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A Novel NDT Method for Measuring Thickness of Brush-Electroplated Nickel Coating on Ferrous Metal Sueface

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Abstract

Brush-electroplated nickel coating has been widely applied to repair and remanufacture ferrous metal component. Generally, the nickel coating has thickness from 0.05 mm to 0.2 mm, and it is also ferromagnetic like iorn metals. Therefore, the traditional supersonic thickness tester and eddy current thickness tester are not competent to measure the nickel coating thickness on iron or steel metal surface, and the brush-electropalted nickel coatings are still lack of NDT method to measure its thickness. In this paper, a novel NDT method for the brush-electroplated nickel coating thickness measuring was investigated on eddy current mechanism. A series of brush-electroplated nickel coatings with various thickness were prepared on SUS1045 steel, whose thickness was confirmed on cross-section with SEM or optical microscope. Then Eddy signals of the coatings was tested, and a fitted relationship between the eddy signal phase and the thickness was found for the nickel coatings. Based on this results, a novel NDT method to measure the nickel coating thickness was set up, which could give precise resuts and be operated simply. Therefore, the method shows wide application in engineering.

Key words：eddy current, brush-electroplated nickel coating, coating thickness, NDT

1. Introduction

Brush-electroplating as well as plating nickel coating has been widely used to surface - treat or repair metal components [1]. In order to guarantee performance and dimension of the coated surface, it is necessary to nondestructively measure the coating thickness.

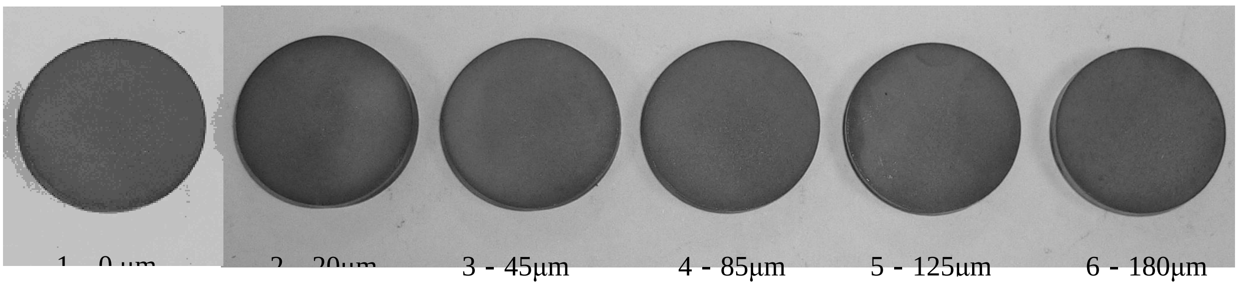
Various methods based on megnetic, supersonic, eddy current, X-ray spectrum or β-ray scattering have been employed to measure the plated coating thickness in some cases [2-5]. Among the methods, magnetic and eddy-current measures are most popular and have gain rapid development in recent years. However, as for the nickel coating on iron or steel, the thickness is generally from 0.05 mm to 0.2 mm, and it is also ferromagnetic like iorn metals. The traditional supersonic thickness tester and eddy current thickness tester are not competent to measure the nickel coating thickness. Actually, as for the brush-electropalted nickel coatings on iron and steel, it is still lack of NDT method to measure its thickness because both the coating and substrate are ferromagetic.

However, there exists difference on electromagnetic characters between the coating and substrate. Because of their electromagnetic difference, the eddy-current information of the coating can be related to its thickness. In this paper, a novel NDT method of the brush-electroplated nickel coating thickness measurement was investigated on eddy-current mechanism.

