Creative conceptual design ideas can be gotten with TRIZ methodology

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Abstract: The essence of the conceptual design is getting the innovative projects or ideas to promise the products with best performance. Innovation is needed more and more urgently in the furious market competition. It has been proved that TRIZ is a systematic methodology for innovation. The design of welding fixture as an engineering example is illuminated in details in this paper to show the significance and approaches of applying TRIZ into getting the creative conceptual design ideas.

Keywords: TRIZ, conceptual design, innovation, fixture

Prelude

I will always remember that afternoon when I first read the book named 'TRIZ: Theory of Inventive Problem Solving', which was placed on professor Huang kezheng's desk. Professor Huang said: 'You should read it, Charlie'. I took up the book reluctantly because I was busy in some design works. 'What I need is working hard, not reading. Is it helpful?', I thinked in my mind. But it was already midnight when I put down the book. Captured by the profound philosophy for design, I finished reading without stopping. From then on, I knew I had been on the journey to TRIZ.

I am a Ph.D. candidate with two-year TRIZ experience now and realise that everyone can be intelligent with right method. Innovation is not the patent to the genius any more. It belongs to every one of us with TRIZ thinking.

1. The urgent need of innovation

Without innovation, the increase of the wealth depends on the investment of funds and labors only. So, economy develops in a low level repeatly. We can say that the history of industrial civilization is the history that consists of the countless technology innovation and the technology innovation is the eternal theme for the development of the human being's civilization.

The ability of technology innovation determines the scales and characteristics of the economy of a country, no matter it is in west or east. Figure 1 below can illustrates this point very well. In developed country, 69 to 70 per cent of the economy progress depends on the contribution from technology. It is only 30 per cent in developing country. The percentage of the contribution of the capital to the economy progress is 61.6 per cent in China. It is only 19.7 per cent in USA. [1]

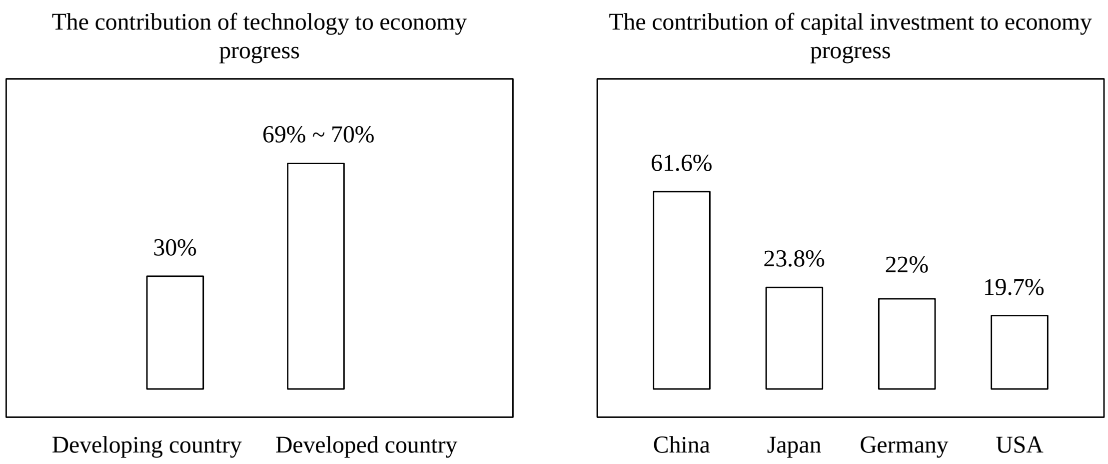

Figure 1: The contrast of contributions between technology and capital investment to economy progress

The significance of the innovation is out of question to all. But the curves showed in Figure 2 always make the readers worry about the current creativity situation in the world. Antwan Ribaut, a French psychologist, demonstrated that creativity peaked at age 18 and then decreased for the rest of a person's life. The Genrich Alshuller's research was more distressing, which pionted that creativity peak of a person was at age 14. In Boris Zlotin's study, creativity dropped quickly to a lifetime low at about age 21. [2]

