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Automatic brush-plating technology for component remanufacturing①

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Abstract: An automatic brush-plating system was developed for component remanufacturing. With this system, Ni/nano-alumina composite coatings from an electrolyte containing 20 g/L nano-alumina particles were prepared. Microstructure, surface morphology, microhardness and wear resistance of automatically plated coatings and manually plated coatings were investigated comparatively. The results show that the automatically plated coatings are relatively dense and uniform and have lower friction coefficient of 0.089 under lubricant condition, when compared with manually plated coatings with friction coefficient of 0.14.

Key words: component remanufacturing; brush-plating; automation; composite coatings
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1 INTRODUCTION

In recent years "sustainable development" has become a worldwide issue. In order to reduce raw material consumption, a number of strategies are applied. Ayres et al[1] suggested that remanufacturing is one approach to deal with the used durable goods after the end of their useful lives. Remanufacturing has been defined as: "…an industrial process in which worn-out products are restored to like-new condition. Through a series of industrial processes in a factory environment, a discarded product is completely disassembled. Useable parts are cleaned, refurbished, and put into inventory. Then the new product is reassembled from the old and, where necessary, new parts to produce a fully equivalent—and sometimes superior—in performance and expected lifetime to the original new product"[2]. A number of products, including cartridges, automobile parts, computers and tires can be remanufactured[3-8]. Remanufacturing can result in significant energy, material and labor savings and is also profitable.

Wear is one of the three most popular causes for the failure of materials and components or products as their surfaces are exposed to environmental influences. Wear protection measures relate directly to the material's surface layer, which is the reason for developing coatings. Brush plating is an electroplating process to provide accurately applied deposits and coatings. Due to its portability and flexibility, brush plating has found wide applications in engineering, especially repairing the worn-out component. However, conventional brush plating is not suitable for large scale remanufacturing of components due to its disadvantages associated with the human nature. It is necessary to improve the automation level of conventional brush plating when aiming at component remanufacturing.

In the present work, Ni/nano-alumina composite coatings were prepared with a newly developed automatic brush-plating system. The microstructure, surface morphology, microhardness and wear resistance of the coatings were investigated.

2 AUTOMATIC BRUSH-PLATING SYSTEM

Brush plating, in its simplest form, resembles a painting operation. There are two major problems with conventional brush plating as follows.

2.1 High labour intensity and low labour productivity

In general, brush plating procedure includes pre-cleaning, electro-cleaning, electro-etching, activating, pre-plating and plating. Each step has specified solution and corresponding plating tool. During each step, the operator soaks the plating tool in a solution and then brushes it against the surface of the part that is to be finished. This solution-dipping operation leads the plating process to

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be carried out discontinuously. When a step is over the operator adjusts the voltage to zero and draws the lead of the power pack out of the hole of the plating tool and then changes another plating tool. This step-changing operation also makes the plating process discontinuously. Although the brush-plated deposits are applied at a rate faster than tank plating, for a large or medium component, the plating process may continue for more than 1 h, which is a challenge for the operator's body and mind.

2.2 Unstable quality of brushed deposits

There are many factors affecting the quality of brushed deposits. Firstly, the solution is provided by soaking or dipping, so the solution concentration decreases during one-dipping plating. Secondly, the solution is provided discontinuously during each step and the whole plating process. The discontinuous plating results in uneven laminar structure of coatings, which significantly affects the coating performance. Thirdly, transformation from one step to the other step interrupts the brush plating process and occupies some time. Fourthly, the movement and the contact pressure between the plating tool and the parts to be finished are dependent on the operator. The combination of these factors significantly makes the quality of brush plated deposits unstable. Furthermore, especially for the last step, a large amount of heat generates during plating process, which will lead the solution and plating tool to overheat. So, more than two plating tools are prepared and used alternately when one plating tool is overheating. This also breaks off the brush plating process.

From aforementioned analysis of conventional brush plating, we can know that the key to the problem is to realize precise control of plating process and fully eliminate disadvantages resulted from the operator. Therefore, we developed an automatic brush plating system, which includes plating machine tool, specially designed plating tool and solution-providing subsystem, power packs, and computer and has characteristics as follows:

1) automatic control of the movement between the plating tool and the part;

2) automatic adjustment on the contact pressure between the plating tool and the part;

3) automatic provision of solution and quick change from one step to the other step within 5 s;

4) automatic temperature control during plating process;

5) on-line control of parameters such as voltage, solution volume flux, relative velocity etc.

