



Co-deposited composite coatings with a ceramic matrix destined for sliding pairs

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ABSTRACT

Composite layers with electrolytic oxide coatings matrix on aluminium and its alloys or composite with its matrix are widely applied in production of machine parts destined for sliding pairings. These layers so far have been produced with a two-stages method, i.e. through anodizing and metallising. So produced layers have disadvantageous surface fractions of hard, abrasive acting aluminium oxide and plastic, friction softening metal. Only 1 unit of metal accrues in the friction surface for every 200 area units of alumina, because there is metal in the pores of the oxide cells only. The new method elaborated by the author, named co-deposition, changes those proportions. The friction-softening metal is deposited through the entire oxide cells' volume, which changes significantly the useful properties of the composite layers. The results of metallographic and tribological investigations of layers produced with the two-stage method and the co-deposition method are presented in this paper.

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1. Introduction

Electrolytic oxide coatings deposited on aluminium and its alloys are widely applied in many areas of industry [1–4]. The structure and properties of the coatings used depend to a large degree on the technology and parameters of the oxidation process. The structure of an anodic oxide coating formed in sulphuric acid electrolyte is presented in Fig. 1. In general, from the user's perspective, oxide coatings can be divided as shown in Table 1, depending on the purpose for which they are produced. Based on the information presented in Table 1, electrolytic oxide coatings are used for decorative, tribological, insulating and other specific purposes. In most cases, the coatings used for decorative purposes are artificially coloured using current or non-current methods. It is also possible to produce self-coloured oxide coatings, whose colour results from the chemical composition of the oxidised alloy and the electrolyte (so-called integral colouring). For some applications, e.g. for tribological purposes (increasing the wear resistance) or electric purposes (improvement of insulating or magnetic properties), metallisation or coating of anodic oxide films with a plastic material is used [5,6]. The professional literature also provides information concerning the introduction of plastic materials into the pores of an oxide film [7] or anchoring these materials on the surface of the film, using a medium which penetrates the nanopores [8].

The briefly outlined coatings intended for tribological purposes have their advantages and disadvantages. A major disadvantage of composite coatings based on an anodic oxide coating, produced using conventional methods, is too high a surface fraction of the

abrasive-working aluminium oxide, which intensifies the wear of the partner rubbing against the composite coatings. In order to mitigate the consequences of this disadvantage, a new, so-called co-deposition method has been developed. By applying this method, ceramic–metal composite coatings of completely new tribological properties can be obtained. The fundamentals of the fabrication process of composite coatings, their structure and selected properties, will be described in this paper.

2. Experimental details

The comparison of the structure and properties of composite coatings with oxide matrix metallised with nickel which are formed by two-stage and co-deposition method has been done in the performed investigations.

In order to verify the usefulness of the co-deposition method in the production of composite coatings on aluminium engineering materials, studies have been performed on two aluminium alloys most commonly applied in machine building: an wrought alloy, EN-AW-AlMg2, and a eutectic silicon aluminium alloy, EN-AC- AlSi12MgCu .

The first of the alloys is used in the production of extruded components, such as guides for sunroofs in motor vehicles. In order to enhance the wear resistance when in contact with a slide made of a composite plastic material (polyacetal matrix), the guides are subjected to anodic oxidation and electrolytic colouring. However, their sliding properties are not satisfactory and the force required to open the roof is too great, thus necessitating lubrication with minimum amounts of a lubricant. The use of the co-deposition method can improve the sliding properties of these guides.

The other alloy finds its application in the production of cylinder sleeves for combustion engines and pistons for combustion engines

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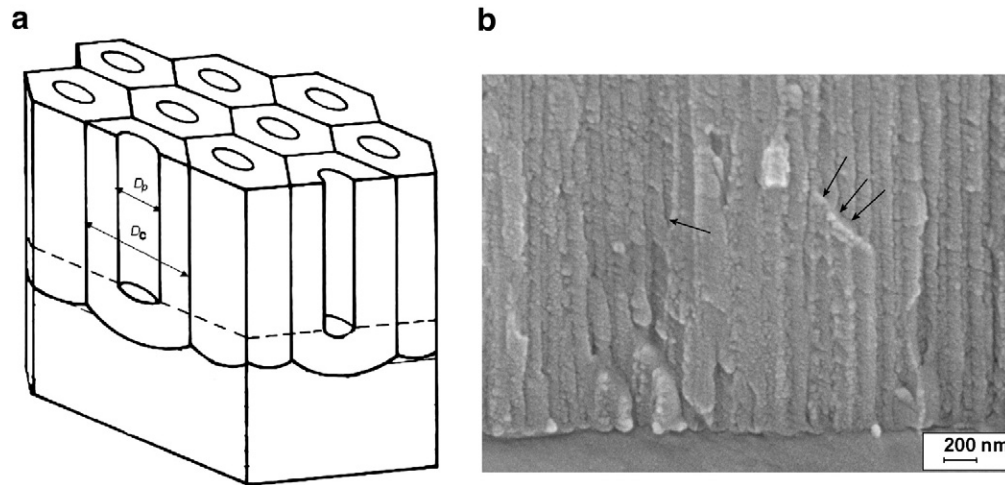