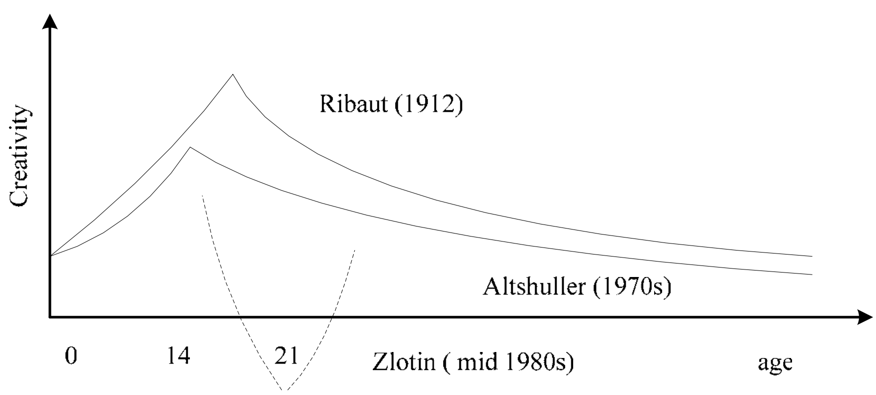

Figure 2: A comparison of the creativity curves of Ribaut, Altshuller, and Zlotin

There are many factors that are conducive to the decline of innovation. But with the development of society and technology, the products competition in the market has become furious. Generating breakthrough concepts and design projects has become the effective impulse for success to all the enterprises. It has been recognized that improving the products quality and reducing the time to the market are the keys to win. But all the facts prove that only acquiring knowledge by university education can not promise people with the breakthrough thinking. With limited time and no guide to solve problems in innovation, the engineers urgently need a systemic methodology to help them analyse the problems and get some innovative solutions quickly. [3]

It is the time for the world to pay more attention to the establishing and applying of innovation theory.

2. Introduction of TRIZ

Since its birth in Soviet Union and introduction to the world, TRIZ has developed successfully as a powerful problem solving tool, especially for product innovation design in conceptual design phase, to promise the engineers with breakthrough thinking.

2.1 The development of TRIZ

TRIZ (the Russian acronym for the theory) is the knowledge-based, systematic approach to innovation. Developed in the former Soviet Union by Genrich S. Altshuller (1926-1998) and his school, TRIZ methods are drawn from analysis of the most innovative inventions in different industries, technologies, and fields of engineering. It began in 1946 when the Russian engineer and scientist Genrich Altshuller discovered that the evolution of a technical system is not a random process, but is governed by certain objective laws. These laws can be used to consciously develop a system along its path of technical evolution.

It has been proved that TRIZ is powerful problem solving methodology through the development of itself for about 60 years. TRIZ provides people with a dialectic way of thinking, which guide us to understand the problem as a system, to image the ideal solution first and to promote the performance of products by solving contradictions. Except for the area of cience and technology, TRIZ also has been applied into the following aspects: (1) non-technical organizational problems relating to communication and personnel issues, (2) the combination with other design methodology, such as QFD and Taguchi and (3) diagnosing failure analysis problems. [4, 5, 6]

2.2 Contents of TRIZ

TRIZ involves a systematic analysis of the system to be improved and the application of a series of guidelines for problem definition. TRIZ classifies innovative problems and offers corresponding problem-solving methods for each class of problem. It can provide some useful tools for us to analyze the problem, including Ideal Final Result, Laws of Engineering System Evolution, Altshuller's Matrix, etc.

Some important notions about TRIZ are introduced briefly below.

- Contradiction

Where there's a challenging problem in an engineering system, there's a contradiction. It can be classified as technical and physical contradiction. TRIZ provides a new perspective on contradictions of the engineering system that the direct confrontation and resolution of contradictions are the keys to breakthrough inventions and ideas.

A technical contradiction is a challenge to be overcome when improving parameter “A” of the system causes parameter “B” to deteriorate. A physical contradiction appears when some aspect of a product must have two opposing states.

Contradiction Table (Altshuller's Matrix or Conflict Matrix) is a TRIZ tool to resolve the technical contradiction, which includes 39 engineering parameters describing the contradiction uniformly and 40 inventive principles offering the possible solutions. A problem can be fitted into the structure of Contradiction Table by structing a problem as a contradiction with 39 engineering parameters. Contradiction Table is a table in which the columns contain the parameters that have been degraded as a result of improving the parameter in the row. The principles are listed at the inersection of the rows and columns in order of decreasing frequency. The principles that are listed in the matrix are the most popular, from statistical analysis of patents, for solving that particular class of problem. It can be shown in Figure 3.

Degraded Feature / Feature to be improved		1	2	...	10	...	38	39
		Weight of moving object	Weight of non-moving object	...	Force	...	Level of automation	Productivity
...	...							
7	Volume of moving object							
8	Volume of non-moving object				2,18, 37			
...	...							
39	Productivity							

Figure 3. Contradiction Table (Altshuller's Matrix)

There are four Separation principles to overcome physical contradictions, which are “Separation in Space”, “Separation in Time”, “Separation within a Whole and Its

Parts” and “Separation upon Conditions”. Each Separation principle should be investigated in order to lead to the most significant breakthrough thinking.

