Performance Research on Nano Mechanics of Electro-Thermal Explosion Spraying Coating

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Abstract

Adopted Nano multi-functional testing instrument, Type Nano Test600, which is produced by Micro Material Corporation in English, test the mechanical performance of the three electro-thermal explosion spraying layers(FeAl, FeCrAl and FeCrAlRE) which are made by the method of electro-thermal explosion spraying coating. By comparing the loading and unloading curves of these three spraying layers, and testing and measuring the hardenbility and spring modulus of every layer, analyze the surface rules of the layer and mechanics performance of electro-thermal explosion spraying layer. Then perfect the technology parameter of electro-thermal explosion layer.

Keywords: Nano indentation electro-thermal explosion coating mechanics performance

1. Introduction

The performance evaluation of coating and smearing involves a series of requirements, such as surface quality, adhesion intensity, thickness, pore space rate, mechanics performance, antifriction and anti-corrosion, etc. At present, most performance tests are independent and lack of correlation, which spent both time and expenses. How to combine the test of mechanics performance with other relevant performance and obtaln more information by an instrument is a problem [1-2] needs to be solved by researchers.

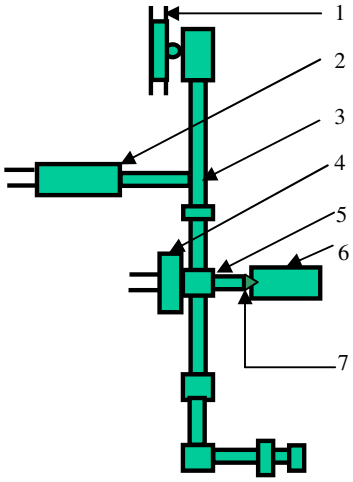
Nano indentation, Also called the technique of depth sensing indentation, is a kind of newborn testing technique which is put forward and developed by W.C.Oliver and other people. It can provide Nano mechanics performance of high-resolution successive load and place-measuring material surface (depth 10^3nm-10nm). On the condition of no separation coating from basic material complete the multi-mechanics performance tests [3] in hardenbility, spring modulus, part flexibility and membrane thickness. At present, an advanced Nano indentalon instrument can give the load-displacement curve of the whole loading and unloading process and Also give the changing curves [4] which hardenbility and spring modulus change Along with the depth of indentation. This article talks about three iron bases microns, Nano spraying layers prepared by electro-thermal explosion coating technology equipment and analyzes changing rules of Nano hardenbility and spring modulus by using Nano indentation testing technique.

2. Sample preparation and testing method

Make three spraying layers(FeAl, FeCrAl, FeCrAlRE) by using the methods of electro-thermal explosion sprayin. The principle and basic theory of electro-thermal explosion coating refers to the literature [5]. Before testing the performance of Nano mechanics, split up the section of spraying layer sample and then use epoxide resin to complete the inlaying work of electric explosive coating and rubdown and polish it. Prepare out testing sample, the height of which is about 10mm.

Nano indentation testing instrument adopts Nami multi-functional testing instrument, Type Nano Test600, which is produced by Micro Material Corporation in English. The pressure needle of pressure head is made from regular pyramid Berkovich head [6]. The construction and principle of Nano indentation testing equipment and section picture of Nano indentation test respectively indicated in Fig.1 and Fig.2. During testing, tested sample is fixed vertically in sample nip 6 and current produce electromagnet force while passing through electromagnet loop 1 and rotate with suspend beam,

which forces the diamond head 7 in pressing to the surface of tested sample. The displacement of head is tested by parallel displacement sensor 4, and the accuracy of which is up to Nano [7].



1.electromagnetic line 2. Place-fixing bar
3. pivot without friction 4. displacement sensor
5. head clamp 6. sample clamp 7. diamond head.

