FAILURE ANALYSIS: THE DEVELOPMENT OF THE VARCA MODEL TO DO FAILURE INVESTIGATIONS

Etienne Human
Carab Tekniva Group, Sasolburg, South Africa

1. INTRODUCTION

Vibration Analysis is mainly used for condition monitoring. Condition Monitoring or an on-condition task is the monitoring for potential failures to ensure that action can be taken to prevent the functional failure or to avoid the consequences of the functional failure. Vibration Analysis is the best known condition monitoring technique. It is a specialized technique using specializing instrumentation. The first vibration meters were introduced during the 1950's and measured the overall or broadband vibration reading. This first vibration meters were analog meters. Little later tunable analog filters were added to the meters in order to make it possible to discriminate between frequency components, giving birth to the vibration spectrum. Personal computers were introduced during the 1970's, and with that the DSP technique that led to the FFT analyzer, as we know it today. The exploitation of the microprocessor followed during the 1980's that was revolutionized to the analysis of machinery diagnostics.

Vibration Analysis can also be used in forensic investigations, to determine the root cause of an incident. This is more a new field in the use of vibration analysis.

The VARCA Model is fairly new in the technology field. There is also not much written on the model, but it already proofed it as sustainable. The VARCA Model was developed in the petrochemical field, but can be used in a wide range of technical scenarios. But what exactly is the VARCA Model, and what is it used for?

2. WHAT IS THE VARCA MODEL?

The VARCA Model is actually standing for **V**ibration **A**nalysis in **R**oot **C**ause **A**nalysis. It is a method or procedure to follow when Vibration Analysis is part of an incident investigation. The model will describe the process to follow to use vibration related information in a failure investigation or Root Cause Analysis. The process is actually an RCA on its own, but deal mostly with vibration data where a formal RCA will deal with all the data and information.

3. ROOT CAUSE ANALYSIS

Root Cause Analysis, or RCA's origin in the engineering field, but was also widely used in the medical field. It expanded to the fields of aerospace, transportation, nuclear power, chemical procession, pollution control, information technology and manufacturing. Most recently it has become an important addition to risk management and health care (medical environment). An RCA is an analytical process to identify the underlying factors that have contributed or directly caused an incident or failure.

There are many interpretations of an RCA. Some people will see the method of trial and error as an RCA, while others will see the RCA as part of the investigations and others will see the RCA as the investigation.

Because of the different interpretations and understanding of RCA's, there are different definitions for RCA's. Coming from some of the definitions (from Human, 2011), an RCA must:

- Be structured
- Be team based
- Be systematic
- Solve the problem

It is also important to take note that it is very seldom that there is only one root cause causing an incident. Root causes are coming in multiples, meaning there is normally more than one root cause causing an incident.

There are different methods of RCA's. Two people may perform an RCA on the same incident with different root causes. The reason is the number of root causes (more than one) and because the method is not outlined. Some of the other issues in the RCA methods may be:

- An expert may provide information or a solution as an individual. The team may rely on that.
- Teams may draw up conclusions that are based on majority opinion. Solutions are implemented without factual basis.

- The team may also rely on hearsay, assumptions and ignorance.

When running an RCA correctly, there are some components that will be part of the process:

- Failure Analysis: the process of collecting data with the purpose to determine the cause of failure and also to prevent a recurrence of the incident and/or to improve performance.
- Forensic Engineering: any kind of expert testimony that will be given in court at a criminal trial. The word "forensic" means "connected with the court room". The type of forensic engineering here is called "Forensic Vibration Analysis" or FVA.

4. VIBRATION ANALYSIS

Vibration Analysis is the best known condition monitoring technique and is many times only referred to as "Condition Monitoring". That is not really the case as condition monitoring consists of many different techniques. The very first vibration monitoring was that of the wheel tapper who checked for crack development in the wheels of locomotives by striking the wheel with a wheel tapping hammer and listening to the sonic response of it. Machines vibrate to a certain degree. A change in vibration, the vibration spectrum, the range of frequencies and the amplitude of the vibration is an indication of a fault or defect. Figure 1 is a basic breakdown of the different types of vibration analysis techniques.

