The microcomputer-based expert system in CAD-PV

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1 INTRODUCTION

As a branch of artificial intelligence, expert system has been revealed day after day in more and more engineering scopes since the successful applications of MYCIN in diagnosis and DENDRAL in the molecular structure of organic compounds etc.. But in the design scope of pressure vessel, as we know, only a few papers have so far been published with respect to the expert system. The necessity and feasibility of accompanying CAD-PV with expert system attracted more scholars to engage in. Although many countries, including China, have regularized the design standards or codes for pressure vessel, but of which no one can solve all of the problems concerning the various practical occasions and experiences. In general, the more domain knowledges a design engineer possesses of, the better decision will be made by him. By virtue of the expert system any less experienced engineer could make the optimum decision in design as well as a skilled senior engineer in addition to the application of design code. It is the due significance for developing high level expert system as an intelligence assistant in the plan option of CAD-PV.

In this paper we attempt to introduce a specified software JACKPV used in the design procedure of jacketed pressure vessel as an intelligence front in CAD-PV. JACKPV consists of the function of expert system based on the personal computer IBM-PC/XT with the language PASCAL in its program. It was proved that an ordinary CAD software could be effectively improved while equipped with expert system.

2 THE STRUCTURE OF JACKPV

In JACKPV it usually needs a lot of calculations for engineering design. On the other hand, those results of calculations will be utilized iteratively through the inference engine. So there are quite a few interactive procedure between calculating and inferring. For instance, if a jacketed pressure vessel made by corrosion proof material, say stainless steel, is subjected to both internal reactive pressure and the superheating steam pressure in jacket. Now, in order to design its shell thickness there are three options as follows:

(1) Take the calculating thickness by use of modified structure like ring-stiffeners etc.;

(2) Take the calculating thickness of stainless steel shell by code rules;

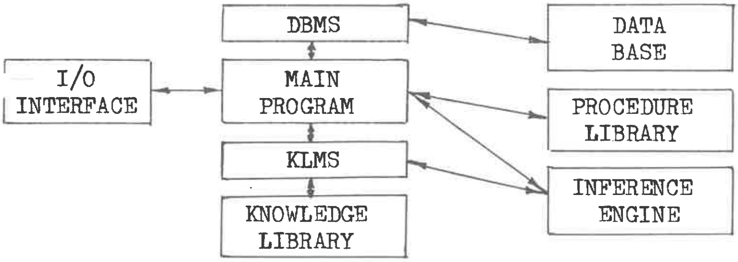

Figure 1. The structure of JACKPV

(3) Take the calculating thickness of lined carbon steel shell (with stainless steel as a liner) by code rules.

On decision making process an engineer should compare the cost, the material supply, the fabrication, the weldability, the inspection and all other feasible factors as well. That is to say, in JACKPV there need a procedure library and an inference engine. In procedure library the necessary procedures of numerical calculus such as general calculation, structural analysis calculation, optimization and so on are inclusive. In inference engine it is mainly responsible for logical and predicate calculus.

The interactive function between the procedure library and inference engine is implemented and controlled by the main program, so that the modular structure of the whole software could likely be more flexible. Inview of such arrangement the additional required informations for the procedure library and inference engine could be also involved through I/O interface directly.

Data base is the another important subdivision for expert system during engineering design. In JACKPV it consists of the material properties, the specifications of preformed steel components, the standard parts, the physical and chemical performances of different media, the necessary design coefficients and other large amount of informations. So a specified data base management system (DBMS) has to be built in JACKPV, by which the entire data operations such as access, modification, deletation could be effectively done. The data could be not only retrieved in the main program, but also retrieved, modified and deleted by the users through I/O interface directly. The conceptual schema of DBMS is hierarchical. By use of multi-layer index and pointer the efficiency of data operation is no doubt increased considerably.

The knowledge library (or knowledge base) is usually the kernel subdivision of expert system, and is described as a "bottleneck" due to its complexity. The performance of expert system depends greatly on the degree of abundance and accuracy of knowledge library. In JACKPV the knowledge library includes two parts: one is called "fact base" that involves many items concerning the design criteria, the fabricating techniques, the instructions about installation, transportation, maintenance and operation etc.. The another one is called "rule base" that involves many rules collected from domain experts. The structure of fact base adopts the list format with key word index, while that of rule base is still hierarchical just like that of data base.

