Prediction and Estimation of Electroplating Characteristics, Corrosion Rate of Zinc Coated Mild Steel Coupling

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Abstract: *This present research work is taken to estimate the corrosion rate of zinc coated mild steel coupling with using of Design of Experiments (DOE). Now a day's mild steel materials are simply corroded in the all medium including atmospheric conditions. Overcome of this planed to applying the zinc coating on the mild steel material. In this study considered of normal use of mild steel coupling for the industrial applications. Main goal of this study to evaluate the Coating thickness (µm), Change of mass (g) and Corrosion rate (mm/y) of the coupling after coating. The L16 Orthogonal array of Taguchi analysis is engaged to find the response values. The different process parameters are considered for to analysis of electroplating characteristics, corrosion rate. Process parameters are namely current density (0.3 amps/ dm2,0.5 amps/ dm2,0.7 amps/ dm2 and 0.9 amps/ dm2), concentration of Zinc (10 g/L, 12 g/L, 14 g/L and 16 g/L), coating time (45 min, 60 min, 75 min and 90 min) and temperature (20 oC, 30 oC, 40 oC and 50 oC).*

Key words: Change of mass; Taguchi; Electroplating; Corrosion rate; DOE; Coupling.

1. INTRODUCTION

Nowadays the protections of the steel components from corrosion resistance is the big issue to overcome this problem need for some coating process. In recent trends the Zinc electroplating is most powerful method to form a effective coating on the surfaces, Now this method focused to using in steel parts to prevent also protect the surfaces from the corrosion process [1]. Zinc electroplating is the simple process and it has low cost method also best suitable for low budget fabrication process. Compared to other deposition methods Zinc electroplating technology was more powerful, in expenditures wise most of the manufacturing industries preferred this deposition process. This type of deposition process mostly used in automotive industries example to protect the power steering components, brake components bolt and nuts etc. In this process are used in military applications for offered the long life and excellent corrosion resistance of the components [2-4] Normally pure zinc offered moderate levels of corrosion resistance but adding of Nickel more than 10 % highly improve the corrosion resistance [5-7]. Some of the process parameters are influenced the deposition rate such as temperature, current density, zinc concentration, time period and additive application. The thin coating on the surfaces through electroplating protected the surface of the metal that thin coating is also termed as substrate [8, 9].

2.Experimental Procedure

This research study considered themild steel coupling for carrying the electroplating process. The Figure 1 illustrates that the before and after electroplating coupling.

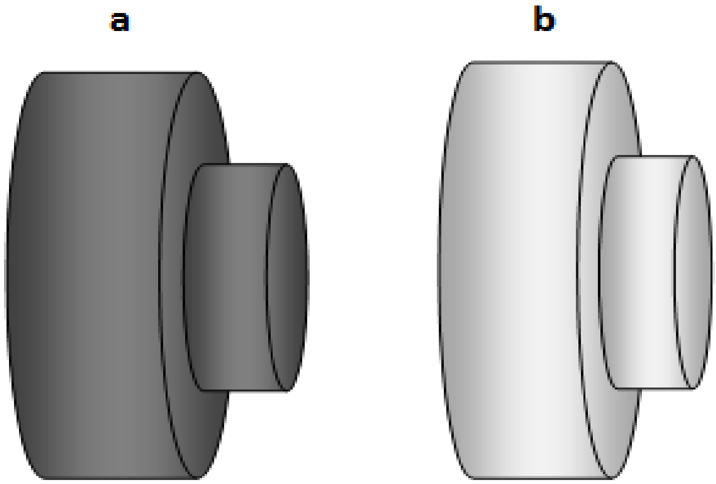

Figure 1. Electroplating Coupling: (a) Before Electroplating (b) After Electroplating

Before carrying the electroplating process the metal part can be cleaned thoroughly to removing contamination on the surfaces of the mild steel coupling, normally alkaline medium was used to clean the surface. After cleaning the mild steel coupling immersed in the acidic zinc solutions [10-12]. The time period and current density are the key role of the electroplating process. DC supply was provided in the elctroplating process when given the supply the zinc ions from the anode depositing on the cathode (mild steel coupling). During the elctroplating process the uniform current will be supplied it is the response of uniform coating. Finally the zinc electroplated mild steel material was taken out and cleaned by running water after then allowed to dried.For this study mild steel chemical constitutents elements and the percentage of each elements possessesof are presented in the Table 1.

