OBJECT - ORIENTED APPROACH FOR EXPERT SYSTEM DEVELOPMENT IN STRUCTURAL INTEGRITY ASSESSMENT OF CRACKED VESSELS

V. POCAJT, V. OGAREVIC, S. SEDMAK and V. LJUBINKOVIC
Faculty of Technology and Metallurgy, Belgrade, Yugoslavia

ABSTRACT

In an effort to develop expert system for structural integrity assessment of pressure vessels at the Faculty of Technology and Metallurgy, Belgrade, we concluded that the basic subtask is to obtain efficient usage of available knowledge and data. Intelligent and/or active database management seems to be an appropriate approach for fulfillment of this subtask, since it gives an opportunity to develop reliable, robust and user-friendly software system. In order to follow this approach, several techniques and methodologies were applied, implemented and presented, having in mind special features of cracked pressure vessels domain.

KEYWORDS

Structrural integrity assessment, pressure vessels, expert systems, information systems, databases

1. INTRODUCTION

Major investments in power, chemical and other industrial plants and significant hazards of catastrophic failures, which may result in high outage costs and put at risk population and environment, induced development of sophisticated analytical techniques for predicting plant components behavior. Considerable experimental efforts and accumulation of empirical knowledge about characteristics of materials and components in service led to great increase of quantity of data relevant for structural integrity assessment. This scope of data is far beyond the capabilities of conventional computer programs, and expert systems (ES) seem to be the only alternative for effective solution of this problem. Consequently, establishing an efficient and semantically powerful method of ES development is very important for further advances of computer aided techniques in structural integrity assessment.

2. EXPERT SYSTEMS AND DATABASES IN STRUCTURAL INTEGRITY ASSESSMENT CONTEXT

It is recognized that ES are evolutionary (not revolutionary) step in software (s/w) engineering, not substantially different from conventional s/w (Parsaye and Chingell, 1988). That attitude is based on fact that ES often interfere with conventional s/w and fulfill some of the conventional s/w environments tasks (automatic programing, quality of interface). On the other hand, it is evident that a significant part of new ("conventional") software products tend to involve some ES concepts and exhibit "intelligent" behavior. Concepts like triggering, assertions and rules begin to appear in commercial Database Management Systems (DBMS) (Dittrich and Dayal, 1991). Since information system is abstract model of real system, applying ES concepts is an opportunity to capture more of real system semantics in this model.

Initial standpoint of this project is that it is possible to regard ES development as general information system building problem and to apply standard software systems development methodology - Object Oriented Transformation (OOT) approach (Lazarevic et al., 1990). This semantically rich method (involves concepts of inheritance, relation, aggregation and generalization) is performed in two steps (Lazarevic, 1991):

1) system specification and
2) implementation.

For dealing with complexity of real system (plant with multiple pressure vessels) and implementation purposes, ES was divided in two basic modules: database (Materials, plant Structure and Service history database - MSE Db) and knowledge base module (Expert Reasoning Module - ERM) (Pocajt, 1992). Stable, "quasi static" characteristics of real system (plant structure, built-in materials and their properties) became objects in the database module, while "dynamic" features, simulation parameters and objects with complex relations were involved in the knowledge base.

3. SYSTEM SPECIFICATION

In system analysis Enhanced Entity-Relationship (EER) model was used. Compared with the original Chen's model (1976, 1983), this specific version is enriched with several concepts (aggregation, complex relations, system integrity specifications). System analysis should result in reliable, concise, formal and clear programming specification.

The result of the database specification is Entity - Relationship (ER) diagram on Fig. 1. Entire plant structure is captured in four classes of objects: STRUCTURE, COMPONENT, ELEMENT and VESSEL. Materials, classified (object MAT_CLASS) and related with relevant standards (INSTITUTION and STANDARD), aggregate with elements entity MADE_OF, which enables reviewing properties (mechanical and physical properties, chemical composition) in objects CHEM_STRUCT, T_CRIT_ST and T_T_CRIT_ST. Objects and relations of MSE DB module involve significant part of a real system semantics.