A knowledge library management system (KLMS) has to be built for manipulating the rules organized by the knowledge engineer, that is, how to make decision table, decision tree and how to carry out. All of these details will be illustrated in next section. The broad outline of JACKPV structure is shown in Fig 1.

3 KNOWLEDGE DESCRIPTION AND RULE BASE

The separation of knowledge from main program in the expert system has been proved by our pratice to be a good suggestion for treating enormous dynamic knowledges. As previously mentioned, the fact base involves a lot of definite knowledges among which no any inevitable relation exists, or say, no inference should be applied. Thus it is only less trouble in setting up fact base. All of the facts are classified and put into external memory facilities according to some specified orders. Afterward the index and pointer will be used to search the required facts if necessary. But it is much more difficult to build a rule base, since among which a series of logical relations are needed. The schema of rule base will directly influence the inference process. In general, there are three kinds of conceptual schema for the structure option of rule base, i.e., relational, network and hierarchical. In JACKPV the hierarchical schema was chosen for application. The advantages of such schema are considered as clear reasoning routine, faster reasoning speed and easier to follow the reasoning trace. But it is trouble in construction and modification of the rule base. Fortunately, the rules in engineering design are relatively stable, that the rule revise is happened occasionally.

The whole tasks of building or revising a rule base are implemented by KLMS. In accordance with the input informations ordered by knowledge engineer through I/O interface, KLMS will set up a decision table at first. Then by means of some manipulations the table will be changed into decision tree automatically. Based on that tree a rule base file will be produced and transferred into external memory facility. While in operation KLMS could retrieve the required root-node of decision tree and transfer their contents into inference engine by some commands or regulations.

A simple pattern is shown as follows to illustrate the procedure of KLMS:

For a jacketed pressure vessel with stirring shaft several rules to determine its thickness of upper head are mentioned below:

(1) IF (the difference of thickness between shell and upper head $\leqslant$ 4 mm) $\vee$ (the number of reinforced openings on the head $\geqslant 3$)
THEN the thickness of upper head is taken as the same value to shell;

(2) IF (the diameter of shell $\geqslant 3$ m) $\wedge$ (the stirring power $\geqslant 100$ kw)
THEN (a) the stiffeners should be considered on the head;
(b) turn to the rules of stiffener reinforcement;
(c) respond to the user;

(3) IF (the diameter of shell $\geqslant 3$ m) $\wedge$ (the stirring power $\geqslant 100$ kw) $\wedge$ ((the number of openings on the head $\geqslant 10$) $\vee$ (it is infeasible to weld stiffeners on the head))
THEN (a) the thickness of head should be increased;
(b) turn to the rules of additional thickening;
(c) respond to the user.

According to those rules KLMS set up a decision table and decision tree shown in Fig 2 and 3 respectively. The tree represents a conceptual structure schema of certain layer. Each root-node shows a record of both node contents and pointer during physical storage.

It is worthwhile to point out that the important problem in pratice would be how to understand user's rule informations through I/O interface. In JACKPV it requests that the user should put each rule information into two parts, i.e., condition and conclusion. Moreover, the condition should be separated into attributes, predicates and values. If an

	R1	R2	R3	R4	R5	R6	R7	R8	R9
C1 the difference of thickness between shell & upper head $\leqslant 4$ mm	N	N	Y	Y	-	-	-	-	-
C2 the number of reinforced openings on the head $\geqslant 3$	N	N	-	-	Y	Y	-	-	-
C3 the diameter of shell $\geqslant 3$ m	N	-	N	-	N	-	Y	Y	Y
C4 the stirring power $\geqslant$ 100 kw	-	N	-	N	-	N	Y	Y	Y
C5 the number of openings on the head $\geqslant$ 10	-	-	-	-	-	-	N	Y	N
C6 stiffener welding is infeasible	-	-	-	-	-	-	N	-	Y
A1 take the calculating thickness	*	*							
A2 take the same thickness as shell			*	*	*	*			
A3 add stiffeners on the head							*		
A4 increase the thickness of the head properly								*	*
A5 go to the rule of additional thickening								*	*
A6 respond to user							*	*	*