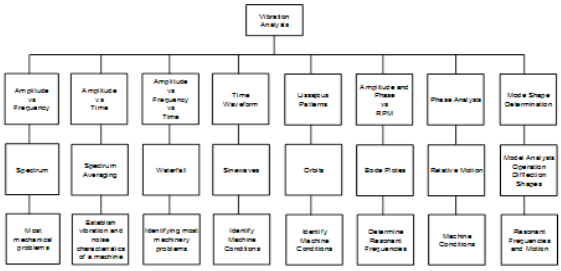

Figure 1 - Different types of vibration analysis techniques (Attachment 1)

5. FORENSIC VIBRATION ANALYSIS (FVA)

Forensic Vibration Analysis is a fairly new term in the engineering field. To use vibration analysis in failure investigation requires much more detail analysis than normal condition monitoring. It also requires not only a primary analysis, but also a secondary and in some cases a tertiary analysis. Another important fact is that alarm levels are not important in failure analysis, but the profile of the spectrum is.

6. MAINTENANCE STRATEGIES

The task of the maintenance function is actually to support the production process with adequate levels of reliability, availability, as well as operability at an acceptable cost. A maintenance strategy can be defined as the decision of what maintenance to do, when to do it and how often to do it. Maintenance strategies can also be divided into different types like Design-out Maintenance, Preventive Maintenance and Corrective Maintenance.

Figure 2 is a breakdown of the maintenance strategies.

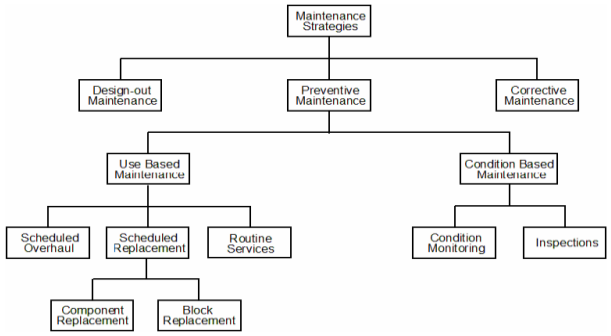

Figure 2 - Maintenance Strategy Breakdown (Attachment 2)

7. VARCA MODEL

The VARCA Model was developed as a solution to the method of using Vibration Analysis in failure investigations and Root Cause Analysis. The reason and motivation was the limited knowledge on the subject of vibration analysis when detailed information was needed during Root Cause Analyses. The model is the process to follow to perform the analysis within the RCA, and is actually an RCA on its own. It deals mostly with vibration related data where a formal RCA will deal with all the data. Vibration data will give a clear picture of the condition of the equipment at or before the time of the incident, the current defects and also the current condition of the equipment, depending on what time the necessary measurements were conducted. The use of a cause map may indicate the root cause or causes. If this process doesn't indicate the root cause or causes, it will be an indication into the direction of the root cause or causes.

Figure 3 is the VARCA Model with its seven steps (in red). For every step there are a few actions (in green).

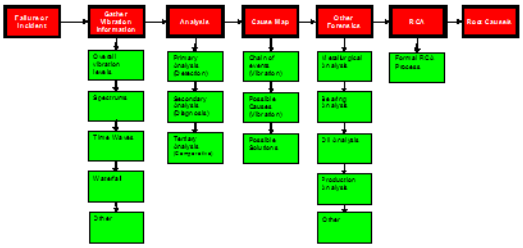

Figure 3 - The VARCA Model (Steps and Actions)(Attachment 3)

The steps of the model can be described as follow:

Step 1: The failure or incident.

Step 2: Gather the necessary vibration related information from the different vibration monitoring systems. Important information is the overall levels, spectrums, time waves, waterfall plots etc.

