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# The development of logical root cause analysis in manufacturing process for mitigation loss and waste

Samart Mahaphol and Panumas Arundachawat*

Design And Manufacturing Research for Industries (DAMRI), The Department of Aerospace Engineering, Faculty of Engineering, Kasetsart University, Ladyao, Chatuchak, 10500, Thailand.

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**Abstract**

This paper aims to develop an approach for identifying root causes of loss and waste in manufacturing process by reducing human judgments. The newly development of root cause analysis is the Logical Root Cause Analysis (LRCA) which has two elements as the Input, Material, Process, Product and Output Chart (IMPPO) and the Cause of Symptom Identification Method (CSIM). IMPPO is applied for characterizing manufacturing process while the other is for identifying the origin of root cause and symptom. Both methods have been tested with the industrial case. It is found that the root cause analysis (RCA) activity is achieved while human judgment is required less than the existing approach.

**Keywords:** Manufacturing process, Root cause analysis, Process control, Problem solving

## 1. Introduction

The existing methods to find root cause of problems in manufacturing process such as Cause Effect diagram (CED), Why-Why, etc. are heavily relying on experiences and human judgments. The disadvantage from the mentioned approaches is taking long learning curve, and it leads to “Jump to the solution”. As a result, the root cause of each problem is becoming “guess” rather than identifying from data [1]. The other aspect to look at is the definition of problem because in literature problem and symptom can use interchangeably. However, Six Sigma [2] acknowledges “symptom” as equivalent to problem which is a significant approach to analyze root cause of problems. Moreover, Harich et.al (2012) recommends analyzing root cause by beginning with symptom [3]. Both findings from literatures are confirmed by field study as detailed in section two.

## 2. Materials and methods

The case study research method [4] has been applied in this project. At the early stage, researchers gather industrial data to confirm findings stated in section one. Industrial entities agree that “Jump to the solution” [1], which is common among experts in industries, deviates root causes of a considered problem. Both Thai Automotive and Aerospace industries define characteristics of a considered problem to be symptoms. This knowledge triggers researchers to set up the hypothesis of research as follow: “The human judgment in RCA can be minimized by defining symptoms as characteristics of a considered problem”.

Samart and Panumas (2015) [5] propose to combine the Fault Tree Analysis (FTA) [6] concept and Total Quality Management (TQM) [7] together; therefore, researchers add the concept of Statistical Process Control (SPC) [8] on the work from [5] then it becomes the Logical Root Cause Analysis (LRCA). It has two elements as the Input, Material, Process, Product and Output Chart (IMPPO) and the Cause of Symptom Identification Method (CSIM). Both elements are methods applied together to capture root cause of a considered symptom.

## 3. Results

Researchers develop IMPPO to be the mapping tool. It is the enhancement of process flow chart by adding a standard list of activities on the right hand side. From Figure 1, The Input is defined to be the Material Characteristics (MCP) which shows accumulated characteristics from the previous process, while the Required Material Characteristics (RCP) is required individualities of the considered process. Both entities must be differentiated from each other because sometimes they are dissimilar. For example in Figure 3, MCP3 and RMC3 are not the same. The RMC3 turning process 2 needs the precise dimension, while the hardness which is embedded in MCP3 is not requested. The same concept is also applied to both the Desired Product Characteristics (DPC) and the Product Characteristics for Next Process (PCN). The other terminology, Process Characteristics (PC), is the standard of process variables. In addition, researchers develop CSIM as a method to find the root cause by using with IMPPO. CSIM has 7 steps as below.

*Corresponding author. Tel.: +6681 845 4917
Email address: g5714501519@ku.ac.th
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CSIM 1: Look at IMMPO and then indicate the location of symptom. CSIM 2: Symptom is an unachievable product characteristic which must be revealed at least at a certain process. Thus, the locale is deliberated by looking at every process corresponding to the considered product characteristic. If there are more than one corresponding processes, look at the one before finding the symptom.


**Figure 1** The Element of IMPPO

CSIM 3: Verify the process indicated in CSIM 2 by statistically inspecting its outputs. If the issued is confirmed, it is set as the first process to be further investigated and continue to CSIM 4. However, if the considered process conforms to the standard, it is defined as out of scope of the research CSIM 4: Each process will be indicated in CSIM 3 until the first process is raised to be Potential Suspect Process (PSP). CSIM 5: The PSP firstly captured from CSIM 3 must be statistically examined its MCP (Figure 1). If the results are conformed, the deliberated process will be the suspected process. If not, we move upward to check the next PSP until we find conforming. If each result in every PSP is not conformed to its MCP, this means all PSP are suspected processes (SP). CSIM 6: Review process variables by comparing to PC. CSIM 7: If the result from CSIM 6 is negative, the considered SP is the root cause; otherwise, it is not. However, if all SP provide the positive result at this stage, it is defined as out of the scope of the research.

