한국표면공학회지
Journal of the Korean Institute of Surface Engineering
Vol. 30, No. 6, Dec. 1997
<연구논문>

AZ91D 상용 마그네슘합금에 코팅된 Cr_2O_3층의 기계적 및 내마모 특성에 미치는 플라즈마 용사조건의 효과

이수완, 박종문, 이명호*, 김진수*

선문대학교 재료공학과, *자동차 부품연구원

Effect of Plasma Spraying Parameter on Mechanical and Tribological Property of Cr_2O_3 Coating Layer on AZ91D Commercial Magnesium Alloy

S. W. Lee, J. M. Park, M. H. Rhee*, J. S. Kim*

Department of Materials Engineering, Sun Moon University
*Korea-Automotive Technology Institute

Abstract

The experimental study has been performed to deposit chromia powder on magnesium alloy for tribological and mechanical properties. The optimal condition was obtained by changing the spray condition such as working distance and gun power. As ceramics was coated onto the a light metal such as Mg according to the weight reduction of the car engine block, it could acquire that the engine efficiency due to the weight reduction and properties such as resistance to heat, as well as wear. Coating qualities are discussed with respect to hardness, tribologicalproperty, and microstructure. The tribological and mechanical properties are investigated by using the reciprocal configuration tribometer and microhardness tester. Wear mode is determined by observing the SEM morphology of wear track and cross section view of wear track.

1. INTRODUCTION

Plasma spray technology has been utilized by many coating manufacturers and is regarded as one of the most universal coating techniques. Plasma sprayed coatings are widely used in a large number of aircraft engine components, for such application as thermal barrier, abradable seal and wear applications.[1] Chrome-oxide coatings are among the category of coatings used for wear application to protect surfaces from severe wear environments, such as, abrasion, adhesion, fretting, and particle erosion. The combination of optimized plasma deposition parameters coupled with the unique properties of C_2O_3 material can produce extremely corrosion and wear resistant coatings. The work conditions to which technological equipment is submitted leads to the use of materials with specific characteristics, for example, good wear resistance to high temperature. The aim of this work is to observe the friction and wear behaviour of plasma C_2O_3 coatings, under the unlubricated sliding conditions against alumina ball. Plasma spray condition was varied as spray distance and gun power. The friction and wear volume of the different testing pairs were evaluated. Finally, the wear mode is discussed by analyzing the worn surface analysis.

2. EXPERIMENTAL PROCEDURE

The C_2O_3 ceramic coating which has a average size, −45±15㎛, irregular shape was plasma sprayed onto AZ91D Mg substrate. An average coating thickness is about 200㎛. And the substrates were grit blasted with alumina grit (80mesh) to increase adhesion of molten particle as well as to eliminate surface impurities. Also, the substrate was pre-heated at about 120℃ before spraying for the purpose of reducing thermal shock which was caused between hot molten particle and cooled substrate in contact. Then, the value of this study were varied by working distance and gun power to acquire optimal condition of the sprayed layer. Table 1 shows the projection parameters.

The tribometer used at room temperature was PLINT high frequency friction machine

Table 1. Plasma spraying parameters

Arc gas	Argon
Gas flow rate (l/min)	70/50
Spray rate (g/min)	35
Powder carrier gas	Hydrogen
Arc power	32.5, 35, 37.5
Spraying distance (cm)	5, 7, 9
Thickness (㎛)	≈ 200

which has ball-on-plate reciprocal type configuration. The alumina balls of 1/2" in diameter were used. The applied load was 10N. The sliding speed was 1Hz. And the sliding distance was 12.2㎜. The frictional coefficients were calculated as the ratio of the recorded friction force to the normal load. Wear volume was measured using a surface profilometer by multiplying the cross-sectional area and the sliding groove length. The microhardness testings were performed, using the ZWICK micro vickers hardness tester. The indentation load and holding time were 1kgf, 15 seconds, respectively. To reveal the wear mode of the coating layers, scanning electron microscopy was used to observe the coating surface and the worn track of the specimens after wear tests.