Figure 2. The decision table

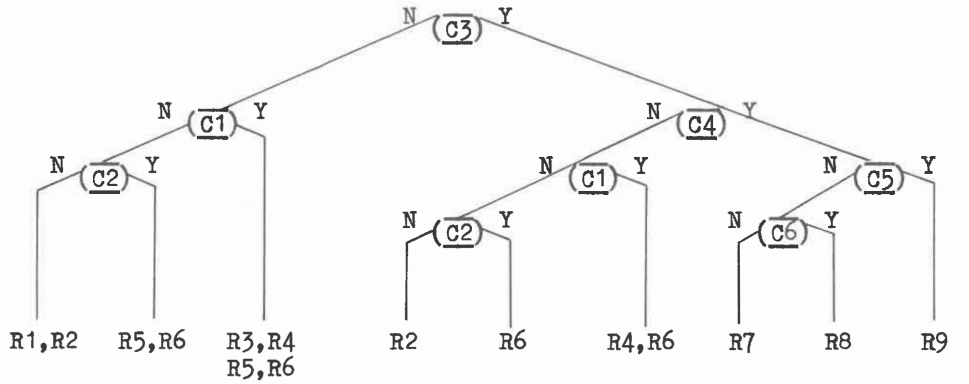

Figure 3. The decision tree

attribute is involved in several rules, its symbol must be consistent everywhere.

4 REASONING STRATEGY AND STRUCTURE OF INFERENCE ENGINE

The forward reasoning system is accepted as the reasoning strategy in JACKPV. The inference engine draws calculating results and other conditions of the rules from the main program and I/O interface. During reasoning procedure the judging engine evaluates step by step whether the conditions of the rules are satified, until the final conclusion is reached. At the same time, the reasoning routine will be recorded by a recorder and could be printed out through I/O interface.

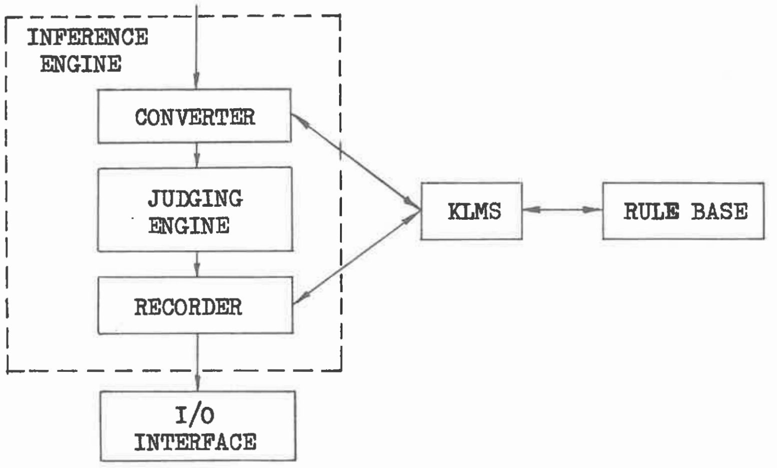

Figure 4. The structure of inference engine

Fig 4 is the structure diagram of the inference engine in JACKPV. Here a converter is necessary, because the most jobs done by the inference engine are the logical operations between variable and numerical value, or variable and variable. This is just the reason for selecting PASCAL as the main language of this software.

5 REMARKS

The study of inserting expert system into CAD-PV has pratical significance in engineering design scope, especially those based on the micro-computer. By virtue of expert system, CAD could gradually be developed into CD due to the function of artificial intelligence on decision making. JACKPV is basically similar to those expert systems like MYCIN and DENDRAL in structural conception. However, in view of the interaction between numerical and logical operations, JACKPV has its own characteristics about procedure library and inference engine. The further work on JACKPV would be the mixing applications of PASCAL, C and PROLOG (or LISP) languages in IBM/PC-XT equipped with ready-made softwares like Arity/Prolog, GCLISP etc..

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