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A framework for identification of maintenance significant items in reliability centered maintenance

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ABSTRACT

Identification of Maintenance Significant Items (MSI) is one of the key phases of the Reliability Centered Maintenance (RCM), which is a screening phase where the number of items for analysis is reduced. But at present, there is little systematic and convenient operation method to identify the MSI. In this paper, we presented a framework for identification of the MSI through combination of quantitative analysis with qualitative analysis. Firstly, we screened out part of non-MSI through the first screening which defines a system boundary, set up a system hierarchy tree and do a Risk Analysis (RA) of a 2th order risk matrix. And secondly, we omitted another part non-MSI in the second screening which carried out a Failure Mode and Effects Analysis (FMEA) and do a RA based on a 5th order risk matrix. Moreover, we carried on a quantitative analysis by establishing evaluation indexes and scoring standard of the MSI based on the Analytic Hierarchy Process (AHP) and Fuzzy Borda Count method (FBC). Finally, we completed a case study about the drilling pump to prove the feasibility and practicality of the method. This study is helpful for the applicable and effective Preventive Maintenance (PM) tasks.

1. Introduction

RCM is a systematic analysis method for planning the PM in the field of the equipment management [1]. In order to ensure successful implementation of the RCM, it needs not only a scientific theory and method as a guide, but also effective and convenient technical tools [2]. Therefore, the present research and application of the RCM attaches great importance to supporting role of mathematical models and applicable analysis methods which have been carrying out a classified research from different angles for the RCM [3]. It is emphasized that effectiveness quantitative evaluation applying the mathematical model enhances the accuracy of the maintaining decision of the RCM as well as plays a very active role for promoting the application and popularization of the RCM [4,5].

Because a system or equipment generally composes of a large number of components, all of them have its own function, failure mode and effects. For those function failures of the components in the system, there are some effects to safety of the people and the environment; some effects to a task completion and some effects to the economic cost [6,7]. But most of them have no a direct influence on the overall system. When they are eliminated in time, the only consequence is the cost of corrective maintenance (CM) which is general lower than PM [8]. Thus, it is no necessary to analyze for all components when making a maintenance decisions for a complex system based on the RCM theory. Moreover, the PM in the RCM is used only for the MSI that is just a small part of all components in a system [9]. But it is the qualitative analysis method that is adopted to identify the MSI in the traditional RCM just by virtue of the experience of maintenance engineer and operating personnel. In the analysis process above, they subjectively omit the non-MSI based on some qualitative terms, thereby leaving part are the MSI [10,11].

However, on the one hand, the boundary partition between the MSI and the non-MSI is vague by only using qualitative analysis method above. Not only it can't prevent some MSI from missing, but also not ensure that the failure of the MSI must have an influence on the system. On the other hand, there are multiple influence factors on whether one component is a MSI in system and their

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weight should be different during this evaluation, but they aren't considered in the traditional RCM. Moreover, it is the importance level of the MSI that isn't identified from the results of the qualitative analysis method. Therefore, in order to scientific and effective to screen the MSI in system, it is necessary to present a systematic framework for the RCM to improve practicality and operability based on quantitative analysis and qualitative analysis, which also is the purpose of this study.

The paper is organized as follows. In Section 2 we presented the qualitative analysis method to screen out the non-MSI in overall system by two screening process. Based on the APH and the FBC, the quantitative analysis method of the MSI is established in Section 3. Then in Section 4, a case study about the drilling pump is done to obtain its MSI and important level. Finally, Section 5 provides some discussions and conclusions.

2. Method for screening out the non-MSI

2.1. Definition system and the first screening

Based on the method defining the MSI in the traditional RCM analysis, we had performed a blue print of the first screening of the non-MSI in all system with the 2th order risk matrix, as shown in Fig. 1 [12].

Considering that the analyzed system may be associated with other systems, we need define the boundary and function of system analyzed in the first place in Fig. 1. As we all known, the composition of a system is general a relatively complex structure which consists of several subsystems, a subsystem consists of several components, a component consists of several parts [13]. In order to illustrate specifically the composition and hierarchy of a system and be useful to the subsequent analysis, we set up a basic structure frame of the system hierarchy tree in Fig. 2.

