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SOURCES OF FAILURES OF ENGINEERING SYSTEMS

*YUSUF A.K **
Department of Electrical and Electronic Engineering
Villanova Polytechnic, Imesi-Ile, Nigeria
engryusufak@gmail.com

HADI Y.S
Department of Electrical and Electronic Engineering
University of Ilorin, Ilorin Nigeria
hadi101sy@gmail.com

OLANIPEKUN S.A
Department of Electrical and Electronic Engineering
University of Ilorin, Ilorin Nigeria

Abstract

This paper looks into the general concepts of failures of engineering systems. It started by defining what an engineering system is, what a failure is, and what it means when an engineering system is said to fail. It then went further to differentiate between sources and causes of failure; which means what, and which helps the overall condition of the system as far as the field of reliability is concerned. Some techniques such as the Root Cause Analysis (RCA) & "the 5-Why" used in determining the root cause (or sources) of failures of engineering systems were highlighted and explained. The general sources of failures of engineering systems were listed bearing in mind that an endless list is imminent if we are to name individually the sources of failure of engineering systems. Lastly, the paper presents FRACAS which is one of the systems or processes used by engineers in collecting failure data, analyzing the riskiest failures to get to the root cause and implement corrective actions. The corrective action part of this process is the area of concentration here, because mere analysis of failure without taking corrective action amounts to nothing.

Keywords: Engineering Systems, Failure, Sources of Failure, Causes of Failure, Root Cause Analysis, The 5-whys, Root Cause of Failures,

1. INTRODUCTION

There's a saying that: "A doctor buries his mistake but the mistake or error of an Engineer buries him". This quote shows how grievous an engineering failure could be. In Engineering, unlike in most other fields, the failure of a system could be disastrous. This is why it is of the utmost importance to have knowledge of all "failure properties" of a system at all level of its manufacturing process; especially at the design stage. By studying failures and their sources, an engineer is able to design a better system in terms of reliability. In our immediate surroundings, there are several systems, both natural and engineered. The solar system is an example of natural system. The engineered systems are designed and manufactured to satisfy human needs and wants. Engineered systems are everywhere ranging from the mobile phone we use to the vehicles we drive to the house we live.

A system is a collection of different elements that interact to produce results that are not obtainable by the elements alone. An automobile is made up of thousands of parts and each part must work with the others if the work is to be as desired. From a functional viewpoint, systems have inputs, process and outputs. Input are the resources put into a system. Processes combine the resources to produce the output which can be a product, service or enterprise. From a physical point of view, the system consists of mechanical, electrical and software components that interact to these functions [4].

Failure, according dictionary.com, can be defined as non-performance of something due, required, or expected. Failure of a system or a product can range from failure of such product to meet market target to physical and functional failure of such product or system. Failure can also be defined as realizing undesirable and unanticipated compromises in the quality of engineered systems. Quality is characterized as resulting from integrated effect of all four attributes: Serviceable (fitness for purpose), Safety, Reliability (freedom from unanticipated degradation in the quality attributes), Compatibility (meets business and social objectives- on time, on budget and happy customer) [5]. Quality is defined [6] as the totality of all the features and characteristics of a product or service that contributes to the satisfaction of a customer's needs. In engineering however, a system is said to have failed if at that point in time such engineering system was not successful in performing the specific function it was designed to perform.

Source is anything or place from which something comes, arises, or is obtained while cause is defined as a person or thing that acts, happens, or exists in such a way that some specific thing happens as a result; simply put, source means origin while cause means the producer of an effect[2]. It can be concluded from the above that when we talk about source of a failure, we are referring to the root cause of that failure; and not the direct/ immediate producer of such failure at that point in time. Therefore, the source of failure of an engineering system is root cause of lack of success (in performance and other functionalities) of such system. The source or root-cause of a failure is the most basic cause (or causes) that can reasonably be identified; and when identified and fixed, will prevent or reduce the failure's occurrence [9]. It is the highest level cause of a problem. It is the "evil at the bottom" that sets in motion, the entire cause-and-effect chain causing the problem(s) [10].

2. METHODOLOGY

"An expert is a man who has made all the mistakes which can be made in a very narrow field"–Neils Bohr

Failure analysis as a process deals with collection and observation of data to determine the source and cause of failure of a system or a product. It assists the failure analysis engineers, after careful study of failed product or system, in designing and manufacturing a better system with higher level of reliability. Simply put, by studying all the causes and sources of a system's failure, a better and more reliable system can be built. In reality, it is not possible to always avoid failure; it is therefore important to think and talk about what it means to learn from failure.