3. RESULTS AND DISCUSSION

Figure 1 shows the variation of hardness of coating layers and wear volume as a function of distance. The hardness has maximum value at the working distance of 70㎜ and also wear volume has minimum value at 70㎜. Figure 2 shows the variation of hardness and wear volume as a function of gun power at 70㎜. The spray parameters change the microstructures,

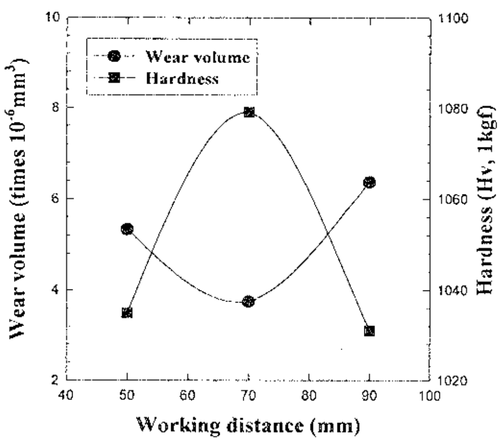


Fig. 1 Variation of the wear volume and hardness as a function of the working distance.

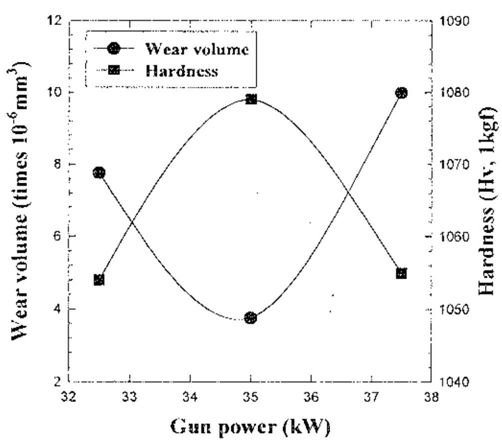


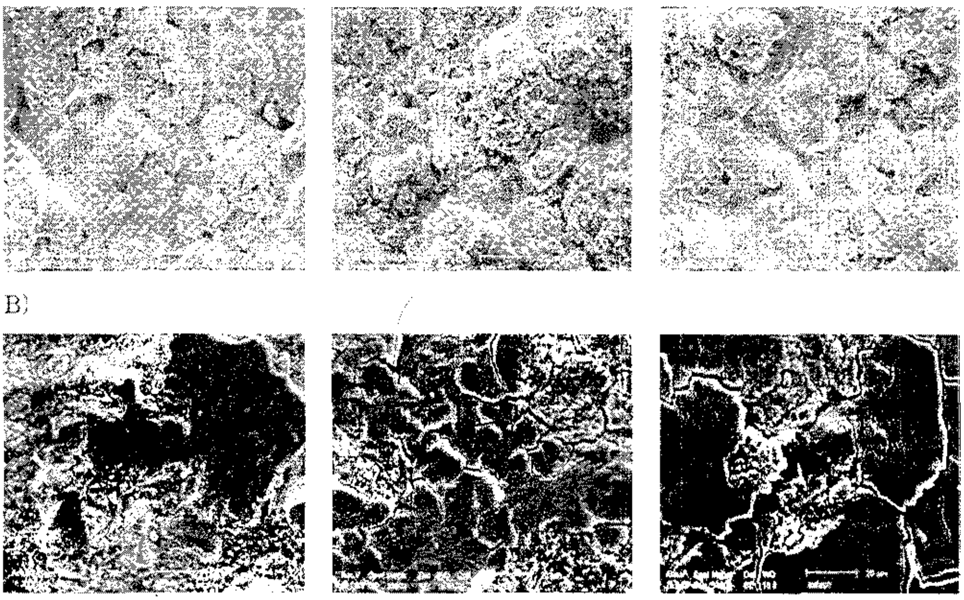
Fig. 2 Variation of the wear volume and hardness as a function of the gun power.

which vary the hardness and wear volume. The molten particles are heated by plasma flame and transported onto the cool substrate. This solidification phenomena cause variations in deposition temperature depending on plasma spray distance. When the spray distance is short, the molten particles can be overheated during colliding on the substrate[2-3]. Probably, hardness has low value and wear volume reveals high values also. When the spray distance is long such as above 70mm, the flying speed is dropped. When the particles are collided on the substrate, the thermal and physical energy is not sufficient and maybe forms pores. So, wear volume has very high value at the working distance of above 70mm.

These subject coincident with the micrographs of cross section and wear tracks. Figure 3 and 4 shows SEM image of before and after wear test at various working distance and gun power, respectively. Small debris particles are more likely to be entrapped within the wear tracks and to be agglomerated to form compact wear protective layers and are beneficial to the transition to mild wear.[4] Bowden and Tabor proposed that when the asperities of the sliding pairs contact, they undergo elastic and plastic deformation to accomodate the applied stresses thereby increases the real contact area[5]. Examination of the wear surface with SEM revealed that even in the unscuffed zones, significant pleatau regions were observed on all coatings, which indicates plastic deformation mode predominantly. Coating with lower porosity level and higher hardness value exhibited better scuffing resistance. Therefore, it may hypothesize that porosity can improve the fracture resistance when small debris fills into pores and play a role of solid lubricant. In Figure 3(a), as it was seen the after wear test, if gun power was low, physical energy is not sufficient so bond strength between ceramic layer and substrate was low. Therefore, it happened adhesion wear. But, as seen at Figure 3(c), if gun power was much high, molten particle was overheated so it appear to splash -splat onto coated surface. The fractured area