Step 3: Conduct the analysis. For this action you need a competent vibration analyst (level three certified) to do a proper, detailed analysis. There are also three levels of analysis to conduct, as indicated by Figure 4. The Primary Analysis is the normal vibration analysis, as conducted for normal condition monitoring. The Secondary Analysis is a detailed analysis (not required for condition monitoring). The Secondary Analysis is the most important analysis in failure analysis (a). The Tertiary Analysis is to determine if there is a common factor on the system (a common fault or defect on all similar equipment).

(a. Failure analysis tools like Prolizer and Prolizer AM will conduct this kind of analysis).

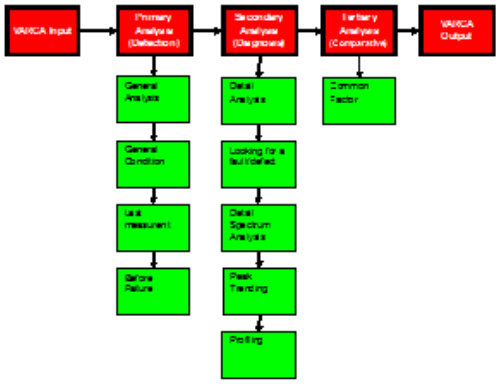

Figure 4 - The different levels of analysis of the VARCA Model.(Attachment 4)

Step 4: Derived a cause map of the whole situation from the information from the vibration analysis. Figure 5 is an example of the cause map.

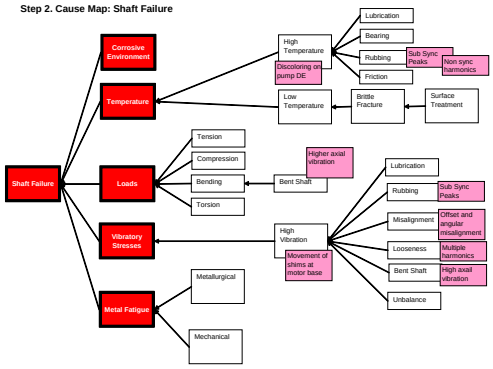

Figure 5 - Example of a cause map of a shaft failure (Case Study) (Attachment 5)

Step 5: Other Forensics – just like the vibration analysis other types of analyses were also conducted. Some of the valuable analyses are wear/debris analysis or oil analysis, bearing analysis, metallurgical analysis, production analysis or any other type of analysis.

Step 6: Time to move with the results of the analysis to the official RCA.

Step 7: The root cause or causes (from the formal RCA).

8. CONCLUSION ON THE DEVELOPMENT OF THE VARCA MODEL

- Vibration Analysis in the normal way will identify general defects like unbalance, misalignment, looseness etc.
- The VARCA Model is a very efficient tool to use in root cause analysis.
- Normal vibration analysis and the presented information from the vibration software program don't provide much better information regarding equipment failures.
- The outcome of such an investigation with the VARCA Model can be a valuable input to a formal RCA and the development of maintenance strategies.

9. ACRONYMS

- DSP - Digital Signal Processing
- FFT - Fast Fourier Transform
- FVA - Forensic Vibration Analysis
- RCA - Root Cause Analysis
- VARCA - Vibration Analysis in Root Cause Analysis

