Knowledge-based System Prototype in Structural Component Design Based on FM

JIANG Tao 1, LI Qing-fen 2, LI Ming 3, FU Wei 2

1. Power Generation Department, Luneng Company, Jinan 250001, China
2. College of Mechanical and Electrical Engineering, Harbin Engineering University, Harbin 150001, China
3. Technique Superintendence Center, Daqing Oil Field Company Ltd, Daqing 163453, China

Abstract: A knowledge-based system in structural component design based on fracture mechanics is developed in this paper. The system consists of several functional parts: a general inference engine, a set of knowledge bases and data-bases, an interpretation engine, a bases administration system and the interface. It can simulate a human expert to make analysis and design scheme mainly for four kinds of typical structural components widely used in shipbuilding industry: pressure vessels, huge rotation constructions, pump-rod and welded structures. It is an open system which may be broadened and perfected to cover a wider range of engineering application through the modification and enlargement of knowledge bases and data-bases. It has a natural and friendly interface that may be easily operated. An on-line help service is also provided.

Key words: Expert system; Fracture Mechanics; Structural component design


0 Introduction

Engineering failures occur in many well designed components and structures, the cause has very often been a pre-existing crack or other defect. Fracture mechanics (FM) is a method which aids in predicting the remaining service life of a part that contains a defect such as a crack. This method has been used by engineers in many industries. It is a tool which relates the size of a defect to the likelihood of its causing fracture in a given material under a given stress regime. In fracture mechanics, the fracture toughness and transition temperature quantities were introduced to characterize material failure behavior in addition to conventional mechanical properties such as critical strength \( \sigma_c \), yield strength \( \sigma_y \), etc. Stress intensity factor (\( K \)), crack opening displacement (\( COD \)), \( J \)-integral, etc, have been adopted for many industrial applications. The design engineers can greatly improve the reliability and serviceability of a structure by using fracture mechanics.

An expert system is a computer program that emulates the behavior of a human expert within a well-defined narrow domain of knowledge. ESs are probably the most practical application in the field of AI and have emerged as useful, deployable systems that are being operationally used worldwide \([1] \). For determining the fracture characteristic of materials and structures, knowledge-based system could be very useful, as shown by H. Liebowitz \([1] \). Several expert systems related to fracture mechanics were developed \([2-4] \), where the usefulness of an AI approach to some deterministic problems were discussed and some ES approach to fracture mechanics problems were devised.

However, the assessment and repair of existing structures is a complex decision-making engineering task. The characterization of the material/structure damage process involving non-linear behavior is complex and cumbersome as it can involve a vast amount of numerical data. Besides, different people...
may make engineering judgement differently according to their knowledge of subject, either from formal training or from experience. Therefore, in addition to a sound theoretical knowledge, it is necessary to develop an easily assessable and usable expert system which can provide the practicing engineer with a powerful tool in design and analysis. A systematic approach that can provide rational conclusions and simulate the judgement of an expert is therefore developed.

In this paper, design knowledge, experience and methods for four types of typical engineering components (pressure vessels, huge rotation constructions, pump-rod and welded structures) are collected and a set of data bases and knowledge bases are then built respectively.

The most important types of defects are discussed and simplified for fatigue and fracture analysis. Stress and crack-size analysis, defect-assessment and fatigue life estimation can be carried out for each kind of component in the expert system.

Although this research is in its infancy, valuable results have already been found which help forecasting promising avenues of research in the development of knowledge-based systems.

1 System composition

The system consists of six functional parts which are a general inference engine, an interpretation engine, some knowledge bases (including both the meta-knowledge and common knowledge bases), a context (including the comprehensive and premise bases), a bases administration system and the interface.

Fig. 1 gives the framework of the ES and the general flowchart of the system is shown in Fig. 2.