A)

B)



(a) (b) (c)

Fig. 3 SEM morphology of before (A) and after (B) wear test at various working distance ;
(a) 50mm (b) 70mm (c) 90mm

is highly larger, it has higher hardness and resistance to wear than that of 32.5kw with gun power. The above can be conformed in Figure 4. Figure 5. shows the comparison of SEM image of the polished cross-sections of the sprayed coatings micrographs as a function of the working distance as well as gun power. The microstructures consist of the curred lamella, pores, embedded solidified particles, referred to as the 'unmelt' for particle along splat boundaries. Another important issue addressed by these figures is that the wear debris particle size is an important factor in the wear testings.

Figure 6 and 7 reveal the comparison of the coefficients of friction of plasma spray coated layers at various working distance and gun power, respectively. In these figures, most of wear was happened mainly at intial state of wear by judging frictional traces.

4. CONCLUSION

To establish of weight reduction of automotive component, this study shows the properties of hardness and wear with the variation working distance and gun power after coating chromia onto magnesium alloy.

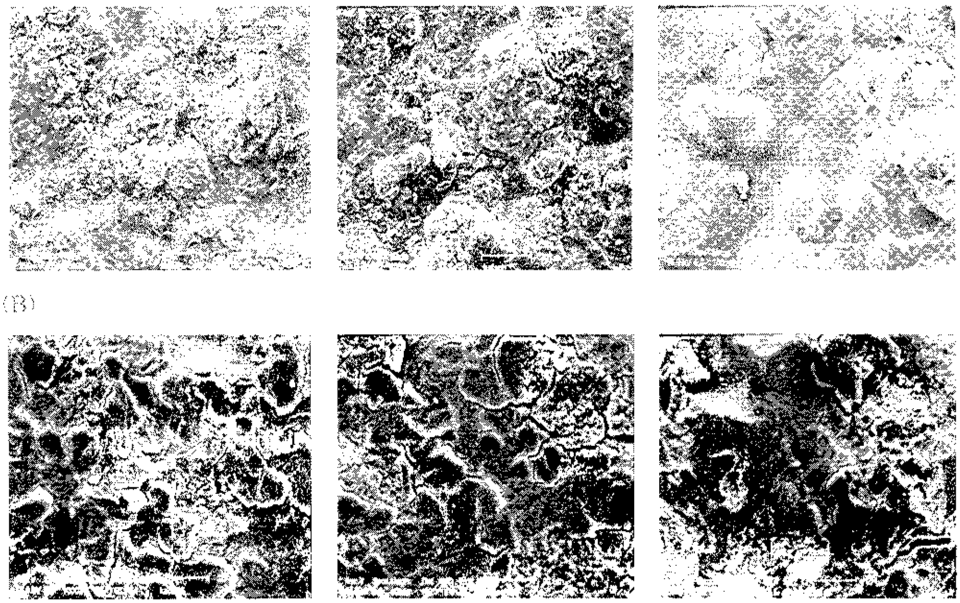
The main conclusions are made as follows.

1) When the working distance and gun power were 7cm and 35kw, respectively, surface hardness of chromia coated layer was superior to that of other coating conditions.

2) When the working distance and gun

(A)

(B)



