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AN INFORMATION-ANALYTICAL SYSTEM OF RANGING ANALYSIS OF CAST IRON GRADES

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ABSTRACT

In this article the information system is presented consisting of a database containing information about cast iron grades and a client application permitting adding, editing, deleting information from the database, as well as searching for cast iron grades by different parameters. The database along with the client application are an automated help system, which contains a chemical composition, mechanical properties, application and possible problems grades of cast iron.

The client application allows analysis through cluster analysis of grades of cast iron on the chemical composition, mechanical properties, or both on the chemical composition and mechanical properties. This analysis identifies a close group of grades. In addition classification analysis to determine the expected properties of newly developed grades of cast iron. At realization cluster analysis were used to calculate the distance interval analysis techniques, for several grades of cast iron parameters specified intervals.

Keywords: information-analytical system, database, cast iron, cluster analysis, interval analysis.

INTRODUCTION

State-of-the-art of IT technologies makes it possible to accumulate large information volume in different fields of activity. These days electronic databases are commonplace in enterprises. In connection with large volumes of the information which is stored in a database, the question of its use is raised. It is necessary to apply methods of intellectual data analysis to the processing and extraction of knowledge from information [1].

The most general databases are reference systems. In this paper the creation of a reference information system about cast iron grades is considered. Storage of information about all of the cast iron grades in one place has certain advantages. First, such a database plays the role of the manual in which information about compositions, properties and the range of applications of grades is reflected at the same time. Secondly, the information which is available in the base may be used for the ranging analysis of cast iron. The ranging analysis can be applied according to different characteristics which are stored in a database.

SETTING AND DESCRIPTION OF THE PROBLEM OF DESIGNING AN INFORMATION SYSTEM OF CAST IRON

The following tasks were set for the creation of an information system:

- to study information about compositions, properties, the range of applications of cast iron grades and possible problems connected with the use of a given grade;

Table 1. Chemical composition of the “coresist” grade.

Iron grade	Mass fraction of elements, %							
	C	Si	P	Mn	Ni	Cr	S	Al
Coresist	3,3-3,6	1,4-1,8	0,08	0,2-0,5	0,2-0,5	0,08-0,1	0,015	0,8-2,2

- to design a uniform information system for storage of information about cast iron grades;

- to create the client software to include information about new cast iron grades, to view and adjust information about grades which already exist in a database, and also to perform selection in a database by different parameters;

- to develop partitioning algorithms of the existing grades in close groups by certain characteristics (composition, properties) on the basis of the interval cluster analysis.

It is possible to mark out four groups of criteria for assessing the quality for each grade of constructional iron: chemical composition, mechanical properties, the priority range of use and possible problems (melting, modifying, quality of casting) [2].

The majority of grades of constructional and pig iron usually contain nine alloying and other elements the concentration of which is provided by the normative and technological documentation: carbon, silicon, manganese, chrome, copper, nickel, sulphur, phosphorus, aluminium. At the same time the presence of all nine elements in one grade is not necessary. The content of each element is set by some interval of the concentration expressed as a percentage (or parts) on mass.

The main mechanical properties by which it is possible to identify a cast iron grade are tensile strength (MPas), hardness (HB) and the elongation (high-strength cast iron with spherical graphite) which is measured as a percentage ratio of change of length of a standard sample in case of loading (% rel.).

These indicators change within some limits of the intervals of distribution which are set according to the requirements of the normative and technological documentation. The range of applications and possible problems are presented as a text description. The obligatory requirement is the possibility of storing and viewing photos of a typical microstructure of all iron cast grades which are available in the program database.

The example of the description of cast iron of the “coresist” grade is given below. The chemical composition of the grade is provided in Table 1.

Mechanical properties: “Tensile strength: 220 – 260 MPas, hardness – 220-250 HB, elongation – 0%”.

Problems: “The experimental cast iron grade – high inclination to a chill of structure at the time of filling thin-walled castings in sandy-argillaceous forms and cold-hardening mixtures; the perlite structure (up to 100%) with a high hardness and inclination to anisotropy of graphite impurities is created: “ flaked graphite + refining foam”, and to gas-shrink defects”.

Range of application: “High-alloy castings of the III-IV complexity groups of responsible purpose – the parts of dipping electric pumps working in hostile environment for pumping oil and blanket liquid “.