3 EXPERIMENTAL

In recent years nano-sized particles are increasingly attracting considerable scientific and technological interest by their unique mechanical and tribological properties. The incorporation of nano-sized particles into metal matrix modifies the electro-crystallization process of metal matrixes and thus, influences their mechanical and tribological properties[9-13]. Du et al[14, 15] and Wang et al[16] reported that Ni/nano-alumina composite coatings prepared by manual brush plating exhibit better properties than those without addition of nano-alumina. In our work, Ni/nano-alumina composite coatings were prepared with this automatic brush-plating system. The nano-alumina particles, with an average size of 30 nm, were added to the electrolyte, which has basic compositions as follows: 254 g/L nickel sulfate, 56 g/L ammonium citrate, 23 g/L ammonium acetate, 0.1 g/L oxalate, 105 g/L aqua ammonia, 20 g/L nano-alumina, and a special organic additive. Prior to the codeposition, the alumina particles were dispersed in the bath for 30 min. Composite coatings were plated on 45 steel cylinder parts with outer diameter of 48 mm. The ambient temperature is 20 ℃. The surface morphology and microstructure of the coatings were investigated using a Quant 200 scanning electron microscope (SEM). Nano-indentation experiments were performed on NanoTest 600 (Micro Materials, Ltd., Wrexham, U. K.) using a load of 15 mN.

Fig. 1 shows the surface morphology comparison between automatically plated coating and manually plated coating. It can be seen that the composite coating prepared by automatic brush-plating is relatively dense and uniform and has a smaller crystalline microstructure than that of the coating prepared by manual plating. It can also be seen that the surface morphology of coating prepared by automatic brush-plating becomes much smoother than that of the coating prepared by manual brush-plating. Fig. 2 shows the cross-sections of automatically plated coating and manually plated coating. The comparison results are in accordance with the SEM surface morphology (Fig. 1).

Fig. 3 shows the force—displacement curves for the automatically plated composite coating subjected to nano-indentation. Five points were tested. The distance between every two neighbor points is 10 μm. Test results show that these five points have nearly the same hardness value, which indicates that the properties of the coating are relatively even.

The wear tests were performed on a block-on-ring MM200 tribometer under lubricant condition and a load of 400 N. The evolution of coefficient of friction (COF) shows the same behavior for both the coatings (Fig. 4). During the running-in period, COF increases from a low value to a very high

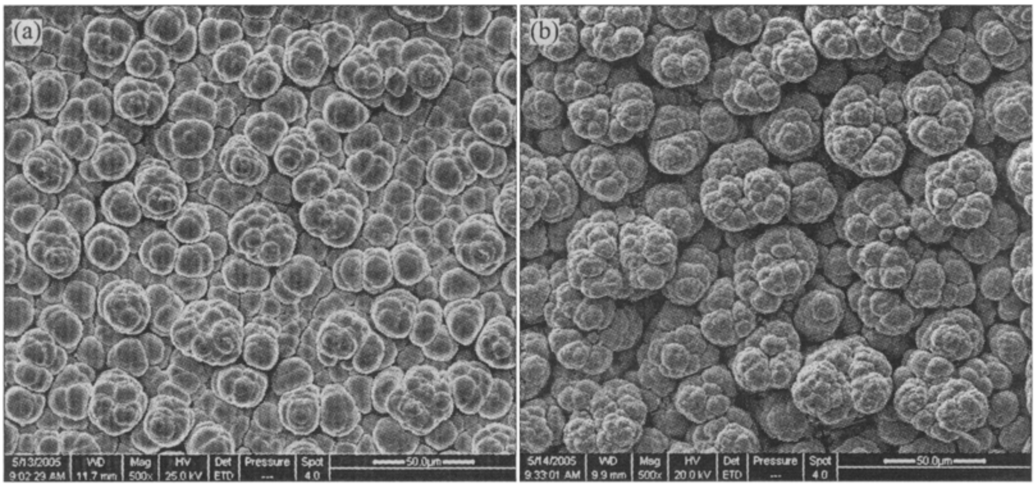

Fig. 1 SEM surface morphologies of automatically plated coating(a) and manually plated coating(b)

