

# A DECISION METHOD OF MATERIEL MAINTENANCE BASED ON FAILURE LIFE CYCLE

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**Abstract:** For a complex materiel, the failure of significant item with higher reliability require can not be satisfied by Reliability Centered Maintenance Analysis alone, nor by Root Cause Analysis and Proactive Maintenance. According to the feature of failure come into being, a concept: failure life cycle, was presented. And it was divide into several parts according to each phase feature. The incidents occurred on each phase can be resolved by this three technics. Integrated them based on failure life cycle, a perfect dynamic maintenance decision technology can be formed in solved any failure on complex materiel.

**Key words:** maintenance decision, life cycle, decision optimized, reliability centered maintenance, proactive maintenance, root cause analysis.

## 1. INTRODUCTION

In the implementing of Reliability Centered Maintenance (RCM), there are many items which failure can not be prevented effectively. After analyzing on three modern maintenance decision technology, RCM, Root Cause Analysis(RCA) and Proactive Maintenance(PaM), it is found that there is not a single method of them able to solve these problems perfectly or economically and meet the require of high reliability or availability level<sup>[1,2,3]</sup>. It is necessary to find a systematic method focus on the whole life cycle of an evident failure in order to determine the best maintenance task. To the important materiel, it is worthy of finding any multifarious preventive maintenance policy for its significant. Based on that, an item, failure life cycle(FLC), was presented. And then, FLC was divided into several parts

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according to its feature. Different maintenance decision technology can be taken for the different parts of FLC. By integrated these three methods, a perfect dynamic maintenance decision technology can be formed finally.

## 2. DIVIDING THE FLC

For complex materiel, the failure forming process of significant function item is always an event chain or tree with a causal relationship (causal chain or causal tree), which can describe from the initial root cause<sup>[3]</sup> to the aimed function failure. FLC was divided into five parts in this paper, see figure I .

1. Pregnant Phase: Pregnant phase is a phase from FSI begin working to the root cause occur, not a necessary phase. There is not a pregnant phase if the root cause existed at the very begging, such as fixing problems.
2. Root Cause Action Phase: This phase begins at the root cause occur and end at the next causal factors occur, a necessity phase. Root cause can be a fault element, a operating/maintenance error, design problem, environment problem, and it can also just the normal work station, such as vibrating. Root cause may be not just one, and it can be combined by several event or factors. These event or factors may occur in different time, while, there is always a key cause, which directly effected whether the causal chain or tree can be formed.

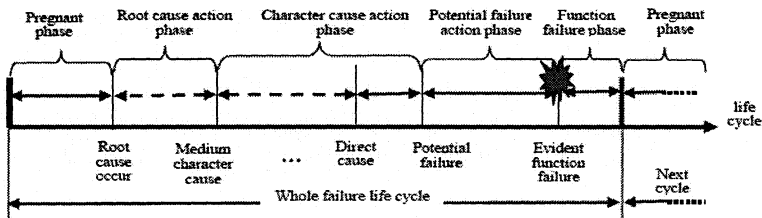


Figure 1. The divided of failure life cycle

3. Medium character causes action phase: This phase began at the next cause occurred after root cause and ended at the potential or function failure occurred, not a necessity phase. These causes prefer the defined identifiable condition that indicates that a degradation/failure process is taking place that will lead to a next item functional failure or the aim item-FSI potential/function failure. It may have several events or have none when the root cause is the direct cause of the aim function failure.
4. Potential Failure Action Phase: This phase begins at the potential failure appearing and end at the evident function occurred. And the potential failure is a defined identifiable condition that indicates that a degradation process is taking place that will lead to the evident function failure.

5. Evident Function Failure Phase: This phase is from the aim item evident function failure occurs until it is repaired.

### **3. MODERN MAINTENANCE DECISION TECHNIQS**

RCM, PaM and RCA are the three methods used commonly in plant maintenance planning currently.

In RCM, it is by answered the 7 questions<sup>[5]</sup> in turn to determine all the potential failure modes or direct cause of the analysis item, and develop a maintenance policy in order to reduce the failure effect by using logic decision<sup>[4]</sup>. And the policy is focus on these potential failure mode or direct cause. While in fact, most of the failures occurred in working are the repeatedly failure which caused only by a root cause in generally, only few of the failure caused by happenstance. Obviously, RCM can not prevented the failure itself, but reduced its effect. So, reference<sup>[6]</sup> considered that the RCM is driven by maintenance policy not by security policy.

RCA is a normalized causal analysis approach, which research and trace the accident and the cause relationship, until to find the root cause of accident, and then adopt correspond measure in solving the problem thoroughly<sup>[3]</sup>. It is focus on the root cause on materiel of failure, not directly cause. The corrective measures of RCA are far beyond traditional maintenance work types, which include all works able to improve the materiel work condition, such as training, improving operation type and design etc. In general, the beginning level of element in RCA is the ending level in RCMA<sup>[6]</sup>. The object of RCA is the item with high reliability require or frequently failure.

PaM is a method which identify the “root cause” of the evident function failure systematically, and then determined maintenance policy before the object performance or material degradation, that is preposition maintenance by dint of modern detection technology in order to reduce the whole maintenance require and extend the service life of materiel<sup>[7]</sup>.

