

# Quality Tools and TRIZ Based Quality Improvement Case Study at PT 'X' A Plastic Moulding Manufacturing Industry

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**Abstract.** Theory of Inventive Problem Solving (TRIZ) is a creative encouraging problem solving method. TRIZ is prepared by Altshuller for product design. Altshuller prepared contradiction matrix and suggestion to solve contradictions usually occur in product design. This paper try to combine TRIZ with quality tools such as Pareto and Fault Tree Analysis (FTA) to solve contradiction in quality improvement problem, neither than product design problem. Pareto used to identify defect priority, FTA used to analysis and identify root cause of defect. When there is contradiction in solving defect causes, TRIZ used to find creative problem solving. As a case study, PT 'X', a plastic molding manufacturing industry was taken. PT 'X' using traditional press machine to produce plastic thread cone. There are 5 defect types that might occur in plastic thread cone production, incomplete form, dirty, mottle, excessive form, rugged. Research about quality improvement effort using DMAIC at PT 'X' have been done by Fory Candra. From this research, defect types, priority, root cause from FTA, recommendation from FMEA. In this research, from FTA reviewed, contradictions found among causes troublesome quality improvement efforts. TRIZ used to solve the contradictions and quality improvement effort can be made effectively. **Keyword** : quality improvement, TRIZ, FTA, manufacture

## 1. Introduction

Theory of Inventive Problem Solving (TRIZ) is a systematic way to find innovative solutions for researches, engineers, employees and decision makers [1]. Altshuller initiated study at 1948 and see that a great number of inventions complied with a relatively small number of basic solution patterns. Altshuller concluded that the vast majority of new inventive problems could be solved by using previous experience and provide TRIZ [2].

The underlying concepts of TRIZ methodology are ideality, contradiction and resources. The term "technical contradiction" is a key to the TRIZ concept. A problem is solved only if technical contradiction is recognized and eliminated [3]. The most important components in TRIZ contradiction matrix and 40 inventive principles [4], that applied in Contradiction Table, that help designer to eliminated contradiction by giving general suggestion of engineering parameters. TRIZ initially established and mostly used in solving contradiction in product design problem..

This research, use TRIZ method that usually implemented in product design, to improve quality and combine it with other quality tools (Pareto Diagram, FTA and FMEA). Quality tools used to identify the quality problem and problem cause, TRIZ used to solving contradictions occur among

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causes. An empirical case study about quality improvement is taken to explain the method implementation.

PT 'X' is a plastic moulding industry that use traditional press machine to produce plastic thread cone. PT 'X' suffering from high number of defective product that cause inefficiency and high quality cost. Research to identify defects, causes and also recommended action to increase quality have been done by Fory Candra [5]. It's found that there are 5 defect types that might occur in plastic thread cone production, incomplete form, dirty, mottle, excessive form, rugged. From Pareto Diagram, it's found that the first defect priority to improve is incomplete form defect, second priority is mottle defect, next priority dirty, excessive form and rugged sequently. From the research fault tree analysis (FTA) identify that there are some causes of defectives that must be eliminated to reduce defects, and from FMEA improvement suggestion and recommendation are generated.

But from further analysis of the FTA, it's found that there are contradictions among causes that makes defects causes elimination effort can't be optimal, because reducing one cause can increase the other and vice versa. In this research the contradictions will be solve using TRIZ method. This research also a case study to experience using FTA as basis to find contradiction to be solve by TRIZ to reduce or eliminate defects and improve product quality.

## 2. Theoretical Background

This research mainly based on FTA and TRIZ generated in earlier research. Fault Tree Analysis used to identify defects causes. The purpose of fault tree analysis is to identify failure pathways, both physical and human, that could lead to an identified fault event [6] The fault tree includes only the fault events and logical interrelationships that contribute to the top event [6].

Theory of Inventive Problem Solving (TRIZ) used to solve contradiction that occur among the defect causes. TRIZ is developed by G. S. Altshuller in Rusia 1946. The main axiom is that evolution of technological systems is governed by objective laws, which Altshuller called Laws of Technological System Evolution. They can be used instead of blind search to consciously develop technological systems (or to solve problems). To formulate these, Altshuller analyzed 400,000 invention descriptions from world-wide patent databases. He selected and examined the most effective solutions--the breakthroughs.