The typical microstructure of the “coresist” grade in the standard technological test of metal and castings obtained according to the cold-hardening mixtures technology is provided in Fig. 1.

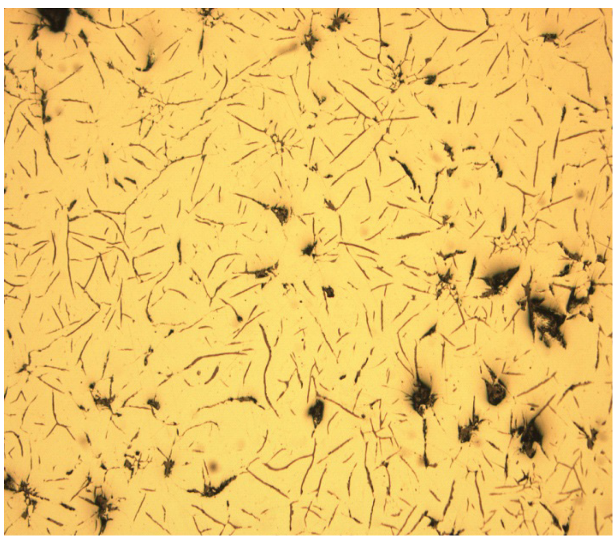

Fig. 1. Typical morphology of graphite in the «coresist» grade (x100).

MODEL OF INFORMATION SYSTEM OF CAST IRON

An infological model of a database (Fig. 2) was designed on the basis of analyzing information about cast iron grades.Thus, we obtain a database consisting of six tables five of which describe the grade and the sixth is the bundle table which contains the cast iron grade identifier, its name and identifiers of properties, identifiers of possible problems, ranges of application, composition and the links according to which an image of a standard microstructure is found.

