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Application of Root Conflict Analysis (RCA+) to Identify Contradiction in Manufacturing Process

Faishal Arham Pratikno[1]✉, Muhamad Imron Zamzani[2], Noni Oktiana Setiowati[3]

[1] Program Studi Teknik Logistik, Jurusan Teknologi Industri dan Proses, Institut Teknologi Kalimantan, Indonesia
[2] Program Studi Teknik Industri, Jurusan Teknologi Industri dan Proses, Institut Teknologi Kalimantan, Indonesia
[3] Program Studi Rekayasa Keselamatan, Jurusan Teknologi Industri dan Proses, Institut Teknologi Kalimantan, Indonesia

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ABSTRAK

Keberadaan cacat pada produk adalah tanda bahwa tingkat kualitasnya belum cukup baik. Proses pengeboran *composite fiber-reinforced plastic* (CFRP) terdapat permasalahan kualitas yaitu kegagalan pada peralatan pemesinan. Oleh karena itu, kami akan membahas analisis akar penyebab dalam permasalahan proses manufaktur. Selain menganalisis akar permasalahan, ada kondisi yang disebut sebagai kontradiksi. Kontradiksi merupakan kondisi di mana efek positif dan negatif terjadi secara bersamaan. Oleh karena itu, metode *Root Conflict Analysis* (RCA+) digunakan untuk menemukan akar penyebab masalah dan pada saat yang sama mengidentifikasi kontradiksi. Berdasarkan penelitian ini, ditemukan bahwa teridentifikasi 3 penyebab masalah dalam proses pengeboran, yaitu kecepatan potong yang tinggi, *feed rate* yang tinggi, dan *point angle* yang besar. Serta ditemukan beberapa kontradiksi, terkait produktivitas pengeboran, temperatur alat potong, *thrust force* proses, dan *drill burr*.

Kata Kunci:

Kualitas, Proses Manufaktur, Kecacatan, *Root Conflict Analysis (RCA+)*, Kontradiksi

***Keywords*:**

Quality, Manufacturing Process, Defect, Root Conflict Analysis (RCA+), Contradiction

ABSTRACT

The presence of defects in the product is a sign that the quality level is not good enough. In the drilling process of composite fiber-reinforced plastic (CFRP) there are quality problems, namely failure of machine tooling. Therefore, we will discuss root cause analysis in manufacturing process problems. In addition to analyzing the root of the problem, there are usually conditions called contradictions. Contradiction means a condition in which positive and negative effect simultaneously occur at the same time. Therefore, the Root Conflict Analysis (RCA+) has been adopted to find the root cause of the problem and at the same time identify the contradictions. Based on the results, it was found that there are 3 causes of problems in the drilling process, high cutting speed, high feed rate and large point angle. As well as found several contradictions, regarding drilling productivity, tool temperature, thrust force during the process and drill burr.

***Corresponding Author*:**
Faishal Arham Pratikno
Program Studi Teknik Logistik, Jurusan Teknologi Industri dan Proses, Institut Teknologi Kalimantan
Jalan Soekarno Hatta KM. 15, Karang Joang, Balikpapan, Kalimantan Timur
Email: faishal.arham@lecturer. itk.ac.id

INTRODUCTION

Quality control process in production and technology industry, which directly affects the efficiency of this process, and which is the most important aspect to improve competitiveness and satisfaction level of consumers' requirements (Ryabchik et al., 2019). Setting appropriate standards is the cornerstone for solving industrial safety problems. The lack of effective standard criteria for assessing product defects, especially design defects, makes product manufacturing companies not have an effective safety design in the product design process (Lin et al., 2012). One of the obstacles to product quality is the defective products, both when it is still in the production process (work-in-process) or which have become finished goods. Defects are deviations from the specification or, in other words, the difference in performance between the desired outcome and the observed result.

