# A Chromium/Graphite Electrodeposited Composite Coating for Unlubricated Sliding Wear

By D. Yang & C. Jiang

**A chromium/graphite electrodeposited composite coating (Cr-C ECC) is obtained by suspending particles of graphite in a conventional hexavalent chromium plating bath, followed by deposition in the normal manner. Under unlubricated sliding wear conditions, the tribological properties of the Cr-C ECC were studied. The test results show that compared with the chromium plating, the Cr-C ECC has good wear resistance and a lower coefficient of friction. It is also more favorable to the running-in of the friction coupling, and can obviously decrease the wear of mating parts.**

Electrodeposited composite coatings are new surface modification technologies that are being used increasingly with metals for industrial applications. They have been widely used to protect plastics, compression molds and casting molds, as well as pumps, spindles and other parts subject to friction.[1] These electrodeposited composite coatings are, however, mostly nickel- or cobalt-based.[2] Reports on chromium-based composite coatings obtained from hexavalent plating baths have been uncommon. It is well known that chromium coatings have good wear resistance. Chromium plating has been widely applied to mechanical parts to enhance their wear resistance.[3-5] Conventional chromium plating, however, is not always satisfactory under unlubricated sliding wear conditions; it can accelerate the wear of mating parts and extend the time of running-in of friction couplings. For instance, to increase the service life of a ring (a part used in a spinning machine) a chromium-plated ring had been used.[6] Although the service life of the ring was effectively increased, chromium-plated rings have not been widely accepted, because the wear rate of the traveler (a part mating with the ring) and the break ratio of the yarn are also increased. In view of the special friction coupling of the ring and the traveler, a new type of chromium/graphite electrodeposited composite coating (Cr-C ECC) was developed. By use of the Cr-C ECC, the surface of the ring was made to take a chromium coating containing particles of graphite. In this paper, the technique of the Cr-C ECC is introduced and the tribological properties of the Cr-C ECC ring and that of the chromium-plated ring were studied and compared.

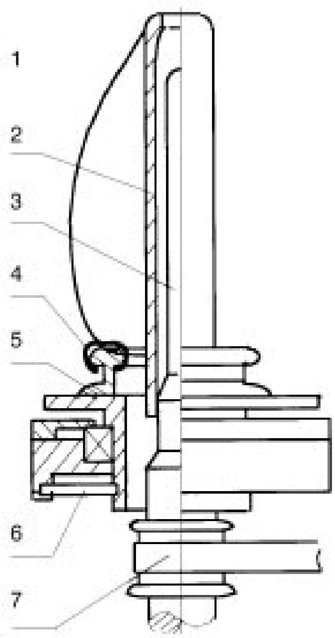


*Fig. 1—Schematic diagram of wear tester.*

## Plating Baths and Operating Conditions

A proper quantity of graphite particles and suitable additives were added to a conventional hexavalent chromium plating bath. The bath composition and operating conditions are given in Table 1. In the bath, the $CrO_3$:$SO_{-2}$ ratio must be about 100:1. Particles of graphite with diameter of 1 to 5 µm were used. The additive is a mixture containing rare earths. The Cr-C ECC containing 0.8 to 1.5 percent of graphite by weight can be obtained by using the data of Table 1.

## Surface Parameters

The surface parameters of the coatings were measured by surface profilometer. The results are given in Table 2, where it is shown that the surface roughness, Ra, of the Cr-C ECC coating is slightly lower than that of a Cr coating.

## Hardness

The hardness of a dispersion coating depends on the properties and numbers of particles embedded in the matrix.[1] Because particles of graphite are soft, hardness of the Cr-C ECC is lower than that of a Cr coating. The average Vickers

Table 1
**Plating Bath & Operating Conditions**

| Components | Cr | Cr-C |
|---|---|---|
| $CrO_3$, g/L | 250 | 180-250 |
| $SO_4^{-2}$, g/L | 2.5 | 1.8-2.5 |
| Graphite, g/L | | 20-50 |
| Additive, g/L | | 2-5 |
| Temp, °C | 50- | 35-50 |
| Current density, A/dm$^2$ | 40-50 | 25-35 |
| Time, hr | 1 | 1 |
| Anode-cathode ratio | 2:1 | 2:1 |
| Anode material | Pb-Sb alloy | Pb-Sb alloy |

Table 2
**Surface Parameters of Coatings**
**µm**

| Coating | Ra |
|---|---|
| Cr | 0.56 |
| Cr-C | 0.48 |

Table 3
**Vickers Hardness of Coatings**
**100 g, 15 sec**

| Coating | Average |
|---|---|
| Cr | 1000 |
| Cr-C | 850 |

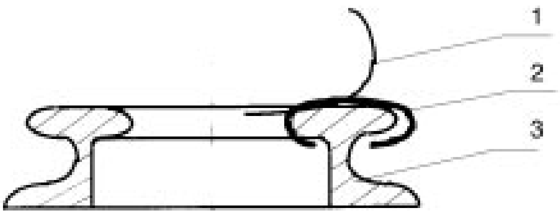


*Fig. 2—Cross section of ring mating with traveler.*

hardness of the two kinds of coatings are listed in Table 3, where it can be seen that the average of the Vickers hardness of Cr-C ECC is about 150 VHN lower than that of the Cr coating.

