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Original Research Article

Effect of heat treatment parameters on abrasive wear and corrosion resistance of austenitic nodular cast iron Ni–Mn–Cu

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ABSTRACT

Influence of heat treatment parameters on abrasive wear and corrosion resistance of nodular cast iron Ni–Mn–Cu was examined. Chemical composition was selected in such a way, that austenitic matrix was obtained in raw castings (relatively good machinability). Heat treatment, consisting of soaking (450, 550, 650 °C for 4, 8, 12 h) and air cooling, led to partial transformation of austenite. At the lowest temperature, martensite was formed. Raising the temperature and prolonging the soaking time caused increase of austenite transformation degree. At the same time, a gradual change in morphology of the coniferous phase was observed in the direction of fine-acicular ferrite found in bainite or ausferrite. As a result, significant increase in hardness and wear resistance of castings was observed. The heat treatment caused slight changes in gravimetric corrosion rate. However, potentiodynamic studies indicate, that the nature of corrosion from local to uniform was changed. From the point of view of corrosion resistance, this is a very beneficial phenomenon.

1. Introduction

Cast iron castings of machine and equipment parts, especially those used in the mining industry, often have to exhibit at the same time increased corrosion resistance and abrasive wear. They may be, for example, deep water pump impellers, carrier inserts for sealing rings of pistons used in engines, or wear parts for operating machines [1–5].

It seems that austenitic cast iron Ni–Mn–Cu can meet these conditions. Because of relatively high content of elements having high electrochemical potential (Ni, Cu), it should demonstrate high corrosion resistance, like other kinds of austenitic cast iron [4–6]. In turn, heat treatment of this type of cast iron, resulting in a partial transformation of the austenitic matrix, offers the possibility of increasing abrasive wear resistance of the castings [7].

This means the need to develop such a cast iron, that will ensure the austenitic matrix of raw castings (introduction of appropriate content of elements stabilizing austenite, i.e. Ni, Mn and Cu). In addition, it will create the possibility of controlled matrix transformation, by selecting appropriate

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parameter values of heat treatment parameters. This will allow, similarly to ADI cast iron, to control mechanical properties of castings and, as could be assumed, their working and usable properties [7–13].

However, there is a question, whether and to what extent the change in heat treatment parameters, causing a change in the structure of the matrix, will change their resistance to abrasive and corrosion wear. This publication is an attempt to answer this question.

2. Purpose, scope and methodology of the research

The aim of the presented work was to determine the effect of soaking parameters on the structure of the matrix, abrasive wear and corrosion resistance of cast iron Ni–Mn–Cu with spheroidal graphite.

Examination were conducted for the cast iron containing 3.4% C; 2.3% Si; 7.2% Ni; 2.6% Mn; 2.4% Cu; 0.11% Mg, 0.15% P and 0.04% S, on the specimens taken from Y-shaped castings (prepared according to PN-76/H-83124). The heat treatment consisted in soaking specimens at 450, 550 and 650 °C for 4, 8 and 12 h and followed by air cooling. All tests were carried-out for at least 3 specimens for each variable, i.e. temperature and soaking time.

Chemical analyses of the castings carried-out spectrally using a glow discharge analyzer LECO GDS 750 QDP and also by the spectroscopic method, using a scanning electron microscope Quanta FEI equipped with an EDS detector [4,5,8].

The scope of the research included microscopic observations, that were carried-out with use of an optical microscope Nikon Eclipse MA200, as well as scanning electron microscopes Hitachi TM 3000 and FEI Quanta, using the SE and BSE technique.

Measurements of abrasive-wear resistance were performed using a T-07 tester produced by the Institute of Exploitation Technology – National Research Institute of Radom. The measuring stand ensured an unspecified type of contact, wear by loose abrasive material (aloxite F90 acc. to ISO 8486:1998), sliding type of movement providing dry technical friction under a constant load (based on GOST 23.208-79). The downforce F (44 N) of the specimen (30 × 30 × 3 mm) against the counter-specimen, that was a metal roller covered with rubber with hardness of 78–85 Sh rotating 60 ± 2 rev/min, was exerted by weights through a lever system. The duration time of the test was 10 min [14].

Corrosion examination were performed the gravimetric and the potentiodynamic methods. In both cases, the corrosion solution was a 3% aqueous NaCl solution at ambient temperature. In gravimetric tests, in order to increase aggressiveness of the solution, aeration with atmospheric air was applied [5].

During gravimetric tests, weight changes per unit time per unit area of the specimen V_C [mg/(dm^2 day)] were determined. Then, according to the following formula, the values were converted to corrosion rate at the time of V_P [mm/year] [15]:

$$V_P = 0.0365 \cdot \frac{V_C}{d} \quad (1)$$

where: V_P – corrosion rate in time [mm/year], V_C – loss in weight of the specimen in time [mg/(dm^2 day)], d – density of metallic material [g/cm^3].

Potentiodynamic measurements were performed in a completely automated three-electrode system. As reference electrode, a saturated calomel electrode was used. The auxiliary electrode was a platinum electrode. Corrosion resistance was assessed on the basis of parameters such as: cathod–anode transition potential (E_{K-A}), stationary potential (E'), corrosion current density (i_{corr}) and polarization resistance (R_p) [5,15,16].

3. Results and discussion

3.1. Examination of the matrix structure

Soaking of the castings, in most cases, led to a partial transformation of austenite. The way and degree of transformation strictly depended on heat treatment parameters. Increasing the temperature and lengthening the soaking time caused an increase of austenite transformation degree and hardness of castings. At lower temperatures, martensite appeared. Increasing the temperature to a gradual change in morphology towards acicular ferrite occurring in bainite. Soaking at 650 °C, regardless of the soaking time, resulted in creation of additional pearlite. The results of metallographic examinations are shown in Table 1. Structural changes are shown in Fig. 1.

3.2. Examination of abrasive wear

Heat treatment of castings caused an increase in their resistance to abrasive wear. This effect is shown in the form

Table 1 – Effect of soaking on hardness and matrix microstructure.

Soaking time [h]	Soaking temperature [°C]					
	450		550		650	
	Fe_γ–Fe_m–P [%–%–%]	HBW [/]	Fe_γ–$Fe_{\alpha'}$–P [%–%–%]	HBW [/]	Fe_γ–$Fe_{\alpha'}$–P [%–%–%]	HBW [/]
4	100–0–0	159	64–36–0	349	45–50–5	368
8	96–4–0	210	8–87–5	452	6–84–10	440
12	94–6–0	250	6–85–9	442	6–78–16	418

Fe_γ – austenite, Fe_m – martensite, $Fe_{\alpha'}$ – fine-acicular ferrite, P – pearlite.