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TRIZ-based trimming for process-machine improvements: Slit-valve innovative redesign

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ABSTRACT

This paper proposed a TRIZ-based integrated trimming process to resolve a process-machine problem by re-designing the problematic processing machine. Applied on a slit-valve failure of chemical vapor deposition equipment in one of major Taiwanese foundry companies, the proposed problem solving process successfully identified the critical key disadvantages of the problem and solved the slit-valve failure with breakthrough results. A number of solutions were generated by the integrated process which involves a number of TRIZ tools. This paper describes only the solution by the trimming process. Unlike the great majority of engineers use “addition” or “substitution” methods to resolve problems, the proposed trimming process used “subtraction” method to solve problem. The integrated systematic method can be used to address any process-machine related problems. The main contributions of this paper include: (1) Establishing an integrated TRIZ-based trimming process to resolve process-machine related problems capable of breakthrough problem solving and/or significant cost savings; (2) solving the slit-valve problem with 83.3% component count reduction, 95% component cost reduction, 99% operational energy reduction, and completely designed-out the original failure mode. The results have been converted into a patent pending approval.

1. Introduction

When facing engineering problems, the great majority of engineers tend to use “addition” or “substitution” methods to solve problems. For example, when an electronic component generates radio interference with other components, engineers almost always introduce a conductive cap to block out the interference. This method of introducing additional elements to solve a problem constitutes the mind set of “addition” to solve a problem. Some people may use “substitution” to solve a problem by replacing the problematic component. It is estimated that some 98% of cpeople tend to use “Addition” or “Substitution” methods to solve problem. This paper established a systematic way of using “subtraction” to solve problems. It is called “Trimming” in the context of TRIZ (Theory of Inventive Problem Solving) methodology (Altshuller, 1999; Altshuller, Shulyak, & Rodman, 1998).

2. Theory of trimming

2.1. Definition of system levels

In the trimming process, it is convenient to differentiate super-system, system, and sub-system. Based on the free dictionary, a system is defined as a group of interacting, interrelated, or interdependent elements forming a complex whole (Web Dictionary, 2012). In the context of trimming, the system is the scope of current level of operations. A “sub-system” is any component of the system. Abroad sense of “super-system” is a bigger system which contains the current system and its external elements which interact with the current system. Depending on the contexts, sometimes, the word super-system is interpreted in a narrow sense where it refers only to the external part of the super-system with the subject system excluded.

2.2. Definition and usage of trimming

The authors define that Trimming is a way of increasing system ideality by removing component(s) of the system. According to Genrich Altshuller (Mann, 2007), a system’s Ideality is defined as Perceived Benefits/(Cost + Harm). Ideality is a measure TRIZ used to define improvements. An improvement is recognized on a system when its ideality increases. A system is “better” than another system performing similar function when the ideality of the system is higher than that of the other system.

Under the premise of increasing or maintaining ideality, trimming provides many benefits. This is contrasted to the great majority of cases where addition or substitution principles are used.

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By reducing components, trimming provides an elegant way of achieving below benefits:

- To fix a problem or remove a harm by trimming either the problem-causing component or the suffering component.
- To reduce product costs by trimming costly components.
- To reduce operational and/or maintenance costs by eliminating high energy consuming or maintenance intensive components.
- To reduce production or operational complexity by reducing part counts and removing complex parts.
- To increase system reliability by reducing part counts or removing the less reliable parts. The less the part count, the less opportunities for errors.
- To circumvent a patent by trimming some components in the independent claims of a problematic patent.
- To create a niche market or differentiate products by removing components responsible for the unnecessary features for certain niche market.

Note that in most cases, trimming can still maintain or enhance the system's original functionality. In minor cases, trimming allows for reduced functionality as long as the ideality is increased. This can be achieved by greatly reducing the cost or harm associated with the system more than fully offsetting the effect of functionality reduction.

The systematic method proposed by this paper can be used to achieve any of the above goals. However, problem solving and cost reduction through system re-design by trimming is emphasized.

2.3. Trimming terminology

This section re-phases some functional definitions from classical TRIZ (Ikovenko, 2009) and defines some new trimming terminology to facilitate the descriptions of trimming processes in the ensuing sections.