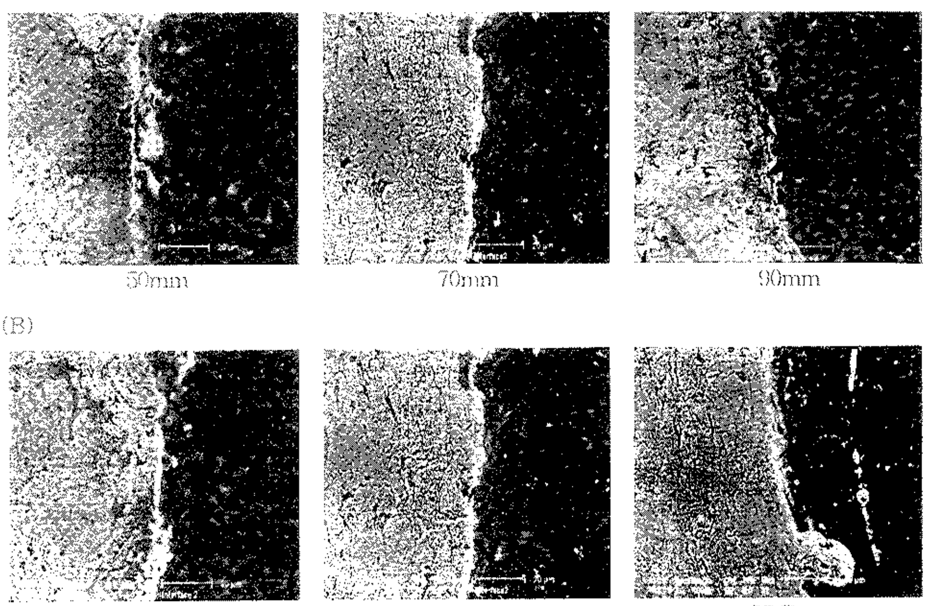
(a) (b) (c)

Fig. 4 SEM morphology of before(A) and after(B) wear test at various gun power ; (a) 32.5kw (b) 35kw (c) 37.5kw

(A)

50mm 70mm 90mm

(B)



32.5kw 35kw 37.5kw

Fig. 5 Comparison of SEM morphology of cross-sectional area at variation of the working distance(A) and at variation of the gun power(B)

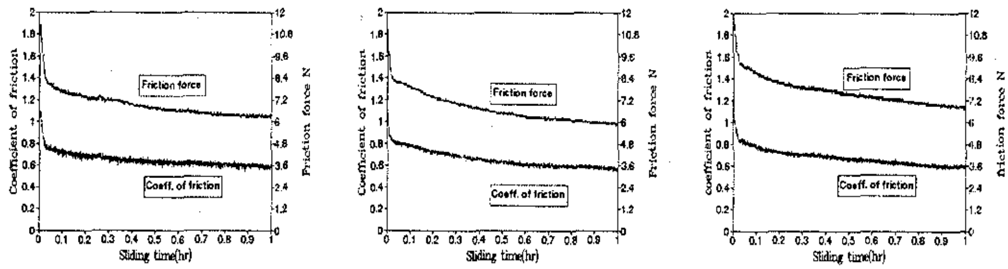


Fig. 6 Variation of the coefficient of friction of the plasma spray coated layer at various working distance ; (a) 50mm, (b) 70mm, (c) 90mm

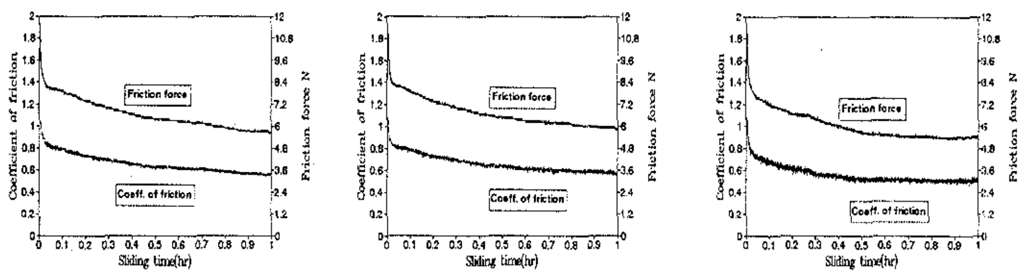


Fig. 7 Variation of the coefficient of friction of the plasma spray coated layer at various gun power ; (a) 32.5kw, (b) 35kw, (c)37.5kw

power was 7cm and 35kw, respectively, the wear resistance was superior to that of other condition. Wear properties of plasma chromia spray coating layers on magnesium alloy were governed by mainly fracture wear as well as plastic deformation.

REFERENCES

1. T. C. Nerz, J. E. Nerz. B. A. Kushner, and A. J. Rotolico : Proceedings of the international thermal spray conference & Exposition, Orlando, Florida, USA (1992) 28.
2. K. Honda, I. China, M. Saito, Y. Itoh and K. F. Kobayashi : Proceedings of ITSC'95' (1995) 411-416.
3. M. Bertagolli, M. Marchese and G. Jacucci : Journal of Thermal Spray Technology, Vol. 4(1), (1995) 41-49.
4. Jiaren Jiang, F. H. Stott, M. M. Stack : 10th International Conference(1995) 20-31.
5. Bowden, F. P. and D. Tabor : Clarendon Press, Oxford(1950).
6. J. A. Peters, F. Ghasripoor : Proceeding of the 8th National Thermal Spray Conference, Vol(9), (1995) 387-392.