The existence of a defect indicates that the production process is still not consistent so that quality improvement is required. Implementation of quality improvement for 10 weeks has an impact on reducing 9% of defects that occur in the painting process in the manufacturing industry (Dhafr et al., 2006). Quality improvement is a process of improvement designed and focused on activities that are responsive to the requirement. Quality improvement projects are focused on increasing customer satisfaction with product quality at its core. The methodology for improving quality consists of several phases: 1) planning phase, 2) phase of innovative workmanship, 3) improvement phase, and 4) phase of completion (Kozień, 2019). Product quality means the elimination of all kinds of defects from the product. A method is needed to identify the root causes of quality problems. Types of defects include design errors or defects, conditions outside standard limits, or product disruptions that cause the product to not function properly (Ulfah et al., 2019).

To eliminate all types of defects that occur in the company's manufacturing process, an action is needed to find what is the cause of the defect. The goal is to eliminate defects entirely by predicting and avoiding defects not only correcting defective products and process parameters (Powell et al., 2022). The systematic process of identifying causal factors to provide a clear focus for identifying and resolving problems is known as Root Cause Analysis (RCA) (Maryanti et al., 2020). RCA is a technique for detecting and classifying the factors behind events that have a negative influence on quality, reliability, productivity, safety, health, or the environment. The term "event" is used to refer to any occurrence that results in or has the potential to result in various types of outcomes. The key to preventing similar occurrences is identifying the root reasons. The root causes identified across the occurrences can be used to focus on significant prospects for enhancement in the future, which is an added benefit of a good RCA. The goal of a good RCA process is to identify the fundamental causes of an unwanted event and to facilitate effective corrective steps to prevent it from happening again (Tomić & Brkić, 2011). The application of the RCA method succeeded in finding the root cause of the problem in the power cord problem, namely an error in the design of the power cord which only uses one condenser (Sarwar et al., 2022).

The way manufacturers conduct root cause analysis of production disruptions is expected to change. With the advent of Industry 4.0 technologies, various solutions support root cause analysis (Vo et al., 2020). When we are identifying an event that causes a product defect, we are often faced with a problem called contradiction. One of the conditions that we often experience when solving a problem is that it also has a bad impact on other things. A contradiction occurs when you try to improve something in one aspect and discover that the result makes the other aspect worse. We cannot avoid this kind of condition in its application (Gadd, 2011). The conflict is called a trade-off which is a term to represent giving up on one goal to achieve another goal (Ndimele et al., 2018). The desired solution cannot be carried out because of obstacles. In other words, if the solution can make a problem better, then on the other hand it will have a bad impact on other things.

A defect in the manufacturing process may arise from the aggregation of minor defects over time. may be the result of the accumulation of minor defects that build-up from the previous step. If not resolved or detected during the initial stages of the manufacturing process life, the defect continues to spread in later life stages into the use phase. Therefore, this study aims to analyze the root causes of the problem as well as identify contradictions in the manufacturing process.

RESEARCH METHOD

Root Conflict Analysis (RCA+)

Root Conflict Analysis (RCA+) is a new additional tool to the TRIZ method that aim to simplify complex problems by identifying the contradictions that are inherent in the problem and the relationships between these contradictions (Souchkov, 2011). RCA+ can be used as an independent tool (without TRIZ methodology) or as a complement to other tools in TRIZ. In this research, RCA+ method is used to describe the main problem which is presented in the form of unwanted effects in a causal tree diagram, by following several rules in its manufacture.

The main purpose of this method is to find the root of the problem as well as to focus on the complex related contradictions. The evaluation of each contradiction is done by making a table listing the causes (conditions when the contradiction occurs), the positive effects that occur, the negative effects that occur, the components involved with the contradiction, the parameters that have the contradiction, and the time when the contradictions occur (Souchkov, 2017).

