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A Study on Surface Characteristics of High Tensile Brass with Molybdenum Flame Spray Treatment

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고력황동의 몰리브덴 화염용사에 따른 표면 특성에 관한 연구

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ABSTRACT

Molybdenum flame spray coatings are widely used in industrial fields to enhance the performance of mechanical component parts such as pistons, shafts and clutches. This study investigates the surface characteristics of high tensile brass with molybdenum flame spray treatment using the clutch material for small ship. The surface characteristics after molybdenum flame spray treatment in high tensile brass were quantitatively analyzed for surface composition, coating layer thickness, friction coefficient, abrasion width and phenomenon, micro-hardness, and surface roughness.

Key Words : High Tensile Brass(고력황동), Molybdenum Flame Spray Treatment(몰리브덴 화염용사) Surface Characteristics(표면특성)

1. Introduction

Various surface treatment technologies have been developed to improve the characteristics of material surfaces and applied to machinery parts, vehicle parts, aircraft parts, and ship parts. In particular, studies on surface characteristics by applying molybdenum coating to various materials have been conducted using arc spray[1,2], flame spray[3,4], high-velocity oxygen fuel (HVOF)[5,6], and plasma spray using ionized gas[7,8] in thermal spray coating. In addition, studies using anodizing[9] and laser[10] have also been actively conducted to achieve improvements on surface characteristics.

This study aimed to investigate surface characteristics according to molybdenum flame spray regarding high-strength brass casting used as transmission clutch materials in small ships.

2. Experiment and molybdenum flame spray method

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2.1 Molybdenum flame spray

A wire type of surface coating materials is used in the flame spray surface treatment method. The temperature of heat source used generally is 2,200℃ to 3,100℃, which is applied differently according to surface-coating materials. A coating material that is made by mixing oxygen and fuel gas as the main heat sources is melted and collided with the product surface in a particle state, thereby producing crushed particles, which are then coagulated and deposited to form a coating layer in the product surface. The particle speed is approximately 50–150 m/sec, and the adhesive power is in a range of 4,000–6,000 psi. Fig. 1 shows the schematic diagram of the flame spray surface-coating method.

2.2 Experimental material

In this study, high-strength brass casting specimens with Ø40mm×20mm diameter were fabricated and tested to analyze the surface characteristics of high-strength brass casting before and after molybdenum flame spray. Table 1 presents the chemical composition of the used high-strength brass casting, and Table 2 presents the chemical composition of the molybdenum material used in the flame spray. Fig. 2 shows the specimen used in the experiment and specimen photo after molybdenum flame spraying.

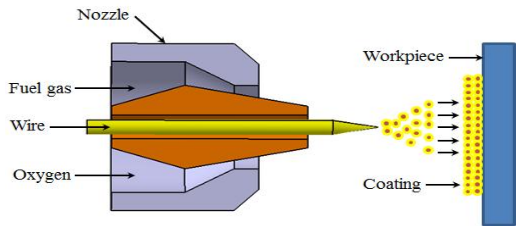


Fig. 1 Schematic diagram of flame spray treatment

Table 1 Chemical composition of high tensile brass(wt.%)

Element	C	O	Al	Si	Mn	Fe	Cu	Zn
Wt.%	20.20	4.84	0.09	0.06	0.18	3.39	45.74	18.51

Table 2 Chemical composition of molybdenum(wt.%)

Element	C	O	Al	Si	Ca	Fe	Mo
Wt.%	39.32	15.14	0.16	0.26	0.20	1.48	43.43

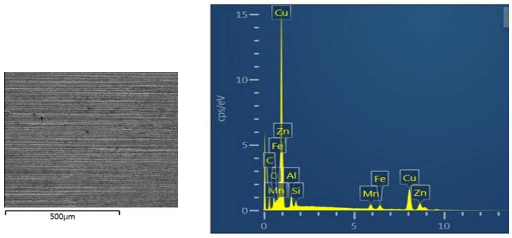
(a) Before flame spray (b) After flame spray

Fig. 2 High tensile brass workpiece

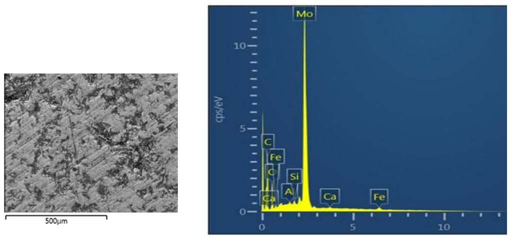
3. Experiment results and discussion

3.1 Surface composition according to molybdenum flame spray

The chemical composition analysis results using a field emission scanning electron microscope (FE-SEM) on surface composition of high-strength brass casting before and after molybdenum flame