Although, the removal of a cause (also known as Causal factor) of failure of a system can improve the performance or functionalities of the system but this does not prevent the failure from recurring in the nearest future. The ultimate solution to a failure is by "digging deep" in finding the source or root-cause of the failure, which will with a relatively higher certainty "uproot" the problem and fix the system. Therefore to achieve a near permanent solution to the problem of a system, the source of the problem of such system should be aimed at.

2.1 Techniques for finding failure

There are several techniques and processes developed mainly for finding the root cause or sources of failure in engineering. Some are ideal for a complete system, others for components. Following are some of the techniques:

2.1.1 The five whys

The Five Whys is a simple question-asking technique that explores the cause-and-effect relationships underlying a particular problem [3]. Primarily, the essence of the 5 Whys Technique is to find the root cause of a problem by repeating the question "why?" five times. The second "why" question is formed on the answer to the first one and this continues till the fifth answer is given. The questioning could go further to a higher level but the fifth iteration is generally sufficient to get to the root cause of a problem.

This technique was formally developed by Sakichi Toyoda for Toyota Motor Corporation during the evolution of its manufacturing methodologies.

It is worthy of note that that the last answer points to a process. The real root cause should point towards a process that is not working well or does not work at all which is one of the most important aspects in the five why approach. This means that the only thing we are concerned about is the process and no other thing. Simply put, we do not just ask "why" but "why did the processes fail" [7]

When looking to solve a problem, it helps to begin at the end result, reflect on what caused that, and question the answer five times. This elementary and often effective approach to problem solving promotes deep thinking through questioning, and can be adapted quickly and applied to most problems. Most obviously and directly, the five whys technique relates to the principle of systematic problem-solving: without the intent of the principle, the technique can only be a shell of the process. Hence, there are three key elements for the effective use of the five whys technique:

(i) Accurate and complete statements of problems,
(ii) Complete honesty in answering the questions,
(iii) The determination to get to the bottom of problems and resolving them [3]. The technique was developed by Sakichi Toyoda for the Toyota Industries Corporation.

Fig. 1 is a sample of the five why's techniques worksheet.

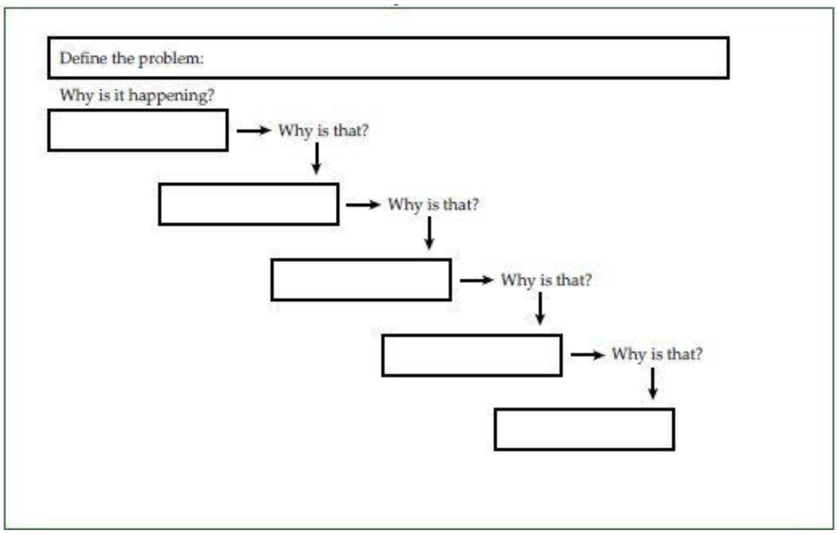


Figure 1: The five whys worksheet [3]

2.1.2 Root cause analysis [11]

Root cause analysis (RCA) is a process designed for use in investigating and categorizing the root causes of events with safety, health, environmental, quality, reliability and production impacts. The term "event" is used to generically identify occurrences that produce or have the potential to produce these types of consequences.

Simply stated, RCA is a tool designed to help identify not only what and how an event occurred, but also why it happened. Only when investigators are able to determine why an event or failure occurred will they be able to specify workable corrective measures that prevent future events of the type observed.

