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QUALITY IMPROVEMENT EFFORT USING TRIZ METHOD CASE STUDY IN CV 'X', A METALCASTING INDUSTRY

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ABSTRACT
CV 'X' is a metalcasting company located in Klaten, Central Java. The problem CV 'X' faced is high percentage of defective brake block metallic product about 8%, higher than expectation about 3%. To reduce defectives, defect cause must identified and then eliminated. From fault tree analysis, it's found that there are some cause of defect that are contradicting. Fix one cause can make other cause worse. So it's difficult to reduce or eliminated the cause dramatically, because there are other cause increasing. In this research, TRIZ method used to solve the contradiction, so as both cause that are contradicted can reduced or eliminated.

***Keywords**: Defective, Fault Tree Analysis, TRIZ.*

1. INTRODUCTION

CV 'X' is a metalcasting company located in Ceper village, Klaten, Central Java. This company begins the metalcasting production with traditional method, tungkik furnance. CV 'X" try to improve their process and change the tungkik furnance with cupola furnance at 1997, and at 2004, the cupola furnance change with electricity induction furnance.

The problem CV 'X' faced is high percentage of defective brake block metallic product, about 8%, higher than their expectation about 3%. Brake block metallic product is braking device for train, one of most important product the company produce. Earlier research about this product quality improvement have been done by by Desiana & Wirawan (2011), it's found that the defectives are consist of 10 type of defectives, and from Pareto chart, 6 major defectives identified : shrinking, fall out mold, improper flow, air cavity, pushed up, swell. In the earlier research From fault tree analysis (FTA) also used and found that there are some causes of defectives that must be eliminated to reduce defects. But from further analysi of the FTA, we found that there are contradictions occur among causes that makes defects causes elimination can't be optimal, because reducing one cause can increase the other and vice versa. In this research the contradictions solve used Triz method. This research also a case study to experience using FTA as basis to find contradiction that TRIZ solved in effort to reduce or eliminate defects.

2. THEORETICAL BACKGROUND

This research mainly based on FTA and TRIZ. Fault Tree Analysis 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. (Kolarik, 1995). The fault tree includes only the fault events and logical interrelationships that contribute to the top event. (Kolarik, 1995).

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 laws, Altshuller analyzed some 400,000 invention descriptions from different fields of engineering gleaned from world-wide patent databases. He selected and examined the most effective solutions--the breakthroughs (Fey and Rivin, 1996).

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TRIZ methodology offers a well-structured and high-power inventive problem-solving process (Chun & Chin, 2007).

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 (Livotov, 2008). The most important components in TRIZ contradiction matrix and 40 inventive principles (Domb, 1997), 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 (Hyo, 2003). Ho Jong Kim 2010, 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 METHOD

The objective of this research is to reduce or eliminate brake block metallic product defects by eliminating the causes. From FTA, analyzed there are contradictions among the causes that must be solved.

Earlier research about quality improvement of brake block metallic product have been done already by Desiana and Wirawan 2011. In the earlier research, The result of earlier research used as base for this research. In the previous research, critical to quality, defect percentage, Pareto analysis, preliminary FTA and Failure Mode Effect Analysis (FMEA) have been done. CV 'X' produce too many defective percentage product higher than the company's target, the control chart shown uncontrolled process, Pareto Chart identified there are 6 major defects. From further analysis from FTA that have been generated, there are contradictions among defects causes. This contradiction have to solve in order to reach optimum defects reduction.

To solve the contradictions, Triz method will be used, because Triz table and principle that have been generated can help engineer or researcher to be creative and reduce trial and error in solving any problem or contradiction. In this research, we use Practical TRIZ steps (4SPS-TRIZ) developed by Kim Ho Jong (Kim, 2010) subject to Kim's book : "Creativitity 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 choosen 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 Fig. 1.

