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Manganese-nitrogen-sulphur surface layers produced on aluminium alloys

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Abstract. The main reason of the surface modification of the components such as pistons and cylinder blocks made of cast aluminium alloys is to obtain high hardness, wear and corrosion resistance of the working surface for larger lifetime of the motor-car and aircraft engines. In that aspect, the new conception of creating – by hybrid method – surface layers containing manganese, nitrogen and sulphur (Mn-N-S) on aluminium alloys was considered. These layers are diffusively connected with aluminium base, have high hardness and good tribological properties. The aim of this paper is to present the influence of the above mentioned consolidation method on microstructure, phase composition, microhardness, wear and corrosion characteristics of the surface layer produced on AlSi13Mg1CuNi alloy.

Keywords: (Mn-N-S) layers, Microstructure, Hardness, Tribology, Corrosion

1. INTRODUCTION

To reduce the mass of machine structures and equipment, the use of light alloys is widely recommended. However, severe operating conditions such as high specific pressures, high temperatures, a corrosive environment or abrasive wear often limit the possibility of using aluminium alloys directly [1]. Research has been carried out to improve the properties of these alloys, and one of the trends in metallurgical development is surface strengthening [2].

In the case of aluminium alloys this can be achieved by burnishing, cladding, padding, metal spraying, electroplating, electroplating with co-depositing or CVD and PVD methods [3].

The co-depositing method depend on chemical or electrochemical co-depositing of metallic, non-metallic compounds or polymers fine particles simultaneous with the base metal of the layers to improve material properties, such as wear-resistance [4-6], lubrication [7] or corrosion resistance [8].

To do this, theoretical and experimental confirmation of the following possibilities was required:

- formation of an electroplated manganese coating on aluminium alloy base,
- generation of a Mn-N-S composite layer by gas sulphurnitriding treatment manganese electroplated coating, resulting in the simultaneous diffusion of nitrogen and sulphur to manganese and diffusion bonding between the electroplated coating and the aluminium base.

The aim of this paper is to investigate the effect of the hybrid method consists of a gas sulphurnitriding treatment with simultaneous diffusion bonding of electroplated manganese coating on an aluminium base on the microstructure, phase composition, microhardness, wear and corrosion characteristics of the casting AlSi13Mg1CuNi alloy.

2. EXPERIMENTAL

Manganese coatings were electroplated onto specimens made of AlSil3Mg1CuNi alloy. The electrolyte composition, process parameters, and other conditions of electroplating are described in detail in the literature [9-11].

The experiments to achieve simultaneous nitrogen diffusion and structural bonding of the electroplated manganese coating with the aluminium base (formation of Mn-N-S composite coating) were carried out during short-duration gas sulphurnitriding process. The results of gas sulphurnitriding depend on temperature, time and nitrogen-sulphur atmosphere.

The phase composition of the formed layers was identified on the basis of recorded X-ray diffraction lines. The structure of the layers was examined by both optical and scaning electron microscopy. The hardness of the layers was determined by microhardness measurement made under a load of 0.098 N.

Polarization tests were performed in aerated 0.01 M sulphuric acid solution at 20°C. Quasistationary data were obtained by applying linear potential sweep at 2 mV·min^{-1}. The surface microstructure observations before and after the corrosion test of AlSi13Mg1CuNi alloy and (Mn-N-S) layers were provided by Scanning Electron Microscope (SEM).

3. RESULTS AND DISCUSSION

Figure 1a illustrates the microstructure of the cast AlSi13Mg1CuNi alloy used as the base material of samples with the (Mn-N-S) layers. Considerable number of pores in the microstructure of the (Mn-N-S) layers created on the AlSi13Mg1CuNi alloy have been observed (Fig.1b).

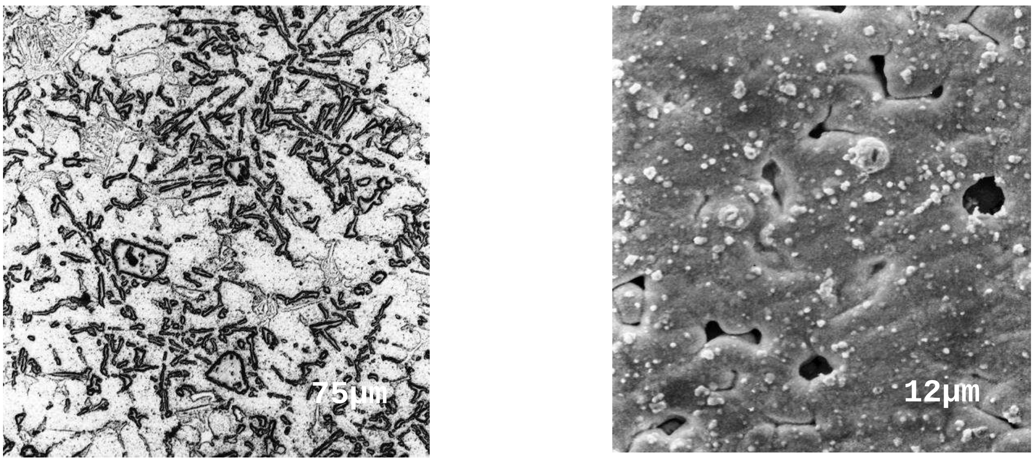

Figure 1. SEM micrographs: a) structure of AlSi13Mg1CuNi alloy, b) surface of (Mn-N-S) layer