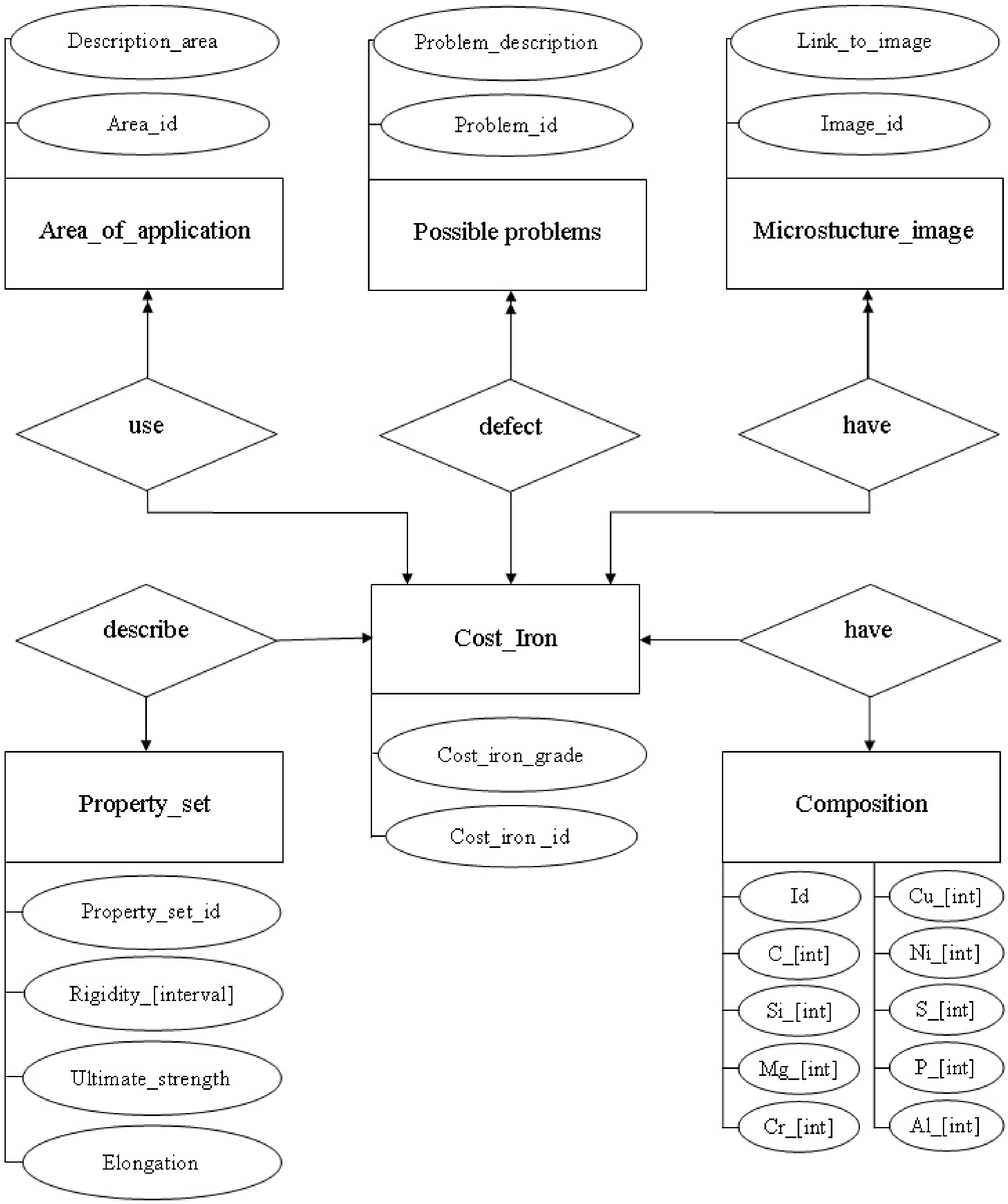

Fig. 2. Conceptual scheme.