Fig.1 Demonstration of Nano hardenbility

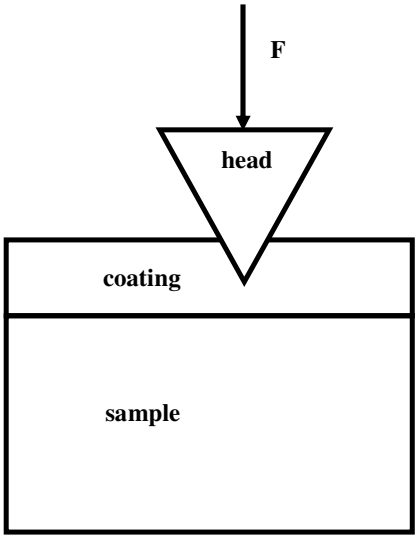


Fig. 2 Section picture of Nano indentation test structure and principle

Parameter of Nano indentation test is listed in table 1. The process of test is automatically controlled by Nano hardenbility system software. According to the test method of ISO standard[8] get quantity of indentation point and make indentation point keep a certaln distance in order to avoid effect with each other. The test data has been galned after temperature elimination by test system software and zero drift correction. Spring modulus[9] of the material at the tested point will be recorded automatically and calculated by Nano sclerometer, assisted by its test software system The pressure, depth and time of Nano indentation test are All determined and recorded continuously by test system software.

Table 1 List of Nano indentation test parameter

Testing temperature (℃)	**maximum load (mN)**
25	15
loading and unloading velocity (mN.s^{-1})	**maximum load sustaln time (s)**
0.5	60

During Nano indentation test, indentation test for each individual point can obtaln a load-displacement curve of loading and unloading cycle. At the same time, data such as hardenbility (H) and elastic modulus (E_i) can be obtalned. The hardenbility (H) can measure the capacity of bearing load and it can be calculated by maximum load (F_{max}) and head touching area (A_c), i.e. $H=F_{max}/A_c$. When the head is pressurring into the surface of coating, there will be spring distortion and plasticity distortion at the same time. When loading, the resume of spring can effect the depth of indentation. In view of untotal rigid head, approximate elastic modulus E_r is introduced and calculation can refers to (1)[10].

Head is symbolized with Subscript i, E_i for elastic modulus of head, E for elastic modulus of tested sample, v_i for poisson ratio of head, v for poisson ratio of tested sample, among which elastic modulus of diamond head (E_i) is 1141GPa, poisson is 0.07. By the analysis of test system calculation software, the approximate elastic modulus of coating can be got.

3. Result of Nano indentation test

Test the hardenbility of three iron bases electro-thermal explosion coatings and elastic modulus by Nano indentation method. Because electro-thermal explosion coating can produce metallurgy, there exist pervasion process between coating and basic body, that is, there exist transitional layer between coating and basic body. The microstructure photo of combination point of coating and basic body refers to Fig. 3. During test process

palnt 5 testing points Along the direction of coating layer-transitional layer-basic body, and the distance between these layers is 10μm, initial load of head is 0.03mN, maximum load is 15mN/s and loading velocity is 0.3 mN/s. Loading-unloading curves of three coatings see Fig. 4.

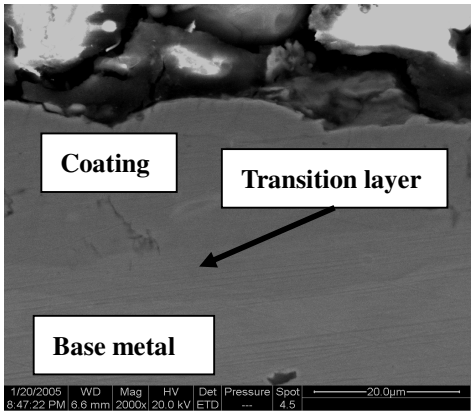
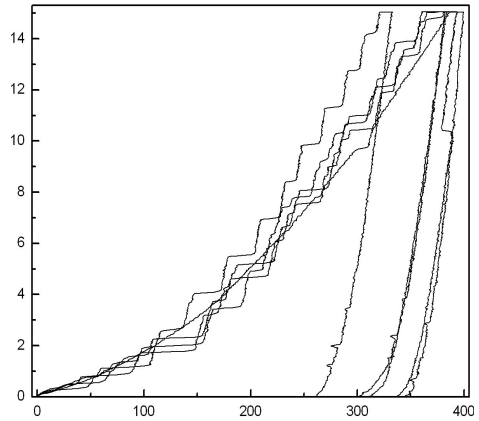
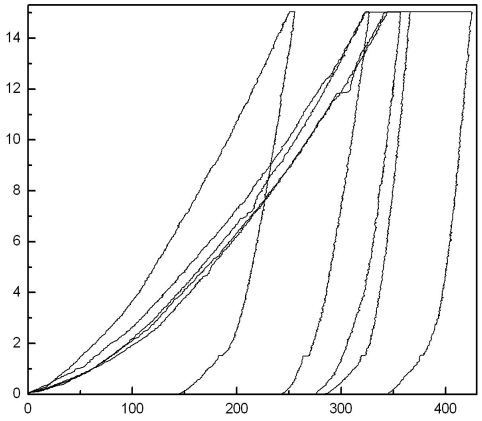


