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The Decision Support System in the Domain of Casting Defects Diagnosis

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Abstract

This article presents a computer system for the identification of casting defects using the methodology of Case-Based Reasoning. The system is a decision support tool in the diagnosis of defects in castings and is designed for small and medium-sized plants, where it is not possible to take advantage of multi-criteria data. Without access to complete process data, the diagnosis of casting defects requires the use of methods which process the information based on the experience and observations of a technologist responsible for the inspection of ready castings. The problem, known and studied for a long time, was decided to be solved with a computer system using a CBR (Case-Based Reasoning) methodology. The CBR methodology not only allows using expert knowledge accumulated in the implementation phase, but also provides the system with an opportunity to "learn" by collecting new cases solved earlier by this system. The authors present a solution to the system of inference based on the accumulated cases, in which the main principle of operation is searching for similarities between the cases observed and cases stored in the knowledge base.

Keywords: Application of information technology to the foundry industry, Castings defects, Diagnosis, Case-Based Reasoning

1. Introduction

Automatic diagnosis and detection of casting defects is a problem studies for years. Previous experience of the authors (disclosed, among others, in [1-4]) points out to the fact that small and medium-sized foundries often lack the equipment allowing for continuous measurement of all parameters of the process responsible for the formation of defects. It often happens that the occurrence of defect is detected as late as during the technical inspection, that is, at the end of the entire production process. The lack of appropriate measuring devices makes the detection of defects during earlier technological operations impossible. In such situations, it is difficult to evaluate the causes of defects. The evaluation is usually based on the experience of an expert - a technologist, who by detecting the type of the defect can predict the parameters that may be responsible for its formation. Yet, such expertise can be both time- and money-consuming. The aim of this study is to support the diagnosis of defects under the technical conditions of a specific foundry, where specific types of defects occur. Such support may significantly accelerate the discovery of the causes of defects and reduce production costs

The quality of castings is determined by a number of parameters which are important at different stages of the process. For example, defects that may result from improper parameters of the moulding and core sand include pinholes due to the presence of hydrogen; sand inclusions; deformation; gas inclusions, fractures, and shape imperfections. Defects that may result from improper construction or improper assembly of the pattern and mould [5] are fractures, shape imperfections, sand inclusions, misruns, cracks, gas inclusions, surface defects, mechanical damage, knob, flash, mismatch, pushing up, warping. Gases tend to dissolve in the liquid steel at all stages of the production of castings, i.e. during melting in the furnace, during tapping, during pouring of moulds, and even after pouring of the mould before complete solidification of the casting. Therefore, reducing or eliminating casting defects such as blowholes, voids in the cast structure, pinholes, non-metallic inclusions or porosity, and scaling on the surface of casting requires strict control of the whole process of melting and casting. The control of charge and compliance with the technological regime during melting of alloys in a furnace for casting are particularly important in the absence of vacuum treatment of liquid metal (in an induction furnace or ladle). Possible defects caused by incorrect melting include misruns, slag inclusions, tears (caused by excessively high temperature), gas inclusions, incorrect chemical composition, and pinholes.

As follows from the above remarks there are numerous parameters that can contribute to the formation of casting defects. Selecting the specific parameters responsible for the formation of a given defect depends, first of all, on the type of defect which has been traced in a foundry. If some deficiencies in the casting quality have been found during inspection, the most important step will be to carefully determine the type of defect to be able to identify as a next step the possible causes of this defect.

2. Computer methodologies useful at casting defects diagnosis

Identification of the type of defect depends on its visible and hidden features identifiable in further studies, which are often costly and time consuming. Therefore, the technologist evaluating the type of defect does not always have complete and certain knowledge of the defect. Often, he is compelled to use his own experience.

Table 1.
Fragment of a knowledge base about the attributes of casting defects

damage name	damage type	distribution	location	occurrence	damage shape	technological operation
Cold lap	wrinkles, scratch, erosion scab	local	insert wall, chaplet surface	numerous	narrow, rounded edges	casting design, pouring, cooling
Cold lap	fissure, scratch	local	surface	single	narrow, rounded edges	gating system design, pouring
Cold shots	metal beads		interior		spherical	gating system design, pouring
Cold lap, cold shots	discontinuity, fissure	widespread	surface, subsurface area	numerous	rounded edges, narrow	feeding system design, pouring
Cold lap near core or other metallic part	discontinuity	local	near inserts		curved walls	pouring, solidification

2.1. Formalisation of knowledge of casting defects

As indicated previously, the diagnosis of defects depends largely on the experience of the technologist who makes this diagnosis. The defect in casting can be described with a number of visible attributes, which occur on the surface, and with those that can be detected only after deeper research. Among them there are the following ones: the type of damage, its visibility, size of damage, the amount of material, distribution, location, mould material, inclusions, rate of occurrence, configuration, penetration, surface colour, orientation, lustre, surface oxidation, surface of defect. Each of these features can assume different values.