- The ideal design

Ideality is defined as the sum of a system’s useful functions divided by the sum of its undesired effects as formula below.

$$\text{Ideality} = \frac{\text{All Useful Effects}}{\text{All Harmful Effects}}$$

The ideal design is a nonexistent system which provides the desired function without existing. It is an important notion that should be consciously applied during the process of resolving problems with TRIZ. Usually, trying to find a solution as close to the ideal design of a problem as possible offers a even more significant challenge than the technical contradiction does, which often lead to a more immense progress of the performance.

As shown in Table 1, there are six approaches to locating the ideal system.

1. Exclude auxiliary functions 2. Exclude elements 3. Identify self-service 4. Replace elements, parts, or total system 5. Change the principle of operation 6. Utilize resources

Table 1. The approaches to improve the Ideality

- Substance-Field Analysis

Substance-Field analysis is a TRIZ analytical tool for modeling problems, which means two substances and a field are the minimum needed to define a system.

It is shown in Figure 5. A function can be performed when an object (Substance 2) acts on the other object (Substance 1) by a field, a type of energy. Substances are objects of any level of complexity.

If any one of the three elements is absence, S-F Analysis indicates that the system should be completed. And the suggestion provides the people with directions for innovative thinking. If a system is a perfect one with three elements, S-F Analysis can also suggest some methods to improve the performance of the system.

There are four basic models of S-F Analysis: Incomplete system (requiring completion or a new system), Effective complete system, Ineffective complete system (requiring improvment) and Harmful complete system (requiring elimination of the negative effect).

Six different connecting lines which mean the corresponding relationships between the elements of S-F Analysis model are shown in Figure 5.

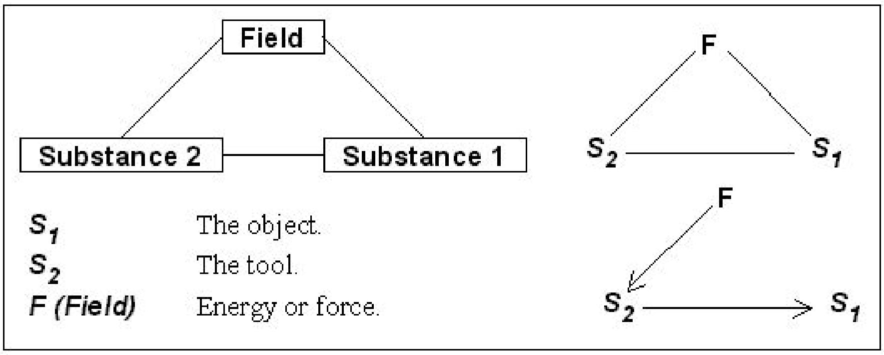

Figure 4. The model of Substance-Field Analysis

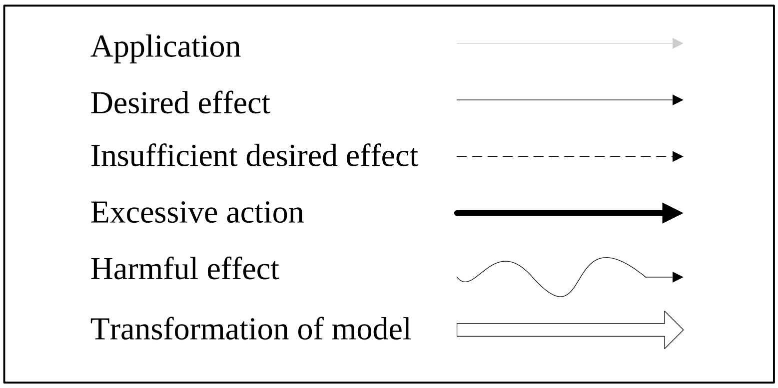

Figure 5. The different connecting lines in S-F Analysis

- ➢ 76 standard solutions

76 standard solutions are completed by G.S. Altshuller et al from 1975 to 1985. It is based on S-F Analysis to illustrate the standard conditions and methods for problem solving of different fields.

After the S-F Analysis modeling and the constraints locating, 76 standard solutions can also applied in ARIZ to attain the advanced conceptual solutions.