2. Experimentals

An EEC-39RFT+ Type of Eddy-current instrument and the probe typed as EPP1.J0.30.020914, invented by Eddysun (Xiamen) Electronic Co., LTD., China, were empolyed to test eddycurrent informations of the coatings with various thickness. The specimen of SUS1045 steel substrate with different thickness of nickel coating was prepared in China National Key Laboratory for Remanufacturing. The substrate specimen was SUS1045 steel with diameter and thickness 10 mm, the pane surface was abraded with 600 grit waterproof sand paper, the coatings bursh-electroplated coatings was fabricated with the following procedures. (1) Rinse the steel panel surface with acetone. (2) Electro-clean the surface while metal substrate as cathode, then rinsed with deionised water. (3) Electro-activate the surface with certain solutions, and rinsed with deionised water. (4) Brush-electroplated special nickel as interface layer. (5) Brush-electroplated the Ni coating with stylus as anode. The Ni coating brush plating was operated via NBP-100 unit in the following parameters: anode speed 8 $m \cdot min^{-1}$ to 12 $m \cdot min^{-1}$, DC voltage 12 V to 14 V, and current density 0.25 $amps \cdot cm^{-1}$ to 0.8 $amps \cdot cm^{-1}$.

The coating thickness was firstly determined by micrometer and also confirmed on cross-section with SEM or optical microscope before testing with eddy-current method. Fig.1 shows the specimens with various coating thickness, which were used to explore the relationship between coating thickness and the eddycurrent information. In Fig.1, as for the numbers under each sample, the former number is the sample serial number, and the latter labels the sample coating thickness at micron.



3 - 45μm 4 - 85μm 5 - 125μm 6 - 180μm

Fig.1 Specimens with various thickness brush-electroplated nickel coatings

The coating thickness testing researches includes the following three aspects. The first is to find out proper testing parameters to distinguish the various thickness in impedance plane, and observe effects of coating thickness on impedance curve. The second is to investigate effects of probe gap on impedance curve for each sample, and get impedance-section for probe gap. The third is to set up the fitted curve between sample coating thickness values and the relative impedance eigenvalues, and then measure standard sample coating thickness to determin the error.

3. Results and discussions

3.1 Effects of testing frequency

Test the various coating with gain 13.5 dB, change the frquency from 50KHz to 150KHz with step of 10KHz,and record the impedance curves at various frequency for each sample. Results showed that at a certain frequency, the scope of each curve reduced with increament of coating thickness. And also, the phase difference between each curves firstly increased with frequency increasing,and then the difference decreased. When the frequence is at about 100KHz, the phase difference between each curves is most obvious,as shown in Fig.2. Testing each sample many times at frequency 100KHz and get the even values of impedence curve amplifier and phase, the results were listed in Table 1.

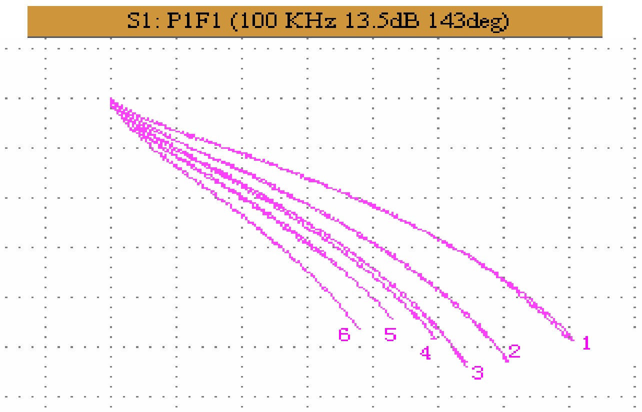


Fig.2 Impedance curves of the six samples at frequency 100KHz

Table 1 Impedance curve amplitude and phase value of each sample

Serial number	True thickness of coatings, μm	amplitude	phase value
1	0	250	31.2
2	20	248	33.6
3	45	226	36.3
4	85	193	36.5
5	125	178	38.1
6	180	167	44.2

3.2 Effects of probe gap

To investigate effects of probe gap on the impedance curve, a certain dielectric film was placed on each specimen surface, then move the probe on dielectric film surface, and the film thickness is the probe gap.