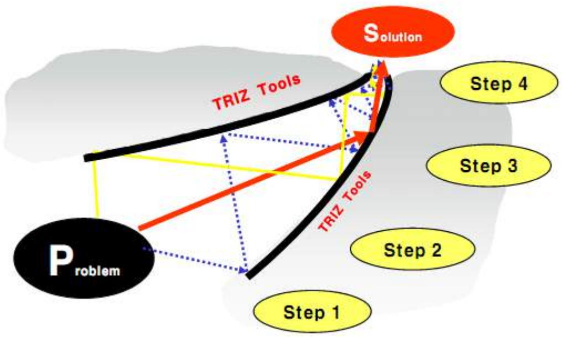

Figure 1. Four Steps Problem Solving – TRIZ (Kim Ho Jong, 2010)

4. RESULT AND DISCUSSION

Research steps followed the 4SPS-TRIZ, begin with problem definition

4.1. Problem Definition

The main objective of this this research is to reduce or eliminate defects by eliminate defects causes. According to the earlier research there are 6 defects : shrinking, fall out mold, improper flow, air cavity, pushed up, swell. Shrinking defect occur when the size of metal casting product smaller than it should be. Fall out mold occur when the sand mold fall out and cause metal castng product non proper and be defective product. Improper flow occur when liquid metal flow improperly in cavity and form improper form. Air cavity defect occur when there are air cavity in metal casting product.

Pushed up defect occur when sand mold pushed up by hot air trapped in sand mold cavity and make improper metal casting product. Swell defect occur when sand mold cavity swollen because of hot air pressure and make metal casting product swell.

Fig. 2 to fig. 7 shown FTA for each defects that identify the causes of each defects. From further analysis, there are problems to be solve, that there are several contradiction among causes that make causes elimination becoming difficult.

