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Evolutionary support vector regression algorithm applied to the prediction of the thickness of the chromium layer in a hard chromium plating process

F. Sánchez Lasheras [a,*], P.J. García Nieto [b], F.J. de Cos Juez [c], J.A. Vilán Vilán [d]

[a] Department of Construction and Manufacturing Engineering, University of Oviedo, 33204 Gijón, Spain
[b] Department of Mathematics, Faculty of Sciences, University of Oviedo, 33007 Oviedo, Spain
[c] Project Management Area, Mining Department, University of Oviedo, 33004 Oviedo, Spain
[d] Department of Mechanical Engineering, University of Vigo, 36200 Vigo, Spain

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A B S T R A C T

The hard chromium plating process aims at creating a coating of hard and wear-resistant chromium with a thickness of some microns directly on the metal part, without the insertion of copper or nickel layers. It is one of the most difficult electroplating processes due to the influence of the hydrogen evolution that occurs on the cathode surface simultaneously to the chromium deposition. Chromium plating is characterized by high levels of hardness and resistance to wear and it is thanks to these properties that they can be applied in a huge range of sectors. Resistance to corrosion of a hard chromium plate depends on the thickness of the coating, adherence and micro-fissures of the latter. This micro-fissured structure is what provides the optimal hardness of the layers. The electro-deposited chromium layer is not uniformly distributed: there are zones such as sharp edges or points where deposits are highly accentuated, while deposits are virtually nonexistent in holes or in the undercuts. The hard chromium plating process is one of the most effective ways of protecting the base material in a hostile environment or improving surface properties of the base material. However, in the electroplating industry, electro-platers are faced with many problems and often achieve undesirable results on chromium-plated materials. Problems such as matt deposition, milky white chromium deposition, rough or sandy chromium deposition and insufficient thickness or hardness are the most common problems faced in the electroplating industry. Finally, it must be remarked that defects in the coating locally lower the corrosion resistance of the layer and that the decomposition of chromium hydrides causes the formation of a network of cracks in the coating. This innovative research work uses an evolutionary support vector regression algorithm for the prediction of the thickness of the chromium layer in a hard chromium plating process. Evolutionary support vector machines (ESVMs) is a novel technique that assimilates the learning engine of the state-of-the-art support vector machines (SVMs) but evolves the coefficients of the decision function by means of evolutionary algorithms (EAs). In this sense, the current research is focused on the estimation of the hyper-parameters required for the support vector machines technique for regression (SVR), by means of evolutionary strategies. The results are briefly compared with those obtained by authors in a previous paper, where a model based on an artificial neural network was tuned using the design of experiments (DOE).

* Corresponding author.
E-mail address: sanchezfernando@uniovi.es (F. Sánchez Lasheras).

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1. Introduction

The commercial process of chromium plating came about mainly thanks to the work of Fink patented in 1926 [1] and based on a 1920 paper by Sargent [2], who discovered that in order to electroplate chromium you need almost exactly 1 part of sulfuric acid to 100 parts of chromic acid. Udy [3] also discovered a workable process, but his results were not made public until much later. The original hard chrome process was put to commercial use around 1930.

As is well-known, chromium plating operations are categorized according to the thickness of the chromium metal layer applied. They can be classified as "hard chromium" and "bright (decorative) chromium" plating [4–7]. The description "hard chromium" as opposed to "bright chromium" is in a sense a misnomer, since hard chromium is in no way harder than bright chromium [8]. Hard chromium plating is produced by electro-deposition in a solution of chromic acid. It has a wide range of applications where wear and a low coefficient of friction are required.

The hard chromium plating process studied in this research is widely used on many mechanical parts and plastic moulds due to its good mechanical properties, good aesthetic appearance and superior resistance to corrosion. This process consists mainly of three operations (see Fig. 1) and their corresponding quality inspections [7,9–12]. It has already been presented by the authors in previous research [8] and is briefly outlined below:

- *Vapour degreasing:* This is mainly a cleaning operation. It is performed on the piece in order to ensure the cleanliness of the surface.
- *Electropolishing:* An electrochemical process that removes material from the work piece. The performance of this operation before the hard chromium plating helps to ensure a good roughness of the surface to be coated.
- *Hard chromium plating:* This is the operation whereby a thin layer of chromium is deposited on the workpiece.

2. The aim of the present study

This research work uses evolutionary support vector regression algorithms for the prediction of the thickness of the chromium layer in a hard chromium plating process. Evolutionary support vector machines (ESVMs) [13–15] is a novel technique that assimilates the learning engine of the state-of-the-art support vector machines (SVMs) [16–19], but evolves the coefficients of the decision function by means of evolutionary algorithms (EAs) [13–15]. In this sense, the current research is focused on the estimation of the hyper-parameters required for the support vector machines technique for regression (SVR) by means of evolutionary strategies, in order to obtain the optimal parameters of the SVM for the system, and to find the best possible prediction of the hard-chromium layer. Finally, the results are briefly compared with those obtained by the authors in a previous paper where a model based on an artificial neural network was tuned using the design of experiments (DOE) [8].

3. Materials and methods

3.1. Support vector regression

Support vector regression (SVR), originally proposed by Vapnik [16–19], is a relatively new nonlinear machine learning technique in the field of chromium plating and can handle higher dimensional data better, even with a relatively small amount of training samples. In support vector regression, the basic idea is to map the data X into a higher feature space F via a nonlinear mapping Φ and then to do linear regression in this space. Therefore, regression approximation addresses the problem of estimating a function based on a given data set $G = \{(\mathbf{x}_i, d_i)\}_{i=1}^{l}$ ($\mathbf{x}_i$ is input vector and d_i is the desired value). SVR approximates the function in the following form [18,20–22]:

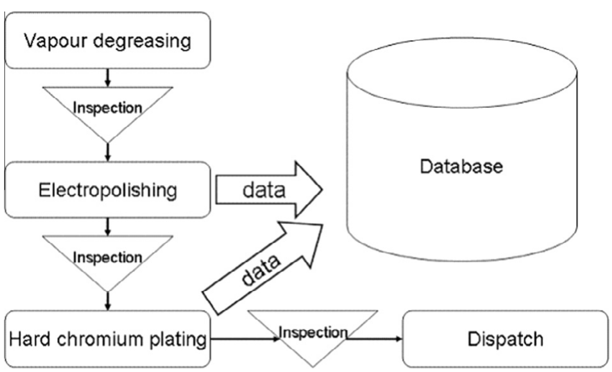

Fig. 1. The industrial process of hard chromium plating.