Fig.3 gives the impedance curves of the six samples with or without the dielectric film on sample surface. From the impedance curve observation in Fig.4, it can be found that the prob gap does not vary impedance curve shape and direction,but only shorten the original curve line. It shows that the probe gap only influences the impedance curve amplitude or scope, but not change the curve phase.

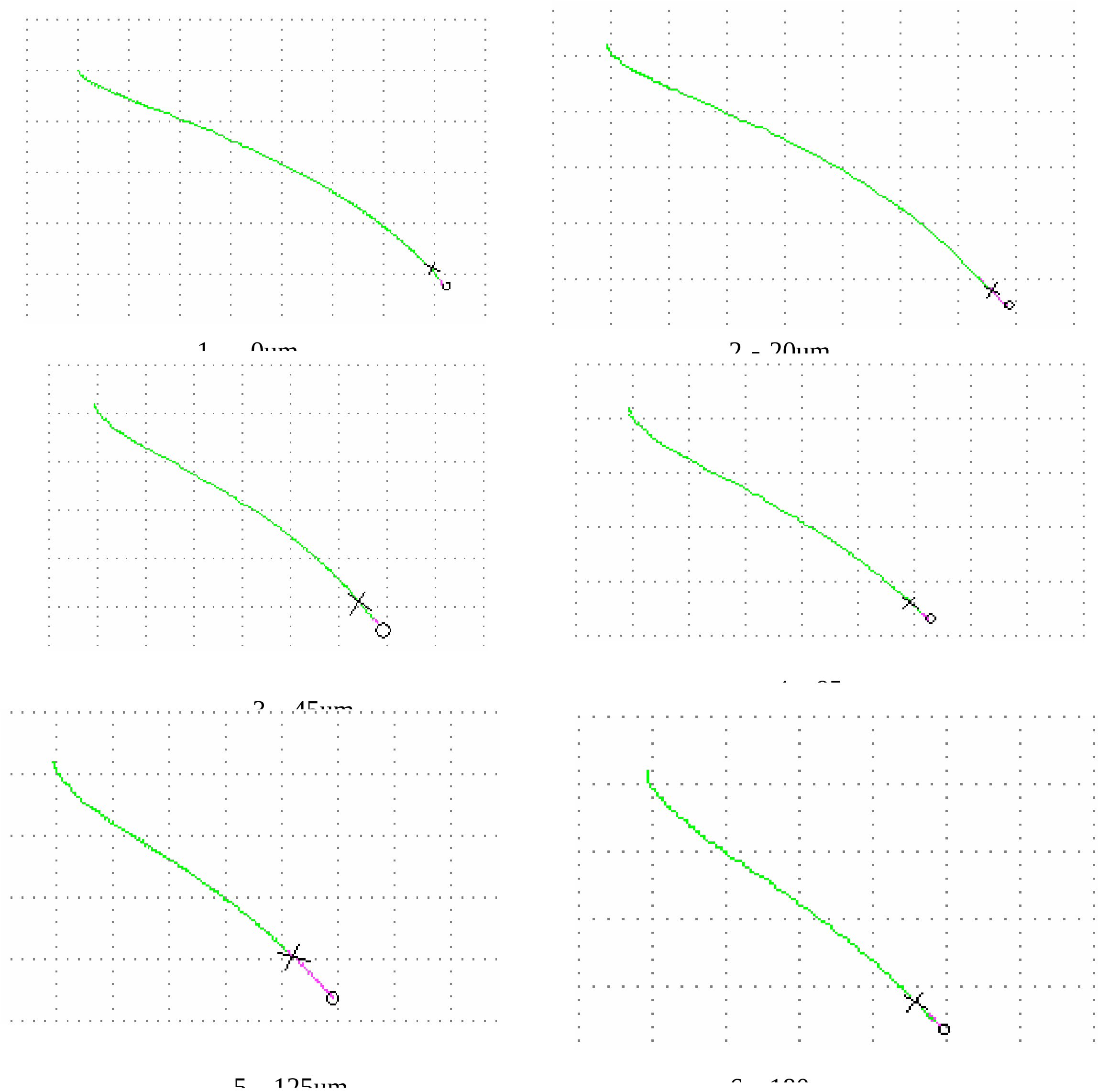


Fig.3 Impedance curves with and without the inserted film

Notes：○ *shows the impedance curve end-point without the inserted film while* × *shows*