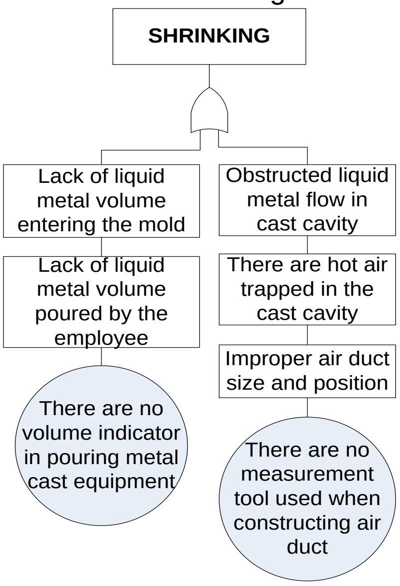

Figure 2. Shrinking Defect FTA

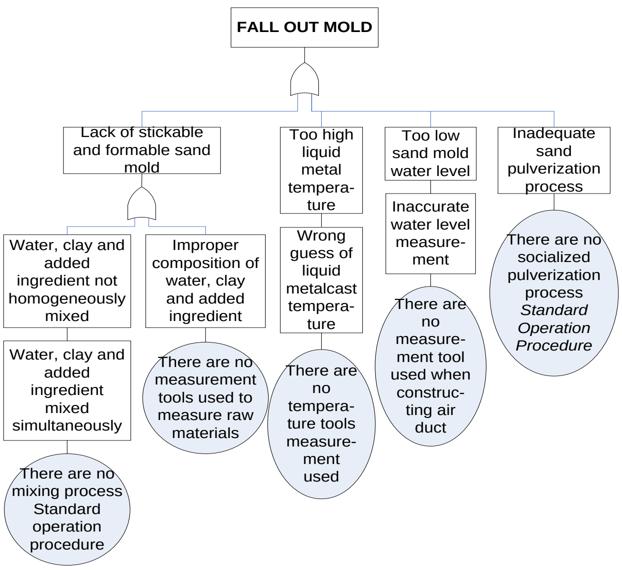

Figure 3. Fall Out Mold Defect FTA

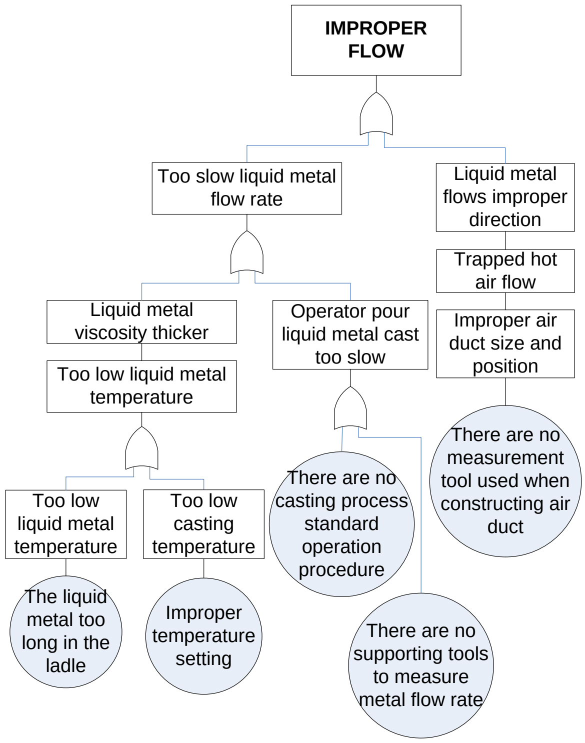

Figure 4. Improper Flow Defect FTA

4.2. Picturing the boundary zone in the problem

Element-Interaction Model for each problem can be seen in Fig. 8 to Fig 9. These model are developed to find characteristic that contradict and solve.

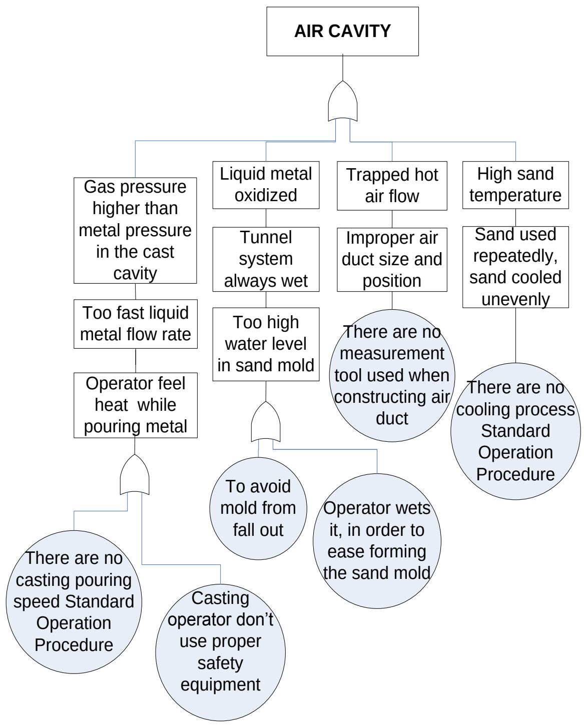

Figure 5. Air Cavity Defect FTA

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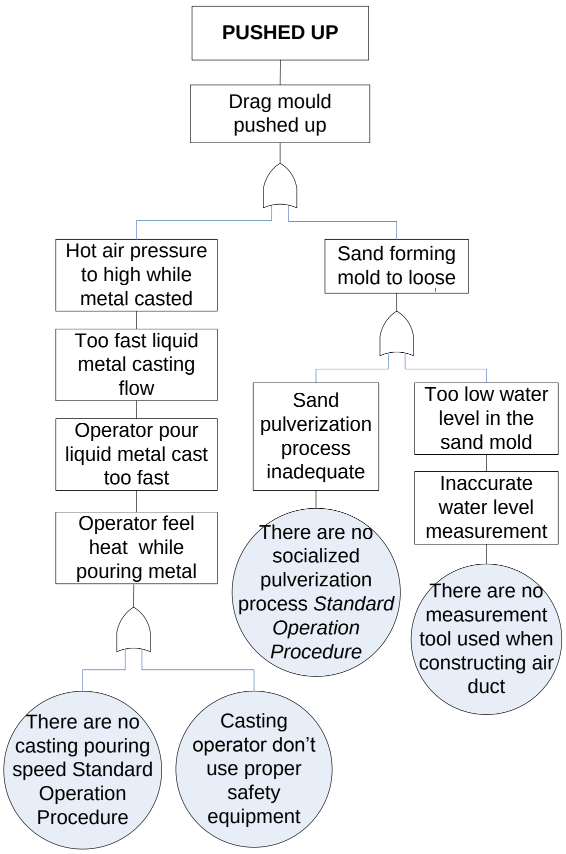