Contrast with RCM and RCA: First, it analysis object should be the high reliability require item with the evident condition that must be identified and controlled by relative advanced detection technology, and there still be some suitable, economic and effectiveness PaM measure; Second, the “root cause” is any surround factors effected the lowest analysis item of RCM, not the “root cause” used in RCA. In this paper, it is taken as the directly cause or medium character cause; The last not the least, PaM is not a independent maintenance work type, but a maintenance measure based on condition monitoring aim at the failure root cause, it contain the failure station

monitoring and elimination.

#### 4. FLOW OF MAINTENANCE DECISION BASED ON FAILURE LIFE CYCLE RESULTS

Traditional preventive maintenance aimed at the phase from directly cause to function failure and the key point is potential failure phase. It is considered that the closer the maintenance task to function failure, the more economics of the work premising the function not occur. While, the principle of RCA is prevented the aimed failure occurred at root by avoiding the root cause or medium characteristic cause occur. And the focus of PaM are the directly cause or the cause of directly cause, such as material performing, the polluting of liquid uncommonly, etc. In PaM, the modern detected technology, such as automatic particle counting, oil and water analyzer, etc, is necessary. And the figure II show the suitable phases of the 3 modern maintenance decision method. Figure III show the flow of integrated maintenance decision method, and it is described in detail as follow.

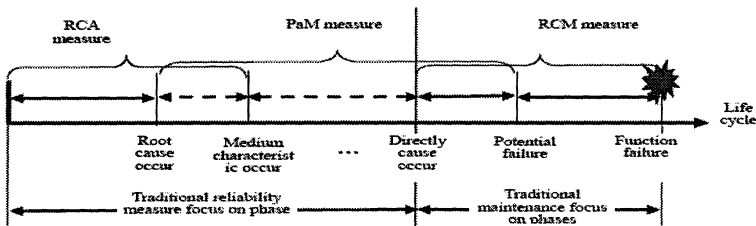


Figure II. 3 maintenance decision technics active phases and failure life cycle.

##### 4.1 Determined the analysis item

The analysis items must be the significant function item(FSI), just as FSI in RCM. And divided these item according to its reliability require and failure feature that obtained by FMEA. The selected criteria as below:

- the FSI with high reliability requirement, and serious failure effect need RCA and/or PaM analysis;
- the FSI with frequency failure feature, and due to some root cause or semi-root cause need RCA and/or PaM analysis.

##### 4.2 Build the causal chain/tree

In this sub-process, RCA is used to resolve two matters: one is

determined whether a root cause exist or not; the other is build the key causal chain. If there is a root cause indeed, relative measure should determine according to the root cause character, if there is not a real root cause, a causal chain should build. It should be noted that<sup>[8]</sup>:

- The data collected include all effective information, such as test data, history data, even the operating information. While the veracity, accuracy of data should be verified. The data collecting direction should be modified according to the real information in time.
- The estimating needs be verified. The process is analyzing one level events, and evaluating, and then verifying, until the root cause was find or the key factor un-convergence.
- Tracking result is most important in analysis processing, it is an effective method with long period and semi-simulation property. In normal analysis, it is unable to practice, but marked to do that after analysis.

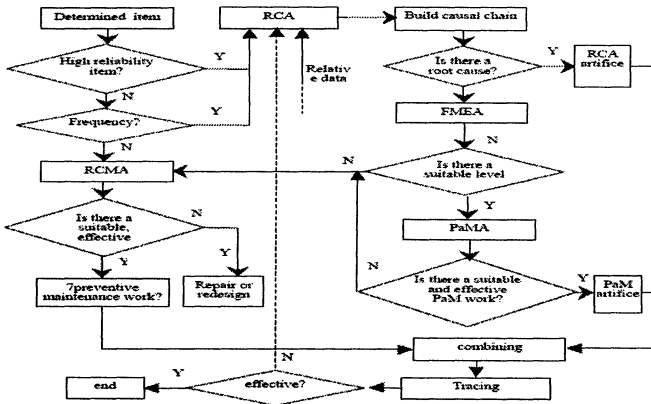


Figure III. maintenance decision flow based on FLC

### 4.3 Proactive maintenance analyzing

PaMA is based on RCA, which focus on the item without real root cause or effective RCA measure. General, there is only one key failure mode/event in on link/level of causal chain/tree with special property. Considering the require of item in PaM, not all the key failure/event are suitable for PaM. So, it is need analysis one by one in order to determine the suitable link. It should be noted that:

- The analysis item must be key factor in the causal chain/tree.
- The location of analysis item in material must be suitable to be monitoring or/and detecting by test devices on line.

- There must be a suitable test devices or test technology to monitoring or/and detecting the item.
- The interval of the analysis item acting phase must be reasonable and constant in order to ensure the worthy of the PaM measure.

#### 4.4 Determined and Combine the Preventive work

The item need RCMA in here is items which failure will cause direct adverse effect on operating capability or economic effect. Otherwise, those items without real root cause or relative measures is still need be analysis by traditional RCM logic decision. And then combing all the preventive work/artifice determined according to the item or the interval of maintenance work and finally come into a maintenance plan or program.

#### 4.5 Result Tracing

Result tracing is an important step in this analysis, the result of tracing will validate the accuracy of maintenance plan or program and modify the RCA process.

### 5. CONCLUSION

Above all, this method can analysis the items with repeatedly failure or/and high reliability requirement on complex materiel preferably which can't be resolved effectively by traditional RCM. The maintenance plan developed by this method is more perfectly. Limited to space, the optimizing analysis of the decision precess and a case study are not present in this paper.

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