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Quality assurance expert system for car cylinder casting①

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[Abstract] A quality assurance expert system, ZJSYS, has been developed for car cylinder casting by use of artificial intelligence technology and C++ for windows. The important feature of this expert system is that it draws not only qualitative conclusions but also quantitative ones in the therapy of defects. ZJSYS uses an expert reasoning strategy based on the rule models with the certainty factor. Reasoning strategy combines forward chaining and backward chaining together to perform qualitative analysis of defects. Meanwhile quantitative analysis of defects is completed by use of mathematical statistics and the principle of optimum. Management system that possesses the functions of adding, modifying and deleting was developed in knowledge base. To meet the practical requirements, the management model of data storage and statistics were developed. Actual run of ZJSYS showed that it played a significant role in improving product quality and reduce rejection ratio.

[Key words] cylinder casting; quality assurance; expert system
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1 INTRODUCTION

With the development of computer technology and artificial intelligence, new methods have been applied to improve casting production[1]. Expert system is an important branch of artificial intelligence, it is essentially an computer program with "intelligent" characteristics, which simulates the thinking process of human experts to solve complex problems in specific domain[2]. Most casting problems fit the case for expert system development, and there have been some expert systems, such as CDAES[3] developed by Kuluarni, and QCES[4] developed by ZENG Yi-dan.

In present casting defect analysis the expert systems have been achieved some progresses. But there are still some deficiencies: 1) the analysis of casting defects is only qualitative; 2) graphs are not connected with production, or graphs are without any production examples; 3) most expert systems are poor in self-studying.

Taking into account of the practicality of production, the cylinder casting quality assurance system was studied by using the expert system technique. An expert system (ZJSYS) with quantitative analysis and graphic display was developed.

2 CONTENTS OF ZJSYS

ZJSYS consists of five modules: defect diagnosis, knowledge base, database, graphic-base and data-analysis.

2.1 Defect diagnosis

The main function of defect diagnosis is to analyze and determine defects existing in castings, predicate rejection ratio of castings, and quantitatively analyze the forming causes and corresponding countermeasures.

2.1.1 Inference mechanism

The defect diagnosis is implemented in ZJSYS by using two-way reasoning strategies based on rule models mixed with certainty factors, and combining forward chaining with backward chaining. Basic structure of two-way reasoning is shown in Fig. 1. Forward chaining is from data to goals, while backward chaining tries to find data to prove a goal . In order to achieve the system's practicability, both reasoning strategies should better be used[5].

Primary object is selected by forward chaining to determine the type of defect, then the object is solved by backward chaining according to their rules dispatched into memory. So casting defect analysis is divided into many tiny regions, each of them contains the rules of defect characteristics, forming reasons and countermeasures. Defects are qualitatively analyzed by inference engine according to the factors of macroscopic state and location of defects.

2.1.2 Diagnosis procedure

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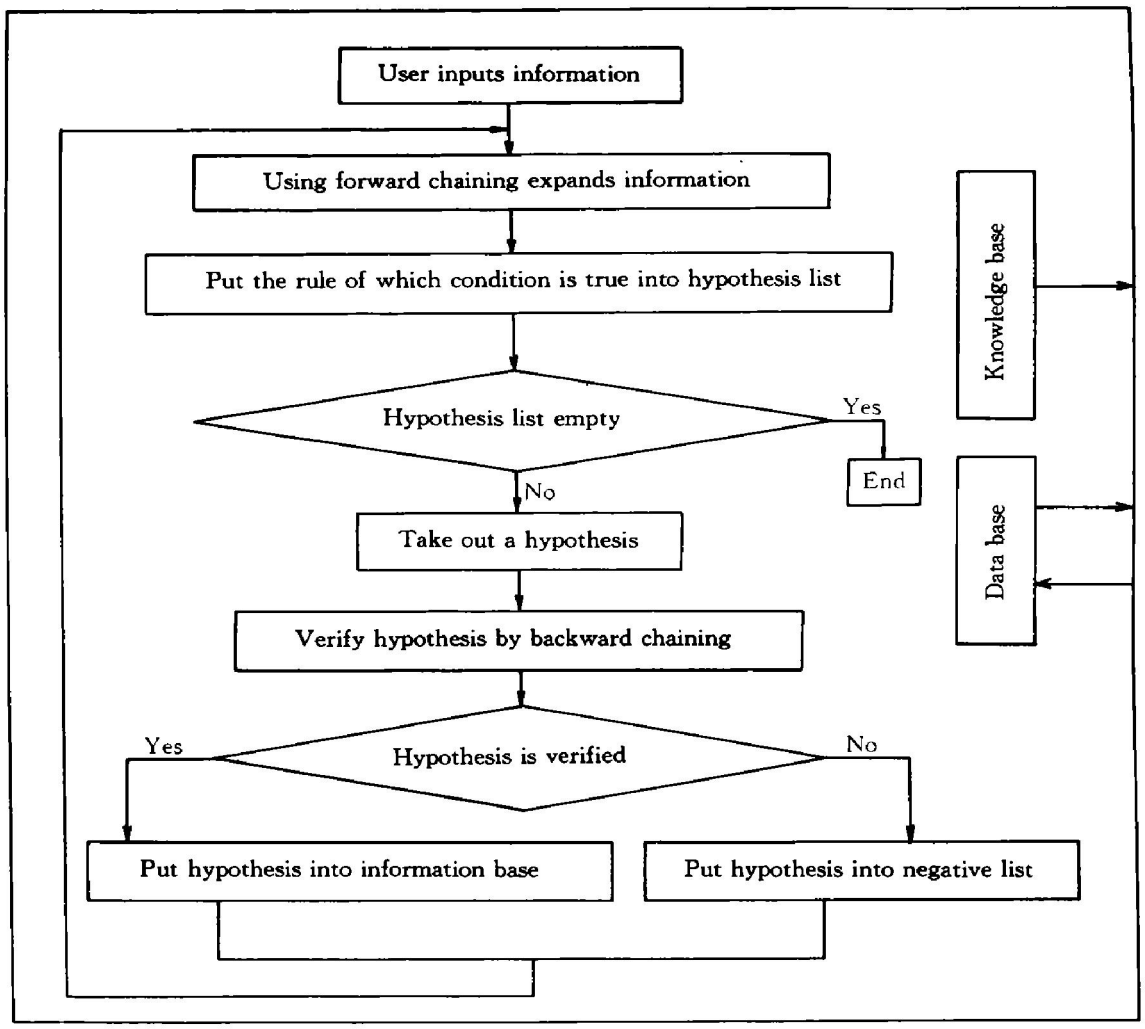