- ➢ ARIZ

ARIZ is a Russian abbreviation, which is the central analytical tool of TRIZ. Its basis is a sequence of logical procedures for analysis of a vaguely or ill-defined initial problem/situation and transforming it into a distinct System Conflict. Consideration of the System Conflict leads to the formulation of a Physical Contradiction whose elimination is provided by maximal utilization of the resources of the subject system. ARIZ puts all the things together in a system, including most fundamental concepts and methods of TRIZ such as Ideal Technological System (Ideal System), System Conflict, Physical Contradiction, Substance-Field Analysis, and the Laws of Technological System Evolution.

- Laws of Engineering System Evolution

The researching analysis indicates that the evolution process of an engineering system is ruled by some certain patterns. TRIZ considers every significant improvement of any design or engin-eering system to be a step in its evolution. The most important steps in the development of design and engineering systems in different fields and industries are common. They are called the Laws of Engineering System Evolution, which are based on analysis of thousands of patents and improvement of thousands of products and technologies.

According to the Laws of Engineering System Evolution, the S-curve of any product has a typical life cycle of pregnancy, birth, childhood, adolescence, maturity and decline.

A brand new design with competitive advantage can be obtained by the Laws of Engineering System Evolution, which always means great improvement over the current design. [7, 8, 9]

The common patterns of Evolution for the engineering system are listed in Table 2.

1. Evolution in Stages 2. Evolution Towards Increased Ideality 3. Non-uniform Development of System Elements 4. Evolution Towards Increased Dynamism and Controllability 5. Increased Complexity then Simplification 6. Evolution with Matching and Mismatching Components 7. Evolution Towards Micro-level and Increased Use of Fields 8. Evolution Towards Decreased Human Involvement

Table 2. Patterns of Evolution

2.3 The application of TRIZ into problems sovling

TRIZ is a powerful methodology which can provide the conceptual solutions. That means the details for the solutions should be developed and completed by other methodology.

Each tool of TRIZ has its strong suit. Before the application of TRIZ, each tool should be mastered skillfully. Which tool should be applied depends on the experience of the practitioner and the characteristics of the problem. The characteristics of each tool of TRIZ are shown in Table 3. It can help the practitioner to choose the effective method for the corresponding problem.

TRIZ can offer competitive innovation ideas. It can resolve the qiestion ‘How to resolve the problem?’. TRIZ is relatively weak at defining the problem to be resolved. QFD can translate all the requirement and responses of customers into a language that the engineers want and understand. It can offer a direction for the product improvemnet and the innovation. Taguchi's Philosophy of Robust Design can provide the designer with a methodology which can help them aim at particular strength and weakness in product's performance to promise a design to perform on target, independently of uncontrolled influences.

In order to get the whole and detail solution, it is suggested that TRIZ should be integrated with other design methodology, such as QFD and Taguchi, etc. All the tools are usually used systematically to resolve a complex problem. The general problem solving process by TRIZ is shown in Figure 6.

TRIZ tool / Characteristic	Contradiction Analysis	Ideal Design	S-F Analysis (76 Standard Solutions)	Patterns of Evolution	ARIZ
Strength	Simple and easy to use with 1021 contradictions	Offering the target to pursue for the future	Structured for different design concepts	Attaining the macroscopical directions of the system evolution	Analyze the problem with systematic thinking
Weakness	Rigidity with 39 parameters and 40 principles	Dependent on experience and knowledge	Requiring the related field background	Difficult in locating the position of the current product	Requiring the related engineering knowledge and the help of other tools
Adept at	Resolving the technical contradictions	Stimulating nontraditional thinking	Attaining the possible ideas for resolving	Identifying the design for next generation	Universal and avoiding psychological inertia