TRIZ methodology offers a well-structured and high-power inventive problem-solving process [7] The underlying concepts of TRIZ methodology are ideality, contradiction and resources. The term "technical contradiction" is a key to the TRIZ concept. A problem is solved only if technical contradiction is recognized and eliminated [3]. The most important components in TRIZ contradiction matrix and 40 inventive principles [4], that applied in Contradiction Table, that help designer to eliminated contradiction by giving general suggestion of engineering parameters.

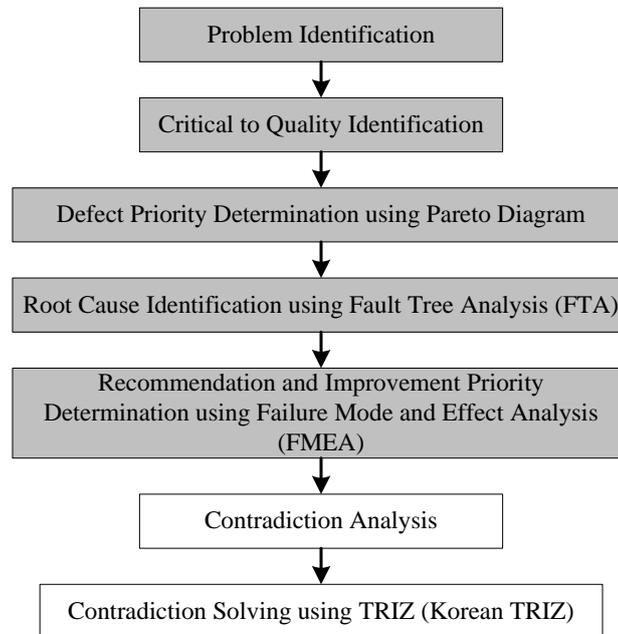
In Korea Triz implement for the first time at 1997 at LG and Samsung. Reference [8] introduce the Practical Triz (4 Step Problem Solving -TRIZ) as very simple, very easy learn, and qualified method. This 4SPS-TRIZ is simpler way to use TRIZ method than Altshuller's first introduce, but still have same base, contradiction matrix and principles.

## 3. Research Methodology

The objective of this research is to reduce or eliminate thread cone product defects by eliminating the causes. From FTA analysis, there are contradictions among the causes that must be solved in order to make effective improvement.

The result of earlier research about plastic thread cone quality improvement is used as base for this research. In the previous research, critical to quality are identified, defect percentage counted, Pareto analysis constructed to determine defect that must be priority to eliminate, preliminary FTA constructed to find defect root cause and Failure Mode Effect Analysis (FMEA) have been identified to determine improvement priority. PT 'X' produce higher defective percentage product than company's target. Pareto Chart constructed in earlier research identified there are 5 major defects. From further analysis from FTA that have been generated, there are contradictions among def ects

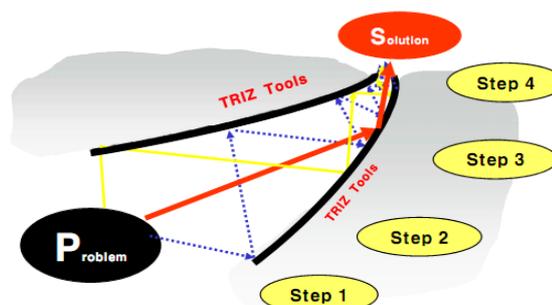
causes. This contradiction have to be solve in order to make quality improvement effort can be done effectively. The research steps shown in figure 1.



**Figure 1.** Research Methodology

To solve the contradictions, TRIZ method will be used, because TRIZ table and principle that have been generated by Altshuller, can help engineer or researcher to be creative and reduce trial and error in solving any problem or contradiction. In this research, Practical TRIZ steps (4SPS-TRIZ) developed by Kim Ho Jong [8] subject to Kim's book : "Creativity Science of Practical TRIZ : Basic", 2007 in Korean, and also known as Korean TRIZ. Practical TRIZ that have been successfully implemented in several industries in Korea.