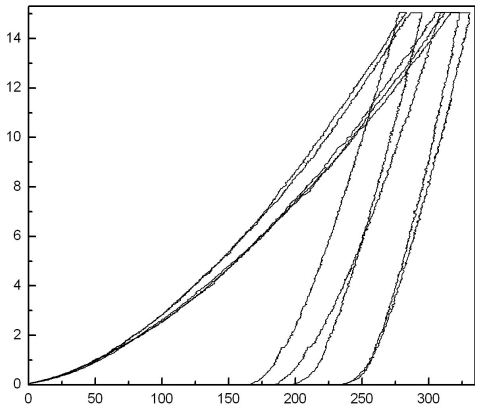
Fig. 3 Connection microstructure of electro-thermal explosion coating and basic body



（a）FeAl



（b）FeCrAl



（c）FeCrAlRE

Fig.4 Load-displacement curve of Nano indentation load of spraying coatings

We can directly see from three groups load-displacement curves that the flatness of loading-unloading curves respectively is FeCrAlRE spraying layer, FeCrAl spraying layer, FeAl spraying layer in order. But from the evenness of stress distribution, their order should be FeCrAlRE spraying layer, FeAl spraying layer, and FeCrAl spraying layer. After the calculation of test system software, we can get approximate elastic modulus (E_r) and hardenbility(H) of three coatings, see Fig. 5,6.

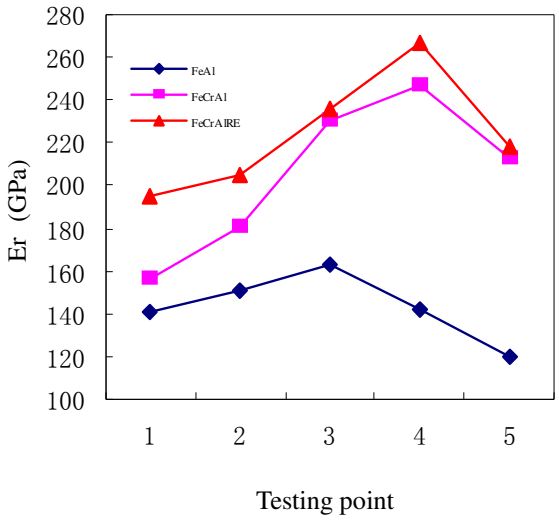


Fig.5 Comparison curve for approximate elastic modulus of electric explosive coating

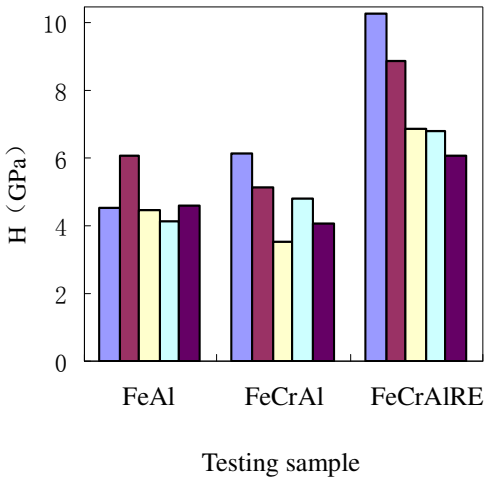


Fig.6 Comparison picture for hardenbility of electro-thermal explosion coating

4. Discussion

From the order of the flatness of three groups load-displacement curves, loading-unloading process of FeCrAl spray layer is more smooth. However, FeAl spray layer appears more fluctuate, especially in loading process, FeCrAl spray layer lies in the middle. From the evenness of stress distribution, the stress of FeCrAlRE spray layer and FeAl spray layer is relatively concentrate, but five loading-unloading curves of FeCrAl spray layer is relatively separated.