Fig. 1. A porous anodic oxide coating formed as a result of electrolytic oxidation of aluminium (a—a diagram with marked oxide cells with lengthwise pores, D_p —diameter of a pore, D_c —diameter of an oxide cell; b—fracture of coating formed in a 15% sulphuric acid electrolyte with visible, mostly parallel, pores).

and air piston compressors. Here, using the co-deposition method to produce composite coatings on the piston skirt/cylinder sleeve pair, which will improve the efficiency of the engine or compressor. By incorporating solid lubricants into the oxide coating, the amount of oil necessary for lubrication can be reduced and the wear of the engine during its cold start can be decreased.

2.1. Coatings produced by two stage methods

Using existing two stages methods, the essence of metallization, of oxide coatings meant for tribological purposes is the introduction of ions of selected metals into the pores of the existing anodic oxide coating (anodic hard coating, or AHC). The formation process involves two stages: oxidation and metallization. The result of the metallisation stage depends strictly on the conditions of oxidation and on the treatment applied before metallisation. The outcome of two-stage metallisation is a composite coating, AHC + Me, with an aluminium oxide matrix, of metal deposits distributed in stochastically arranged oxide pores [6,9]. The metallisation process can be performed in two ways:

- with metal precipitates brought out above the oxide coating surface,
- without bringing out the metal above the oxide coating.

The diagram in Fig. 2 illustrates both techniques, whilst Figs. 3–7 show some photographs of the surface of coatings and transverse microsections taken with a scanning microscope, and qualitative analyses of their chemical composition. The coatings deposited using these methods have different tribological properties at the wearing-in stage. If, as a result of alloy oxidation, an oxide coating is obtained

of high surface roughness and with a large number of high peaks or non-oxidisable alloying components standing out of the coating, or in the case of aluminium matrix composites (AlMC), with a pronounced reinforcing phase, the metallisation process must be conducted so as to bring out metal precipitates above the peaks of irregularities and the reinforcing phase particles. The metal precipitates should be higher than the maximum height of the peaks of roughness ($H > R_{max}$). In this way, at the wearing-in stage, where considerable unit pressures are present, the sliding partner will be separated from the abrasive-working aluminium oxide, which will mitigate the friction and wear of the couple. A coating where the metal is brought out above the oxide surface partly loses its ability to absorb lubricants, because the pores are filled with metal to a greater extent. This loss is partly compensated by the spaces formed between metal precipitates, Fig. 3. However, sorption of oil on such non porous surface is lower than on the surface of a porous aluminium oxide.

If an oxide coating with low roughness can be formed on oxidised materials, this means that it is possible to produce a composite coating without bringing out the metal above the oxide surface, or to produce a coating where the height of the precipitates brought out is significantly lower than in the first method. Protruding precipitates usually occur on an oxide surface in areas where the pores do not have a regular shape, e.g. where they run diagonally or are narrowed, which causes filling of the pores not from the barrier part (not from the bottom), but from the place where a defect has occurred (as indicated with arrows in Fig. 1b), thereby causing faster occurrence of metal on the surface. Pores of a regular shape or with a larger diameter are not entirely filled up with metal and they serve as micro-depots of oil. By penetrating into pores, the oil is more firmly bound (is absorbed) with the oxide than in the spaces between metal precipitates in the method where the metal is brought out above the oxide surface (is adsorbed). Such composite coatings can slide with a small amount of lubricant, namely in the start-up conditions of cold machines.

Taking into account the cellular structure of an anodic oxide coating, the proportions between the metal and the oxide obtained in the composite coating are not advantageous from a tribological point of view, i.e. a cylindrical pore, 10–20 nm in diameter, filled to a certain degree with metal, and a ceramic sleeve with an inner diameter of 10–20 nm and outer, 250–300 nm, Figs. 1 and 2. The proportion of the oxide surface (A_o) to the metal surface (A_m) in one cell equals 225:1. This is how a contact surface is formed between the metallised coating and, e.g., cast iron. In such coating, there is ca. 200 times more

Table 1
Purposes of oxide coatings on aluminium engineering materials.

Purposes of oxide coatings			
Aesthetic	Tribological	Insulating	Functional
–Decorative purposes	–Friction mitigation	–	–Increasing wettability
–Anticorrosive protection	–Protein against wear	–Thermal insulation	–Increasing the active surface
			–Special purposes, e.g. matrices for nanomaterials

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