The creation and investigation of the wear resistance multicomponent surface layer on aluminium alloy

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Abstract

There are many methods of surface consolidation of aluminium alloys. This paper is a presentation of the hybrid method of creation of (Mn-N-O) layer on aluminium alloy, its hardness and microstructure. The results of tribological investigations of AlSi10Cu2Mg1Ni1 alloy coated (Mn-N-O) layer with the perlite grey cast iron under sliding friction are shown. Inereation of wear resistance in consolidated aluminium alloy surface by (Mn-N-O) layer is proved.

1 Introduction

Aluminium alloys are the materials of choice when high-strength-to-weight ratios are required in structural components, and are used widely in the automotive and aerospace industries [1]. As an example, the use of aluminium components in the automobile industry has greatly increased due to weight savings and resultant fuel economy improvements. However, strong unit pressure, high temperature, corroding medium or wear and friction limit the use of the aluminium alloys. Thus, new methods of both total and surface consolidation of the construction elements made from aluminium alloys are
sought. The consolidation is usually done by burnishing, cladding, padding, spraying, sputtering or electroplating [2, 3, 4, 5]. Among the above-mentioned methods, electroplating is the most commonly used one. However, electrolytic coatings on aluminium are less adhesive than the layers made by the hybrid method. One of such methods is the multicomponent layer containing manganese, nitrogen and oxygen.

The aim of this paper is to present the technology of creating, the microstructure and some of the characteristic features of the presented layers.

2 Description of the experiment and methods of study

The multicomponent layers containing manganese, nitrogen and oxygen (Mn-N-O) were created on the samples measuring 15x15x5 mm, made from cast aluminium alloy (AlSi10Cu2Mg1Ni1) used in the production of internal-combustion engine pistons. The production process of the layers, using the hybrid method includes manganese electroplating and then diffusion alloying of the manganese coating with oxygen and nitrogen. The resulting, (Mn-N-O) layers consist of manganese, nitrogen and oxygen and are structurally connected (by diffusion) with the aluminium base. The technological details of creating above mentioned layers have described in [6, 7, 8, 9].

The research included measuring of microhardness, the study of microstructure, phase composition and wear. The microstructure of the layers was observed by a scanning electron microscope (SEM), with magnification 1000 and 3000x. The hardness of the layers was found by measuring the microhardness using a load of 0.098 N. Phase composition of the obtained layers was found by an X-ray diffraction analysis. The study of the wearing of the (Mn-N-O) layers and the base (AlSi10Cu2Mg1Ni1 alloy) were made on the tribometer PT-3 (Fig.1) [10]. In order to measure the quantity of wear by slide friction, the following were used:

- samples (size: 15x15x5mm),
- anti-sample (bush Ø 11/ Ø 8mm),
- nominal pressure 27MPa and sliding speed 0.1 m/s.

The sliding elements were inserted in oil SAE 15/40 at the temperature 80°C. The anti-sample was made from perlite grey cast iron (hardness 197 HB). The lineal wear of the samples was measured by the profile measurement gauge after 2, 5, 8, 11, 14 hours of exploitation. The value of the friction resistance was measured to find out the friction factor (µ).

3 The results of the study and its evaluation

The considerable number of pores and remainders in the structure of the electrolytic coat in the microstructure of the (Mn-N-O) layers on the AlSi10Cu2Mg1Ni1 alloy have been observed (Fig.2).
Figure 1: Scheme of PT-3 tribometer [10]: 1 – sample, 2 – anti-sample, 3 – spindle, 4 – hydrostatic bearing, 5 – plunger, 6 – pump of oil

The existence of the pores in the (Mn-N-O) layer on the AlSi10Cu2Mg1Ni1 alloy can be accounted for by the presence of silicon (next to aluminium it is the main phase ingredient of the base microstructure) and its influence on the process of formation of the manganese electrolytical layer. The above-described features of the layer and the presence of the pores can be decreased during thermo-chemical treatment.