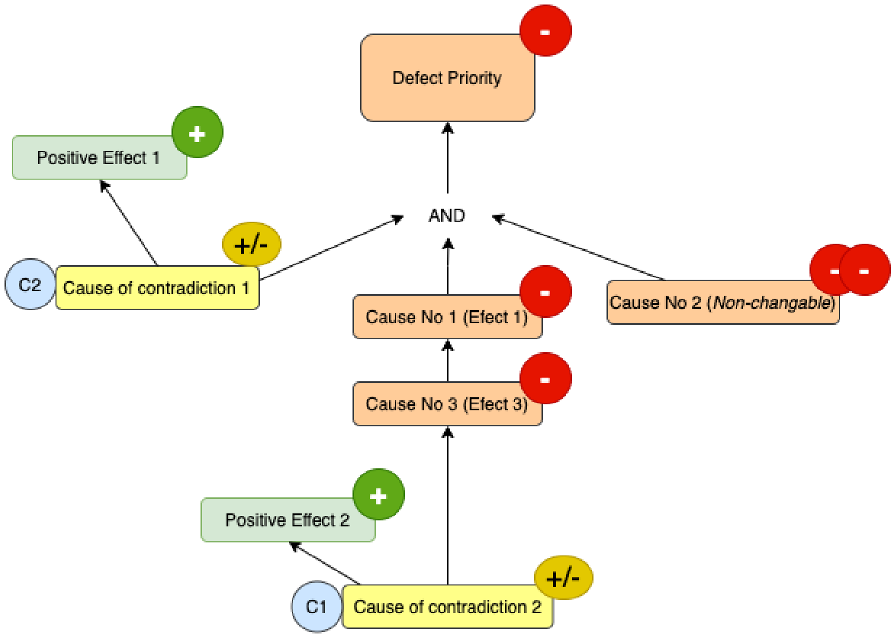

Figure 1. Problem Identification Using RCA+

In most of the techniques developed for cause and effect analysis, this is done by asking the question "Why?". However, in RCA+ as shown in the example in Figure 1, this is done by asking the question "What is the cause of (undesired effect)?", or "What causes (undesired effect)?"(Souchkov, 2011). The contradictions in the RCA+ diagram are depicted as causes that contribute to negative and positive effects. All negative causes are marked with a minus sign (-) and all positive effects with a plus sign (+). Top-down exploration of RCA+ stops after (Souchkov, 2017):

1) a contradiction (+-) is identified, or

2) "non-changeable" causes (- -) are identified.

Data collection for application of the RCA+ for quality improvement in this study comes from Mo and Suparayan (2019) research. The research was carried out on the drilling process of Composite Fiber-Reinfirced Plastics (CFRP). In the aviation industry, the assembly of the fuselage is done by drilling large number of holes for fasteners. However, the drilling process for CFRP materials is considerably more complex than for conventional materials. due to their abrasive nature and high brittleness. This can cause the CFRP material to have poor quality and high rework rate in the hole drilling process (Geier et al., 2020). To develop the principles underlying risk management, defect data in CFRP product assembly is obtained from the moveable trailing edge manufacturing process as shown in Figure 2. The components of this product consist of upper shell, lower skin, ribs, and spars. The proper execution of the drilling process is necessary for assembling these parts. If there are components that are not suitable and then assembled, it will not achieve the technical requirements and airworthiness. Therefore, there are many advantages that can be obtained when improving the quality of this production by eliminating existing defects (Mo & Suparayan, 2019).

