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Original Research Article

Heuristic modeling of casting processes under the conditions uncertainty

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ABSTRACT

In the first part of this paper will be described an analysis of control problems and technical lifetime modeling of continuous casting device crystallizers. A full exploitation of continuous casting equipment (CCE) advantages can only be achieved through a control system that minimizes all undesirable effects on the technological process. Some of the undesirable effects influencing the CCE process effectiveness are the failures and service interruptions. This problem was solved by connection of dependability theory and artificial neural networks.

The second part of the article refers to a model in linguistic form used to identify the type of defects present in the tested casting. This model, having the form of an attribute table, has been based on the concepts taken from the theory of rough sets and fuzzy logic. A methodology for construction of a heuristic model of linguistic knowledge was presented along with an example of its implementation based on the use of distributed sources of knowledge.

1. Introduction

In the computer-supported decisions for foundry industry, a vital role is played by the selection of sources and the presentation of information and knowledge, which are intended to provide a basis for the implementation of decision algorithms. A typical way to obtain information about the process is by making physical measurements the parameters characterising this process.

It should be noted, however, that numerous casting process parameters are either immeasurable or their measurement takes time and requires considerable costs. In addition, a growing role is that of the data and information acquired from external sources (mainly WEB).

In this situation, when constructing the decision-making procedures, it is necessary to take into account not only the data of a numeric nature but also information expressed in linguistic form (in natural language).

The intention of this article is to present specific solutions based on experimental data in digital form, as well as information and knowledge expressed linguistically. The first case concerns the inspection and control of the process of crystallizer wear, the other – the identification of the type of defects in castings.

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The material presented in the article, on the one hand shows original solutions which can find practical application, while – on the other hand it creates a plane for comparison of different forms of the incomplete knowledge representation, which may provide inspiration for further research in the field of construction of heuristic models, and in particular hybrid solutions using both numerical data and knowledge expressed in natural language.

2. Modeling of crystallizer wear

2.1. *General base and development of solution*

The technological systems service life control includes the process and its control when we determine the period of time during which the equipment or its parts are able to perform the required function under given conditions of use and maintenance up to the moment when the limiting state has been achieved. When dealing with this problem it is necessary to be aware of the fact that the meaning of service life term varies in various stages of equipment life cycle therefore we must distinguish the terms as follows [1]:

- Planned technical life
- Rated technical life
- Technical
- The total
- The residual
- Limiting state

The crystallizer is one part the CCE that significantly influences the continuous casting blank's quality both in view of the internal structure and the surface purity and the dimensional accuracy. The crystallizer service life is influenced first of all by its wear. The physical mechanism of crystallizer wear can be described as follows.

If the surfaces of two functional surfaces (liquid steel or slightly solidified blank's crust and the crystallizer walls) by virtue of the self-weight of steel/blank or the oscillatory mechanism there will be the first contact, theoretically in three points. In these points the real surface pressure is as big as to cause the plastic deformation and parts of surface breaking off (this all in microscopic dimensions). Consequently other places on the parts surface are contacted. On these parts the same processes are running as long as the real contact surface has achieved the level when the real surface pressure does not induce any other deformations. Obviously the achievement of this equilibrium state depends on more factors. For a better description of crystallizer surface wear mechanism it is possible to base it on a general model of the metal polished component surface layer [2].

2.2. *Reliability model*

The important element of this rationalize approach is analytical expression of proper theoretical model of stochastic quantities characterizing reliability of monitored object's types, i.e. such model, which assign to the object in any time probability of fault occurrence. This theoretical model of stochastic quantities has much narrowed meaning, than previously mentioned complex reliability model of whole device. Reliability evaluation of complex mechanisms, where can be assigned also metallurgical devices, shows, that optimal theoretical model is Weibull model, because it is able to cover almost all possible running of random quantities, which can occur when solving reliability of production devices.

From the view of reliability theory can be crystallizer considered as non-renewal object. The first step of solving is the statistical and probabilistic analysis of the technical life of crystallizers. In the frame of this analysis 23 crystallizers was investigated upon which many measurements during its lifetime was made (device MKL 100/420 DASFOS Company, PLC) [3].

The value of variation coefficient confirms apriori assumptions that the mechanism of the limit state of the crystallizer is caused by wearing of the material. The value of variation coefficient using (Table 1.) shows that the random variable will have a normal probability distribution, which further demonstrates the histogram [4].

2.3. *Two-parameter Weibull distribution*

It is the most widely used distribution for data analysis on the time of life. Weibull probability density is presented by the equation [1]:

$$f(t) = \beta \times \frac{t^{\beta-1}}{n^{\beta}} \times e^{-(t/n)^{\beta}} \quad (1)$$

where:

$f(t)$ is probability density; t is variable time; n is characteristic lifetime of the scale parameter; β is shape parameter.

Examples of application are:

- the period of early failures;
- the period of random failures;
- the wear and tear disorders.

Shape parameter β determines the most appropriate member of the Weibull distribution group. Weibull distribution is different from the other division that the data meet him during his life in a wide range. The parameter t is generic, that is general and can represent various parameters, such as distance, time, number of cycles or the application of mechanical stress [5,6].

Distribution function thus obtained was compared with the empirical distribution function obtained from the measured values of the technical life of the crystallizer, Fig. 1 and were performed validation of the distribution function obtained using the Kolmogorov–Smirnov test for a single selection. The

Table 1 – Statistical parameters for solution.

Middle smelting count through the technical lifetime of the crystallizers	842.28 smelts
Selective standard deviation	568.67 smelts
Selective dispersion	323396.77 smelts
Variation coefficient	0.675162648
Middle time of models technical lifetime	892.47 smelts