An X-ray analysis of the phase composition of the (Mn-N-O) layers created on the AlSi10Cu2Mg1Ni1 alloy proved the presence of Al, α-Mn, MnO and Mn4N. The arrangement of MnO in the studied layers can be seen in the form of surface zone penetrating in discontinuity points into the multicomponent layer (Fig.3). It is assumed that the Mn4N phase is the dispersion in the α-Mn matrix saturated by nitrogen. The previously mentioned oxide phase (MnO) can also occur in the matrix of the layer in the form of high dispersion particles.
Figure 2: SEM of (Mn-N-O) surface layer on AlSi10Cu2Mg1Ni1 alloy

Figure 3: SEM of cross section of (Mn-N-O) layer on AlSi10Cu2Mg1Ni1 alloy

The author of this paper has all the figures and X-rays of the distribution of the concentration of Al, Mn, N, O, Si, Cu, Ni, Mg and Fe in the studied multicomponent layers (not included in this paper).

The study of the microstructure shows that the structure of the layers on AlSi10Cu2Mg1Ni1 is zonal. There are major differences in the microhardness on the surface of the layers and the base-adjoining zone. The results of the
measurement of the microhardness in the respective zones of the (Mn-N-O) layer are shown in Table 1.

Table 1: Microhardness HV0.01 of (Mn-N-O) layer

<table>
<thead>
<tr>
<th>Surface</th>
<th>base- adjoining zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>359 HV0.01</td>
<td>583 HV0.01</td>
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The following tribological features are among the most important in case of mixed friction: friction resistance (μ factor), the quantity of wear and the microstructural changes of the friction surface of the elements making the sliding pair.

The value of lineal and weight wear is presented on Fig. 4 in the form of pile diagrams.

![Figure 4: The value of linear and weight wear of AlSi10Cu2Mg1Ni1 alloy with (Mn-N-O) layer](image)

The value of friction factor of the sliding elements of the AlSi10Cu2Mg1Ni1 alloy with the perlite grey cast iron is 0.087, while in case of the AlSi10Cu2Mg1Ni1 alloy coated with the (Mn-N-O) layer it is between 0.130 and 0.110.

The wear resistance of the metallic materials is known to mainly depend on their hardness and microstructure. As shown by Fig. 4 the values of friction wear of the AlSi10Cu2Mg1Ni1 alloy and the (Mn-N-O) layer are much smaller than those of the uncoated alloy. Such behaviour may be attributed to the greater hardness of the subsequent zones of the (Mn-N-O) layer (Table 1) in comparison to the uncoated the AlSi10Cu2Mg1Ni1 aluminium alloy at the dispersion hardened state(mean hardness 105 HB). The decrease of wear is performed due
to multiphase structure of the (Mn-N-O) layer. The microstructure of the tested layer consists of very thin MnO surface zone, the alpha-Mn matrix saturated with nitrogen, and hard dispersive MnO and Mn4N particles. The described microstructure is specific of a lot of composite materials and coatings possessing unique tribological properties.

In the studies of the friction path surface of the AlSi10Cu2Mg1Ni1 alloy (Fig.5) has been observed an increase of surface roughness from \( Ra = 0.189 - 0.235 \) up to \( Ra = 0.282 - 0.324 \). In case of the AlSi10Cu2Mg1Ni1 alloy coated with the (Mn-N-O) layer the surface roughness decreases from \( Ra = 0.683 - 0.798 \) to \( Ra = 0.320 - 0.523 \) (Fig.6).

The high initial value of the surface roughness of \( (Ra) \) in the (Mn-N-O) layer can be accounted for by the remains of the features of the electrolytical coating during the manufacturing process.

Figure 5: SEM of the AlSi10Cu2Mg1Ni1 alloy friction path, (500x)

Figure 6: SEM of the (Mn-N-O) layer friction path, (500x)
4 Conclusions

1. It is possible to create layers containing manganese, nitrogen and oxygen on the AISi10Cu2Mg1Ni1 alloy using of the hybrid surface treatment.
2. The created (Mn-N-O) layers are structurally linked with the aluminium base and have a zonal structure of varied hardness.
3. The consolidation of the surface of the elements made from the AISi10Cu2Mg1Ni1 alloy with a coat containing manganese, nitrogen and oxygen results in the decrease of frictional wear of the alloy connected with perlite grey cast iron.
4. The friction co-operation of the AISi10Cu2Mg1Ni1 alloy coated with (Mn-N-O) layer, and cast iron in case of mixed friction is characterised by little frictional resistance. At the same time there is no tendency to seizing and spalling of the sliding surface.
5. The properties of (Mn-N-O) layers depend on the choice of the parameters of the electroplating and thermo-chemical processes.

References