### Wear Testing

The wear tester is the Ring-Traveler wear tester introduced elsewhere.[7] Figure 1 is the schematic diagram of the tester. Figure 2 shows the sectional drawing of the ring mating with the traveler. It can be seen that the traveler is driven by yarn wound on the ring. Friction force is measured by a dynamic force sensor that transmits an electrical signal proportional to the force. This signal is magnified and transmitted to a recording oscilloscope. Conditions for wear testing are listed in Table 4.

### Ring Weight Loss

The weight loss from wear of the ring was determined on a balance with a sensitivity of 0.1 mg and was measured once/hr. The general test time for each kind of specimen is 6 hr. The resulting data is the average of four identical specimens. To obtain high accuracy of weight determination, each specimen tested was cleaned in petroleum ether and forced-air-dried immediately and weighed. The results of these measurements are listed in Table 5.

From Table 5, it is seen that the average weight losses from wear of the two kinds of coatings are approximately equal. It shows that the Cr-C ECC has good wear resistance, as does chromium plating. Moreover, in the first hour, the wear rate of the Cr-C ECC is higher than that of the chromium plating, which is favorable for running-in of a friction coupling.

### Friction Force

Under the test conditions above, the friction force of the two kinds of coatings was measured after running of the new traveler became stable (after about one min). A measurement was made once each hr. The results are given in Table 6. Data in the table are the averages of the amplitude of dynamic friction force. It shows that the average friction force of the chromium plating is 1.22 times as great as that of the Cr-C ECC.

### Traveler Service Life

The time to wear-out of the traveler is its service life. The service life is used to evaluate coatings influencing the wear resistance of the mating parts. The longer the service life, the lower the wear of the mating parts. The results are shown in Table 7, where it can be seen that the average service life of the traveler mating with the Cr-C ECC is 1.45 times as long as that with the chromium plating. It shows that Cr-C ECC can

Table 4
**Wear Test Conditions**

| Components | Requirement |
|---|---|
| Specimen | Ring |
| | Traveler (Ni-Co alloy deposit) |
| Motion | Traveler around ring |
| Rotation | 15,000 rpm |
| Sliding speed | 33 m/sec |
| Average load | 2.1 N |
| Lubrication | None |
| Wear evaluation | Ring: weight loss |
| | Traveler: time to wear-out |

Table 5
**Ring Wear Weight Loss**
**mg**

| Time, hr | Cr | Cr-C |
|---|---|---|
| 1 | 0.9 | 1.3 |
| 2 | 1.1 | 0.9 |
| 3 | 0.7 | 0.8 |
| 4 | 0.7 | 0.8 |
| 5 | 0.9 | 0.8 |
| 6 | 0.8 | 0.8 |
| Average | 0.85 | 0.91 |

Table 6
**Friction Force (N)**

| Time, hr | Cr | Cr-C |
|---|---|---|
| 1 | 0.59 | 0.59 |
| 2 | 0.72 | 0.69 |
| 3 | 0.72 | 0.64 |
| 4 | 0.79 | 0.55 |
| 5 | 0.74 | 0.59 |
| 6 | 0.73 | 0.64 |
| Average | 0.72 | 0.62 |

Table 7
**Service Life of Traveler**
**min**

| Time, hr | Mating with Cr | Mating with Cr-C |
|---|---|---|
| 1 | 14.0 | 28.0 |
| 2 | 19.8 | 27.5 |
| 3 | 18.8 | 23.5 |
| 4 | 17.0 | 22.5 |
| 5 | 15.1 | 23.4 |
| 6 | 15.4 | 20.2 |
| Average | 16.7 | 24.2 |

decrease the wear of the mating parts. Moreover, the service life of the first traveler mating with the Cr-C coating is twice as long as that with the Cr coating, which shows further that the Cr-C ECC is favorable to running-in of the friction coupling.

## Conclusions

This study has shown that the tribological properties of the Cr-C ECC have obviously been improved compared with those of chromium plating, although the content of the particles of graphite of the Cr-C ECC is less than 2 percent by weight. The wear test results show that the Cr-C ECC can not only decrease wear of the mating parts, but has good wear resistance like chromium plating. Moreover, compared with chromium plating, the Cr-C ECC has good friction behavior and is more favorable to running-in of the friction coupling under unlubricated sliding wear conditions.

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