Table 1. Chemical Composition of Mild Steel

Constituent Elements	Percentage level (%)
Carbon, C	0.25 - 0.290 %
Copper, Cu	0.20 %
Iron, Fe	98.0 %
Manganese, Mn	1.03 %
Phosphorous, P	0.040 %
Silicon, Si	0.280 %
Sulfur, S	0.050 %

Table 2. Mechanical Properties of Mild Steel

Mechanical Properties	Values
Ultimate tensile Strength	400 - 550 MPa
Yield Strength	250 MPa
Modulus of Elasticity	200 GPa
Bulk Modulus	140 GPa
Poissons Ratio	0.260
Shear Modulus	79.3 GPa

The Table 2. presented the mechanical properties of mild steel, the mild steel possesses highest ultimate tensile strength and the yield strength offered as 250 MPa. All the mechanical properties are good compared to other materials. Mild steel has normally better ductility nature as well as superior strength and also low cast material. It has used in all types of industries laborateries, fabrication process units, in construction work due to long life. Table 3 presented that the Input Process parameters of electroplating process and their levels. In this test taken as a four process parameters such as current density (amps/ dm^2), concentration of Zinc (g/L), coating time (min) and temperature (^oC). All the parameters are considered four levels of input readings to used in the statistical analysis.

Table 3 Input Process Parameters of Electroplating Process and their Levels

Process Parameters	Level - 1	Level - 2	Level - 3	Level - 4
Current Density (amps/ dm^2)	0.3	0.5	0.7	0.9
Concentration of Zinc (g/L)	10	12	14	16
Coating Time (min)	45	60	75	90
Temperature (^oC)	20	30	40	50

3. Results and Discussion

Trial No.	Current Density (amps/ dm^2)	Concentration of Zinc (g/L)	Coating Time (min)	Temperature (^oC)	Coating Thickness (µm)	Change of Mass (g)	Corrosion Rate (mm/y)
1	0.3	10	45	20	0.91	25.78	0.0350
2	0.3	12	60	30	1.24	32.64	0.0680
3	0.3	14	75	40	0.97	40.29	0.0470
4	0.3	16	90	50	1.45	33.27	0.2800
5	0.5	10	60	40	1.37	29.65	0.0430
6	0.5	12	45	50	1.26	31.48	0.0940
7	0.5	14	90	20	0.86	30.89	0.0089
8	0.5	16	75	30	1.02	39.24	0.0750
9	0.7	10	75	50	1.56	29.98	0.1030
10	0.7	12	90	40	1.42	41.23	0.0280
11	0.7	14	45	30	1.51	37.85	0.0610
12	0.7	16	60	20	0.99	28.67	0.0097
13	0.9	10	90	30	0.82	41.26	0.0190
14	0.9	12	75	20	1.38	35.37	0.0420
15	0.9	14	60	50	1.64	36.81	0.0640
16	0.9	16	45	40	1.19	34.69	0.0346

Table 4. Output summary of Electroplating process

The Table 4 presented the entire output summary of the electroplating process. There are three response values are to be considered for this experiment as Coating thickness (µm), Change of mass (g) and Corrosion rate (mm/y). The maximum coating thickness 1.64 mm was obtained by using of 0.9 amps/ dm^2 of current density, 14 g/L of concentration of Zinc, 60 min of coating time and 50 ^{0} C of temperature. Next the maximum change of mass 41.26 g was obtained by the influence of 0.9 amps/ dm^2 of current density, 10 g/L concentration of Zinc, 90 min of coating time and 30 ^{0} C temperature. Minimum corrosion rate was recorded as 0.0097 mm/yr and the parameters influenced were 0.7amps/ dm^2 of current density, 16 g/L of concentration of Zinc, 60 min of coating time and 20 ^{0} C of temperature.