10. REFERENCES

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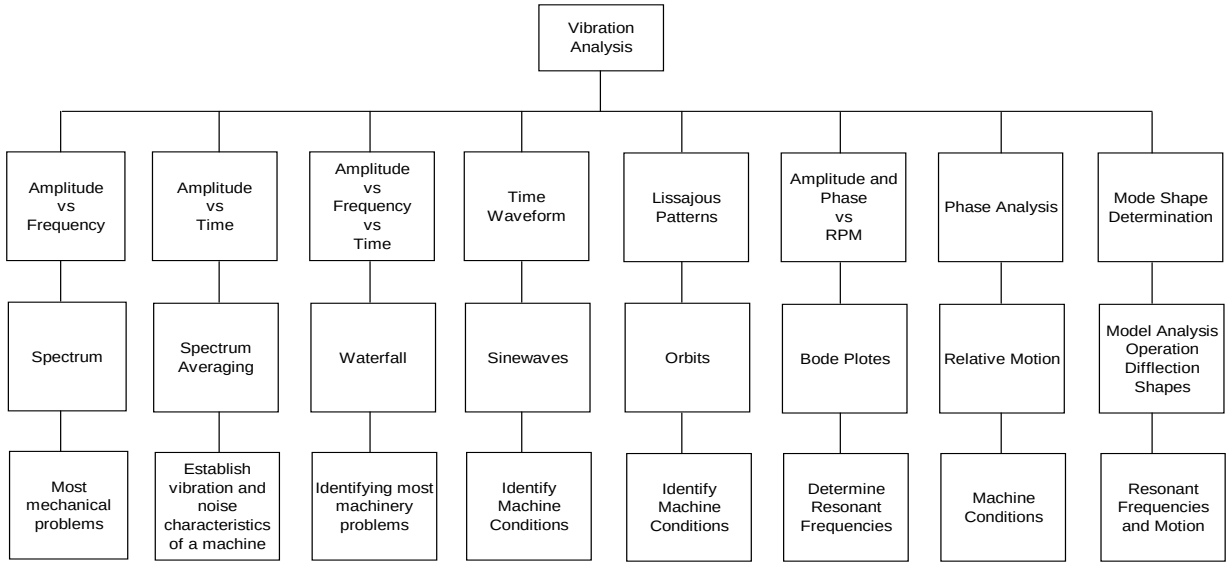
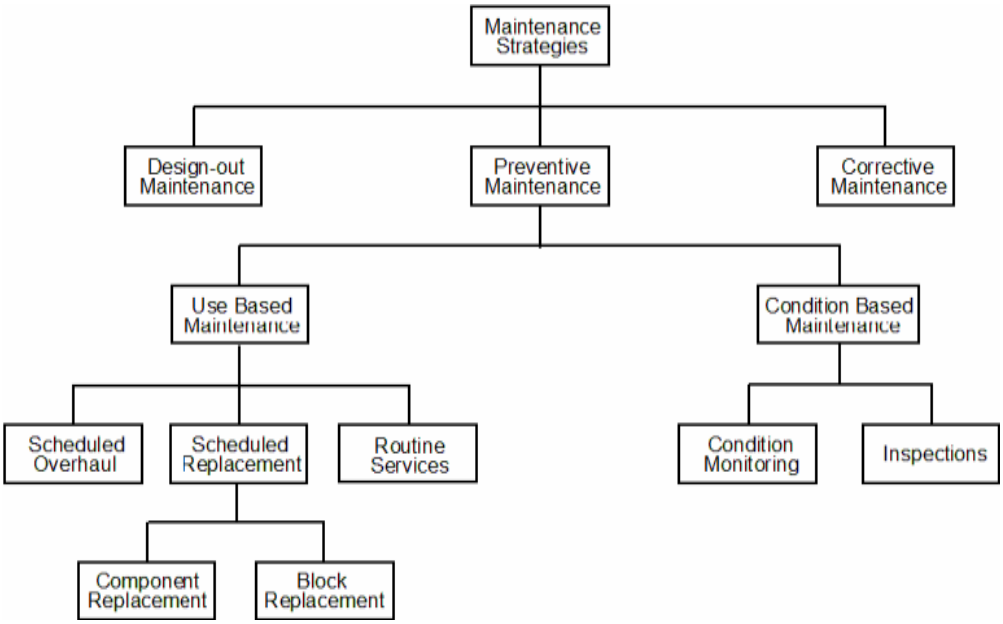
[12] Innes BJ and Jones A, *The Science of Forensic Investigations*, Thicktok Media, 2006.

Author: Etienne Human is a Reliability Engineer and holds a master's degree in Mechanical Engineering from the University of Johannesburg. At present he is the senior asset management and reliability engineer at the Carab Tekniva Group. He is also registered as a senior member of the South African Institute of Electrical Engineers (SAIEE) and as a member of the South African Institution of Mechanical Engineering (SAIMechE).

