaries the relevant attributes that cause failure. Then, fully explore the system resources and summarized the attributes they have. Next, comparing the two types of attributes by similarity, derived system risk resources. Finally, according to the risk resources, derived the implicit contradictions of the system.

*Case study*

The pipe cutter is a widely used tool in manufacturing, construction and firefighting applications. We use the proposed method to analyze the implicit contradictions of a pipe cutter shown in the Fig. 3 [8]. This pipe cutter includes a cutting mechanism, a clamping mechanism, and a control mechanism. It is easy to operate with a flat cutting surface and can cut a wide range of materials.

Fig. 3: A pipe cutter [8].

Using the reverse thinking of AFD to find how the function can be failed, appropriate failure modes are obtained. The failure attribute group is determined based on failures in the list of 128 attributes and failure modes. By comparing the similarity of the failure attribute group to the system resource attributes, potential problems are obtained, shown in the Tab. 1.

| *Technical system* | *Failure mode* | *Failure attribute group* | *Potential problems* |
|---|---|---|---|
| Part 1 | 1.Cannot tighten or loosen the clamping knob | {humidity, viscosity, absorptivity, hardness, fluxility} | Oil or water sticks to the clamping knob and the friction of the operation rotation is too low to operate. |
| Part 2 | 2.Inability to fix and clamp the pipe | {diameter} | The machining range is limited and the pipe diameter cannot be clamped when it is outside the specified range. |
| Part 3 | 3.Saw blade thermal decay | {friction, Thermal conductivity, time, temperature} | The saw blade rubs against the pipe over a long period of time generating a lot of heat |
| | 4.The location of the pipe changes | {friction, frequency, flatness} | The base is not fixed to the floor and the pipe tends to move during the process |
| Part 4 | 5.Excessive resistance to the advance of the pipe cutter | {force, friction, pressure} | The clamping plate exerts too much force on the pipe, making it difficult to move the saw blade |
| | 6.The cutting process is not smooth | {force, frequency} | Low pressure between the clamping plate and the pipe to limit the non-essential relative movement of the pipe cutter to the pipe |

Tab. 1: Potential problems of the pipe cuter.

According to potential problems as well as new problems found when solving them, the implicit contradictions of the system are identified as shown in Fig. 4.

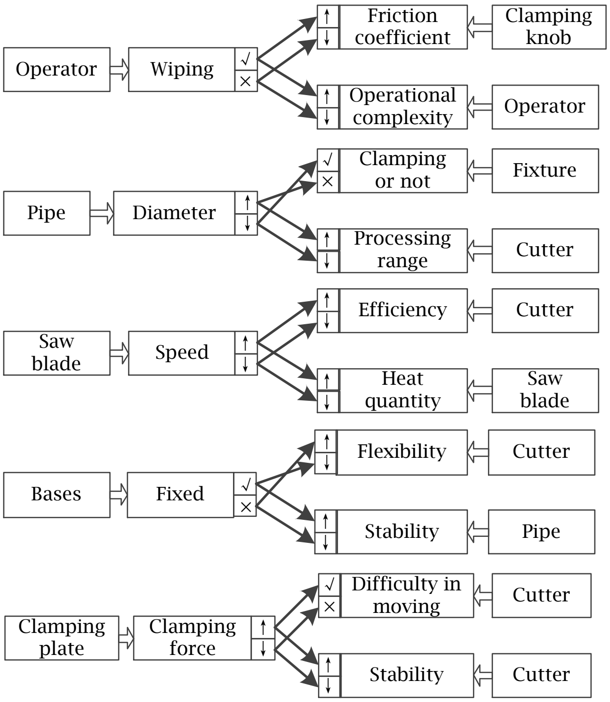


Fig. 4: The implicit contradictions of the pipe cutter.

For contradiction 1: According to the invention principle No. 28, the interaction with the object is accomplished with electric and magnetic fields as well as electromagnetic fields, the solution is to use electric clamping instead of manual operations.