2.3.1. Tool, function and object

When a component A acts upon a component B, if certain attributes (parameters) of component B is changed or maintained due to this action, then component A provides the function to the component B. In this case, the action becomes a function. Component A is called a Function Carrier or Tool. Component B is called the Object of the Function, short as Object. For example, a heater heats water. Here, the Heater is component A and the Water is component B. The temperature of the Water got changed due to the "heat" function.

2.3.2. Trimming task

The process of trimming components can be decomposed into multiple Trimming Tasks. The Tool–Function–Object triplet described previously is the target of trimming operation in a trimming task. The goal of each trimming task is to trim the function of the triplet or making it unnecessary. Once all useful functions of a tool (function carrier) are trimmed, the tool is useless and can be trimmed. Only the useful functions are the target of trimming. The harmful functions are not concerned during the process of trimming as it will disappear once the component producing the harmful function or the component suffering from the harmful function is trimmed.

2.3.3. Trimming rules

Trimming rules are the modes of function trimming in the triplet (thus the function carrier). They serve as guiding principles for trimming. Six trimming rules are identified (Verduyn, 2006; Weaver, 2009) and re-phased as followed (Sheu, 2011):

Trimming Rule A: The functions (thus its carrier) can be trimmed if the object of the function is trimmed. See Fig. 1. If executed successful, Rule A is very powerful as it trimmed two components in one shot.

Trimming Rule X: See Fig. 2. The functions carrier can be trimmed if its useful function is trimmed or not needed. Rule X is also powerful as doing away with the current function often means using a completely different operational principle.

Trimming Rule B: See Fig. 3. The functions carrier can be trimmed if the object of the function can perform the useful function by itself. Rule B makes the object self-serve itself thus no need to involve another component.

Trimming Rule C: See Fig. 4. The functions carrier can be trimmed if another existing component in the system or super system can perform the useful function by the current function carrier. Rule C needs to involve another existing component to perform the useful function regardless the component being from the system or its environments.

Trimming Rule D: See Fig. 5. Function carrier can be trimmed if a new or niche market can be identified for the trimmed product. In this case, the function of the system may be degraded, but the ideality presumably increased due to the reduction in costs/harm more than offsetting the reduction in the function/benefits.

Trimming Rule E: See Fig. 6. Function carrier can be trimmed if the function can be performed better by a new/improved part providing enhanced performance, lower cost, or other benefits. Unlike in Rule C, the replacement component in Rule E does not already exist in the system or its environments. It is an additional part. Strictly speaking, this mode is not a trimming mode but a replacement mode. However, it is one of the valid options to improve the system during the full trimming process. In order to qualify it as a "trimming" rule, the component replacement must improve the system ideality by enhanced functional performance and/or reduction in costs/harm.

Priority of the trimming rules: In general, the recommended priority of the trimming rules is A, X, B, C, D, E in that order based on their effectiveness. However, there might be cases where Rule B maybe preferred over Rule X. In addition, the priorities between Rule D and Rule E may be reversed depending on practical situations. Once a higher priority rule is successfully attempted, the function is trimmed and the remaining rules can be neglected for this function. As long as any one rule is successfully achieved, the trimming on this function is successful. Otherwise, the trimming of this particular function fails and the function carrier cannot be trimmed. Section 2.5 in the later part describes a 2-loop trimming process using the trimming rules to trim parts.

2.3.4. Trimming plan

Refer to Table 1, the trimming plan is a form which is used to guide us through the proper sequence of the trimming tasks. Each task makes up a line on the trimming plan and attempts to trim a function at a time. On each task, the plan prompts the users to address the issues of this trimming task in proper order. These issues are shown as columns on the trimming plan and explained in Table 2. Additional explanations follow.

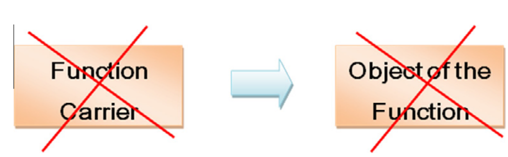

Fig. 1. Trimming rule A.