Table 3. The characteristics of TRIZ tool

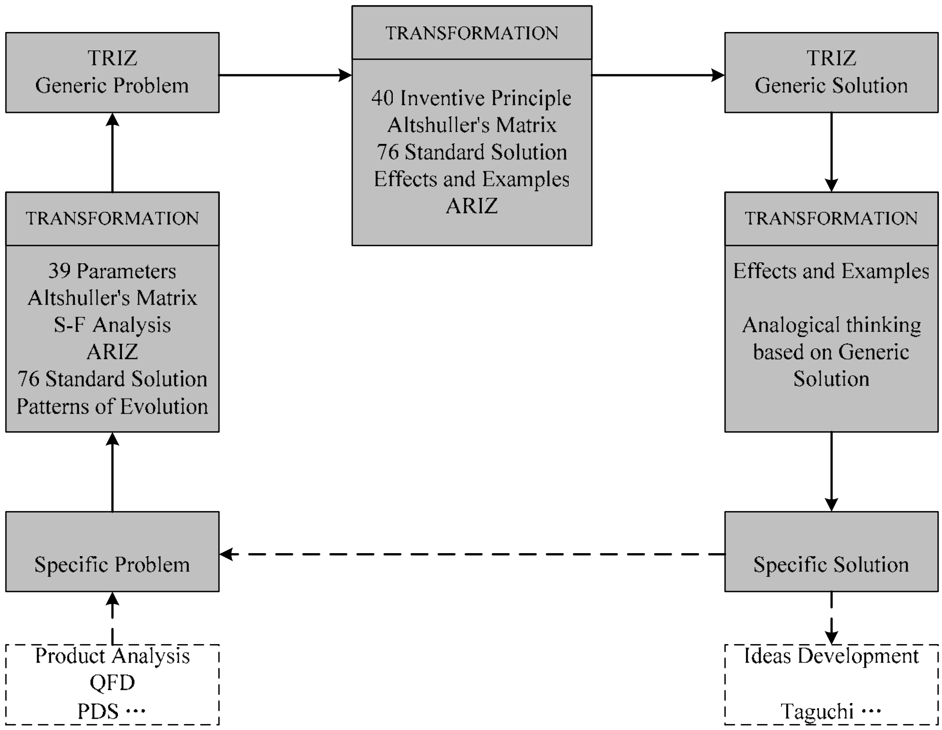

Figure 6. The general problem solving process by TRIZ

3. Case study (Resolving the design contradiction by TRIZ)

Fixture is an important device of a manufacturing system, which can promise the perfect locating and clamping for the parts or components in order to accomplish the manufacturing process. With the shortening of the product's lifecycle and the advancement of the technology, the design projects are more and more various. And it makes the design of fixtures more challenging. The quick innovative fixture design is a powerful promotion for the win of the products in market competition. But the traditional design methodology for fixture is dependent on the personal experience much. The innovative thinking is needed in the fixture design process.

3.1 The problem describing

The component used in vehicle shown in Figure 7 is the object, which is composed of 80 parts, including Part I and II. According to the design requirement, the parts contacting with the Part I and Part II are welded with them. Most of the other parts' contacting technology is welding, too. With the fixture, all the parts are required to be located and clamped together by one assembling procedure. Then all the welding technology can be accomplished in one procedure with a welding robot. It can promise the high productivity.

The material of all the parts is steel. Most of the parts are the punched sheetmetal parts with complex shapes.

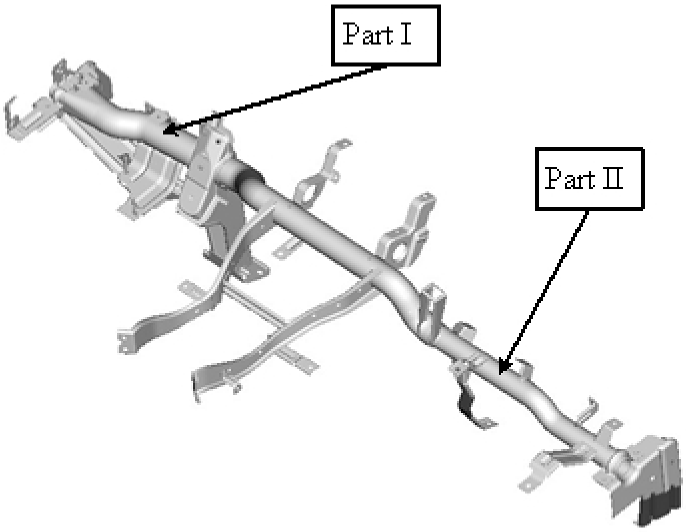

Figure 7. The component

As shown in Figure 8, the design of welding fixture is almost finished with the last problem. But it is a really obstacle to stop the advancing of the design. All the location and clamping of the other parts are attained with perfect fixture design, except Part 1 and Part 2.