Without complete knowledge of the defect, and this is the case whenever we want to avoid costly research, one can nevertheless try to diagnose this defect avoiding costly analysis. Even bringing in several types of defects that can meet the described attributes is already considerable help in the diagnosis. At the same time it can be assumed that in one particular foundry plant certain types of defects are more common than others, and thus it is easier to choose the right one.

Studies [6,7], standards for defects in castings (e.g. PN-85/H-83105) and Atlas of Casting Defects [8] indicate what features different types of defects have in common. Based on these materials, the descriptions of defects were collected in the form of sets of attribute values and an array of attributes was created [1]. This array, a fragment of which is illustrated in Table 1, is the beginning of knowledge base, which allows building a system for automatic detection of the type of defect.

Considering the, presented in subsequent chapters, inference techniques, knowledge base in this form must be brought to a form in which to each attribute will correspond one value only. It should be noted that to a single defect may correspond numerous records reproducing all possible combinations of attribute values permissible.

2.2. CBR – Case-Based Reasoning

The main paradigm of CBR methodology is the inference regarding the current case by reuse of knowledge relating to the previously solved cases. This approach is different from other techniques of artificial intelligence, which use knowledge of the problem domain, as is the case of expert systems or systems based on fuzzy logic paradigm. CBR methodology also provides a possibility of learning by considering the current results of action in the later inference. This characteristic should provide customisation of the system to the specific nature of the problem solved, which is important for all problems related with the diagnosis of defects in small and medium-sized enterprises active in the foundry industry.

From a technical point of view, the main algorithm in a CBR system is the, so called, CBR cycle. CBR cycle begins when current case is introduced to the inference system, which defines a new problem to be solved. Then, four CBR cycle phases are performed in sequence [9]:

1. Retrieve phase.
2. Reuse phase.
3. Revision phase.
4. Retention phase.

In the retrieve phase, the inference system searches the database of cases, which is a collection of previously solved problems. Searching is done to find past case, which will be most similar to the current problem. The measure of similarity used in this phase assumes different forms depending on the field of application of the system. In the case of problems described by parameters which are real numbers, the measure of similarity can be based on Euclidean distance. The item found in the database of past cases which has the highest similarity to the current problem becomes the basis of next phase – the phase of reuse. In the phase of reuse, the solution of the found out case is adapted or, in multiple domains of the system operation, directly copied to the current case, which defines the problem currently solved. The phase of revision makes an assessment of the solution that has been returned by the system in the previous phase. This assessment usually can not be performed automatically and requires expert intervention or implementation of the proposed solutions to the real environment, whose problems are solved by the CBR system. In this phase, a correction of the proposed solution is possible, if the expert considers it appropriate, or if the results of the implementation of the proposed solution are not correct. After the revision phase, the retention phase follows. Its aim is to add to the case base the current case, which already contains a description of the problem and the solution. This complement to the case base allows the CBR system to learn, i.e. to use knowledge of the problems solved by the system in later inference. After completing the database of cases, the system is ready to solve a new problem, which involves the performance of the next full CBR cycle.

3. The CBR system in the domain of casting defects diagnosis

As part of the disclosed research, a CBR system was implemented to the extent enabling the name of the occurring casting defect to be specified. The created system has been implemented using Java and jCOLIBRI programming library, which contains a set of tools helpful in implementation of the CBR system. The main programming activities consisted in determining the development of the formal description of a single case, creating a database of cases and determining the course of the four phases of the CBR cycle. A formal description of a single case consists of a description of the problem and of a description of the solution. In the description of the problem, sixteen attributes have been separated (e.g. the size of the damage, the location and inclusions), fourteen of these attributes have assumed discrete values, while two were in the form of real numbers from a fixed range. The description of the solution contained only the name of the defect. The prepared formal description of a single case was the basis for the creation of the database of cases containing examples of problems along with their solutions.

The system and the knowledge base have been written in Polish for a Polish user, hence the screen shot images are also described in the Polish language.

For example: Case 6 (Figure 1) relates to the defect described by a set of 16 attributes, the first of which takes the value 'channels ' (which indicates the type of damage), while the second one assumes the value of 3.5 (indicating that the defect is moderately visible). The solution of Case 6 is the name of defect defined as " External Blowhole" (Figure 2).