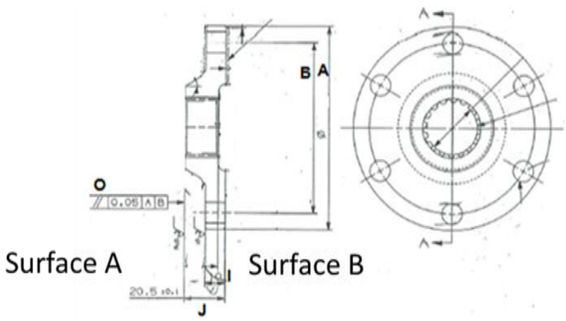


**Figure 2** Picture of Hub Flange

Researchers apply the method to find the root cause of "nonparallel between surface A and B (A//B=O)" of the hub flange. It is an automotive machining part. Its manufacturing process represents in IMPPO format as shown in Figure 3. Usually, IMPPO is applied for every processes, however, it is not demonstrated on receiving mat' l process and Turning1 process to simplify Figure 3. Its specifications are the conformation of diameter (Ø□□and thickness (t) as shown in Figure 2. There are four processes for producing the hub flange. Once the material is received, then it is passed to process Turning 1 and 2. Finally, the work piece is inspected. All of standard values are replaced by alphabet; e.g., A, B, C. After finishing each turning process, every values change to A', B', C' and A", B", C"; consecutively, as shown in Figure3.

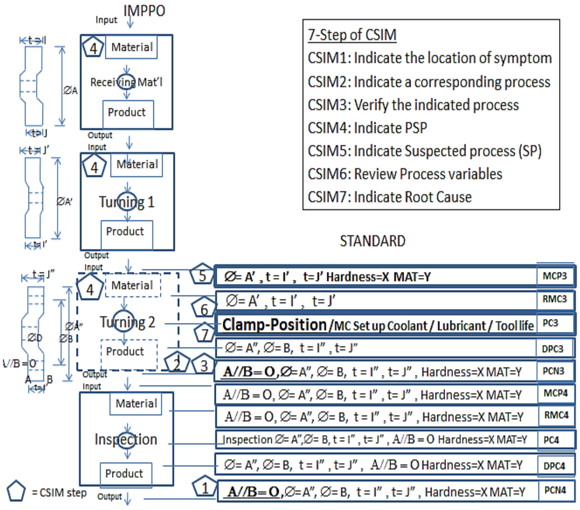


**Figure 3** Diagram of IMPPO and Identify Root Cause by Using 7 Step of CSIM

Researchers select the symptom from Product Quantity analysis (PQ analysis). It is "nonparallel between surface A and B" of hub flange because it has the highest numbers of defects in PQ chart. Next, the researches develop IMPPO for this case and use CSIM to find the root cause of this symptom. It starts from CSIM 1: Researchers indicate that "the output of inspection process" is the location of symptom because the "nonparallel between surface A and B" emerges in the inspection process. Then, CSIM2: The "turning 2" is the process that corresponds to the considered product characteristic (A//B=O), so it is set as the locale to be confirmed in the next step. Then, CSIM 3: Verify the output of "turning 2" by statistically inspecting. After verification with PCN 3, the nonconformance in "parallel between surface A and B" still exists. Hence, it is insisted that the symptom still occurs at Turning 2, so it is the locale. Then, step into CSIM 4: The locale is Turning 2 process as mentioned. Thus, each process from Turning 2 until the upward to the Receiving material process is the Potential Suspected Process (PSP). Each of them will be found out for SP in the next step. CSIM 5: Considering each input of PSP one by one from the Turning 2 to the Receiving material processes. Each MCP must be statistically examined. The result of the examination is Turning 2 conforming to MCP3. Hence, the SP is just only Turning 2. After that, CSIM 6: The process variables of Turning 2 are reviewed with PC3. And the last step, CSIM 7: Identify the root cause. The result of CSIM 6 shows that "clamp position" between work-piece and chuck is nonconforming with standard in PC3. The standard gap between work-piece and chuck in PC3 is zero but the process variable of the gap is greater than zero. Hence, researchers indicate the root cause of "nonparallel between surface A and B" is "the clamp position". From this case, initially, researchers can imply that the combination of CSIM and IMPPO can be used to find the root cause logically by mitigation the experience.

## 4. Discussion

From Table 1, even though both traditional or experience based RCA and LRCA are able to define problems (column four), the differences between both approached are existed

**Table 1** Comparison of Experience Base and Logical RCA

| Type of RCA | Methodology/Tool | Method | Define problem |
|---|---|---|---|
| Experience Base RCA | Why-Why Analysis | Brain stroming to reply 5why question and fill in tree diagram | Yes |
| | Cause & Effect Diagram analysis | Fill each bone by process data or brainstroming | Yes |
| Logical RCA | CSIM/IMPPO | 1. PQ Analysis to Identify symptom<br>2. Write IMPPO<br>3. Root Cause Finding by CSIM | Yes (Symptom) |

(column three). The good practice from both why-why and cause and effect diagram analysis is brainstorming which still relies on experts' experiences. On the other hand, the LRCA is based on data collection from manufacturing process. The faster data collected the less time to find out root causes of a considered problem. The LRCA reduces cost and time in problem solving activities because it reduces the risk of choosing wrong root cause for problem solving. Selecting wrong root cause itself means loss and waste in manufacturing process. The key success is using collected data rather than the best guess from experiences. Moreover, practicing IMPPO and CSIM strengthens team members to understand their own process. As a result, the LRCA could be applied as a training tool for new team member.

## 5. Conclusions

Reducing human judgment in root cause analysis activities is achieved by using IMPPO chart and CSIM, as a result, the LRCA method is claimed for the success at this stage. It can reduce loss and waste in problem solving activity. However, both IMPPO and CSIM still need to be validated with other industrial case studies. The faster to collect data from manufacturing process will gain the more accomplishment for the LRCA method. Fortunately, information technology is getting more advance, as a result, implementation of LCRA is achievable. Additionally, developing an IMPPO chart for a complicate product is still an exhaustive work to achieve; thus, this is another aspect to be developed in the future.

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