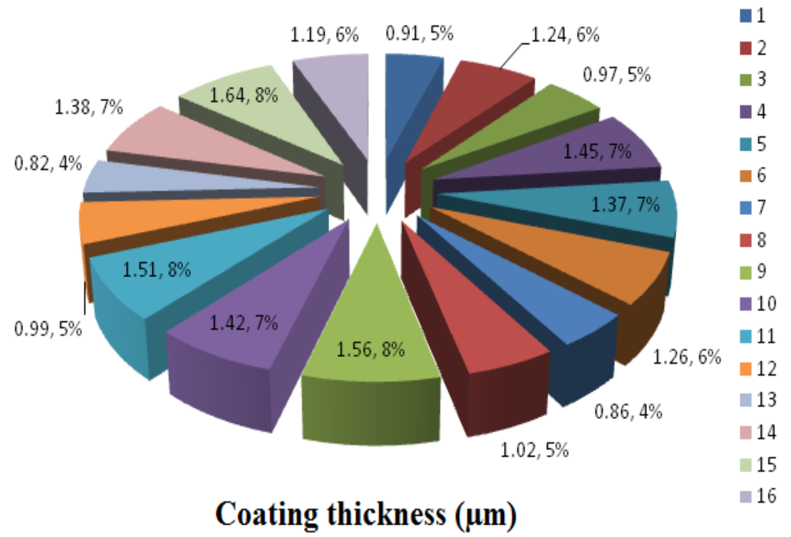

Figure 2. 3D Pie Chart for Coating Thickness in Electroplating

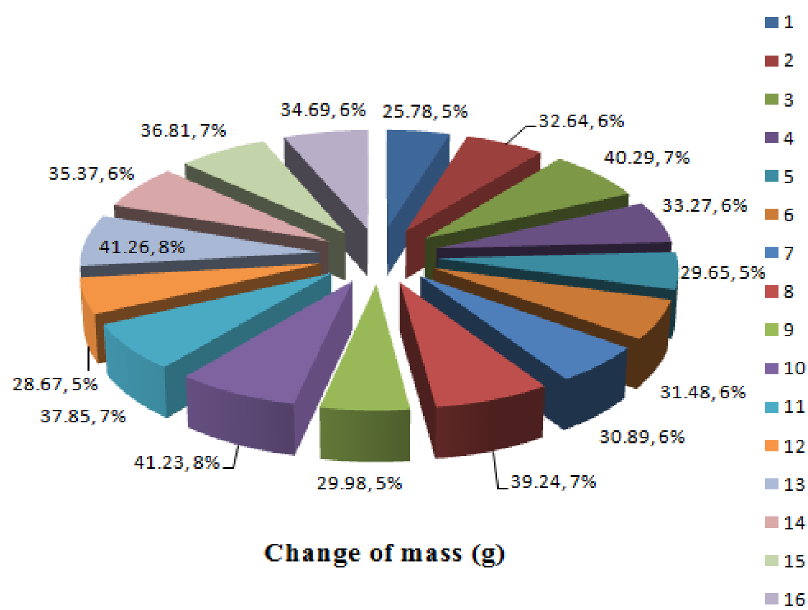

Figure 3. 3D Pie Chart for Change of Mass in Electroplating

Figure 2 clearly shows that the 3D Pie chart for coating thickness in electroplating, more than 1.5 µm of coating thickness reflected in terms of 8 %. The experimental trail number fifteenth proved the maximum of coating thickness such as 1.64 mm was obtained. Figure 3 illustrated that the 3D Pie chart for change of mass in electroplating, in this analysis more than 41 g of change of mass are reflected in 8 %. Maximum change of mass was obtained as 41.26 g by thirteenth experimental trial.