Fig. 1 Two-way reasoning basic structure

The defect diagnosis procedures used by ZJSYS are as follows:

1) Defects are qualitatively analyzed by two-way reasoning strategy according to the macroscopic state and location of defects inputted by operators through the user interface and stored in the knowledge base.

2) On the basis of qualitative analysis, processing parameters are obtained through the control interface and stored in the knowledge base, and then the defects are quantitatively analyzed.

The rationality of processing parameters is taken into account at first, then the data collected from casting production are statistically analyzed by the theory of mathematical statistics. A mathematical model about defects rate and its influence factors (moisture content, compressive strength, permeability, carbon content, silicon content, manganese content, carbon and silicon equivalent, pouring time, pouring temperature) is established[6]. The mathematical model is shown as follows:

$$Y_1 = -138.603 - 2.967x_1 - 28.344x_2 + 0.0652x_3 + 7.8311x_4 - 11.250x_5 - 10.344x_6 - 17.712x_7 + 0.1541x_8 - 0.437x_9 \quad (1)$$

$$Y_2 = 1056.129 + 19.898x_1 + 1.034x_2 + 0.129x_3 + 7.296x_4 - 48.066x_5 - 26.648x_6 - 113.694x_7 - 0.465x_8 + 1.449x_9 \quad (2)$$

$$Y_3 = 584.484 - 5.096x_1 - 59.481x_2 - 0.297x_3 - 4.317x_4 - 16.39x_5 + 2.8457x_6 - 84.406x_7 - 0.133x_8 + 1.546x_9 \quad (3)$$

$$Y_4 = -167.562 + 2.129x_1 + 4.245x_2 + 0.019x_3 + 1.012x_4 + 15.162x_5 - 2.272x_6 + 57.031x_7 - 0.057x_8 + 0.065x_9 \quad (4)$$

where Y_1, Y_2, Y_3, Y_4 are gas hole rate, slag inclusion rate, deficient casting rate, and cold shut rate respectively; x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9 are moisture content, compressive strength, permeability, carbon content, silicon content, manganese content, carbon and silicon equivalent, pouring time, pouring temperature respectively.

Mathematical model is highly significant at the level of 0.01 through F checking and the calculation of related coefficient (Table 1). Results show gas hole rate, slag inclusion rate, deficient casting rate and cold shut rate have linear dependences with nine

processing parameters. Defect rate is calculated by means of mathematical model and the contents of process parameters modified by the principle of optimum are given out. Quantitative analyzing of the defects reaches the goal to predict defect rate and control it within range.

Table 1 Related coefficient and checking of F

Regression equation	Related coefficient	$R_{0.01}(9)$	F	$F_{0.01}(9, 16)$
Eqn. (1)	0.8156	0.8310	9.978	3.78
Eqn. (2)	0.7260	0.6940	6.492	3.78
Eqn. (3)	0.9807	0.8723	16.79	3.78
Eqn. (4)	0.9215	0.8029	13.25	3.78

2.2 Knowledge base

Knowledge base is the foundation of defect diagnosis. It stores all knowledge needed by inference. The establishment of knowledge base should be convenient for defect diagnosis.

2.2.1 Expressing of knowledge

The expression of knowledge is to summarise knowledge, form concepts, establish various relations and describe them in a way suitable for computer handling and expressing. This system uses production rules to express knowledge through studying the relation between knowledge expressing and two-way inference mechanism. The general form of production rules is:

R# IF E CF(E) THEN C CF(C)

with CF(C, E) = X

where R# is the number of the rule, E pre-conditions of the rule, C the conclusion caused by conditions, CF(E) the certainty factor of pre-conditions, CF(C) the certainty factors of conclusions, X the certainty factors of rule which expresses the supporting degree of E to C with range from 0 to 1. If X is 1, E completely supports C. If X is 0, pre-conditions have no relations with conclusions.

