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Tribological characteristics of electroless Ni–B coating and optimization of coating parameters using Taguchi based grey relational analysis

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ABSTRACT

Electroless nickel coating is an autocatalytic coating whose characteristics are very much dependent on the composition of electroless bath. The present study is an attempt to minimize the friction and wear characteristics of electroless Ni–B coatings simultaneously by optimizing the three coating parameters viz. bath temperature, concentration of reducing agent and concentration of nickel source together with the annealing temperature. Taguchi based grey relational analysis is employed for the optimization of this multiple response problem using an L_{27} orthogonal array. Analysis of variance reveals that concentration of reducing agent has the maximum contribution in controlling the friction and wear behaviour of Ni–B coating. The interaction between bath temperature and nickel source concentration is also found to possess significant contribution in controlling the friction and wear characteristics. The surface morphology, composition and phase structure analysis are done with the help of scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDX) and X-ray diffraction analysis (XRD), respectively. Moreover the wear mechanism is studied and found to be in general abrasive in nature.

1. Introduction

The discovery of the electroless method of coating is mainly accredited to Brenner and Riddell [1] in the middle of the last century. Since then, the potential of the process has been well recognized especially through a series of research works and now the process is widely used in various industries like electrical, aerospace, automotive, chemical, electronics, etc. [2]. Electroless nickel coating is the autocatalytic deposition of nickel based alloys (Ni–P, Ni–B, Ni–W–P, etc.) on the substrate dipped in a solution of metal ions, complexing agents, reducing agents and stabilizers, operating in a specific metal ion concentration, temperature and pH ranges. The advantages of this process include uniform deposition and the ability to coat even non-conducting materials. Hypophosphite reduced Ni–P [3–5] coatings have already been widely accepted and superior properties (hardness and wear resistance) of Ni–B coatings have already created a stir among the researchers [6–16]. Ni–B coatings are found to possess superior hardness in as-deposited phase compared to Ni–P coatings [10]. Again the hardness of Ni–B coating increases even more with heat treatment [10–13]. The increase in hardness of Ni–B coating with heat treatment is generally attributed to the modification of deposit structure allowing the precipitation of Ni–B phases according to the Ni–B phase diagram [11]. The Ni–B phases act as barriers for dislocation movement, thereby increasing the hardness further. As harder materials generally encounter lesser wear, heat-treated Ni–B coatings are found to be more wear resistant than the as-deposited ones [9,10,15]. Use of higher heat treatment temperatures and longer times leads to the progressive hardness decrease, which can be attributed to the nickel grain growth and to the boride coarsening leading to surface brittleness and enhanced dislocation propagation. Moreover, Ni–B coating possesses a columnar structure, which is useful in retaining lubricants under conditions of adhesive wear [16]. Krishnaveni et al. [9] have found that specific wear rate and coefficient of friction (COF) of electroless Ni–B coating increases with increase in applied load under pin-on-disc arrangement. Heat treatment is also found to reduce the COF of electroless Ni–B coatings [9] by presenting a virtually incompatible surface for the hard counter face material. Scratch test by Delaunois and Lienard [11] point towards the fact, that heat treatment could also increase the adhesion between the Ni and B deposit and the substrate. Search of improved tribological properties has led to the formation of duplex coatings of Ni–P and Ni–B [10] and three component coatings of Ni–B–P [17,18]. Composite coatings with improved wear resistance have been formed by incorporating several particles in Ni–B coatings, viz. diamond, alumina and silicon carbide [2].

The tribological characteristics such as friction and wear are highly dependent on the composition of the material. In case of electroless Ni–B coatings, although the composition primarily consists of nickel and boron, the characteristics of the coating is found to vary depending on the bath composition [6]. Thus, the present study is primarily devoted to the investigation on the dependence

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