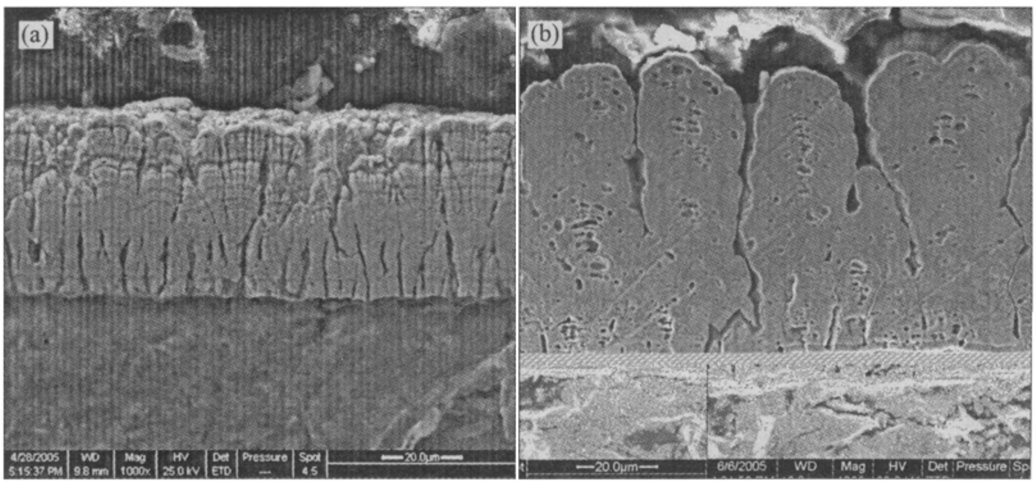

Fig. 2 SEM images of cross-section of automatically plated coating(a) and manually plated coating(b)

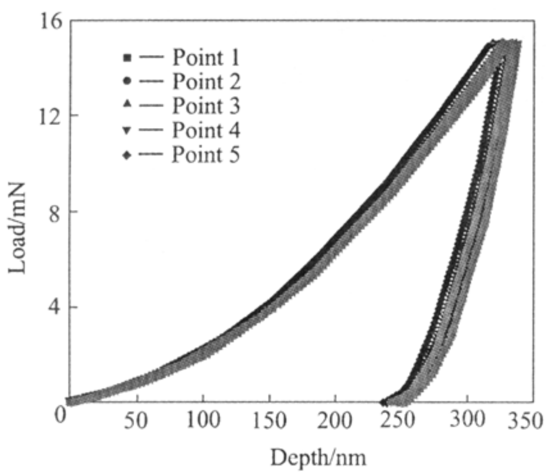

Fig. 3 Force—displacement curves of Ni/nano-alumina prepared by automatic brush-plating

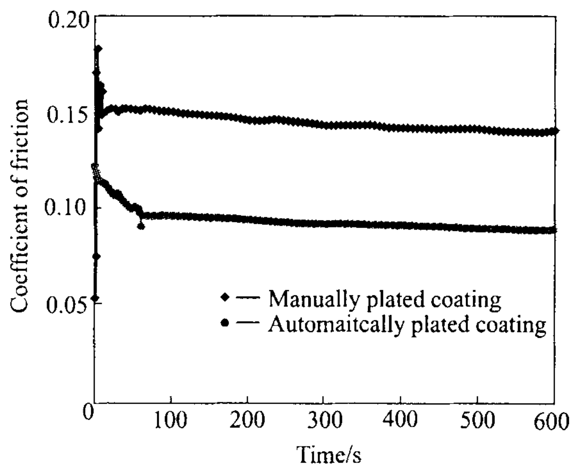

Fig. 4 Coefficient of friction vs time for automatically plated coating and manually plated coating

value, and thereafter, COF marginally decreases and attains a steady state value. Comparing the steady state COFs, manually plated coatings show a higher value of 0.14, whereas it is much lower in the case of automatically plated coatings.

4 CONCLUSIONS

Ni/nano-alumina composite coatings were produced with an automatic brush plating system. Investigation of surface morphology, microstructure, and microhardness shows that the automatically plated coatings are relatively dense and uniform. Under lubricant condition, the COF of automatically plated coatings (0.089) was lower than that of the manually plated coatings. We think this automatic brush plating system can be used for component remanufacturing.

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