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Original Research Article

Multistage discretization and clustering in multivariable classification of the impact of alloying elements on properties of hypoeutectic silumin

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ABSTRACT

The properties of hypoeutectic Al–Si alloy (silumin) with the addition of elements such as Cr, Mo, V and W are described. Changes in silumin microstructure under the impact of these elements result in a change of the mechanical properties. The research includes presentation of procedure for the acquisition of knowledge about these changes directly from experimental results using mixed data mining techniques. The procedure for analyzing small sets of experimental data for multistage, multivariate and multivariable models has been developed. Its use can greatly simplify such research in the future. An interesting achievement is the development of a voting procedure based on the results of classification trees and cluster analysis.

1. Introduction

Innovation of research is based on demonstrating the possibility of obtaining higher strength properties of silumin casts under pressure. The high rate of heat removal from the casting to the pressure mold makes it possible to saturate solid silumin solutions with these additives. This should lead to strengthening solid solutions of silumin and, as a consequence, improving its strength properties.

There is a special group of additives that can be introduced into silumins, and it includes the high-melting point elements such as Cr, Mo, V and W. All these elements are characterized by the lack of solubility or insufficient solubility in solid aluminum. According to Ref. [1], Cr is not soluble in Al,

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whereas according to Ref. [2], the solubility of Cr in Al is negligible and amounts to 0.71% at 661.5 °C. The solubility of Mo and W in Al is 0.0% [3]; whereas the solubility of V in Al is 0.6 wt% at most (0.3 at%) [2]. This threatens the release of a number of intermetallic phases in the microstructure of the silumins containing these additives, which significantly increases the brittleness of Al alloys and reduces their strength and plastic properties. Paper [2] presents types of intermetallic phases formed in the Al–V and Al–W alloy phase diagrams. The ranges of their chemical composition as well as crystallographic parameters are also described there. The phases in the Al–Cr and Al–Mo equilibrium phase diagrams are presented in papers [1] and [3] respectively. Preliminary investigations have confirmed the possibility of obtaining relatively high strength properties in silumins cast by this technology, due to the introduction of the above mentioned high melting-point elements [4]. In these papers, the hypoeutectic silumin 226 grade was used as the initial alloy. The addition of 0.1% Cr and 0.1% W resulted in an increase in yield strength by 21% [4]. In paper [5] the silumin with the addition of V and Mo is presented. Application of the abovementioned elements at the level of 0.1% resulted in an increase in the tensile strength R_m by 17.5%. The addition of W and Mo in an amount of 0.2% caused an increase in the relative elongation A by 27% [6].

The authors have previously used the data mining and artificial intelligence techniques in materials design and manufacturing processes of metal products, in case of bronze [7] and aluminum products [8], cast steel [9] or ADI cast iron [10]. The acquired experience has proved to be very helpful in shaping the process of discretization, clustering and creation of classification models in situations where only a few learning data is available. Another purpose of the study was to acquire knowledge in the form of rules and patterns, which in the future will be used in the creation of semantic knowledge bases [11].

Several exploratory techniques have been used in this study, which are linked to each other in such a way that their results increase the precision and the ability to draw conclusions. The procedure is shown in Fig. 1.

The article consists of seven sections. Section 2 describes the material testing procedure. Section 3 describes the results of the experimental research and basic results of the statistical analysis, including the first steps to build statistical models. Section 4 provides a theoretical description of the data mining methods used in analytical studies. Section 5 gives the results of data mining analysis, a description of the procedure presented in Fig. 1 and discussion of results. Section 6 illustrates model validation, while Section 7 comprises a summary, conclusions and guidelines for the future research.

2. Research methodology

The base material used in this study was EN-AC 46000 (EN-AC AlSi9Cu3 (Fe) silumin. The range of its chemical composition is included in the standard [12]. The master alloys were introduced into the starting silumin as single additives or jointly in such quantities that in the melt the chemical composition of the examined silumin corresponded to the range given in Table 1.

The predominant wall thickness in the castings was 2 mm. Three specimens of 2 × 10 mm rectangular cross-section were cut out from each cover to test the strength of the die castings.

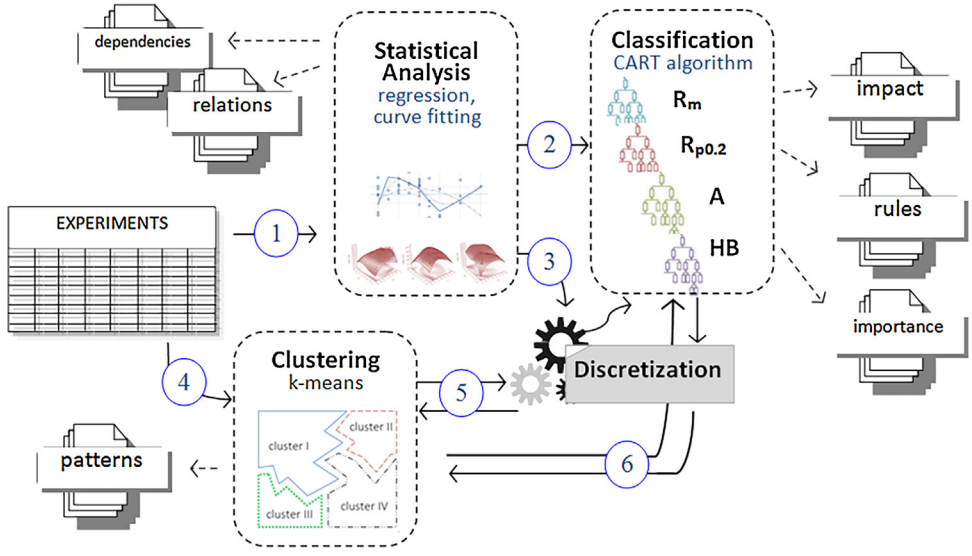

Fig. 1 – Procedure developed in analytical studies.

Table 1 – The range of chemical composition used in the tested EN-AC 46000 silumin containing Cr, Mo, V and W.

Chemical composition, wt%											
Si	Fe	Cu	Mn	Mg	Ni	Zn	Ti	Cr	Mo	V	W
7.58–11.0	0.64–0.98	1.72–2.65	0.15–0.27	0.18–0.38	0.04–0.13	0.81–1.09	0.03–0.08	0.00–0.50	0.00–0.50	0.00–0.50	0.00–0.50