This method chosen because it's simpler than 7 Steps TRIZ introduced earlier. Four Steps of Korean Triz are as follow. Step 1 : New problem definition, to obtain list of problem that become consideration in trolley design. Step 2 : Picturing of the boundary zone in the problem, as an effort to be focus and also to identify interaction between elements. Step 3 : Physical contradiction (deduction and analysis). Step 4 : Solution and evaluation. In this step, design will be finalized and evaluated. The model of this steps shown in figure 2.



**Figure 2.** Four Steps Problem Solving – TRIZ [8]

#### 4. Result and Discussion

Research steps followed the 4SPS-TRIZ, begin with problem definition. The research object is plastic molding manufacture that produce plastic thread cone. This company produce plastic thread cone with traditional and manual process and machines. Nowadays the company has 65 machine, called pressing machine.

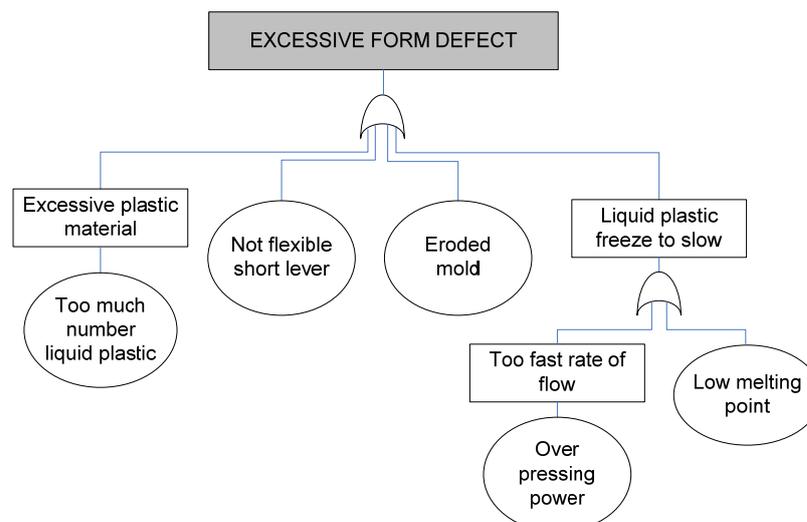
Raw material is plastic ore. Plastic ore heated in a ladle by a gas stove and become liquid plastic in certain temperature. If it's necessary, liquid plastic will be added by coloring powder and stirred. From the ladle, liquid plastic will be pressed to a mold. Pressing process used manual process, operator press a lever that will push liquid plastic entering a mold and molding process done. The plastic thread cone removed from the mold, placed at cooling place. After the thread cone cool enough, the process continue to cutting process to remove excess plastic, continued with quality control process and packing process.

##### 4.1. New Definition of Problem

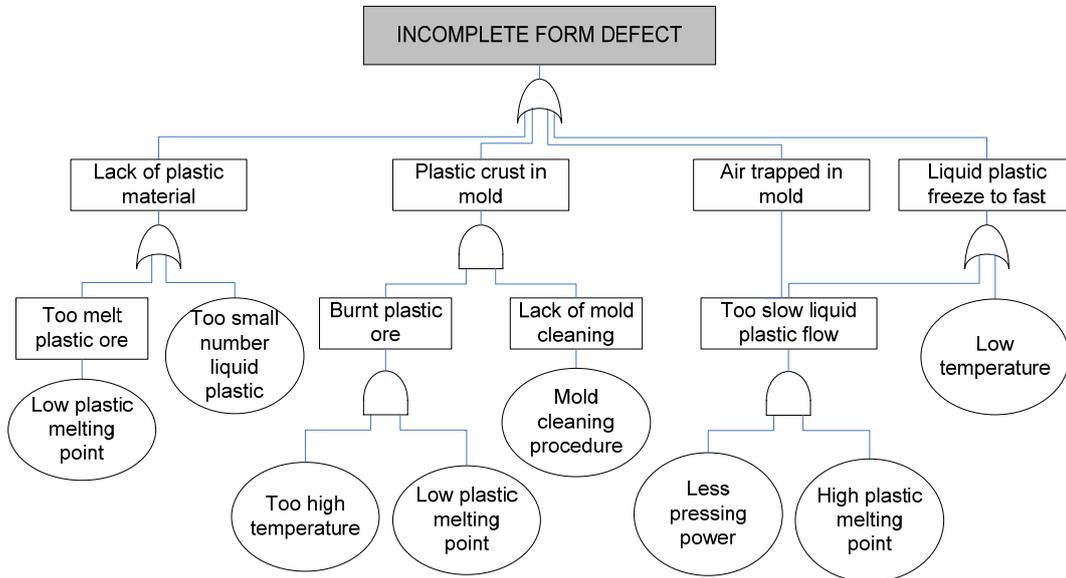
The main objective of this this research is to improve quality by reduce or eliminate defects causes. From earlier research, it's found that there are 5 defects : incomplete form, dirty, mottle, excessive form, rugged. Incomplete form defect is plastic thread cone condition that not complete, there are some shortage in the product. This defect cause thread cone can't be use. Dirty defect is condition that the plastic polute by dirt. Mottle defect is condition that thread cone product becoming mottle, the color of the product not homogen. Dirty and mottle defect cause bad looking cone. Excessive form defect is condition when there are excessive plastic around the product, this defet cause cutting rework to fix it. Rugged defect is condition when there are some rugged surface at thread cone, this defect cause smoothing rework to fix.