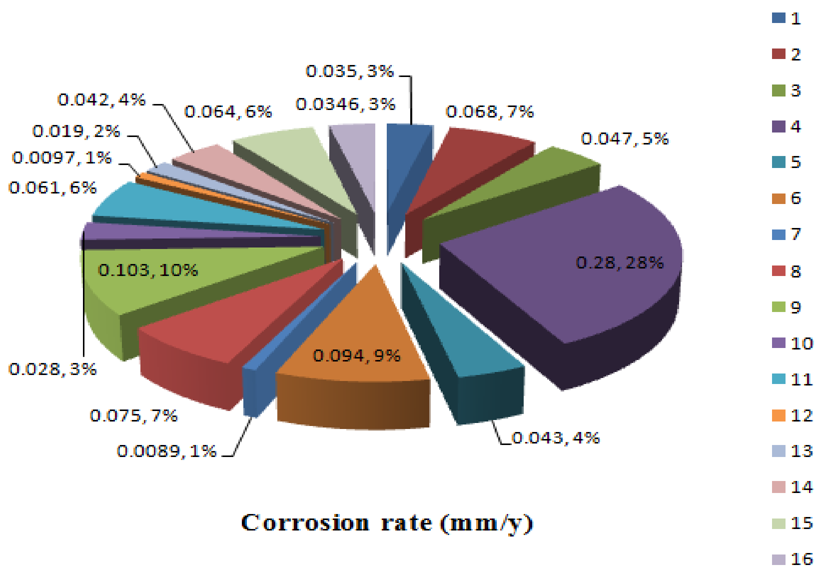

Figure 4. 3D Pie Chart for Corrosion Rate in Electroplating

In Figure 4. presented the 3D Pie chart for corrosion rate in electroplating, for this study less than 0.008 mm/yr of corrosion rate was reflected in terms of 1 %. Minimum corrosion rate was recorded as 0.0097 mm/yr by 12thexperimental trial.

Table 5 Comparison of Experimented and Predicted Values of Electroplating Process

Trial No.	Coating Thickness (µm)		Change of Mass (g)		Corrosion Rate (mm/y)	
	Experimented	Predicted	Experimented	Predicted	Experimented	Predicted
1	0.81	0.89	23.78	24.33	0.0350	0.0477
2	1.24	1.25	32.64	34.91	0.0680	0.0776
3	0.97	1.18	39.29	39.18	0.0470	0.0678
4	1.19	1.25	33.27	33.55	0.2200	0.2367
5	1.05	1.17	29.65	29.93	0.0001	0.0002
6	1.26	1.47	30.02	30.37	0.0940	0.1148
7	0.86	0.87	30.89	33.16	0.0089	0.0185
8	0.89	1.00	36.24	37.79	0.0750	0.0877
9	1.56	1.57	29.98	32.25	0.1030	0.1126
10	1.32	1.40	38.23	39.78	0.0280	0.0407
11	1.28	1.31	37.85	38.13	0.0010	0.0177
12	0.99	1.20	26.67	27.56	0.0097	0.0305
13	0.82	1.03	39.89	40.15	0.0190	0.0398
14	1.13	1.18	35.37	35.65	0.0008	0.0012
15	1.57	1.62	34.81	35.36	0.0640	0.0767
16	1.19	1.20	34.69	36.96	0.0346	0.0442

In the Table 5 tabulated the comparison of experimented and predicted values of electroplating process effectively. Three output response values of Coating thickness (μm), Change of mass (g) and Corrosion rate (mm/y) recorded through experimental work as well as the predicted values are analyzed through DOE mode. From these comparisons all the experimental values are within the limits of predicted values.