Figure 6. Pushed Up Defect FTA

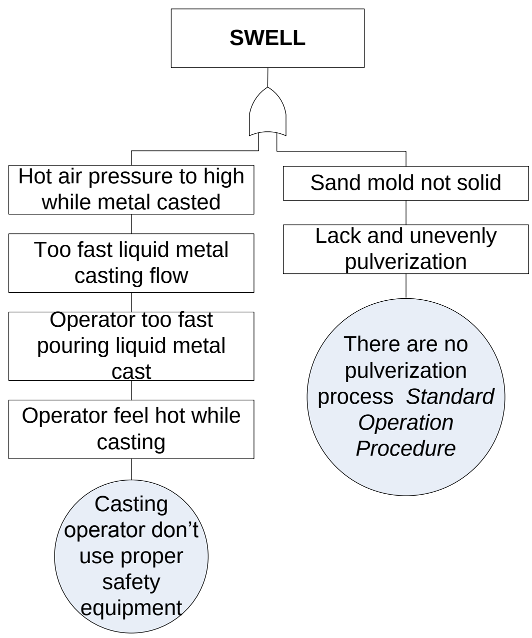

Figure 7. Swell Defect FTA

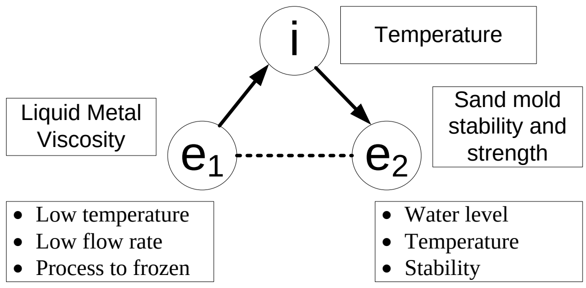

Figure 8. Element Interaction Model Liquid Metal Temperature

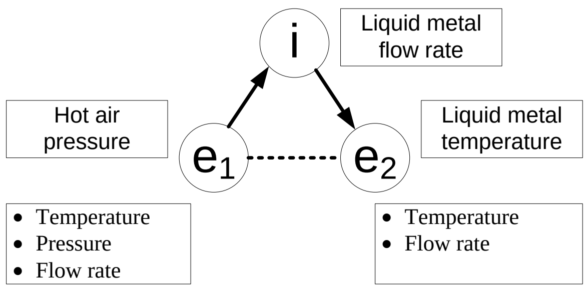

Figure 9. Element Interaction Model Liquid Metal Flow Rate

4.3. Physical Contradiction Analysis

The key concept of TRIZ is "technical contradiction" (Kim, 2010). 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 2 problems to eliminate defects in metal casting products :

(1) Problem of determine liquid metal temperature to maintain viscosity but also maintain sand mold stability and strength.

(2) Problem of determine liquid metal flow rate to prevent hot air trapped in cast cavity, but the liquid metal temperature still have to maintain not too low.

Solid Creativity, 2004 in TRIZ40 and Glenn Mazur, 1995, tabulized contradiction and suggestion to eliminate, based on 40 inventive principles by Altshuller (1956).

Contradictions that occur in this quality problems are :

(1) From the FTA in figure 2 and 4, the metal temperature must high enough to prevent liquid metal viscosity thicker and cause improper flow or air cavity or shrinking defect, but the high liquid metal temperature can cause sand mold drying and lost strength that can cause pushed up and fall out defect as can be seen in figure 3 and 6.

(2) Hot air can be trapped in cast cavity because and cause high pressure in cast cavity, because of too high flow rate and cause pushed up and swell defect as can be seen in figure 6 and 7, but the liquid metal temperature still have to maintain not too low caused by flow rate pouring too slow, that can cause improper flow and air cavity defect as can be seen in figure 4 and 5.

In problem (1) in can be identified there is contradiction between temperature (liquid metal viscosity depend on temperature) versus stability of object and strength (stability and strength of sand mold). In problem (2) there is contradiction between tension, pressure (hot air trapped) versus temperature (liquid metal temperature).