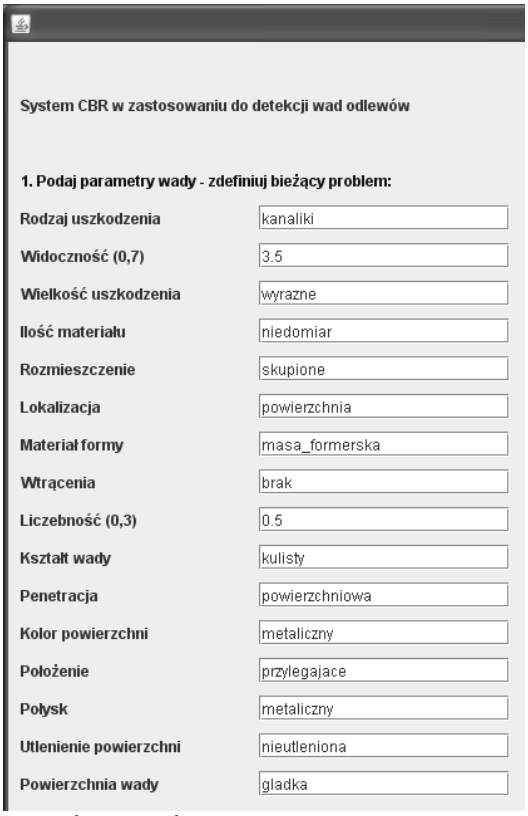

Fig. 1. The form to define the case using attributes. The system and the knowledge base have been written in Polish

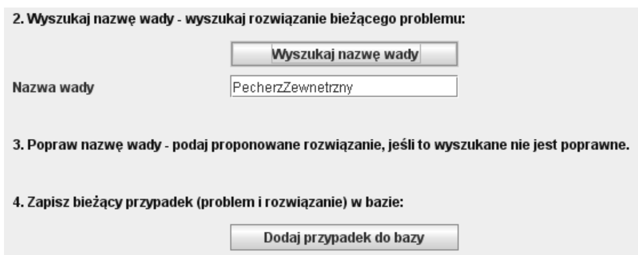

Fig. 2. The window with the result of diagnosis and form adding solutions to the knowledge base

By determining the course of the phases of the CBR cycle, the most important was to identify the function which is a measure of the similarity between the description of the current problem and the description of the problem, which is one of the cases included in the database. This function returns information about the similarity, when the attributes which are strings of signs have consistent values. For attributes that are real numbers, the function uses the measure of Euclidean distance.

The entire operation of the created system can be presented in five steps:

1. The user specifies the problem - gives values of the individual parameters of the defect (Figure 1).
2. The system retrieves the most similar case in the case base (the CBR search phase) (Figure 2).
3. As a solution to the problem, the system indicates the name of the defect by copying it from the case being found in the previous section (the CBR reuse phase) (Figure 2).
4. The user has the ability to display a different name of the defect than the name that was returned by the system in the previous step. This is important when, e.g. in the initial stage of operation, the system is supervised by an expert (the CBR revision phase) (Figure 2).
5. The system saves in the case base the current case as a, specified under item 1, problem with the, set under item 4, solution (the CBR retention phase) (Figure 2).

After retention done under item 5 the case base is supplemented with knowledge related to the currently solved case. The way to describe this case does not differ from those initially introduced, which allows their use in further operation of the system to support the diagnosis of casting defects. It is important to make the system operate in one company, what enables a spontaneous adaptation of the system to the specific characteristics of the production process (it occurs through the inclusion of cases of problems and their solutions actually occurring in the enterprise).

4. Conclusions

The proposed solution based on presented computer system using CBR methodology can solve the problem of the diagnosis of casting defects in establishments which do not have highly developed measuring devices monitoring on-line the production process. Especially for innovative materials like Ausferritic Ductile Iron or modern processes for witch literature is still not rich [10-12], such solutions could be useful. In addition, the system enables supplementing the knowledge base in the course of its operation, thus making the database a key resource defining knowledge in foundry. Developing the knowledge base is done by acceptance or possible change of result given by the system. This does not require any programming knowledge from the user, or additional labour input. Formalism of the knowledge base in the form of numerical encoding of the attribute values gives, in turn, the ability to write in a clear and unambiguous manner the knowledge of the defects, allowing also for the calculation of a similarity between the case solved and records in the knowledge base. Although the project is in the initial stage of implementation, the prototype version of the system helps to determine the type of defects occurring. An important feature of the system is the ease of use, which can solve the problem of barriers which the level of complexity of other inference systems often poses to the user.

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