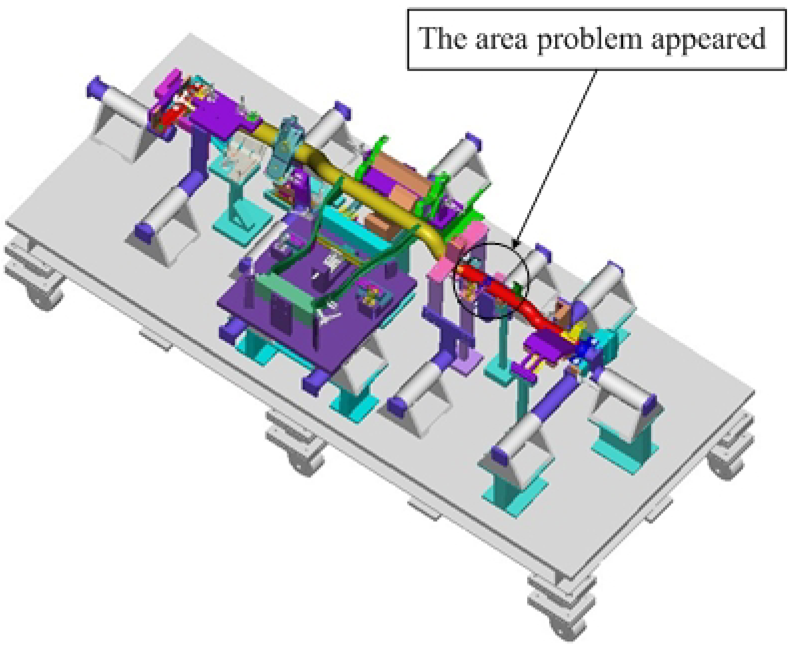

Figure 8. The welding fixture design for the components

As shown in Figure 9, it can be seen that the space around Part 1 and Part 2 is very congested. The fixtures of the parts near Part 1 and Part 2 have taken up so much room. And the shapes of Part 1 and Part 2 are unregular. All those things make it difficult to work out a fixture for Part 1 and Part 2 in the congested space with traditional thinking. It is hard to provide a traditional fixture usually including the locating elements and the mechanical clamping device that always has a relatively big volume. So it is the last obstacle to the accomplishment of the whole fixture system design. The design process has been suspended for a long time.

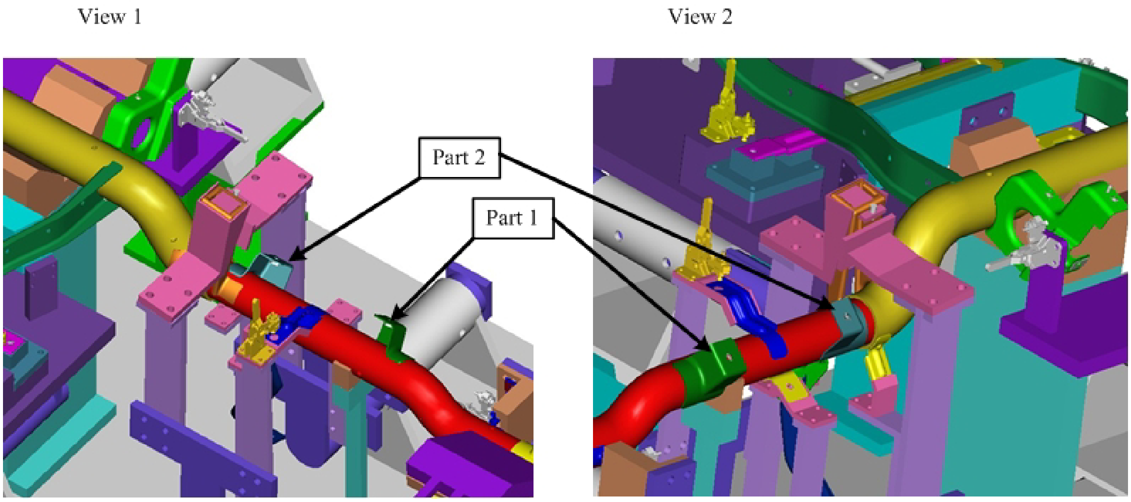

Figure 9. The zoomed in views of Parts with design contradictions for their fixtures

3.2 The problem resolving process with TRIZ methodology

Now let's illustrate the problem resolving process with TRIZ methodology.

Obviously, there is a contradiction in this technology system. The contradiction is: though the fixture of the parts needs locating elements and clamping device, the congested space can not provide the necessary room for them. It is a typical technology contradiction.

As shown in Figure 10, the most convenient and traditional locating way for Part 1 and Part 2 is by the three surfaces that are Surface 1, Surface 2 and Surface 3. This locating way is so simple that the part number of the fixture can be only one. It is shown in Figure 11. But it's hard to work out a clamping device based on the locating way above for the congested space.