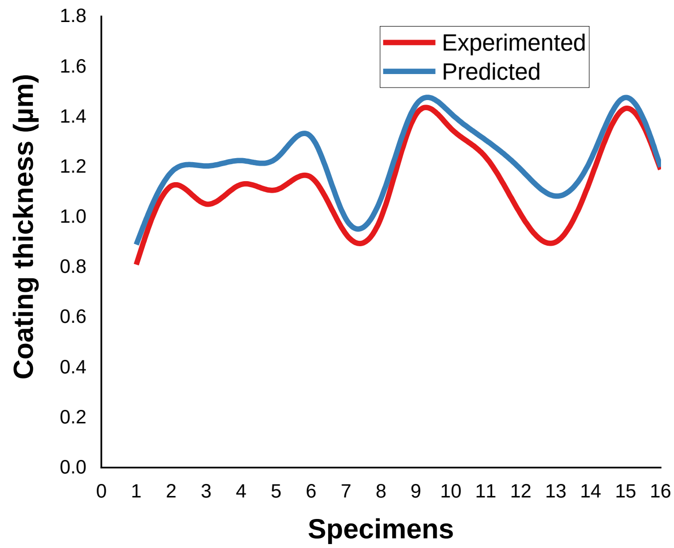

Figure 5. Number of Specimens and Coating Thickness Graph

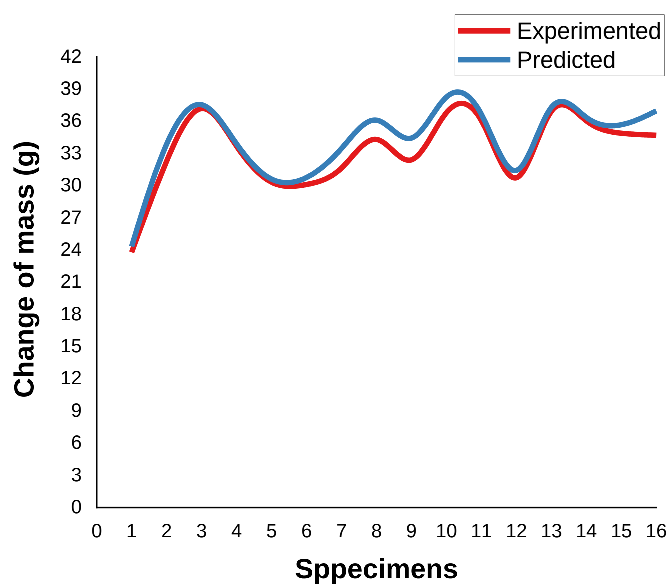

Figure 6. Number of Specimens and Change of Mass Graph

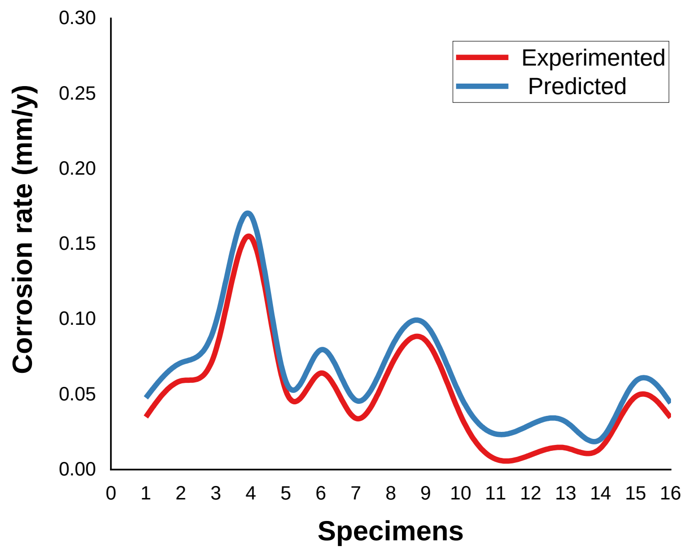

Figure 7. Number of Specimens and Corrosion Rate Graph

In the Figure 5 illustrates that the number of specimens and coating thickness, Figure 6 illustrates number of specimens and change of mass and Figure 7presented the number of specimens and corrosion rate. All three graphs evidently registered that the experimental values were within the limit of predicted values.

