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Ranking the Cobalt Coating Nanostructures, Produced by Direct current Through the Analytic Hierarchy Process (AHP)

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In recent years, cobalt coating has been known as an alternative material instead of chromium in corrosion and erosion resistant behavior. Extensive research has been carried out on a variety of electroplated cobalt coatings. In this study, for the first time, the relative priority of the cobalt coating has been calculated and ranked theoretically by the Analytic Hierarchy Process (AHP). For this purpose, through the AHP and the Expert Choice software, benefiting from expert opinions, the relative weights of the effective parameters on achieving nanostructure coating have been calculated. Then, by using the weights obtained, the relative priority of five available Co coatings was calculated and the quality of them was ranked. Among available Co coatings, the coating with 5 mA/cm^2 current density, pH 3, electrolyte saccharin of 0.25 grams per liter and a temperature of 45 °C during 30 minutes, in comparing with others had more favorable conditions for achieving nano-grain size. This shows that before experimental tests, the best alternatives to achieve the ultimate goal could be anticipated. This anticipation leads to reduce in trial and error and the multiplicity of the tests in investigations.

Keywords: Co electroplating, Nanostructure coating, Analytic Hierarchy Process (AHP), Expert choice.

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1. INTRODUCTION

Increasing demand for transformers, motors and generators, in order to manufacture electrical equipment and devices that are used at high temperatures, caused extensive research on the magnetic susceptibility and high iron group alloys having high Curie temperature. Cobalt and its alloys have suitable magnetic and electrical properties for applications in technologies such as magnetic recording, core material of transformers, thin layer induction and magnetic - impedance sensors [1]. Recent researches have shown that the Nano crystalline cobalt coatings can be replaced by chromium layers as a material for erosion resistant coatings [2]. Cobalt coatings via electroplating have a range of applications due to their attractive appearance, hardness and resistance against oxidation. Among the advantages of electroplating is that in this method control of thickness and properties of thin layers is much better possible than other coating methods [3].

According to favorable physical, chemical and metallurgical properties of microstructures, the need to develop methods that present easier and faster ways to achieve is strongly felt. In this study, while "The Analytic Hierarchy Process" is introduced as a powerful method for multi-criteria decision making in various ways, the possibility of utilizing this method in engineering science and especially in Metallurgy and Material Engineering for further targeting research is presented.

In this paper the quality of five available cobalt coatings on copper by direct current is ranked through the AHP. Indeed by this research, the possibility of doing theoretical work to know and choose the best parameters and the most efficient alternatives instead of laboratory trial and error checks is studied.

2. METHOD

In this study, the relative priority of the cobalt coatings applied by direct current in different conditions is ranked by theoretical studies. The theoretical findings is studied through the Analytic Hierarchy Process and Expert Choice software based on AHP algorithm.

The goal in this review is to achieve the nanostructure. The pairwise comparison matrices between effective factors and alternatives were prepared and completed by the experts. Then by using the AHP algorithm, the ranking of the effective criteria and five available coatings was obtained.

2.1 The Analytic Hierarchy Process (AHP)

The "Analytic Hierarchy Process" was developed by Thomas L. Saaty for the first time in 1970 [4]. The main components of this method are [5]:

1. Determining the main goal and configuring the decision components: in this process, choosing the smallest grain length, which is depended on various factors, is divided to simpler sub factors.
2. Constructing a set of pairwise comparison matrices in which criteria in each level of hierarchy diagram compare with respect to upper level and also alternatives compare to each other with respect to criteria.
3. Evaluating the relative priority: By mathematical calculations on pairwise comparison matrices and comparing the obtained relatives, the best alternative for coating selects.

2.2 Pairwise comparison matric

In pairwise comparison matric, affective criteria in decision-making in each level, i.e. current density, temperature, pH and saccharin or five coating alternatives are compared to each other. In this matric, main diameter is always one and the symmetric data is reverse [6].The advantage of this pairwise comparison is that at the moment of paired comparisons, only two criteria or alternatives are compared with each other.

For implementation the pairwise comparison matrices in qualitative data, a numerical basis is required to show the importance and priority of one alternative to other with respect to the criteria and one criterion to other with respect to the purpose. Thomas Saaty has proposed scale of Table 1 [7].

Table 1 – A numerical scale for determining the importance of criteria and alternatives in the pairwise comparison matric [7]

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Judgment strongly favor one activity over another
6	Strong plus	
7	Very strong	An activity is favored very strongly over another
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order

2.3 Algorithm of AHP

To achieve criteria weights and alternatives rankings, the following algorithm is performed on the n×n pairwise comparison matrices. Thomas Saaty proved that the best way to turn pairwise comparison matrices to weights and alternatives ranking is calculating the "Eigenvector" . To calculate the Eigenvector and final weights, the following steps had been proposed [5]:

1. The n×n pairwise comparison matric squares and a new matric is derived.
2. Elements located in each row of the new matric add together. The result is a n×1 matric.
3. Elements located in the n×1 matric add together and a number is the result.
4. Elements of n×1 matric are divided by the result of step 3 and the "Eigenvector" achieves.
5. To calculate the final weights, the following steps should be done on the eigenvector:
6. For the obtained matric of step 1, steps 1 to 4 are repeated to achieve a new eigenvector.
7. The difference between the previous eigenvector and the eigenvector of step 5 is calculated.