3.3 Calibrated curve between coating thickness and phase

To nondestructively measure the brush-electroplated coating thickness in this study, it is necessary to set up the calibrated curve of coating thickness vs phase.

Supposed 180μm as 100% thickness, and the ratio of other coating thickness to 180μm is labeled as a number point (thickness ratio, phase), then a fitted curve of thickness vs phase can be setup, as shown in Fig.5, which acts as the calibrated curve to measure the coating thickness. Table 2 gives the measured coating thickness values and their errors. Table 2 results of the five samples show that there exist errors between measured values and nominal values. The errors are related to sample coating thickness uniformity, coating surface morphologies, accuracy of the coating thickness nominal value, and the fitting methods for the calibrated curve of coating thickness vs phase. And further study should be performed to reduce the errors. For example, in Fig.5, the curve has a sharp discontinuity as 40 Deg, it is necessary to seek better fitting methods for the calibrated curve.

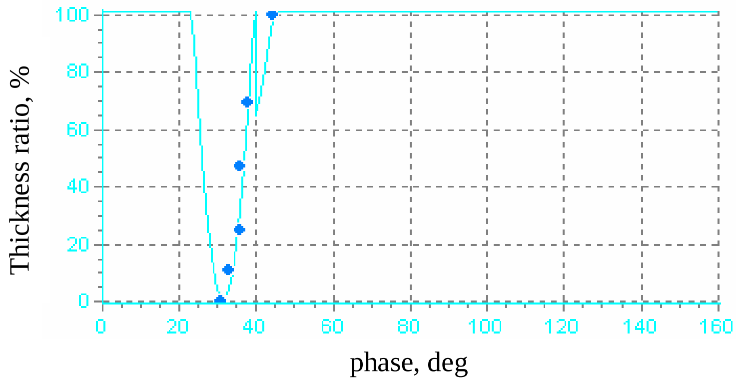


Fig.4 calibration curve of coating thickness vs phase

Table 2 the coating values measured by this study and their errors

No.	**Nominal value, μm**	**Measured value, μm**	**Relative error, %**
2	20	21.6	8
3	45	52.2	16
4	85	82.8	2.59
5	125	120.6	3.52
6	180	176.4	2

Eddycurrent technology has been successfully used to measuring plated coating thickness.It is to meausure thickness of non-metal coating on metal surface, which is based on the probe-gap effects of the eddycurrent. It is also to measure thickness of the nonferromagnetic coating on ferromagetic substrate surface, for example the titanium film on ferromagnetic steel SST4340.

In fact, when measuring thickness of the brush-electroplated nickel coating on ferrous metal surface, the probe circle impedance change is related to many factors, such as electrical conductivity, magnetic conductivity, material uniformity, thickness, infects, probe-gap, temperature and frequency[6]. In order to eddycurrent NDT measure the nickle coating thickness, the single relationship between thickness and impedance eigenvalue should be setup while other factors should be limited. Supposing the coating is uniform and free of infects, as for certain substrate and coating material, when the gap effects are limited, the relationship between coating thickness and impedance can be set up.

4. Conclusions

Eddycurrent method cannot afford to directly measure thickness of the brush-electroplated coating on iron substrate. This paper gives it a relative-measuring methods.

It found that the gap effect only influence the impedance amlitude. And calibrated fitting curve of coating thickness vs phase was set up and used to measure coating thickness. It can easily measure good thickness values of the coatings. Therefore, it is properous to applied to engineering.

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