(a) Non-coating(Cu:45.1Wt.%)



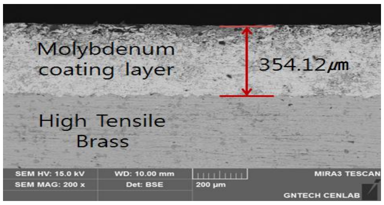
(b) Mo coating(Mo:43.4Wt.%)

Fig. 3 Variation of chemical composition before and after molybdenum flame spray

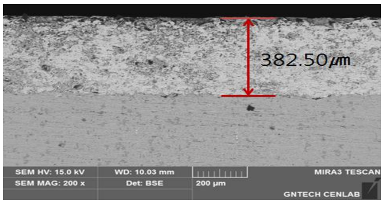
spray are shown in Fig. 3. Fig. 3(a) shows the chemical composition of the specimen surface in the high-strength brass casting before molybdenum flame spray, in which Cu was verified as the main chemical component, at about 45.1Wt%. Fig. 3(b) shows the chemical composition of the specimen surface in the high-strength brass casting after molybdenum flame spray, in which Mo was verified as the main chemical component, at about 43.4t%. As shown in the figure, chemical component of Cu was not detected, which verified that the surface of the high-strength brass casting was completely coated with molybdenum layer.

3.2 Thickness of molybdenum coating layer

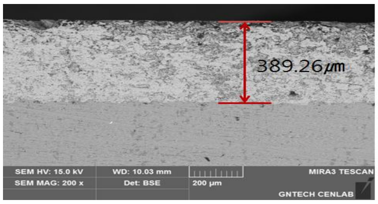
To check the thickness of the molybdenum coating layer after the molybdenum flame spray on the high-strength brass casting, five specimens were cut, and the thicknesses of the molybdenum coating layers were measured using FE-SEM. Fig. 4 shows the measurement results. As shown in the figure, the thickness of the molybdenum coating layer ranged from 354.12 to 389.26㎛, and mean thickness was approximately 375.74㎛.



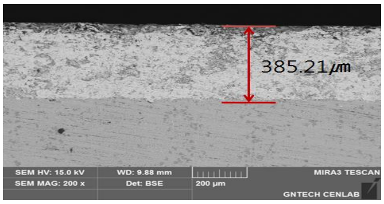
(a)



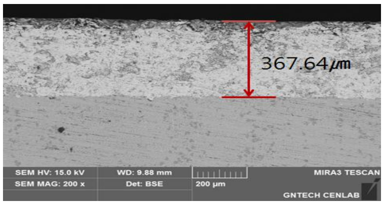
(b)



(c)



(d)



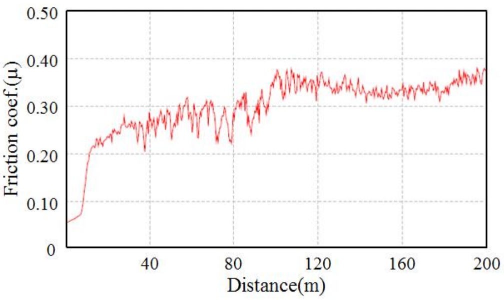
(e)

Fig. 4 Molybdenum coating layer thickness

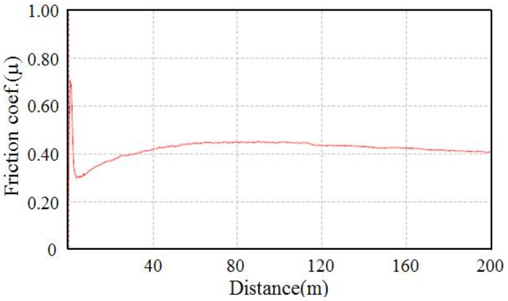
3.3 Changes in frictional coefficient

To verify the change in frictional coefficient before and after molybdenum flame spray, abrasion tests were conducted using a tribometer (CSM-instruments) of ball on disk. Applied loads were 3, 5, 8, and 10N, the number of revolutions was 80 RPM, the abrasion distance was set to 200M.