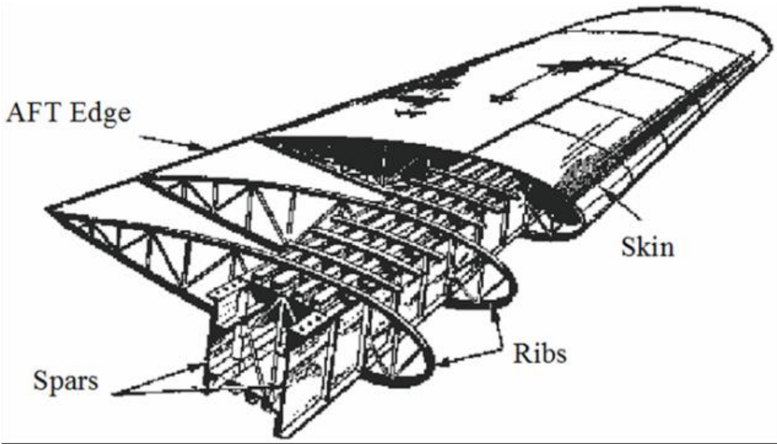

Figure 2. Illustration of Using CFRP on Moveable Trailing Edge

RESULTS AND DISCUSSIONS

Results

In this study, the application of the RCA+ for quality improvement comes from Mo and Suparayan (2019) research data. The drilling process was the main area of focus in the research of Composite Fiber-Reinforced Plastics (CFRP). Based on this research, it was found that the main problem in this manufacturing process is drilling failure in machine tooling. This result is obtained from the value of risk costs from the problem of drilling failure in machine tooling which is the largest compared to other problems. The risk costs is the value calculated based on the multiplication of categorized costs with the probability of failure (Mo & Suparayan, 2019).

The purpose of the problem analysis with the RCA + method is to describe the main problem, which is presented in a causal tree diagram. In this study, the main problem is the priority defect identified in Mo and Suparayan (2019) research data, which is drilling failure in machine tooling. This method will analyze priority defects to discover the root causes and contradictions. RCA+ analysis on defect drilling failure in machine tooling is shown in figure 3. The first thing that is very important to take after looking at the RCA+ diagram in figure 3 is that all causes of the problem have an independent relationship. The contradiction involved in "drilling failure in machine tooling" problem of the CFRP assembly process is with independent relationship.

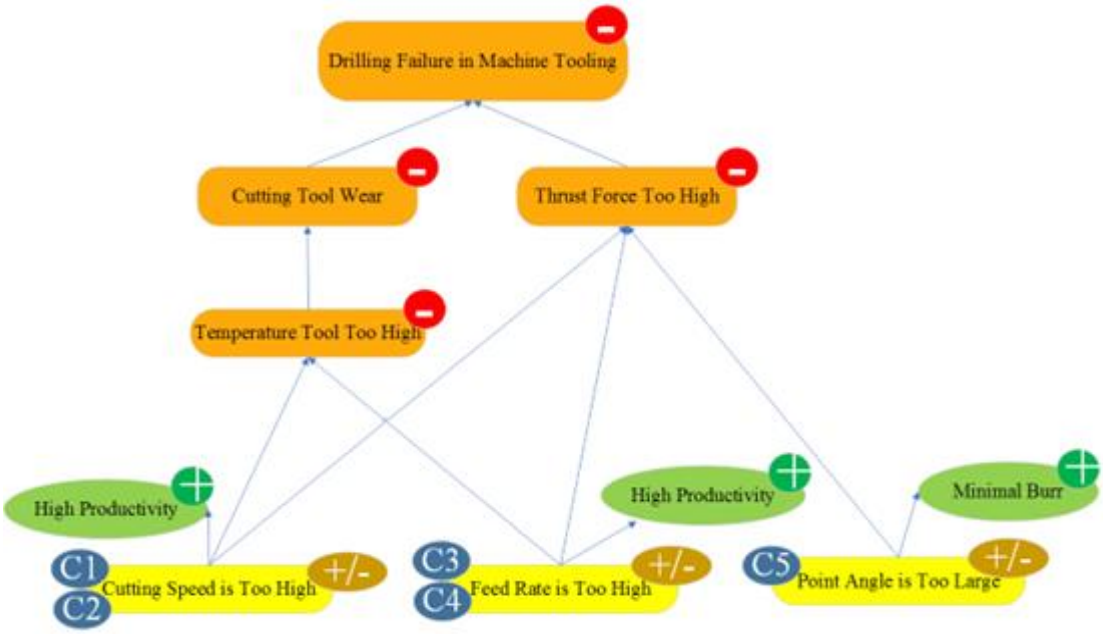

Figure 2. RCA+ Analysis on Defect Drilling Failure in Machine Tooling

Based on the RCA+ analysis results, it was found that there are 3 root causes for the drilling failure in machine tooling,

1) cutting speed is too high,

2) feed rate is too high and

3) point angle is too large.