Figure 3 to figure 7 shown FTA for each defects that identify the causes of each defects. From earlier research, some improvement effort have been identified to eliminate causes, there are :

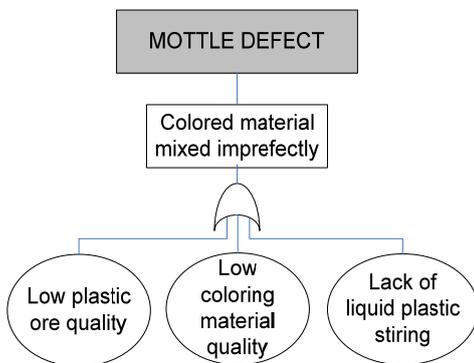
- *Mixed color pasta completely*, determine the mixing procedure and time
- *Remove crust and clean mold periodically*, determine cleaning procedure and schedule
- *Clean workstation periodically*, determine cleaning procedure and schedule
- *Determine the proper temperature and pressing power using experimental design*
- *Check and change mold periodically*



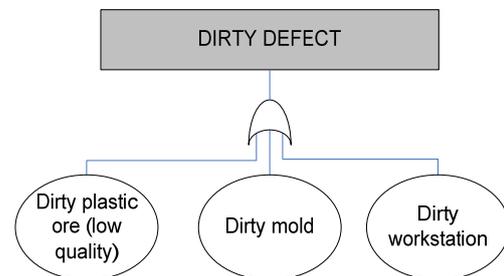
**Figure 3.** Excessive Form Defect Fault Tree Analysis



**Figure 4.** Incomplete Form Defect Fault Tree Analysis



**Figure 5.** Mottle Defect Fault Tree Analysis



**Figure 6.** Dirty Defect Fault Tree Analysis

FTA further analysis done to trace new problem.

- (1) From FTA, it can be seen that bad or low quality plastic ore become cause for several defects. High quality plastic ore is needed to produce high quality product, because it can reduce or eliminate mottle, rugged and dirty defect that cause by the bad quality plastic ore. High quality plastic ore have more homogeneous composite and have highest quality plastic substances that can easily proceed. High quality plastic ore have higher melting point that prevent plastic liquid too melted that can reduce incomplete form defect. High plastic ore melting point also prevent burnt plastic liquid that can sticking in the mold and also can cause incomplete form defect. But high melting point plastic ore can cause liquid plastic temperature too low that can make liquid plastic temperature cooling too fast that cause liquid plastic thicken and freeze too fast also that cause incomplete form defect. Using high quality plastic ore, can ease the molding operation and raise product quality but on the other hand, it's need higher temperature to melt the plastic ore, that surely need more energy that increasing production cost.

- (2) The press machine is manual pressing power. To fill the mold properly need proper pressing power. Too high pressing power can cause excessive form defect and too low pressing power can cause incomplete form defect. The thread cone design can also affect mold filling. A design can make plastic liquid difficult to fill properly but other design can make it easier. In this company, the form of thread cone is as in figure 8.

