ISSN 1068-3755, Surface Engineering and Applied Electrochemistry, 2023, Vol. 59, No. 1, pp. 1–6.

Interrelation between the Composition of Steel Treated by Electrospark Alloying and the Properties of Resulting Composite Surface

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Received June 11, 2021; revised July 15, 2021; accepted July 19, 2021

Abstract—The study of elemental composition of surface composites produced by electrospark alloying (ESA) of Type 45, 65G, and St3 steels with hard T15K6 and VK8 alloys and Type 45 and St3 steels (in the "steel-on-steel" mode) showed that the formed surface layers consisted of the ESA-modified steel substrate material by ~70%. The effects that the steel composition has on coefficients characterizing the transfer of the processing electrode material onto the substrate, surface roughness, microhardness, and wear resistance of resulting surfaces were investigated. It was found that the wear resistance of the composites is mainly determined by the nature of surface being processed and, to a much lesser extent, by the processing electrode material, surface roughness and microhardness.

Keywords: electrospark alloying, steel, hard alloy, composite materials, surface, wear resistance

DOI: 10.3103/S1068375523010039

INTRODUCTION

Largely, electrospark alloying (ESA) is used as a method for applying a coating with improved properties on a manufactured item. The degree of continuity of the coating may vary, but it must have strong adherance to the substrate due to melting of material in the electric spark discharge zone.

It was shown [1] that so-called ESA coatings do not necessarily justify their name, because they represent a surface system consisting mainly (up to 70%) of the substrate material (i.e., steel). It is well known that ESA layers necessarily include the substrate material modified by ESA treatment; however, this aspect was rarely the subject of detailed investigation. There is a large body of literature on broad capabilities of ESA in the context of modification of metal surfaces [2–5]. In addition, a number of recent studies have shown that ESA involves surface nanostructuring [6–15], which occurs either unintentionally [6–8, 12, 15] or by using a processing electrode (PE) in which ultradispersed materials were incorporated intentionally [9–11, 13].

Nanostructuring of surface layers is an effective strategy to hardening of recent constructional and tool materials [16, 17]. Methods for engineering of the properties of surface layers based on nanostructuring [16, 17] are developed with the idea that nanostructured materials are materials in which the volume of individual elements, i.e., grains, is smaller than the intergrain volume [18]. ESA is one of these methods.

Typically, composite materials are defined as materials that include two or more components that have different properties but impart new properties to the resulting system. Typically, such phase components retain their individual properties. In ESA, both the PE and substrate materials undergo changes as a result of thermal and dynamic effects during processing, which gives rise to a new system that includes both elements of the starting materials and a new intermediate structure. With some degree of obscurity, in the absence of a better term, such a system can be referred to as a composite or a surface composite layer.

Evidently, engineering of the properties of such composites requires detailed study of the effect that the substrate material (i.e., material being processed) has on the properties of resulting surfaces, and this is the subject of the present study.

Mostly, ESA is applied to various types of steel. In this work, the substrate effect was revealed in several grades of steels. It is however evident that this approach could open broad possibilities for ESA, if

CONCLUSIONS

The detailed study of the properties of surface composites formed as a result of electrospark modification of various steels (St3, 45, and 65G) using electrodes made from T15K6 and VK8 hard alloys, as well as from St3 and 45 steels (in the steel-on-steel mode) showed that:

– The produced composite surface layers consist of a mixture of the electrode and substrate materials, with the substrate material constituting up to ~70 wt %; W and Ti carbides, ~20–25 wt %; and the Co content, >50 wt % (up to ~ 90%) of its content in the electrode.

– The mass transfer coefficients depend on discharge energy E (they increase with increasing E) and the nature of surface material being treated (the lowest values were observed for grade 45 steel), and exceeding the E values for which $K \sim 1$ results in a decrease in K.

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