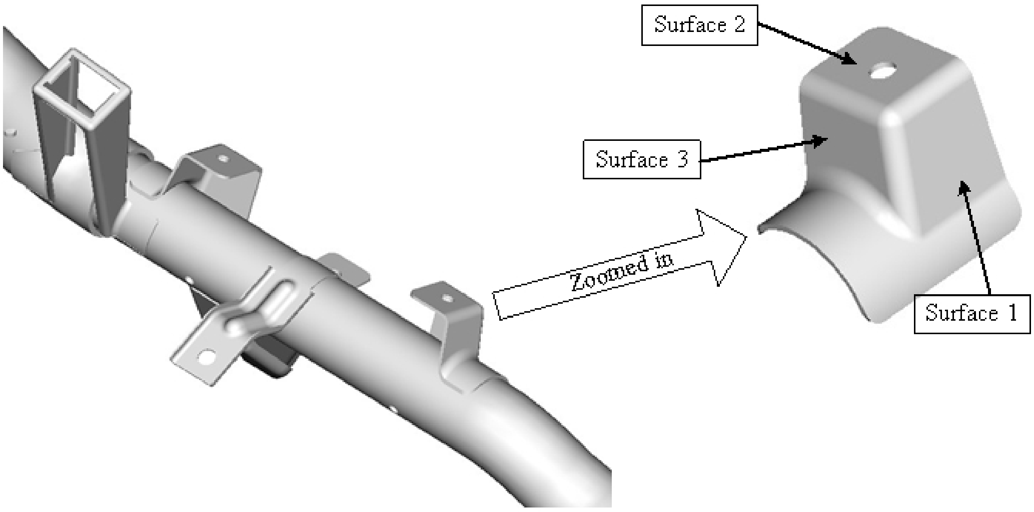

Figure 10. The surfaces for locating of the parts

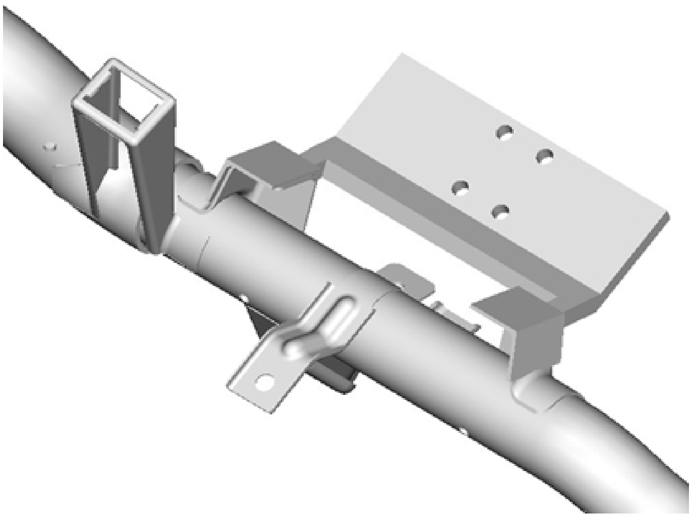

Figure 11. The simplest way for location of the Parts

The Contradiction Table (Altshuller's Matrix) is chosen to resolve the contradiction above following the general problem solving process by TRIZ shown in Figure 6.

First, the right engineering parameters should be chosen to describe the contradiction. Based on the analysis above, the engineering parameters of No. 26 and No. 33 can descibe the contradiction correctly. The corresponding inventive principles can be obtained by the Altshuller's Matrix. It can be seen in Table 4.

Contradiction identification	To adopt the traditional locating way and need the clamping device (Improved)	Can not adding the clamping device for the congested space (Degraded)
The chosen engineering parameters describing the contradiction	No. 26 Amount of substance (The simple locating way with few parts of fixture)	No. 33 Convenience of use (Can not accomplish the 'clamping' action)
The corresponding inventive principle	No. 35 No. 29 No. 25 No. 10	
To resolve the problem with the inventive principle	No. 35 Transformation Properties No. 29 Pneumatic or Hydraulic Construction No. 25 Self Service - make an object serve itself by performing auxiliary helpful functions. - use waste resources, energy, or substances. No. 10 Prior Action	

Table 4. Resolving the problem with corresponding inventive principle

Next, from the four recommended inventive principles, No. 25 'Self Service' is chosen to be considered emphatically because of the most possibility of relativity to the problem. One of the important meanings of 'Self Service' is 'make an object serve itself by performing auxiliary helpful functions'. It is the generic solution to the problem. In this case, it means that 'the locating structure shown in Figure 11 should serve itself by performing 'Clamping' function'. How can the locating structure produce a force to perform 'Clamping' action?

Then, Invention Machine Co.'s TechOptimizer is used to look for the correct science effect to meet the requirement. Effects module is applied during this process. Among all the science effects, which can produce 'force', magnetic force is the right way that is needed in 'Clamping' action because the magnetic force is a kind of field force, which makes the 'Clamping' device with simple structure.