The RCA is a 4-step process involving the following:

(i) Data Collection

(ii) Causal Factor Charting

(iii) Root Cause Identification

(iv) Recommendation, Generation and Implementation

The first step in the analysis is to gather data. Without complete information and an understanding of the event, the causal factors and root causes associated with the event cannot be identified. The majority of time spent analyzing an event is spent in gathering data. This provides a structure for investigators to organize and analyze the information gathered during the investigation and identify gaps and deficiencies in knowledge as the investigation progresses. The causal factor chart is simply a sequence diagram with logic tests that describes the events leading up to a failure, plus the conditions surrounding these events. The investigator begins root cause identification after all the causal factors have been identified. This step involves the use of a decision diagram called the Root Cause Map to identify the underlying reason or reasons for each causal factor. This map the structures of reasoning process of the investigators by helping them answer questions about why particular causal factors exist or occurred. The identification of root causes helps the investigator determine the reasons the event occurred so the problems surrounding the occurrence can be addressed.

Following identification of the root causes for a particular causal factor, achievable recommendations for preventing its recurrence are then generated. The root cause analyst is often not responsible for the implementation of recommendations generated by the analysis. However, if the recommendations are not implemented, the effort expended in performing the analysis is wasted. In addition, the events that triggered the analysis should be expected to recur. Organizations need to ensure that recommendations are tracked to completion.

3. SOURCES OF FAILURES

The field of engineering is a very wide one and if one is to start listing the sources of failures of engineering systems, the list will be an endless one. In the general sense, the sources of failure can be placed under each of the following headings:

1. Processes
2. Operators
3. Management
4. Regulator
5. Government

The list above is like a cadre where reporting and monitoring happens between each of the adjacent levels. On the monitoring side, The Government monitors the Regulator, the Regulator monitors the Management, the management overviews the performance of the system Operators while the Operators check on the Processes. In the level of reporting, it is in the reverse order; the Operators take report from the Processes by studying it. The system Operators brief the Management while the Management report to the Regulatory bodies.

At each of the levels, you have at least one source of system failure to mention; That is to say any source of failure of engineering system you can think of falls under the above mentioned levels of monitoring and reporting [12].

4. CORRECTING AND ANALYSIS OF FAILURE

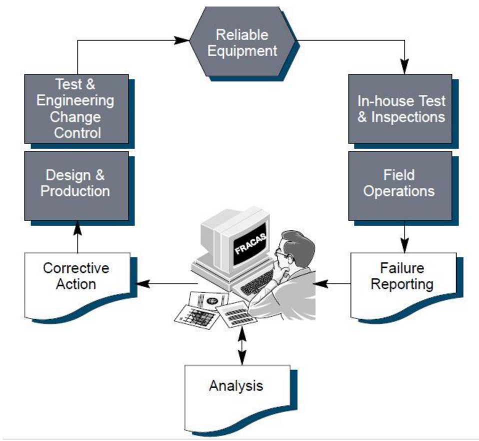
Although finding the root cause of a system's failure is a very important step in the field of engineering, but that alone is not enough. Obtaining the source of failure without applying a correction to such system or using the result obtained to engineer a better system is as good as not analyzing the system. There are several processes used in correcting failure. Below is one of such processes.

FRACAS

FRACAS stands for Failure Reporting, Analysis and Corrective Action System. It is used to collect data, record and analyze the failure of a system; then plan corrective actions to the failures. The system is a continuous improvement one that utilizes a closed-loop feedback path in which the entire organization works together to collect failure data, prioritize the failures according to risk, analyze the riskiest failures to get to the root cause and implement corrective actions to eliminate repetitive failures[13].

FRACAS can be useful throughout an asset's lifecycle, but it is most valuable as a tool for evaluating failures that could not be eliminated during the design stage. When your system is not meeting the desired or necessary levels of reliability due to the amount of unplanned failures or faults, FRACAS can help. It is implemented such that the user and the manufacturer of a system or product work together to collect, record, and analyze failures data sets. The user captures predetermined types of data about all problems and submits the data to that supplier. A Failure Review Board (FRB) at the manufacturer end analyzes the failures. The resulting analysis identifies corrective actions that should be implemented and verified to prevent failures from recurring [14].

A simple FRACAS process is as shown in Fig.2



5. CONCLUSION

In the field of engineering, failure is not something to be taken with levity; doing so may lead to catastrophe. Although, failure is not a positive thing but it is an option because it is bound to occur at one point or another in the life of an engineered system. This is why it's very necessary in engineering to study the source of failure.

The sources of failures of engineering systems are the "deep" causes of failures. They are the "evil at the bottom" that sets in motion, the entire cause-and-effect chain causing the failures. A lot of techniques and processes are in place to collect, analyze data and provide corrections to failures of systems. Therefore, instead of attempting to list all sources of failure, it is sufficient to know at least one technique of failure analysis and apply it to the situation at hand.

ENDNOTES

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