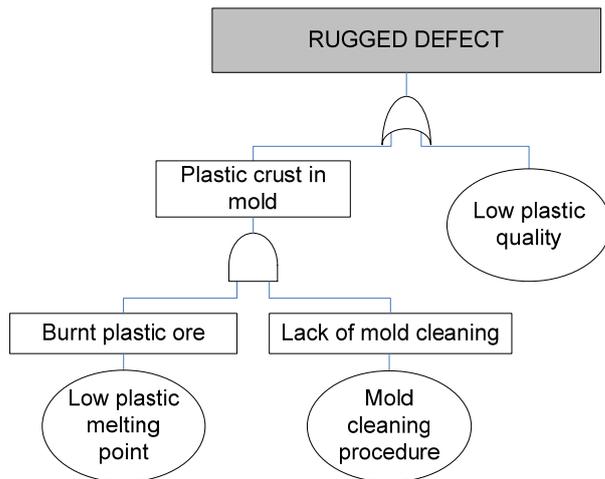


Figure 7. Rugged Defect Fault Tree Analysis



Figure 8. Plastic thread cone design

It can be conclude that new problems that can identified are :

- (1) Problem to determine degree of plastic ore quality.
- (2) Problem to determine new thread cone design.

4.2. Picturing the boundary zone in the problem

Element-Interaction Model for each problem can be seen in Fig. 9 to Fig 10. These model are result from FTA analysis and developed to find characteristic that contradict and solve.

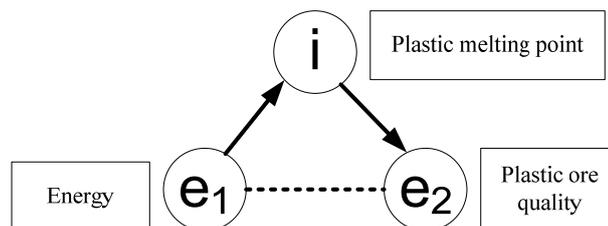


Figure 9. Element-Interaction Model for Energy and Plastic Ore Quality

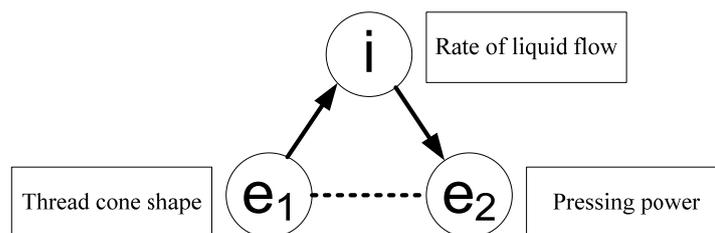


Figure 10. Element-Interaction Model for Thread Cone Form and Plastic Ore Quality

#### 4.3. Physical Contradiction Analysis

The key concept of TRIZ is “technical contradiction” [8]. According to TRIZ, a problem is solved only if technical contradiction is recognized and eliminated.

From further analysis of the FTAs it can be conclude that there are contradictions. Contradictions that occur in this quality problems are :

- (1) Contradiction between waste of energy to melt high quality with high melting point plastic ore versus ease of molding process with high quality product. Refer to TRIZ matrix, we match high plastic ore quality, that means high plastic melting point, that means lot of energy needed, to waste of energy in TRIZ matrix and ease of molding process matched to ease of operation.
- (2) Contradiction between thread cone design versus pressing power. Refer to TRIZ matrix, thread cone design matched to shape in TRIZ matrix, and pressing power matched to power.

Reference [9] and [10] tabulized contradiction and suggestion to eliminate, based on 40 inventive principles by Altshuller (1956).

