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Expert System for Analysis of Casting Defects - ESVOD

T. Elbel*, Y. Králová, J. Hampl
VSB Technical University of Ostrava, Faculty of Metallurgy and Materials Engineering,
17. listopadu 15/2172, 708 33 Ostrava-Poruba, Czech Republic
* Corresponding author. E-mail address: tomas.elbel@vsb.cz

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Abstract

The powerful tool for defect analysis is an expert system. It is a computer programme based on the knowledge of experts for solving the quality of castings. We present the expert system developed in the VSB-Technical University of Ostrava called 'ESWOD'. The ESWOD programme consists of three separate modules: identification, diagnosis / causes and prevention / remedy. The identification of casting defects in the actual form of the system is based on their visual aspect.

Keywords: Expert system, Identification of casting defects

1. Introduction

The powerful tool for defect analysis is an expert system. The expert system is a computer programme simulating the decision-making process of an expert, man, solving complicated tasks. This paper presents the Expert System developed in the VSB-Technical University of Ostrava called the 'ESVOD'. Programme ESVOD consists of three separate modules: identification, diagnosis / causes and prevention / remedy. The identification of casting defects in the actual form of the system is based on their visual aspect. It is a Decision Support System (DSS) which includes a knowledge based system that supports decision making activities in the area of casting defect identification.

Knowledge based expert systems are computer programs which use a collection of facts, rules of thumb and other knowledge about a given field to suggest solutions to specific problems. Foundry related practices are rich in rules of thumb and knowledge bases which can be implemented in such programs to help the analysis of casting defects.

The idea of utilizing the ES for solving casting defects is more than 30 years old. K.Sudesh, G.R.Prakash, and H.Md.Roshan [1] were its pioneers in the foundry branch. Artificial intelligence (AI) is a field of computer science engaged in the design and development of intelligent computer systems. Knowledge Based Computer Systems (KBCS), known by the other popular name as Expert Systems (ES), are a very successful field of AI. According to the above mentioned authors [1] the following requirements in the development of knowledge- based expert systems (KBES) include:

- There must be at least one human expert or team of experts, who have the ability to solve problems in given task area.
- The primary attributes of the expert must be specialized knowledge, judgment and experience.
- The expert must be able to articulate his special knowledge, judgment and experience and explain the methods used to apply it to a particular task.
- The task must have a well-bounded domain of application.
- An understanding of these systems must not involve much of conventional computer knowledge as the technology of software development to allow non-experts in informatics to apply the expert program.

The Expert System ESVOD created by the authors of this paper is based on long term experience with the diagnostic and casting defects prevention [3], meets the requirements mentioned above.

2. Architecture of ESVOD programme

The knowledge data base was created from the expertise of the book "Defects of Castings from Ferrous Alloys" [4]. The authors of this book are a team of experts with specialized knowledge, judgment and extensive industrial experience. The principal role of ES is defects identification. The identification of casting defects in the actual form of system is based on their visual aspect. Descriptions of the defect visual attribute have been worked out for 72 defect types from 90 existing according to a classification of casting defects, including their numerical expression in the above quoted book [4]. This classification the marking and terminology respects fully the International Atlas of Casting Defects.[5].

The ES for identification of casting defects is created in the information system (IS) Visual FoxPro. This IS can be initialized on a personal computer of a user – foundry staff. The system contains three levels as follows:

- identification of defects according to outer attributes
- defect diagnosis and its causes
- prevention and remedies.

When forming the ES the attributes (external aspect of a defect) were divided into 13 groups. Inside the groups there are a certain number of possible variants of attributes. For every group the attribute '0' – none of possibilities given hereinafter – is automatically presupposed. A list of attribute groups is given in Table 1.