In order to effectively and quickly to complete initial screening for components of every hierarchy in the system, the 2th order risk matrix was established, as shown in Fig. 3 [14]. This 2th order risk matrix determines risk level of every component including High Risk (H), Medium Risk (M) and Low Risk (L) based on its probability of failure (PoF) and consequence of failure (CoF) [15]. According to the process diagram of the first screening in Fig. 1, we can first filtered out the low risk system which is judged by the 2th order risk matrix in Fig. 3, and then omitted no risk and low risk subsystem. Similarly, we can rule out no risk and low risk units and parts. Then we obtain the relatively significant items of the system to prepare for the next step screening.

2.2. Failure mode and effects analysis and risk analysis

FMEA is an inductive analysis tool to analyze failure mode and failure effect of the critical components whose failure will lead to undesirable consequences [16]. In the FMEA, all possible failure modes and all the possible consequences of every component also be analyzed and classified with the severity of its failure mode and frequency of occurrence [17]. Based on the system hierarchy tree and the results of the first screening, we can performed the FMEA for the relatively significant items to obtain their function, failure mode and failure effect on the system.

However, the different components have different failure modes which will lead to different PoF and CoF. In order to distinguish the CoF, we divided it into four categories, namely, safety risk (SR), environmental risk (CR), economic cost risk (ECR) and maintenance cost risk (MCR) [18]. Therefore, we combine the experience of experts and field investigation to divide out the PoF in Table 1, and the CoF of four categories, as shown in Tables 2–5 [19].

In Table 6, we created a record chart for the FMEA and the RA. We can fill in the FMEA results of every component and the corresponding PoF categories and CoF categories by reference to the above relevant tables.

2.3. The second screening based on risk matrix

Because the PoF and the CoF in the last step analysis are divided into 5 categories, we work out a 5×5 risk matrix to estimate level of risk, as shown in Fig. 4 [20]. In this 5th order risk matrix, the level of the risk are divided into four types including high risk (H), medium risk (M), low risk (L) and no risk (N). The risk matrix is suitable for the safety risk, the environmental risk, the economic cost risk and the maintenance cost risk of the function failures of the component.

As an analysis item may existing multiple failure modes, their

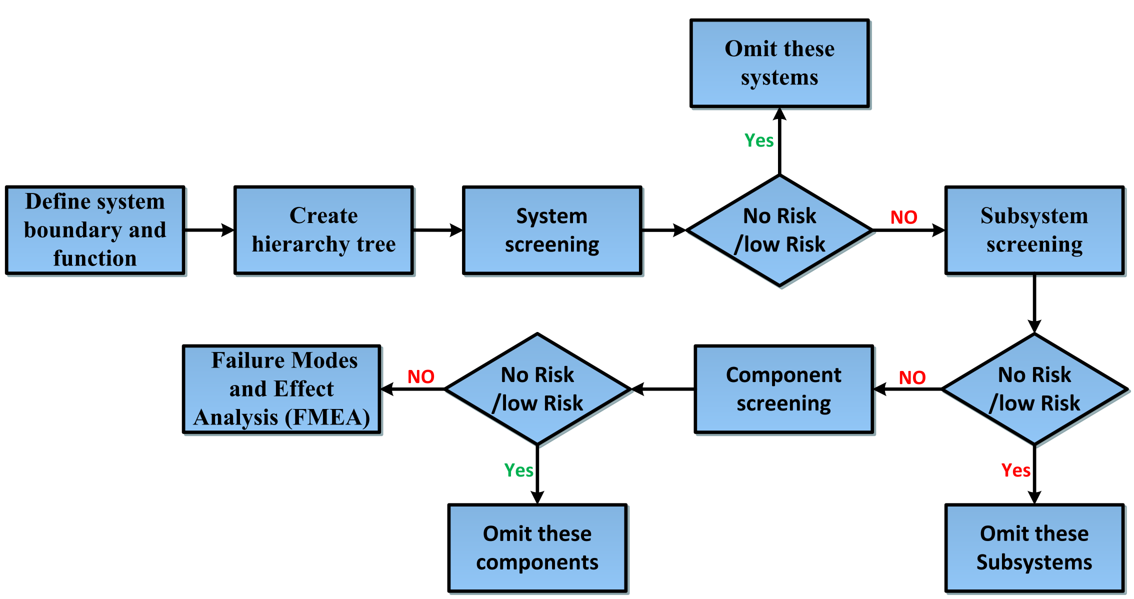

Fig. 1. The first screening process.