Contradiction (1) waste of energy vs ease of operation, suggestion from TRIZ matrix :

- Principle (35) Parameter changes: (a) change an object's physical state, (b) change the concentration or consistency, (c) change the degree of flexibility (d) change the temperature
- Principle (32) Changing colour or optical properties : (a) change the colour of an object or its surroundings, (b) change the degree of translucency of an object or processes which are difficult to see, (c) use coloured additives to observe objects or processes which are difficult to see, (d) if such additives are already used, employ luminescent traces or tracer elements
- Principle (1) Segmentation : (a) divide an object into independent parts, (b) make an object sectional, (c) increase the degree of an object's segmentation

Contradiction (2) shape vs power, suggestion from TRIZ matrix :

- Principle (4) Asymmetry, (a) replace a symmetrical form with an asymmetrical form, (b) if an object is already asymmetrical, increase the degree of asymmetry
- Principle (6) Universality, multi-functionality : (a) combine in space homogeneous objects or objects destined for contiguous operations, (b) combine in time homogeneous or contiguous operations
- Principle (2) Extraction, separation, removal, segregation : (a) extract (remove or separate) a "disturbing" part or property from an object, or (b) extract only the necessary part or property

Table 1. shown the problem, contradiction, solving suggestion found from contradiction matrix and 40 TRIZ principle, and contradiction analysis as suggestion for plastic molding process improvement, to eliminate defects causes.

#### 4.4. Solution

There are 6 suggestion can be made, base on idea from TRIZ 40 principles and any description and example in reference [11] :

- (1) Use higher quality plastic ore to reduce various type of defects. Using higher plastic ore can produce higher quality of plastic thread cone product, because the defects can be reduced or eliminated.
- (2) Change heating device to reach high temperature more quickly with lower energy consuming. In existing, the company use liquid petroleum gas stove to melt the plastic ore, make it too slow to reach high temperature and also use much energy. The suggestion is to use electric stove that can produce higher temperature that can save energy and time.
- (3) Add dirt and rugged material filter before plastic liquid enter the mold. If lower quality plastic ore still used, a steel filter can be added to filtrate dirt and rugged material substance in liquid plastic before entering mold. This filter can reduce dirt and rugged defect.
- (4) Add sign at the pressing lever to standardize pressing power. The molding process is manual process, pressing power determined by operator pressing power. Operator press the levere at the machine to blow liquid plastic to enter mold by pressing a lever. Add a sign to show how far operator must press the lever, so pressing power can be standardized.

**Table 1.** Contradiction Analysis and Solving Suggestion

PROBLEM	CONTRADICTION		SOLVING SUGGESTION	SUGGESTION
Problem of determine plastic ore quality	1	Waste of energy vs ease of operation	35. Change parameter	Use higher quality plastic ore to reduce various type of defects
				Change heating device to reach high temperature more quickly with lower energy consuming
				Add dirt and rugged material filter before plastic liquid enter the mold
			32. Changing color or optical properties	Add sign at the pressing lever to standardize pressing power
			1. Segmentation	Segment market to segment product quality and plastic ore quality
Problem of determine new thread cone design	1	Shape vs power	4. Asymmetry	Make asymmetry design to ease liquid plastic fill mold completely
			6. Universality, multi-functionality	
			2. Extraction, separation, removal, segregation	Remove a part of thread cone

- (5) Segment market to segment product quality and plastic ore quality used. The company can make market segmentation to determine different product quality for each segment. If a segment need high product quality, company can use higher plastic ore quality and priced higher. For other segment, company can use lower plastic ore quality and priced lower.
- (6) Make asymmetry design to ease liquid plastic fill mold completely and remove a part of thread cone. The existing plastic thread cone design is as in figure 8. The cone can be redesign as in figure 11. A part of thread cone removed, and the design become asymmetric, but with this design, molding process easier to prevent incomplete form defect. Another benefit gain with this design is plastic material saving that automatically save production cost.

**Figure 11.** Plastic Thread Cone Design Suggestion

## 5. Conclusion

From this research we can conclude that TRIZ can be combined effectively with quality managements tool, like Pareto Diagram, FTA, FMEA to solve quality problems. In some cases, there are contradiction between causes.

FTA and TRIZ can be used together to solve the contradiction enable make effective solution to reduce or eliminate defect causes.

TRIZ is not greatest tool that always can solve every problem, but TRIZ can help to flexibly explore creativity to solve problems for many reasons, conditions, and objectives, not only for product design purpose, but also to solve quality problems. Using TRIZ must accompanied by creativity of researcher to generate proper suggestion.

For further research, TRIZ can be combined with other well known tools and other reasons, also can be research about experimental design to determine the proper plastic ore quality, pressing power, temperature.

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