The advantage of RCA+ compared to other root cause analysis methods is that it can discover contradictions in the system, in this study case there are 5 contradictions that were successfully analyzed. There are a total of 5 contradictions that occur which come from a combination of 2 effects and 3 causes of the problem. High cutting speed and high feed rate are contradictions that cause two effects, namely high tool temperature and too large thrust force. 5 contradictions that occur in the drilling process include:

1. When the cutting speed is too large, the contradiction that occurs is that the process productivity is high but the tool temperature will be high
2. When the cutting speed is too large, the contradiction that occurs is that the productivity of the process is high but the thrust force of the process will be high
3. When the feed rate is too large, the contradiction that occurs is that the process productivity is high but the tool temperature will be high
4. When the feed rate is too large, the contradiction that occurs is that the process productivity is high but the process thrust force will be high
5. When the point angle is too large, the contradiction that occurs is that the burr drill is minimal but the thrust force of the process will be high

The analysis of RCA+ diagram stops as soon as all the branches of the diagram reach the conditions: i) contradictions are identified; or ii) non-changeable is identified. Based on the results of this study, it was found that all contradictions in this drilling process can be identified. Which means the negative effects and positive effects of each component in the RCA+ diagram are identified. So that this diagram stops in an identified state, there are 3 root problems in drilling failure in machine tooling. When you look at Figure 1, the relationships between components in the RCA+ diagram are independent.

Discussions

Resolving contradictions that are at the very bottom (root cause) usually results in wider consequences/effects for the whole system. The strategy for finding a new solution is determined by the cause of contradiction analysis for the entire RCA+ diagram because the root cause of several causes is the same. High cutting speeds and high feed rates are the cause of the negative effect of high machine tooling temperatures. Meanwhile, the causes of the large thrust force in the drilling process are high cutting speed, high feed rate and too large tooling point angle. The contradictions that occur in the drilling process in this study include: 1) When you want to increase the process productivity, the tooling temperature becomes high, 2) When you want to increase process productivity, the process thrust force is too high, and 3) When you want to reduce the burr drill, the process thrust force is too high.

The contradiction contained in the "drilling failure in machine tooling" problem of the CFRP assembly process is related to the "OR" relationship. This relationship means that all causes must be eliminated to eliminate the problem, not being able to solve only one of the causes. In general, the entire complexity of the problem is determined by the number of contradictory causes that contribute to the priority defect. Resolving contradictions that are at the very bottom (root causes) usually results in wider consequences/effects for the whole system.

The results of this study are also in accordance with the RCA+ made by Laoh (2021) which analyzes the contradictions that occur in the problem of flat tires. The contradiction found with RCA+ is that the tire material is used over a long period of time. This contradiction has a negative effect in the form of many cracks in the tire material and the tire material is less elastic but has a positive effect in the form of long tire durability (Láoh, 2021).

CONCLUSION AND SUGGESTION

Conclusion

The result of the RCA+ method in this research is to find the root of the problem as well as the contradictions that occur in the drilling process. There are 3 root causes of defect drilling failure in machine tooling, namely high cutting speed, high feed rate and large point angle. These three root problems are the cause of contradictions in the drilling process, the contradiction that occurs is that if the cutting speed and feed rate is high, it will cause high temperatures and large thrust forces which have a negative impact on the quality of drilling results, but high cutting speed and feed rates cause productivity in the drilling process. also increased. While a large point angle will have a large thrust force which has a negative impact on the quality of the drilling results, but a large point angle causes the drilling process to be minimal.

As per the results obtained from this research, it can be concluded that the RCA+ method can analyze the root causes of the manufacturing process as well as identify any contradictions in the process. In addition, analysis using this method can be a reference for other research that requires identifying contradictions in the process and does not rule out the possibility that it can only be carried out in the manufacturing sector but also in other fields such as the natural resource processing industry, logistics, food and beverage and others.

Suggestion

Suggestions for further research is an analysis of the root of this problem can be a sign that the manufacturing process has a problem and a solution must be found immediately to eliminate the problem by considering the existence of contradictions in the process.

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