For contradiction 2: According to the invention principle No. 35, changing the flexibility of the object, the solution is to change the rigid clamping plate into a flexible one.

For contradiction 3: According to the invention principle No. 28, changing a static field into a dynamic field, the solution is to add a wind cooling device.

For contradiction 4: Searching for effects on Constrain Solid and Rotate Solid, respectively, it is found that effects available are Static Friction and Axle, the solution is to add a friction wheel to help rotate the pipe when cutting to replace manual control.

For contradiction 5: Searching for patents based on the keywords {clamping pipes and dynamic} and find a patent titled An adaptive welding track for pipe ellipticity and extract the elastic feet technology. Installing elastic feet on the fixture allows the clamping force to change dynamically and not to be too tight or too loose.

Combining the above solutions results in a conceptual design solution as shown in Fig. 5. This solution resolves the above contradictions. Using flexible clamps allows the length to be changed as required. Flexible legs are fitted to each piece of the clamp to avoid excessive clamping forces. Using a motor to control the clamping and piping improves controllability and stability. Adding a wind cooling turbine prevents the saw blade from overheating.

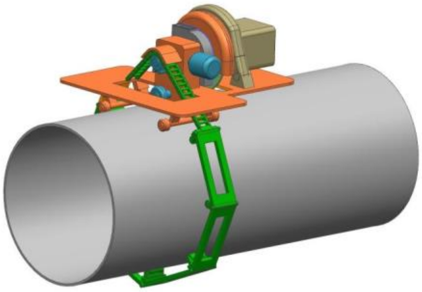

Fig. 5: Concept design proposal for the pipe cutter.

Conclusions:

To address problems in identifying implicit contradictions, this paper proposes a method for determining implicit contradictions in products based on AFD and resource attributes, which enriches the theory of contradiction resolution. The method can detect and resolve implicit contradictions effectively to improve product reliability. An analysis of the pipe cutter illustrates the effectiveness of the method. The method also provides an opportunity for companies to discover new directions of innovation for their products.

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References:

[1] Ali M, Muhammad A, Park K.: A spiral process model of technological innovation in a developing country: The case of Samsung, African Journal of Business Management, 5(7), 2011, 2874-2889. https://doi.org/10.5897/AJBM10.1370

[2] Ilevbare, I. M.; Probert, D.; Phaal, R.: A review of TRIZ, and its benefits and challenges in practice, Technovation, 33(2-3), 2013, 30-37. https://doi.org/10.1016/j.technovation.2012.11.003

[3] Dubois, S.; De Guio, R.; Rasovska, I.: Different ways to identify generalized system of contradictions, a strategic meaning, Procedia Engineering, 9, 2011, 119-125. https://doi.org/10.1016/j.proeng.2011.03.105

[4] Bai Z, Zhang S, Yu F.: Research on Trimming Method of Standard Solutions Aided Multi-level System Resource Derivation, Chinese Journal of Mechanical Engineering, 56(11), 2020, 108-120. https://doi.org/10.3901/jme.2020.11.108 (in Chinese)

[5] Silva, R. F.; Carvalho, M. A.: Anticipatory Failure Determination (AFD) for product reliability analysis: A comparison between AFD and Failure Mode and Effects Analysis (FMEA) for identifying potential failure modes, Advances in Systematic Creativity, 2019, 181-200. https://doi.org/10.1007/978-3-319-78075-7_12

[6] Xu, B.; Tan, R.: Failure Analysis of Mechanical system based on TRIZ, Higher Education Press, China, 2016. (in Chinese).

[7] Liu, LM.: Research on Key Technologies to Mechanical Radical Innovation Design Based on Technological Recombination, Ph.D. Thesis, Hebei University of Technology, Tianjin, 2022. (in Chinese).

[8] Hu, G.: Pipe cutting machine, Zhejiang: CN303692108S, 2016-06-01. (in Chinese).