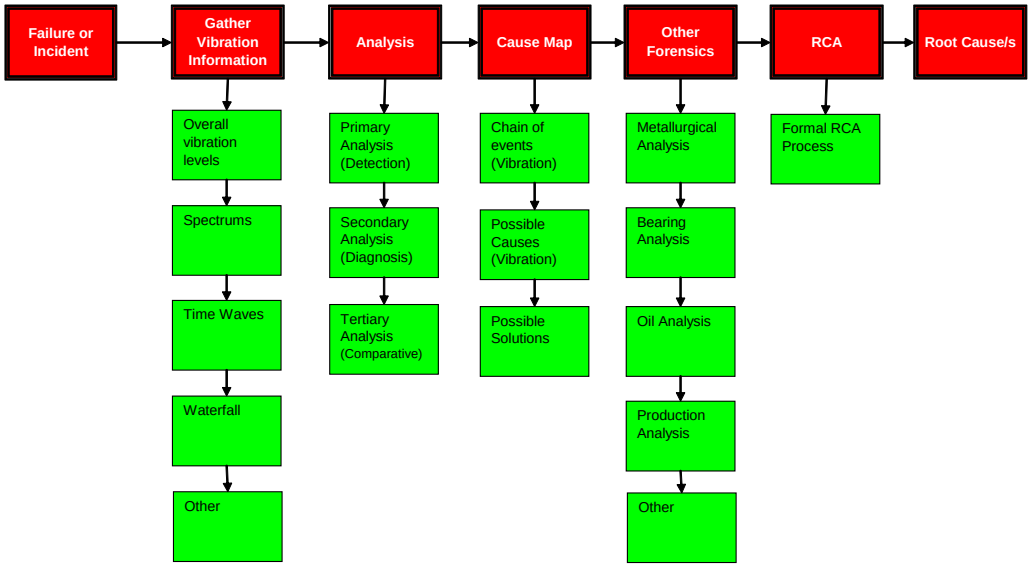
Attachment 1: Different types of Vibration Analysis techniques.



Attachment 2: Maintenance Strategy Breakdown.



Attachment 3: The VARCA Model

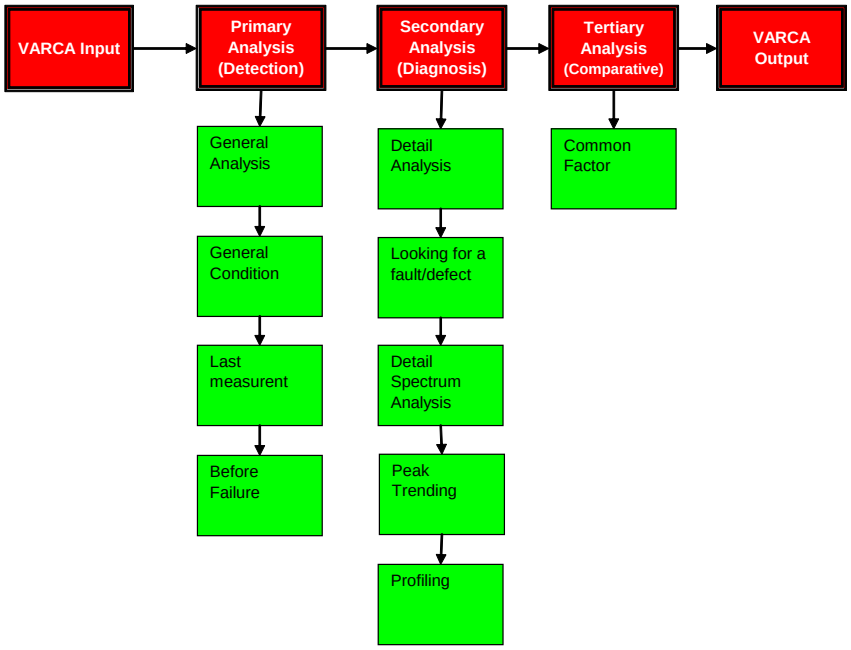


Legend

Steps

Actions

Attachment 4: Different levels of analysis of the VARCA Model.



Attachment 5: Example of a cause map of a shaft failure.