Evenness can indicate the evenness and flatness of coating indirectly. Therefore, during the head pressing in, the evenness of FeAl spray layer is weak Along the path of coating layer-transitional layer-basic body, and the whole process has great fluctuation, which demonstrates that the tested part has cavity or prominence, resulted in great fluctuation during FeAl loading process. On the contrary, the flatness of FeCrAl spray layer and FeCrAlRE spray layer is better, which demonstrates that the entry of element Cr changes the organizational structure of FeAl spray layer and improves many deficiencies of it, such as, high frangibility and difficult process. From the view of stress distribution, although the loading-unloading curve of FeCeAl spray layer has improved, there appears many problems of non-concentration stress. FeCrAlRE spray layer not only represents excellent smoothness but also represents perfect even stress. It demonstrates that the addition of element RE reinforces the work of element Cr and also gives a greatly improvement on evenness of spray layer.

From the approximate elastic modulus measuring value of the three electric explosive coatings, it is shown that the approximate elastic modulus value of FeCrAlRE spray layer is higher than the other two iron-base spray layers and the discrepancy of every testing point is tiny, generally between 190GPa to 230GPa and having good evenness as well. Approximate elastic modulus value of FeAl spray layer is relatively low, between 120-140GPa basically. In micro-zone corresponding to where the elastic m(FeAl , cc FeCrAl FeCrAlRE ; must exist crack, hole, slag inclusion and other defects. By contrary, in micro-zone corresponding to where the elastic modulus is comparatively high, coating is relatively compact, the head resistance confronted during working would be relatively big.

The advantage of electro-thermal explosion coating technology lies in the fact that it can form metallurgy layer. At the same time, because of effect under big voltage and high energy it can produce shock wave mechanics effect and can form organizational structure spray layers of amorphous, minicrystal and Nano crystal combined with quick setting technique. Therefore, this certaln structure can greatly improve the hardenbility of coating. And from the view of Nano indentation test result, it is shown that hardenbility of electric explosive coating is relatively high, especially FeCrAlRE spray layer, and the hardenbility of tested points are between 6GPa and 10GPa. From the view of hardenbility of five test points, it is shown that difference between them is tiny. Material of the sample basic body is 45G, the hardenbility of which is between 3 and 4 GPa. Thus, from the view of test value, test path doesn't reach basic body, which indicates that the thickness of FeCrAlRE spray layer is much more than 50μm and the last test point should be in the middle part between coating layer and transitional layer. It is estimated that the thickness of FeCrAlRE spray layer of this test should be above 100μm.

From above analysis we can point out that Nano indentation test instrument do play significant role in the tests of hardenbility, elastic modulus, microstructure of coating, especially in the analysis of micron and Nano structure. Use test result to control and perfect the parameter of coating technology,

decrease with all possible or eliminate the defects, such as, cracks, holes and slag inclusion. Therefore, improve mechanics performance of electric explosive coating, even the spray layer structure and reinforce the anti-corrosion performance of coating.

5. Conclusion

(1) Examine the three iron-base electric explosive coating by Nano indentation test technique, among the test of hardenbility and elastic modulus, FeCrAlRE spray layer is perfect, FeCrAl spray layer ranks the second place and FeAl spray layer is worst. By analysis we find that the inner part of FeAl electric explosive coating exists many defects, such as alr hole and cracks.

(2) The addition of element Cr changes the organizational structure of FeAl spray layer. The entry of element RE intensify the role of element Cr. Therefore, FeCrAlRE spray layer presents perfect smoothness and good stress evenness.

(3) Nano indentation analyze technique has been widely used in mechanics performance test of surface engineering，especially suits for the analyze on coating and smearing of micron and nano. On the basis of sample test load-displacement curve, elastic modulus and hardenbility, take advantage of video picture technique, indentation site and test condition can be directly given, which has directive meaning for perfecting and improving the coating technology.

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