Finally, the solution idea can be gotten. Magnetic force is used to clamp the parts. The process of getting the solution idea by TRIZ thinking can be seen in Figure 12.

In order to get a controllable operation, electromagnet is configured with a controllable circuit. The final conceptual design can be seen in Figure 13. It shows a good effect in practice.

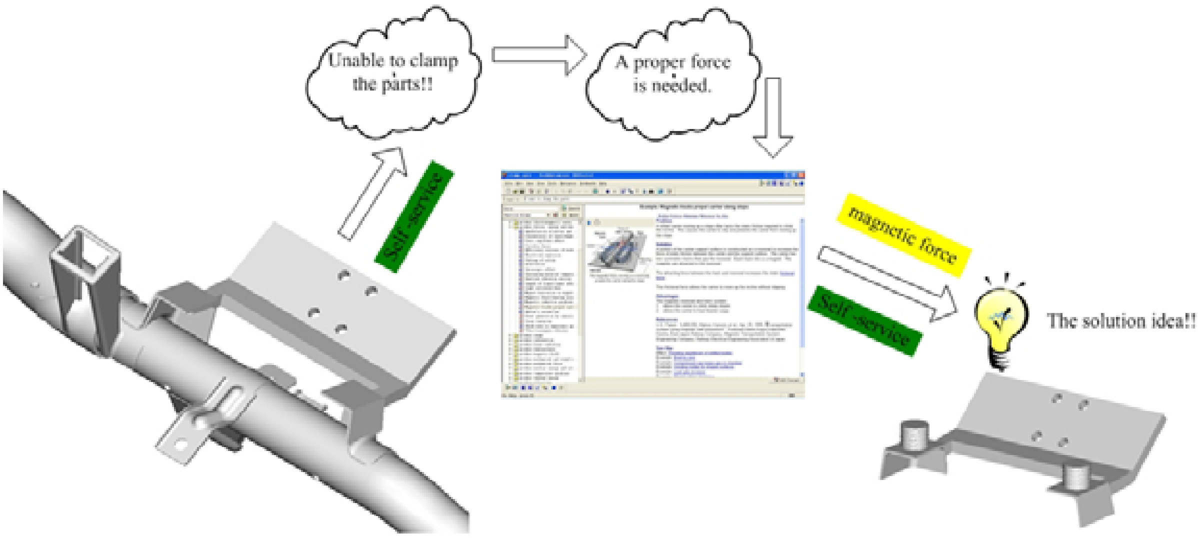

Figure 12. The process of getting the solution idea by TRIZ thinking

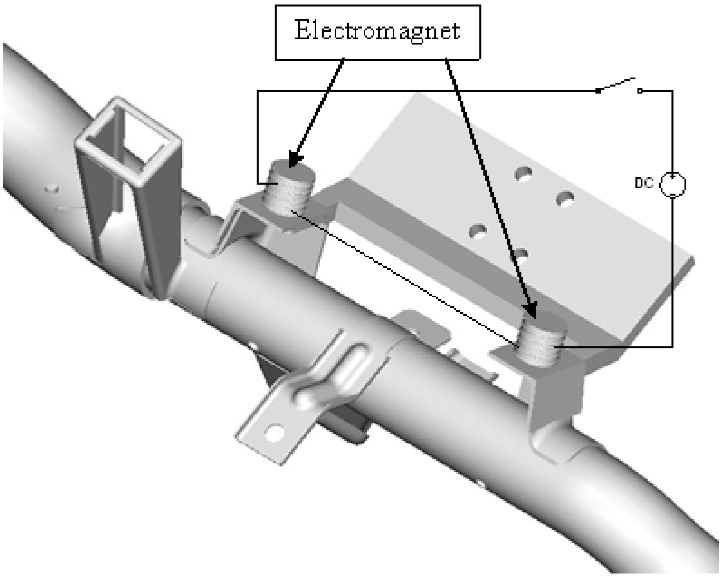

Figure 13. The final conceptual design
of the fixture for Part 1 and Part 2

4. Conclusion

TRIZ is a powerful tool when the innovative idea is needed. It can help the engineers to get an innovative conceptual idea for the design project by following the innovation roadmap with some tool kits provided by TRIZ. TRIZ is a treasure including the correct methodology and related knowledge base. As Toru Nakagawa stated, “TRIZ is the recognition that technical systems evolve towards the increase of ideality by overcoming contradictions mostly with minimal introduction of resources. TRIZ provides a dialectic way of thinking, to understand the problem as a system, to image the ideal solution first, and to solve contradictions.” [10]

As a creative problem solving methodology, TRIZ should be advocated and popularized in the world.

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