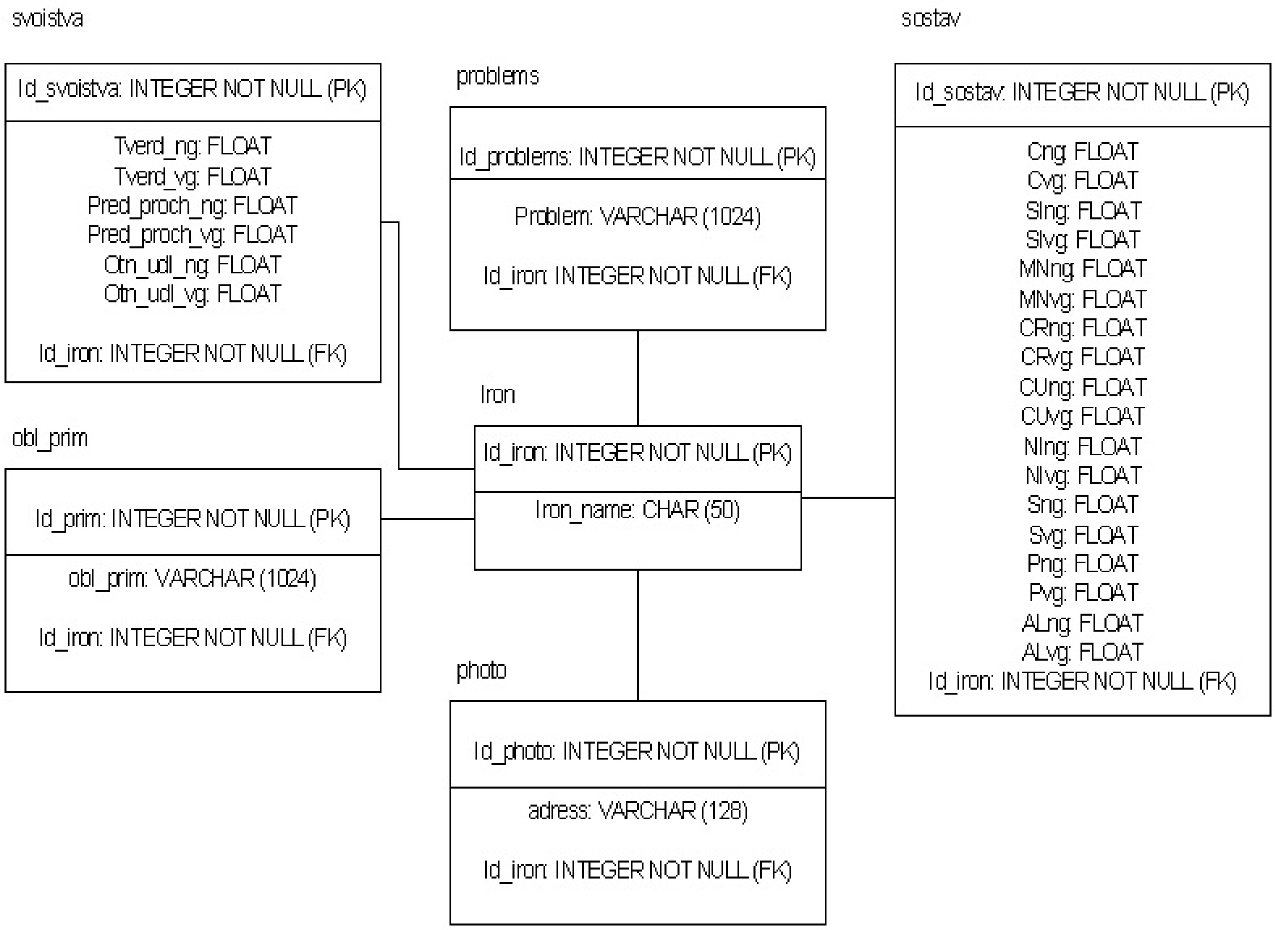

Fig. 3. Physical design (scheme).

The physical model of a database of cast iron grades is given in Fig. 3. The database was realized in the database management system [3] on the basis of a physical model. Cross-table relationship of the database is carried out by means of secondary key. For the tables containing information about cast iron grades, the secondary key is the number of the cast iron grade to which these characteristics belong.

Also the client application was developed for the operation with the database [4]. The program solves the following task list [5]:

– information input in the database (the name of a cast iron grade; information about compositions, properties, possible problems, ranges of application; loading of the image of a cast iron standard microstructure);

– output of the complete list of cast iron grades contained in the database and the possibility of obtaining detailed data about each selected cast iron grade;

– cast iron grade search ;

– properties search; the search is carried out in two ways: output of all properties (the list of all properties of cast iron grades is displayed on the screen, and in the case of choosing a specific property the user receives information about the grade, composition, possible problems and the image with the standard microstructure of cast iron), the selection of properties according to characteristics;

– composition search; the search is carried out in two ways: an output of all compositions (the list of all properties of cast iron grades is displayed on the screen, and in the case of choosing a specific composition the user receives information about the grade, properties, possible problems and the image with the standard microstructure of cast iron), the selection of compositions according to characteristics;