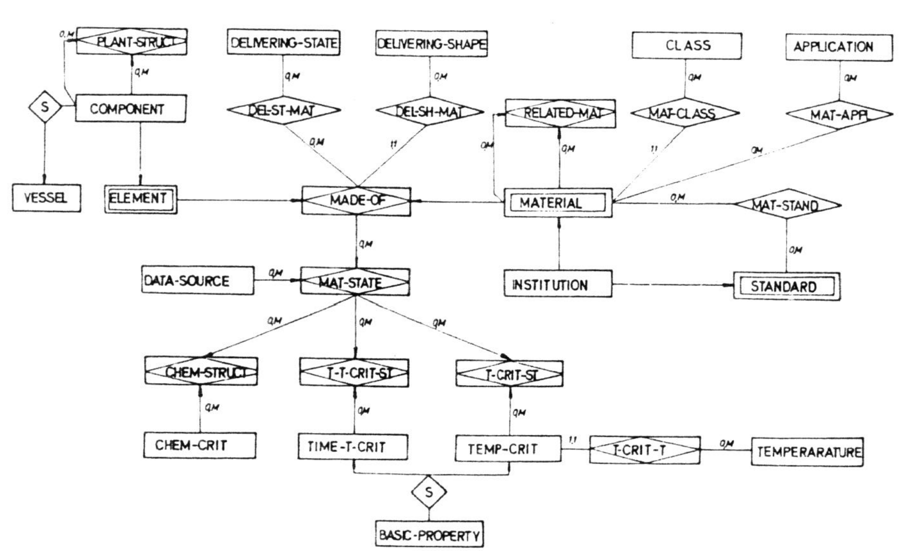

Fig 1: Entity - Relationship (ER) Model for MSE DB

The knowledge base (KB) can be treated as an "active" part of the system. Although the very same development methodology was applied, there are some differences in the database and KB specification, since the relations between objects of knowledge base are more complex. These relations, which are not obvious from KB structure (Fig.2), were described by rules, functions and numerical procedures. External programs (e.g. for finite element modeling) can also be used to support extremely complex relations between attributes of KB objects.

In this phase of development (rel. 1.0), numerous attributes of the object CRACK (for crack treatment) are interconnected and connected with the object STRESS (for nominal stress defining) by numeric procedures and functions which originates from linear elastic fracture mechanics, R6 approach and leak-before-break analysis (Kanninen and Popelar, 1985). The object PLASTIC_DEF for treatment of plastic deformations of vessel elements also relates with the STRESS, and it is possible to instantiate the object CONTROL_CALC which calls external programs for more detailed "conventional" analysis. These objects are generalized in the object DAMAGE, which relates them with the set of heuristic rules, in order to asses level of vessel safety and consequences of eventual propagation of damage. Object CORROSION is entirely heuristic, and treats risks and basic mechanisms of corrosion damage of vessel materials.

Geometry and properties of vessel parts and materials, which are kept in MSE Db, are necessary in whole ERM and all objects inherit them from the object VESSEL_CHARACTERISTICS. This object also relates CORROSION and DAMAGE with a group of heuristic rules and provides a final conclusion about structural integrity to the root object VESSEL.

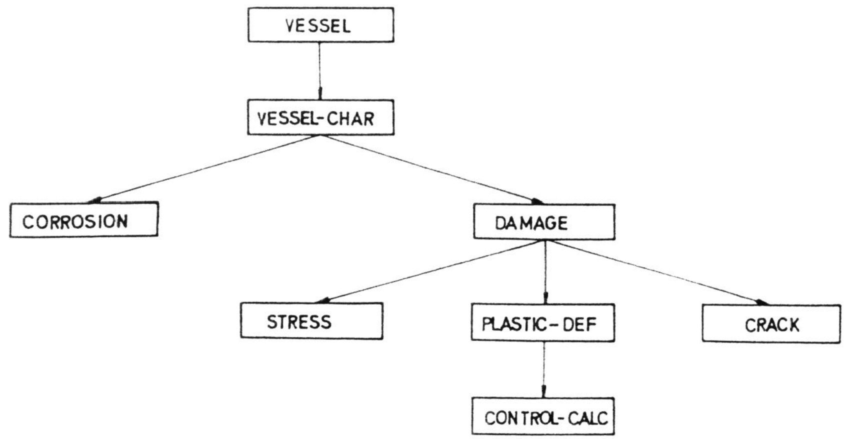

Fig 2: Structure of Knowledge Base in Expert Reasoning Module

4. SYSTEM IMPLEMENTATION

Implementation phase of MSE Db development was performed by translating objects and relations of EER model to a semantically simplyfied relation model, which can than be directly implemented in a commercial DBMS. In this case dBase III+ DBMS was used. Unfortunately, in this step a part of system semantics have to be coded using conventional computer programs. ERM was implemented with Personal Consultant Plus, an object-oriented expert system building tool, which exhibited satisfactory interface with database (dbf format) files (Tello, 1987).

With programing specification which resulted from previous step (system analysis), time for implementing ERM and coding of approximately 70 program modules in MSE Db was kept at minimum. Therefore, significance of development methodology can never be overestimated.

MSE database was installed in "Nikola Tesla" Power Plant (2x620 MW) for off-line monitoring of state of parts and material properties in service. Whole system (with ERM) was tested on a real, food industry plant with satisfactory simulation results.

REFERENCES

Chen P. (1976): The Entity - Relationship Model: Towards a Unified View of Data, ACM TODS, Vol.1, No.1

Chen P. (1983): A Preliminary Framework for Entity - Relationship Models, in Entity - Relation Approach to Information Modelling and Analysis (ed. P.Chen), North Holland

K.Dittrich, U.Dayal (1991): Active Database Systems, Conference on Very Large Databases, Barcelona

Lazarevic B., Ilic S., Marjanovic Z. (1990): An approach to Computer - Aided Transformational Method of Information System Development, Proceedings of International Academy of Management & Marketing, Dallas

Lazarevic B (1991): Information Systems Projecting (in Serbian), Faculty for Management, Belgrade

M.Kanninen, C.Popelar (1985): Advanced Fracture Mechanics, Oxford University Press, New York

Parsaye K., Chingell M. (1988): Expert Systems for Experts, John Wiley & Sons, New York, USA

Pocajt V. (1992): Developing of KBS for Remaining Life Assessment of Pressure Vessels, 9th European Conference on Fracture, Varna

Tello E. (1987): Personal Consultant Plus, Byte, October, pp. 229-234