From contradiction matrix, generated by Altshuller, There are several solving suggestion.

Table 1. shown the problem, contradiction, solving suggestion found from contradiction matrix and 40 TRIZ principle, and contradiction analysis as suggestion for metalcasting process improvement, to eliminate defects causes. There are 7 suggestion can made, base on idea from TRIZ 40 principles :

Table 1. Contradiction Analysis to Solve Problems

PROBLEM	CONTRADICTION		SOLVING SUGGESTION	CONTRADICTION ANALYSIS
Problem of determine liquid metal temperature	1	Temperature vs stability of object	Parameter change	
			Segmentation	Make sand mold connection with autolock construction
			Color change	
	2	Temperature vs strength	Flexible shells and thin films	Humidify sand mold while casting
			Preliminary action	Design air duct in proper position and size
			Composite material	Use more clay and sticky material in sand mold
Problem of determine liquid metal flow rate	1	Tension, pressure vs temperature	Parameter change	Lower the flow rate standard while pouring metal to cast cavity
				Liquid metal in the ladle continuously or periodically heated
			Inert atmosphere	
			Periodic action	Pouring metal cast discontinuously
			Taking out	

(1) Make sand mold connection with autolock construction (like puzzle construction) in connecting parts of sand mold. With this construction, the mold become stronger and can avoid mold pushed up when there are high temperature and pressure in the cast cavity because the hot metal enter the sand mold cavity.

(2) Humidify sand mold while casting, to maintain water level and sand not too dry, so the stickable of sand mold still can be maintain and sand mold not breaking or changing form, although the liquid metal with high temperature enter the sand mold cavity, so the metal thickness can be kept thinner.

(3) Design air duct in proper position and size, in order to make channel for hot air to go out, to prevent hot air trapped in cast cavity and make temperature in cast cavity lower and prevent fall out defect,

(4) Use more clay and sticky material in sand mold, to maintain stickable of sand mold, so it's can't easily break or change form when there trapped hot air in the sand mold cavity while the high temperature liquid metal entering the sand mold cavity.

(5) Lower the flow rate standard while pouring liquid metal unto cast cavity, to prevent hot air trapped and make high pressure in cast cavity, because the lower flow rate allow hot air to gone out first before more hot air generated and reduce pressure in cast cavity.

(6) Liquid metal in ladle continuously or periodically heated, to maintain the temperature of liquid metal still high enough and will not thicker when it's poured unto the cast cavity even if the pouring process is slow and prevent improper flow.

(7) Pouring liquid metal cast discontinuously to give time for hot air to gone out before next metal entering cast cavity, and there are no high pressure in cast cavity that can make swell and pushed up defect.

Implementing the suggestions, can reduce and eliminate the metal casting products defects, because (1) shrinking defect can be prevent because hot air not trapped in cavity, when air duct designed properly, (2) fall out mold defect can be prevent, when air duct designed properly, sand mold humidified, used more clay and sticky mold material, (3) improper flow defect can be prevent because the temperature can be raised without causing another defect and liquid metal cast poured discontinuously, (4) air cavity defect can be prevent, when standard liquid metal pouring rate decreased and air duct designed properly, (5) pushed up defect can be prevent, when sand mold constructed with autolock construction, humidified, used more clay and sticky material to strenghten the sand mold, and when air duct designed properly so there are no hot air trapped and pushed the sand mold, (6) swell defect can be prevent, when standard liquid metal pouring rate decreased.

5. CONCLUSION

From this research it can be concluded that to improve product quality can be done by eliminating defects causes. In some cases, there are contradiction between causes. FTA and TRIZ can be used together to solve the contradiction.
For this metal casting quality case, there are 2 contradiction occur and 7 suggestion to solve contradiction are made based on TRIZ contradiction matrix and 40 Principles.
TRIZ is flexible enough to use to explore creativity to solve problems for many reasons, conditions, and objectives, not only for product design purpose because.
For further research, TRIZ can be combined with other well known tools and other reasons.

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