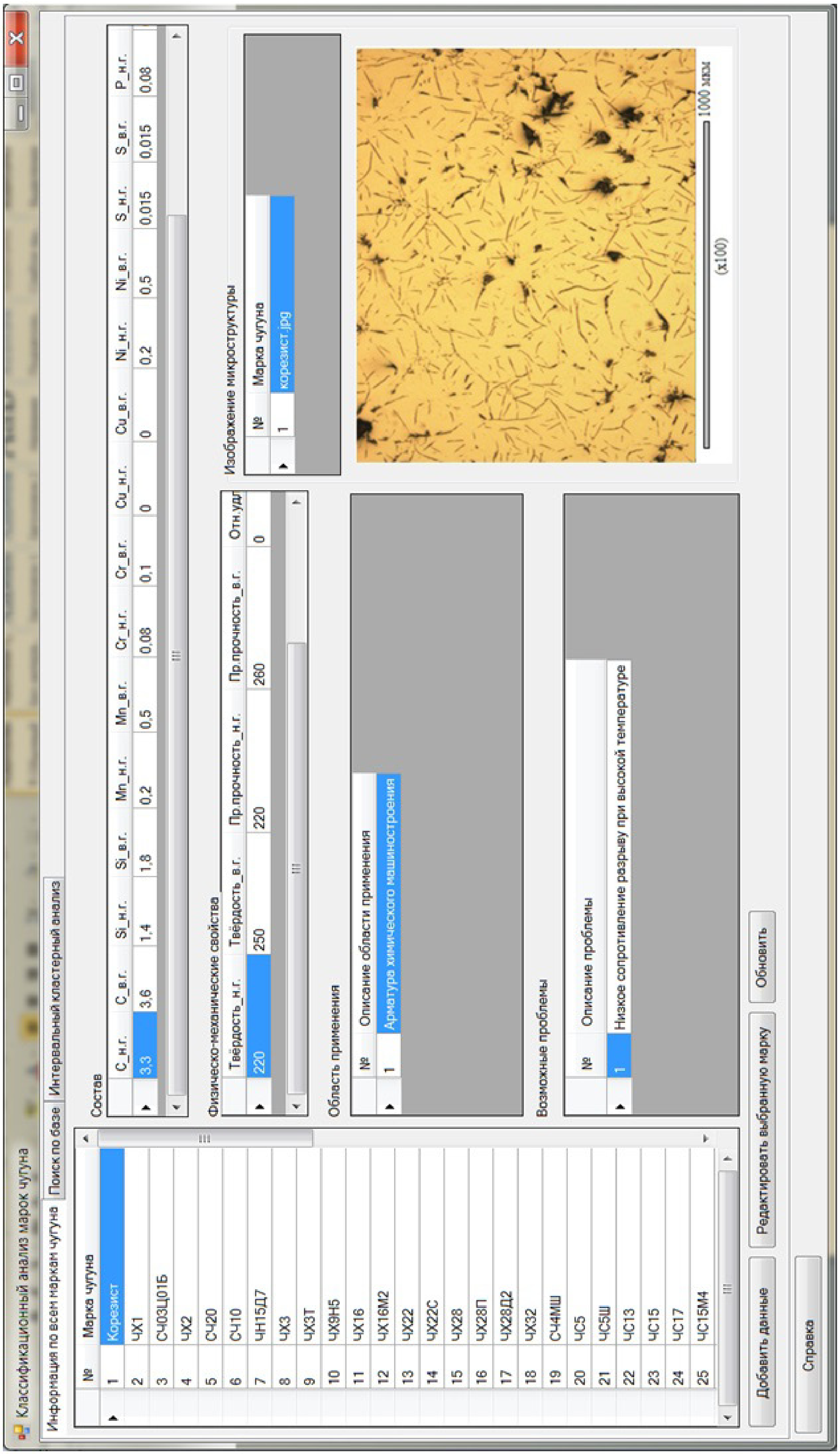

Fig. 4. The program "Information on all iron grades".

Table 2. The composition of clusters.

№	Grades in the cluster	Interpretation of the cluster	Description of the cluster
1	11	Grades: SCh4MSh, ChS5Sh, ChVG30, ChVG 35, ChVG 40, ChNHMD, ChNHMDSh, ChN3HMDSh, ChN30D3Sh, ChNMSh, ChN2H	The group of low-alloy cast iron, similar to the mechanical properties of vermicular graphite iron
2	5	Grades: ChS13, ChS15, ChS17, ChS15M4, ChS17M3	Siliceous high-alloy special cast iron, high resistance to chemical corrosion
3	11	Grades: Korezist, ChH1, SCh03C01B, ChH2, SCh20, SCh 10, ChH3, ChS5, ChNHT, ChJuHSh, ChJu6S5	Group complex alloy iron with alloy elements content up to 7% (including Al)
4	5	Grades: ChVG45, ChG7H4, ChG8D3, ChN11G7Sh, L- NiMn 13 7	Manganese iron and spheroid graphite cast iron (similar mechanical properties)
5	3	Grades: L-Ni 35, S-NiCr 35 3, S-Ni 35	Austenitic high-alloy cast irons (non-magnetic) with high heat resistance and heat tolerance
6	5	Grades: L-NiCr 30 3, L-NiSiCr 30 5 5, S-NiCr 30 1, S-NiCr 30 3, S-NiSiCr 30 5 5	Highly alloyed austenitic cast iron (austenitic-carbide structure), chrome-nickel with high heat resistance and rigidity
7	14	Grades: ChN15D7, ChN15D3Sh, ChN19H3Sh, ChN20D2Sh, L-NiCuCr 15 6 2, L-NiCuCr 15 6 3, L-NiCr 20 2, L-NiCr 20 3, L-NiSiCr 20 5 3, S-NiCr 20 2, S-NiCr 20 3, S-NiSiCr 20 5 2, S-Ni 22, S-NiMn 23 4	Austenitic (nickel) cast iron class "Ni-Resist" and its analogs (complex mechanical and performance properties being the same), with the effect of a stable growth of the structure at low temperatures
8	7	Grades: ChH3T, ChH9N5, ChH16, ChH16M2, ChH22, ChH28D2, ChH4H2	High-alloy chromium wear-resistant special irons
9	3	Grades: ChJu7H2, ChJu22Sh, ChJu30	Aluminum cast iron, with a very high resistance to corrosion
10	4	Grades: ChH22C, ChH28, ChH28P, ChH32	High-alloy chromium white cast irons (carbide structure), high abrasion resistance