Table 1.
List of groups of foundry defects attributes

Group number	The defect attribute
1	Position of material towards casting surface
2	Roughness of defect surface
3	Defect location towards the casting surface
4	Defect shape
5	Defect distribution, the course
6	Defect location towards the mould
7	Colour appearance and other special aspects
8	Accompanying defect
9	Technological circumstances related with the defect
10	The defect contains
11	Casting material
12	Mould material
13	Appearance of fracture surface

In every one of the 13 given groups there is a different attribute number (9 on average, 22 as a maximum). On the first application display the user makes one of two options:

1. The defect identification according to outer attributes.
2. List of defects with their numerical marking.

If the user chooses the option No 1 he will choose in individual application screens the defect attributes according to the external (outer) appearance of the casting defect until he is shown the defect number with its description, the cause of its formation, the method of defect determination, the remedy for removing the given defect, and with the literature reference (most cases) available on the last screen. The defect numbering and the word description result from the book [4] and based on the latest research work will be updated.

Before using Option 1, knowledge of basic technological parameters and material of casting is necessary to detect which defect is present: for example position of a casting in a mould, parting lane, position of risers, gating system, chills, material of casting and a mould etc. To process visual evaluation easily it is possible to cut a casting, separate a smaller sample and so on. Users must always know from which part of the casting a sample has been taken. Be aware! It is not possible to assess an anonymous sample.

When choosing the option No. 2, a list of all defects is displayed on another screen. By clicking on the defect number the description of the chosen defect, causes of its formation, the method of defect determination, remedies for removing the given defect, and the literature references are displayed to the user. Digital photographs of individual defects that can be seen and compared with the particular new situation by the user can be stored in the data base of casting defects too. This procedure is suitable for such users that have determined the casting defect by themselves and want to gain data about that defect and instead of consulting a book, they communicate with a computer. The expert system was tested in Czech foundries with satisfactory results.

ES can be further extended by a data base, in which the user himself should insert data for any casting (or a casting series), e.g. about the melting process, chemical composition of a melt, its casting temperature, moisture of moulding mixture, solidification time, a method of fettling of castings, etc. Processing of those data will help to properly identify the defect causes; subsequently it will enable prevention of the casting defects formation and in such a way improve their quality.

3. Example of the use of knowledge based Expert System ESVOD

Fig 1 shows the defect analysed. It is a section of casting of a cylinder from a block engine. The weight of the casting is 12 kg. The casting has been poured in a vertical position (as in the photo). The core used for manufacturing mould cavity has been made from a Croning shell, the external surface consists of a Hot Box mixture. The casting material is cast iron with flake graphite. The casting has been poured from the top, through a Connor Sprue (around the edges of the cylinder perimeter).

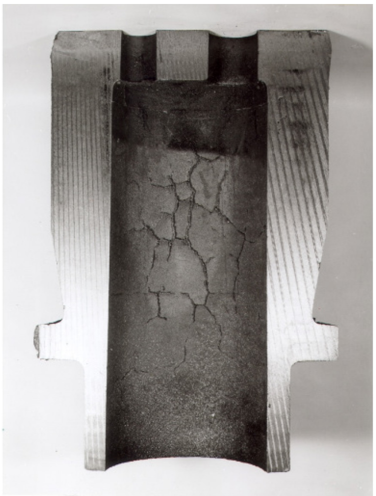

Fig. 1. Vertical section of casting with defects on inner surface

If users want to identify a defect, in the opening screen of ES (Fig. 2) they select an option called 'Identification of defect based on external (visual) attributes' and click on the button marked [>].

EXPERT SYSTEM »ESVOD« OF CASTING DEFECTS ANALYSIS

- **Identification of defect based on visual (external) aspects**
- List of defects with numeric code

START < >

Fig. 2. An introducing ESVOD screen

Next screen (Fig. 3) shows a list of attributes describing a position of defect towards casting surface that have been revealed in a process of identification. The user searches for the most applicable attribute in the offered menu. When he needs more information on what the particular attributes mean he can click on the attribute line in question.

- **In the place of defect material extends casting surface**
- In the place of defect material is missing, failed continuity
- In the place of defect material extends and also is missing casting surface
- In the place of defect material does not extend nor is missing casting surface
- Shift or displacement of one part of casting shape against other
- Reduction or enlargement of casting dimension
- The change of shape or castings dimensions

START < >

Fig. 3. Position of material towards casting surface

When an attribute has been selected (it is underlined, in bold type) the ES automatically selects another screen and identification goes on. If the user chooses an improper attribute, ES will lead him to an incorrect defect. In case a user makes a mistake selecting attributes, he can click the button [<] and go back one or more screens, he can correct his mistake and continue identifying defects.

