Sensitivity Analysis of Heat Treatment Parameters on Cylinder-head Aluminum Alloy Properties by Regression Method

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1. Introduction

The cylinder-head is one of most important components of an automotive engine that is subjected to various mechanical and thermal loading conditions. Therefore, improving the mechanical properties, as well as investigating the effect of the temperature on the mechanical properties and the microstructure have always been a topic of the interest for researchers.

In this article, by the regression analysis, suitable patterns for the hardness and the microstructure of the cylinder-head aluminum alloy have been presented. Objective functions were the hardness, the phase size of Si, Al-Cu, and their spherical degree. Furthermore, the temperature and the time of the solution and ageing, were selected as variables of the experiments.

2. Materials and Experiments

Standard specimens were prepared by the stir-casting method. To enhance the quality of samples, degassing and preheating were performed. The casting temperature was 745°C. Dissolution temperatures were selected based on the literature, from 490 to 510°C and the ageing temperature was considered from 175 to 250°C, in order to investigate the effect of ageing on the hardness and the microstructure.

For the microscopic examination, specimens were firstly grinded to 2000 grit and polished with the alumina powder, with 0.3 μm particles. The Keller solution was used to etch samples. In addition, an image analysis software (Image J) was utilized to evaluate microscopic images. To study the influence of the heat treatment on the hardness, specimens were subjected to the Vickers hardness test. The applied force was 30 kg.

The statistical analysis was done using the MINITAB software. After the sensitivity analysis and using regression analysis, a function was fitted based on variables, considering P1, P2,… to estimate the hardness (H).

3. Results

The optimal heat treatment was determined to achieve the smallest value of the phase area, as well as the higher amount of the spherical phases. Results showed that the highest hardness (164 VHN) obtained, when the sample was heated at 510°C for 300 minutes; and then, aged for 360 minutes at 175°C. It has been reported that the longer time of the dissolution heat treatment, the greater the solubility of the precipitates, such as intermetallic phases in the aluminum matrix. In addition, the temperature was more effective than the time of the dissolution process. Microstructural studies also implied that the sample that dissolved at 500°C for 300 minutes and aged at 200°C for 120 minutes had the highest spherical degree factor (as shown in Figure 1).

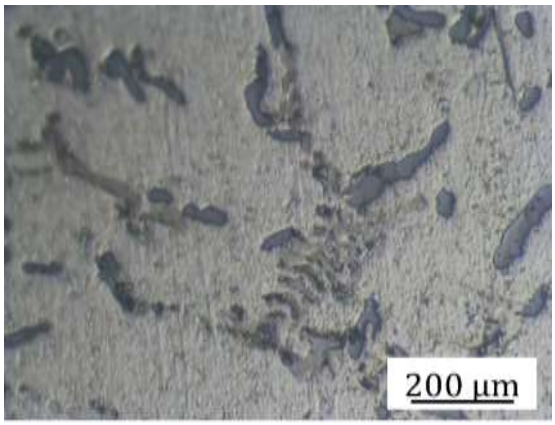

Figure 1. The optical microscopy image of a specimen, heated at 500°C for 300 minutes and aged at 200 °C for 120 minutes

The lowest hardness value was measured for the sample that was dissolved at 500°C and then, aged at 250°C due to the increase in the area of the Al-Cu phase. Finally, the optimum heat treatment was achieved according to the smallest phase area, as well as more spherical degree of phases.

4- Conclusions

In this research, the effect of the heat treatment i.e., the dissolution temperature, the dissolution time, the ageing temperature and the ageing time on the hardness and the

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microstructure of the aluminum alloy (Al-Si-Cu) of the engine cylinder-heads, has been studied.

Obtained results of the sensitivity analysis and empirical measurements indicated that the effect of the ageing process on the increase in the hardness value was much greater than the dissolution process. Regression functions, which were obtained by the statistical analysis, implied high accuracy in predicting the hardness value of such a material.