The algorithm stops when the difference of two eigenvector of two consecutive rounds, is less than a certain amount.

By algorithm stopping, final weights of criteria or alternatives prepared [8]. For determining the best alternative, weight matric of alternatives compared to each criterion must be multiplied by matric of final criteria weight. The largest number is the best alternative for being choosen [9].

3. RESULTS AND DISCUSSION

In figure 2, the hierarchy diagram of achieving the nanostructure Cobalt coating is shown. In this study, to achieve the smallest grain size was the main criterion and placed in the first row. This criterion increases the corrosion resistance and improves metallurgical properties of the coating surface.

In the second row of hierarchical diagram, four factors of pH, current density, temperature and the amount of saccharin have been introduced as effective characteristics on the nanostructure. Given that the different range of these factors have different effects on grain size, in the third row each criteria is divided into several subs in order to those ranges, their effect on the grain size is checked. In this figure the current density for short is shown: (CD), Saccharin: (Sa) and temperature: (T).

Then pairwise comparison matrices of criteria developed and completed by the experts. In Table 2, pairwise comparison matric of Figure 2 is presented and in figure 3 final weight results of effective criteria are shown.

Table 2 – The comparison matric of the second row of hierarchical diagram presented in Figure 2

	CD	T	pH	Sa
CD	1	5	7	7
T	1/5	1	3	4
pH	1/7	1/3	1	1
Sa	1/7	1/4	1	1

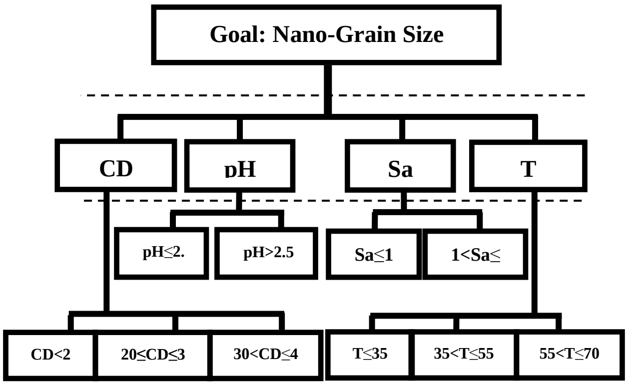

Fig. 2 – Hierarchy diagram of criteria for achieving the Cobalt coating smallest grain size

Five available coatings, using AHP for selecting the best, is shown in Table 3. These coatings were ranked according to the weights of criteria by AHP algorithm through Expert Choice software. The results of these coating priorities and rank of them is presented in the last column of this table.

Table 3 – Experimental conditions, relative priorities and ranking of coatings for choosing the best nanostructured coating

Coating's alternatives	Current Density mA/cm²	pH	Saccharin g/l	Temperature °C	Relative priority	Rank
pH = 1.5	20	1.5	0.25	45	0.163	4
Current Density = 5 mA/cm²	5	3	0.25	45	0.314	1
Current Density = 40 mA/cm²	40	3	0.25	45	0.165	3
Temperature = 70 °C	20	3	-	70	0.207	2
Temperature = 25 °C	20	3	-	25	0.151	5

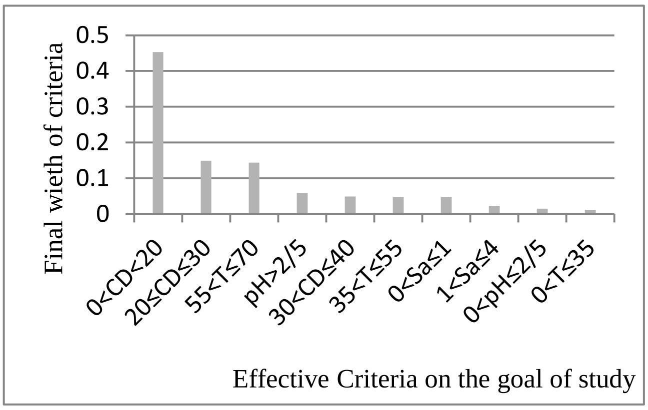

Fig. 3 – Diagram of final weights of effective criteria in the goal of study

4. CONCLUSION

1. Among the five available coatings, the coating with 5 mA/cm² current density, pH 3, electrolyte saccharin of 0.25 grams per liter and a temperature of 45 °C during 30 minutes, in comparing with other conditions had more favorable conditions for achieving nano-grain size.
2. Since the Analytic Hierarchy Process presented the ranking of available coatings and introduced the best coating, it seems that utilizing AHP in experimental fields of metallurgy and material engineering science and other technical sciences is possible.
3. It is possible to carry out the AHP before practical experiments. By implementing the AHP, alternatives that the most likely to achieve the goal are predicted. Because of the possibility of predicting the best alternative to achieve the ultimate goal, the researcher or industrialist can reduce their experimental tral and error and reach the best operational alternative more quickly.

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