The user interface of a working window of the program with the output information about casts of iron grades is provided in Fig. 4.

CLASSIFICATION OF GRADES OF CAST IRON

The cluster analysis is a convenient classification method [6-9]. The cluster analysis can be performed on the composition, properties or composition and properties simultaneously. K-means was chosen as a clustering algorithm. The square Euclidean distance was chosen as a metric

$$p(X_i, X_j) = \sum_{k=1}^{z} (x_{ki} - x_{kj})^2 \tag{1}$$

where X_i, X_j – objects including sets of interval parameters x_{ki}, x_{kj} – intervals within the scope of the object

Before the cluster analysis was performed all the parameters were normalized using formula (2)

$$z = \frac{x - \overline{x}}{x_{max} - x_{min}} \tag{2}$$

As the classification parameters are set by the intervals, calculating the distance is impossible in the ordinary sense. If the middle of the interval is used as parameter values of a certain grade of cast iron, the width of the interval is not considered. Therefore, interval arithmetic methods are used to calculate distances between intervals [10, 11]. The formula of the square of the Euclidean distance between the objects of the cluster takes the following form (3):

$$x_{ki} - x_{kj} = [\underline{x_{ki}} - \overline{x_{kj}}; \overline{x_{ki}} - \underline{x_{kj}}] \tag{3}$$

$$(x_{ki} - x_{kj})^2 = [\underline{x_{ki}} - \overline{x_{kj}}; \overline{x_{ki}} - \underline{x_{kj}}] \cdot [\underline{x_{ki}} - \overline{x_{kj}}; \overline{x_{ki}} - \underline{x_{kj}}],$$

$$(x_{ki} - x_{kj})^2 = [\min\{(\underline{x_{ki}} - \overline{x_{kj}})^2, ((\underline{x_{ki}} - \overline{x_{kj}})(\overline{x_{ki}} - \underline{x_{kj}}))^2, (\overline{x_{ki}} - \underline{x_{kj}})^2\};$$
$$\max\{(\underline{x_{ki}} - \overline{x_{kj}})^2, ((\underline{x_{ki}} - \overline{x_{kj}})(\overline{x_{ki}} - \underline{x_{kj}}))^2, (\overline{x_{ki}} - \underline{x_{kj}})^2\}],$$

$$p(X_i, X_j) = \sum_{k=1}^{z} [\min\{(\underline{x_{ki}} - \overline{x_{kj}})^2, ((\underline{x_{ki}} - \overline{x_{kj}})(\overline{x_{ki}} - \underline{x_{kj}}))^2, (\overline{x_{ki}} - \underline{x_{kj}})^2\};$$
$$\max\{(\underline{x_{ki}} - \overline{x_{kj}})^2, ((\underline{x_{ki}} - \overline{x_{kj}})(\overline{x_{ki}} - \underline{x_{kj}}))^2, (\overline{x_{ki}} - \underline{x_{kj}})^2\}].$$

RESULTS AND DISCUSSION

Experiment was performed during which the results of the segmentation of cast iron grades were analyzed using the interval cluster analysis on the composition, the composition and properties of 5, 10, 15 clusters.

Grades of one cluster have approximately the same physical and mechanical properties, application and similar problems of application. Absolutely correct is the partition into 10 clusters according to the composition and properties simultaneously. The result is given in Table 2.

CONCLUSIONS

This information and analytical system can significantly reduce the time of work and effort for the processing engineer and the development engineer in the foundry industry which are necessary for the correct and comprehensive choice of a particular iron grade satisfying in its complex properties (composition, structure, problems) and the requirements of the normative and technical documentation for the nomenclature of castings produced nowadays.

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