PERGAMON

Expert Systems with Applications 19 (2000) 45–57

Expert Systems with Applications

www.elsevier.com/locate/eswa

An expert system for reliability centered maintenance in the chemical industry

D.J. Fonseca[a,*], G.M. Knapp[b]

[a]Department of Industrial Engineering, The University of Alabama, Box 870288, Tuscaloosa, AL 35487-0288, USA
[b]Department of Industrial and Manufacturing Systems Engineering, Louisiana State University, Baton Rouge, LA 70803, USA

Abstract

A new framework for the implementation of reliability centered maintenance (RCM) in the initial design phases of industrial chemical processes was developed and implemented. Fuzzy reasoning algorithms were designed to evaluate and assess the likelihood of equipment failure mode precipitation and aggravation. Furthermore, an approximate reasoning scheme which considers local, product, and adjacent machinery effects was constructed to prioritize the equipment failure modes likely to precipitate in the process.

The new RCM approach was implemented through an expert system. The computer system reads the process flowsheet generated by ASPEN Plus and, based on relevant machine operating data, it provides the user with the final process RCM availability structure diagram. This availability diagram consists of a listing of all critical machine failure modes likely to precipitate, prioritized according to their overall negative impact on the process, as well as important information on their corresponding local and system effects, and suggested controls for their detection.

Keywords: Reliability centered maintenance; Fuzzy reasoning algorithms; Approximate reasoning scheme

1. Introduction

1.1. Background

During the last decades, the need for identifying cost-effective maintenance programs for production plants and manufacturing facilities has generated a proliferation of global analysis methodologies oriented to the development of competent reliability management policies. Among these analytical methods, Reliability Centered Maintenance (RCM), which was first introduced by the civil aviation industry in the 1960s, is, indeed, not only the most frequently used but also the technique that has proven to be the most effective worldwide.

The RCM methodology provides a practical and structured approach for arriving at a satisfactory maintenance strategy for each component of a given system. In choosing a strategy, the methodology takes into account safety requirements, maintenance costs, and costs of lost production (Vatn, Hokstad & Bodsberg, 1996). In essence, RCM can be defined as a technique for organizing maintenance activities to be cost-effective. Its central objective is to determine the actions required to ensure that all physical asset continue to fulfill their intended functions in its current operating environment.

During the last years, several different frameworks have been adopted by industrial practitioners in order to accommodate the RCM's principles to their increasing equipment maintenance demands. The development of computer software packages that embed either mathematical optimizing algorithms or managerial rules of thumb or heuristics represent the most recent efforts in the area of reliability management modeling.

Expert systems have been defined as consulting systems that simulate the problem-solving ability of human experts through the use of expertise drawn from an information base and specific rules employed to interpret such knowledge. Expert systems are structured in three distinct components. The knowledge base is a set of rules about the problem domain, supplied by the expert or obtained through in-depth research. The working memory carries out the tracking of what has been concluded or learned at any stage of a particular consultation. The inference engine evaluates what is true at any given time in the working memory and the knowledge base, resolving conflicts when necessary (Ignizio, 1991).

* Corresponding author. Tel.: + 1-205-348-3337; fax: + 1-205-348-7162.

E-mail address: dfonseca@coe.eng.ua.edu (D.J. Fonseca).

0957-4174/00/$ - see front matter
PII: S0957-4174(00)00019-1

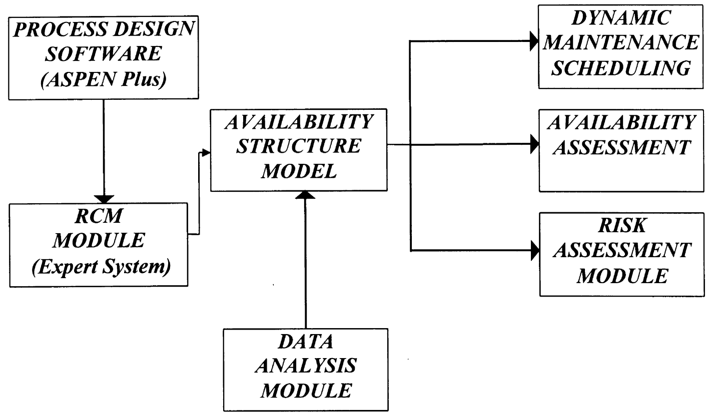

Fig. 1. A proposed industrial equipment reliability management environment.

1.2. Objective

This research was oriented to the development of a new computerized RCM framework to be employed as the basis of the preliminary design for production processes commonly used in chemical industry. Fig. 1 depicts the intended reliability management environment, whose final goal is the generation of optimal equipment maintenance strategies once the manufacturing process is set and functioning.

Typically, chemical processes are highly complex. Their design, development, and control involve such a vast effort that engineers must use sophisticated computer software. In order to facilitate and minimize the user data input and ntervention, the conceived maintenance environment directly utilizes the equipment condition and operational data generated by ASPEN Plus, a process simulation package, as the main input for the RCM module. The RCM module consists of the developed expert system, which produces the Availability Structure Model, a model that serves as a preliminary failure assessment during the designing phases of the production system. This Availability Structure Model eventually becomes the platform for the overall preventive maintenance program of the plant.

The framework devised for implementing the RCM analysis module involved the accomplishment of three major tasks. First, the RCM module had to properly interface with ASPEN Plus and be able to recognize the distinct pieces of equipment and type of chemical process under analysis. Second, it had to determine all the different failure modes associated with the involved manufacturing equipment, how they may affect each other, and how they may obstruct the normal functioning of the overall system. Finally, the RCM module should elaborate an availability structure model that could serve as the basis of the design process, where issues such as machinery procurement, production resource control, maintenance strategy selection, and labor allocation are resolved.

2. Knowledge engineering

2.1. Process selection

The first step in the development of the expert system was the selection of a set of representative industrial chemical processes that could be used for extracting the needed equipment maintenance expertise.

Ten industrial processes were selected on the basis of commercial importance. According to the 1992 Survey of Industrial Chemistry (Chenier, 1992), the following (listed in order of importance) are the most produced industrial chemicals in the world; and hence, their production processes were taken as the main sources of the expertise used in this research.

- Sulfuric acid, H_2SO_4
- Nitrogen and oxygen, N_2, O_2
- Ethylene and propylene
- Calcium Oxide or lime, CaO
- Ammonia, NH_3
- Phosphoric acid, H_3PO_4
- Sodium hydroxide or caustic soda and chlorine, NaOH, Cl_2
- Sodium carbonate or soda ash, Na_2CO_3
- Nitric acid, HNO_3
- Ammonium nitrate, NH_4NO_3

2.2. The pieces of equipment covered by the system

From the previously mentioned chemical processes, 62 different industrial process machines were identified, and their most relevant failure modes extracted from the pertinent literature and field experts. Nevertheless, for the development of the intended expert system, a subset of 11 of such machines was selected on the basis of universality of use in the industrial settings. The 11 chosen pieces of equipment are the following:

- Burner
- Centrifugal blower