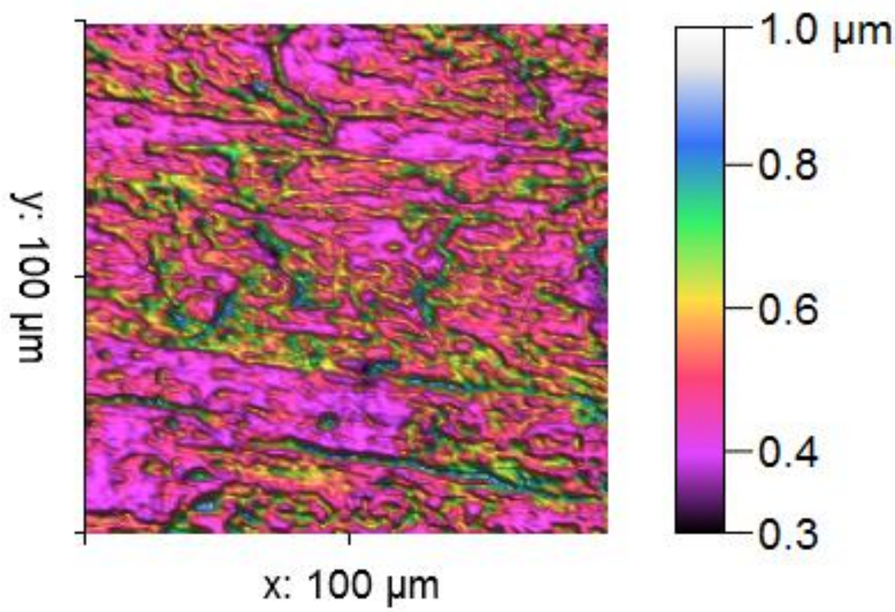

Figure 8. 2D Profilometry Images of Corrosion Rate of the Material

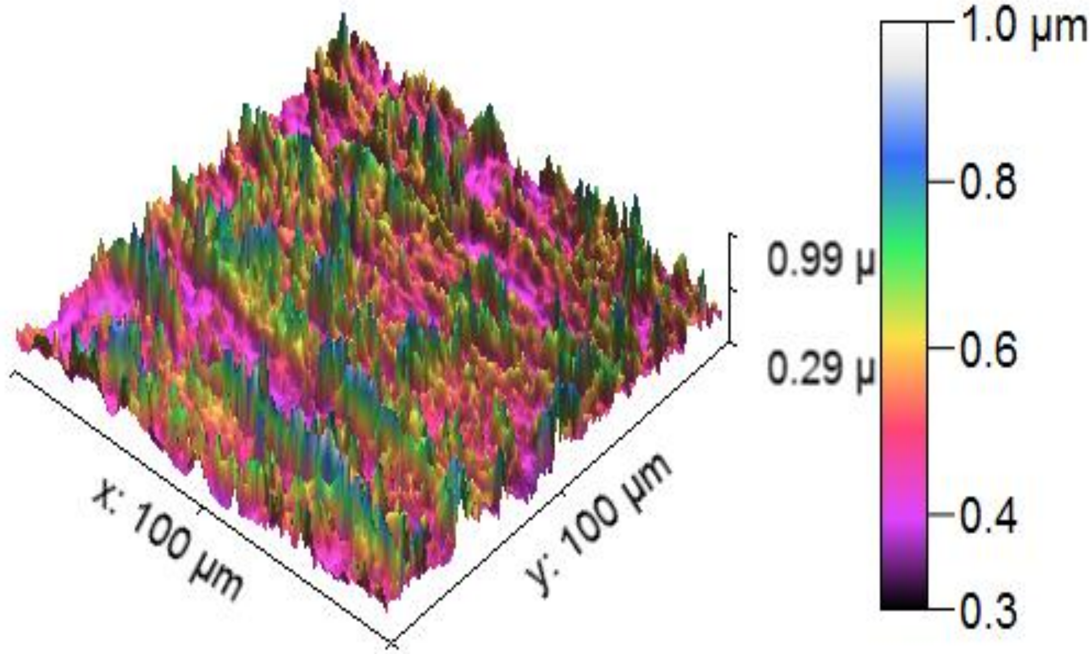

Figure 8. 3D Profilometry Images of Corrosion Rate of the Material

The Figure 8 & 9 visibly shows that the 2D and 3D profilometry images of corrosion rate of the material. The pink colour revealed that the maximum corrosion rate obtained of the material, the bluish colour denoted that the minimum corrosion rate.

4. Conclusion

The electroplating of mild steel coupling was successfully conducted and the output values of Coating thickness (µm), Change of mass (g) and Corrosion rate (mm/y) were checked with predicted value. The result of this work was demonstrated as follows:

- From the electroplating analysis the maximum coating thickness 1.64 mm was found by applying of 0.9 amps/ dm^2 of current density, 14 g/L of concentration of Zinc, 60 min of coating time and 50 ^{0} C of temperature. Further the maximum change of mass 41.26 g was evaluated by the influence of 0.9 amps/ dm^2 of current density, 10 g/L concentration of Zinc, 90 min of coating time and 30 ^{0} C temperatures.
- Minimum corrosion rate was found to be as 0.0097 mm/yr and the parameters influenced were 0.7 amps/ dm^2 of current density, 16 g/L of concentration of Zinc, 60 min of coating time and 20 ^{0} C of temperature.
- Among sixteen experimental trails, the fifteenth number proved the maximum of coating thickness such as 1.64 mm was obtained. Maximum change of mass was recorded as 41.26 g by thirteenth experimental trial. For corrosion study minimum corrosion rate was recorded as 0.0097 mm/yr by twelth experimental trial.
- All three output response values of Coating thickness (µm), Change of mass (g) and Corrosion rate (mm/y) were recorded by experimental work as well as the DOE mode. From these comparisons all the experimental values were within the limits of predicted values.

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