When the specific rules are set up, the unusual states useful for defect diagnosis are firstly collected. The defect models are set up using fault tree and the value of certainty factor is determined. The value of certainty factor has relation with empirical knowledge and state of system running.

2.2.2 Steps of establishing knowledge base

Steps of establishing knowledge base are as follows:

1) The knowledge with fixed expressing forms is obtained. ZJSYS uses two methods to obtain knowledge, one by inputting from interface, the other through machine studying. The former stores knowledge directly into the knowledge base, and the later uses the way of self-studying. System uses parameter modification method which combines the information of pre-conditions, rule and conclusion to form a mathematical rule:

CF(C) = CF(C, E) * CF(E)

The certainty factor is modified to make its value reach correct conclusions. During the inference, system gives priority to factor with high certainty degree and the factor of which certainty degree is less than a certain value is neglected.

In the process to obtain knowledge, this system divided the casting defects into eight kinds according to the defect characteristics, especially the formation mechanism[7]: **a.** metallic projections, **b.** incomplete casting, **c.** cavities, **d.** defective surface, **e.** inclusion, **f.** discontinuities, **g.** metallography abnormal, **h.** structural anomalies.

2) The knowledge base is partitioned, obtaining the knowledge. The file zone for each concrete defect characteristic, name, forming reasons and countermeasures is established. A concrete aggregation set of defect analysis is built up for each defect in the form of files.

2.2.3 Management system of knowledge base

The knowledge base has management function of adding, removing and modifying information. In terms of the point of object-oriented, the maintenance system of knowledge base is defined as class, which offers basic abstract operation, such as listing element, eliminating element. Defect analysis knowledge base provides concrete operation through self-defining class, which consists of a particular base management system.

2.3 Data base

Data base records the amount of various defects and the processing parameters of production, providing physical assurance for quantitative inference defects. During the establishment of database, data need to be encoded, and to dispose the problem of data inputting, storing, and outputting by using C++ functions of data handling. In order to improve the running speed of ZJSYS, a reasonable data structure must be established. For this ZJSYS to be fully applicable, database takes on the management function of adding, removing and deleting data[8]. Chain data format is developed in order to approve data base management function. Data need to be inserted or deleted from maintenance chain.

2.4 Graphic base

Graphic base stores common defects. During establishing the graphic base, a method of "part plus ensemble" is used to express defects. First, the whole cylinder diagram and diagrams disposed by rotating and dividing are drawn by using AutoCAD software, then primary defects diagrams are drawn. Each of them is assigned an emblem name. For example, gas hole is named as ID_ HOLE. So defects can be displayed at any cylinder position according to different

results analyzed.

The finished defect diagrams drawn by AutoCAD are stored in the format of bitmap and included in resource file. Then the loading of the bitmap can be performed using loading and showing bitmap functions in C++ [9].

2.5 Data analysis

Data in database are analyzed to effectively manage the product quality. The module of data analysis is set up to handle the data as follows: 1) draw the table of production conditions every month, analyze disabled reasons, quality index and main and sub charts of rejection ratio; 2) seek a fore mentioned three kinds of table and figure; 3) print.

The three kinds of tables in data analysis have the following features: 1) most data shown in the table need to be calculated; 2). the data are shared in three kinds of tables while the latter table has relation with the former one, so the tables must be drawn in the sequence of production conditions, analysis of disabled reasons and quality index[10].

Because the present drawing software can not perform these functions, our software is developed by structural design method.

3 RESULTS OF APPLICATION

ZJSYS was applied in Harbin Dongan Auto-engine Joint-Stock Co. ltd. In 462 cylinder castings, small holes in a thin section were often observed. When process parameters were checked, their values were within the reasonable range required. Practical data were input into the system as: moisture content 3.2%, compressive strength 0.25 MPa, permeability 1 520 L/m^2, carbon content 3.3%, silicon content 2%, manganese content 0.7%, copper content 0.4%, pouring time 17 s, pouring temperature 1 420 ℃. Quantitative conclusions were given by running ZJSYS. After processing parameters were adjusted, the rejection ratio of cylinder castings reduced by 1.2%. Therefore, a remarkable economic profit can be achieved.

4 CONCLUSIONS

1) A expert system for car cylinder casting has been developed by artificial intelligence technology and program design method of Windows. On the basis of qualitative analysis, the rejection ratio is predicated and can be controlled in a permitted range by adjusting processing parameters.

2) The graphic base was established using drawing functions of AutoCAD and C++ operational bitmap. Data are stored and analyzed using the functions of data handling and the method of structural program design. The efficiency of ZJSYS is improved.

3) ZJSYS was applied in Harbin Dongan Auto-engine Joint-Stock Co. ltd. to 462 cylinder castings, and the rejection ratio of cylinder castings reduced by 1.2%.

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