The third screen displays menu of attributes called „Defect location towards casting surface". Users again selects one attribute and click on button [>].

- **Surface defect**
- Subsurface defect
- Defect is on surface and interferes below the surface
- Defect is on casting edges or corners
- Defect is in casting cavity (from a core)
- Defect goes from the surface and projects over casting surface
- Internal (Inherent) defect

START < >

Fig. 4. Third ES screen DEFECT LOCATION TOWARDS CASTING SURFACE

The fourth screen (Fig 5) displays „Roughness of defect surface".

- Defect surface has a standard roughness
- **Defect surface is coarser than standard**
- Defect surface is smoother than standard
- Defect surface is oxidized
- Defect surface is granular and clear
- The surface has appearance of fine net
- The defect edge is smoother, inwards the casting is coarse

START < >

Fig. 5. Forth ES screen ROUGHNESS OF DEFECT SURFACE

- **Defect has an irregular network structure aspect**
- Defect appears as a knife blade
- Defect has a round shape
- Defect appears as orange peel
- Defect is undulating and wrinkled
- **Veined nodulation, veining**
- Small craters, pitting, dimples
- Narrow, elongated gap
- Hardly visible gap or discontinuity
- Menu includes 20 attributes

START < >

Fig. 6. Fifth screen DEFECT SHAPE

After selecting last attribute in the fifth screen, the following screen No. 7 shows the result of defect identification: its description, numeric code, general cause of its origin, measures for its elimination, and references to relevant publications.

To identify particular defects a user needs to specify different numbers of attributes that is why the number of screens required for selecting attributes of particular defect varies. There are some defects, e.g. the defect number 133 "Casting dimension incorrect" identifiable within second screen of ES. Different defect number 521 "Sand inclusions" may require up to 9 screens.

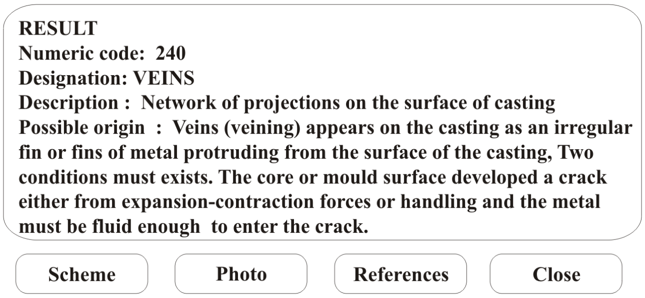

Fig. 7. Sixth screen THE RESULTING IDENTIFICATION OF DEFECT

4. Conclusions

The use of methods serving for determination of metallurgical, foundry and other causes of casting defects is an inseparable part of the complex system of securing the production of high quality castings. Expert systems become a powerful tool for foundrymen for identification and analysis of casting defects and they are also one of several possibilities how to secure higher quality of castings and lower costs for rejects. The authors of the contribution developed their own ES which is based on visual aspect of defects.

ESVOD can serve as:

- Adviser for identification of casting defects in foundry plants.
- Source of information of causes and remedies for defect prevention.
- Teaching manual for students and foundry staff.

New projects with higher pretension to create a computer assisted identification of defect causes have been realized [6, 7]. The aim is more complicated than simple defect identification presented here. But it is closely connected. Without correct identification and description of a defect we are unable to recognize their causes and contrarily the investigation of causes helps to define verifiably the defect.

Systematic work about utilization of artificial neural networks in metallurgy and material engineering has been published by Jančíková [8]. Neural networks have started to be applied at present in different fields of diagnostics and they have become a part of the quality control system of steelmaking products. Neural networks are increasingly used in the field of knowledge engineering in application to problems of diagnostics and prediction of defects of different types of steelmaking products, for recognition and classification. This is the way for future Expert Systems development for casting defect analysis.

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