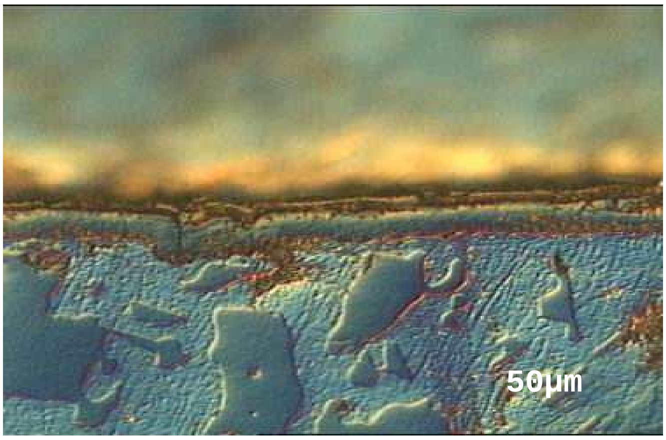

Figure 2. SEM of cross section of (Mn-N-S) layer created on AlSi13Mg1CuNi alloy

An X- ray analysis of the phase composition of the (Mn-N-S) layers created on the AlSi13Mg1CuNi alloy proved the presence of Al, α-Mn, MnS and Mn_4N (Fig. 2). The arrangement of MnS in the studied layers can be seen in the form of surface zone penetrating in discontinuity points into the multicomponent layer (Fig. 2).

It is assumed that the Mn_4N phase is the dispersion in the α-Mn matrix saturated by nitrogen. The previously mentioned phase (MnS) can also occur in the matrix of the layer in the form of high dispersion particles. The study of the microstructure shows of the zonal structure of the (Mn-N-S) layers created on AlSi13Mg1CuNi alloy (Fig. 2). There are marked differences between the surface and the base-adjoining zone microhardness of these layers. The measured microhardness of the (Mn-N-S) layer exhibited 358HV0.01 on the surface and 571HV0.01 in the base-adjoining zone. In work [9] were determined the tribological characteristics of the (Mn-N-S) layers created on the AlSi13Mg1CuNi alloy (Fig. 3).

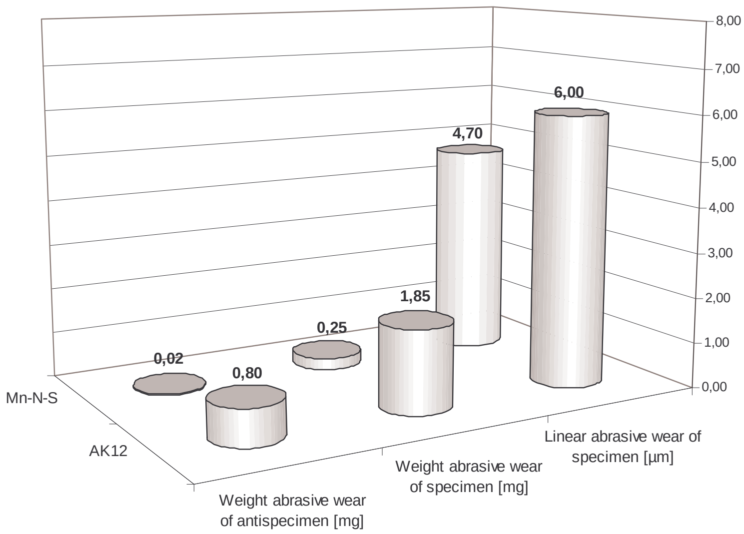

Figure 3. The value of linear and mass wear of the AlSi13Mg1CuNi (AK12) alloy with and without (Mn-N-S) layer

The corrosion potential (Ec) and corrosion current density (Jc) of AlSi13Mg1CuNi alloy and (Mn-N-S) layer were observed:

- AlSi13Mg1CuNi alloy:Ec = - 450 mV, Jc = 11 $\mu A/cm^2$,
- (Mn-N-S) layer: Ec = - 1291.0 mV, Jc = 335.68 $\mu A/cm^2$.

The current density is a measure of corrosion resistance at anodic condition, often used for comparative evaluation of materials in a certain environment. The corrosion potential and corrosion current density strongly depends on the surface conditions of AlSi13Mg1CuNi alloy and (Mn-N-S) layer.

4. CONCLUSIONS

It is possible to create of the tribological beneficial layers containing manganese, nitrogen and sulphur on the AlSi13Mg1CuNi alloy using of the hybrid surface treatment.

1. The created (Mn-N-S) layers are structurally bonded with the aluminium base and have a zonal structure of varied hardness (358HV0.01 – on the surface and 571HV0.01 – in the base-adjoining zone).
2. The uncoated and coated with (Mn-N-S) layer AlSi13Mg1CuNi alloy exhibit the susceptibility for the pitting corrosion in 0.01 M sulphuric acid solution.
3. The (Mn-N-S) layers demonstrate worsening corrosion resistance of AlSi13Mg1CuNi alloy in mentioned solution.

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