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A framework for intelligent reliability centered maintenance analysis

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Abstract

To improve the efficiency of reliability-centered maintenance (RCM) analysis, case-based reasoning (CBR), as a kind of artificial intelligence (AI) technology, was successfully introduced into RCM analysis process, and a framework for intelligent RCM analysis (IRCMA) was studied. The idea for IRCMA is based on the fact that the historical records of RCM analysis on similar items can be referenced and used for the current RCM analysis of a new item. Because many common or similar items may exist in the analyzed equipment, the repeated tasks of RCM analysis can be considerably simplified or avoided by revising the similar cases in conducting RCM analysis. Based on the previous theory studies, an intelligent RCM analysis system (IRCMAS) prototype was developed. This research has focused on the description of the definition, basic principles as well as a framework of IRCMA, and discussion of critical techniques in the IRCMA. Finally, IRCMAS prototype is presented based on a case study.

Keywords: Reliability-centered maintenance (RCM); Case-based reasoning (CBR); Analysis system

1. Introduction

Reliability-centered maintenance (RCM), as a procedure to identify preventive maintenance (PM) requirements of complex systems, has been recognized and accepted in many industrial fields [1–6], such as steel plant, aviation, railway network or ships maintenance. The countries applying RCM include the United States, Britain, Japan, etc.

RCM was introduced into China in the late 1980s, and the first RCM standard GJB1378 was published and put into practice in 1992. Since then, RCM has been a popular methodology widely used in China's military to identify PM requirements of weapon systems. Numerous RCM programs of the in-service equipments have been developed. The major problem in the application of RCM is that the quality of RCM program is highly dependent on the experience and skills of the RCM analysts [16,20].

In order to ensure the proper use of RCM, two efforts have been made in our application: (1) to strengthen the training of RCM group to ensure that the analysts have consistent understandings of RCM terms and principles; (2) to develop a computer aided RCM system (CARCMS) to ensure the consistency of the RCM procedures.

Although the traditional CARCMS is a preferred tool for RCM analysts, it is not an intelligent system and cannot provide the similar cases for analysts. RCM practitioners were surveyed and responded noting need to access RCM cases of similar equipments or similar items for their reference in conducting RCM practice. A good RCM case reflects not only reliability data of the analyzed equipment, but also the principles and right understanding of RCM concepts.

Based on the above considerations, case histories of approximately 70 RCM cases conducted in the past 10 years were compiled and analyzed. These RCM cases covered a wide range of ground weapon systems.

RCM case includes all historical records in the RCM process, such as the list of functionally significant items (FSIA), the failure mode and effect analysis (FMEA) information and the RCM decision information. Apart from these, the basic reliability prediction information in current industry standard is also collected. At the same time, case-based reasoning (CBR) technology is explored

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and successfully introduced into RCM analysis process. A framework for intelligent RCM analysis (IRCMA) is studied, in which RCM cases and the basic reliability data of electrical and mechanical items are integrated. The (IRCMA) approach was implemented through an expert system.

2. RCM analysis process

RCM analysis process is as follows [8,10]:

(1) Identification of the functionally significant items (FSI). The FSIs are the items whose failure modes have significant economic, safety or mission effects on the system. The items may be system, subsystems, components or parts. The meaning of identification of the FSIs is to identify the functionally significant items in system, subsystem, component or part levels.
(2) Failure mode and effect analysis (FMEA): The goal of FMEA is to identify functions as well as functional failure modes of the bottom FSI, their failure causes and effects.
(3) RCM logic decision. Each failure cause of FSI is decided by RCM logic decision chart. The specific PM policy and its interval are ascertained according to reliability data.
(4) Combining the PM policy and developing the preventive program. The optimization of the interval of single policy cannot ensure the optimal result of general policies. In order to ensure the efficiency, maneuverability and practicability of PM, we need to combine the different policies into suitable groups. Generally, the combination of maintenance policies and development of preventive program should be based on existing maintenance systems and regular intervals (date, week, month, season, year), see Fig. 1.

From the above RCM process, we may find that complex equipments are generally made up of many FSIs. If we conduct RCM analysis on them, we must input FSIs, carry out FMEA, conduct RCM logic decision and combine the PM policy. The characteristics of RCM process are plenty of data, information, and many tables. Conducting RCM analysis on complex equipments needs many analysts at the same time. In order to conduct RCM analysis, plenty of information needs to be input and much time is consumed, especially in the stages of identification of FSIs and FMEA.

There are generally similar structures in the same category equipment, and some common parts and mechanism in the different categories equipment. Namely, there are similar FSIs in the different equipment. By the adaptation of RCM analysis information of these FSIs, the repeated analysis tasks can be reduced and time is saved. RCM analysis efficiency can be improved without compromising the quality of the analysis [11–15].

3. Definition and basic principles of IRCMA

By introducing CBR into RCM analysis process, IRCMA transforms traditional RCM analysis, which is completely conducted by expert for specific equipment, into the retrieval process of the RCM analysis result of similar equipments by computer, and the adaptation or check process of the RCM analysis result of the similar equipments by expert. So the repeated analysis work is avoided or reduced, and the efficiency of RCM analysis can be improved.

(1) The meaning of IRCMA is to conduct RCM analysis on the specific equipments based on the existing cases.
(2) The main task of IRCMA is to identify the PM program for the specific equipment.
(3) The goal of IRCMA is to improve RCM analysis efficiency and to reduce the costs as well as time of identifying the PM program.
(4) The key to realize IRCMA is computer technology.

The basic principles of IRCMA are as follows:

(1) If the structure features, function and application environment of equipments are the same or similar, then their failure modes and measures to prevent failure are usually close or similar.
(2) When the analysts conduct RCM analysis on the specific equipments, they often unknowingly refer to historical records of RCM analysis on similar items, and achieve the satisfactory outcomes by the adaptation of the similar cases.
(3) There are usually similar structures in the same equipment category, and some common parts and

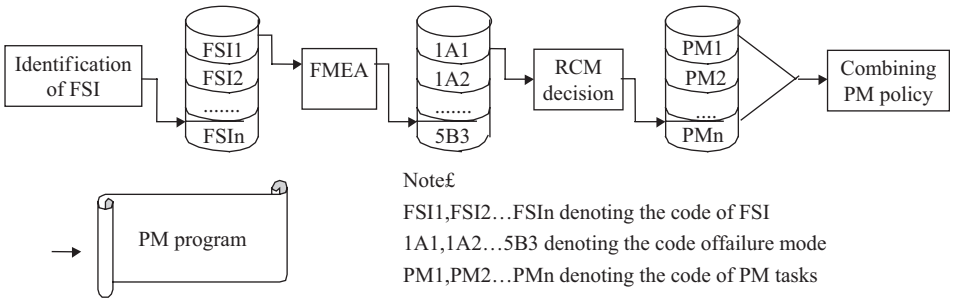

Fig. 1. RCM analysis process.