Figs. 5 to 8 show the changes in frictional coefficients before and after the molybdenum flame spray on the high-strength brass casting according to test conditions. As shown in the results, mean frictional coefficient before the molybdenum flame spray treatment at the tested condition was approximately 0.315μ, and no significant effect on changes in frictional coefficient due to the applied load was found. After applying the molybdenum flame spray treatment on the high-strength brass casting,

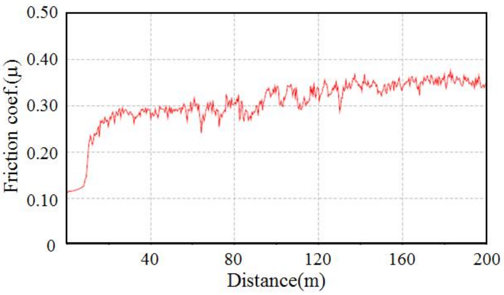


(a) Non-coating(mean : 0.321μ)

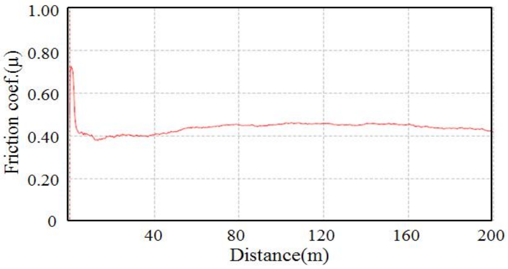


(b) Mo coating(mean : 0.412μ)

Fig. 5 Variation of friction coefficient(3N)

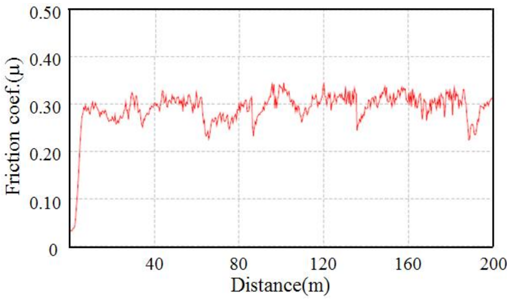


(a) Non-coating(mean : 0.310μ)

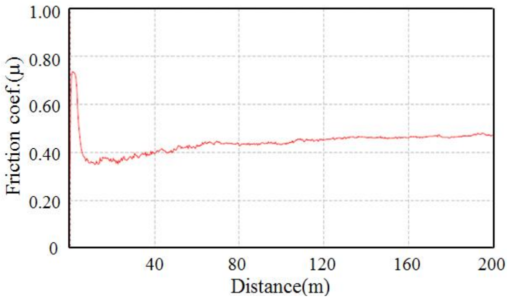


(b) Mo coating(mean : 0.429μ)

Fig. 6 Variation of friction coefficient(5N)

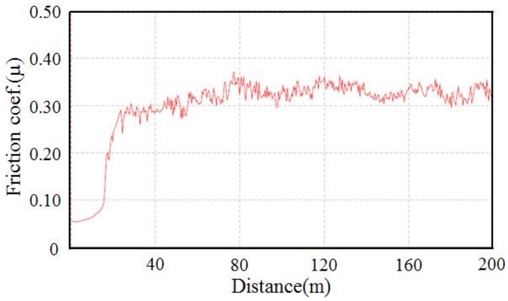


(a) Non-coating(mean : 0.318μ)

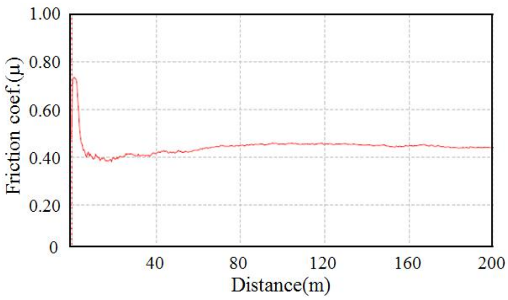


(b) Mo coating(mean : 0.438μ)

Fig. 7 Variation of friction coefficient(8N)



(a) Non-coating(mean : 0.314μ)



(b) Mo coating(mean : 0.432μ)

Fig. 8 Variation of friction coefficient(10N)

mean frictional coefficient was 0.427μ and the applied load did not have a significant effect on frictional coefficient. The increase in frictional coefficient after the molybdenum flame spray treatment was approximately 0.112μ. The reason for this was that the size of fine molybdenum particle had an effect on the frictional coefficient at the time of surface deposition due to the molybdenum flame spray treatment.

3.4 Wear width and wear phenomenon

The wear width was measured according to the applied load after the abrasion tests before and after the molybdenum flame spray on high-strength brass casting. Fig. 9 shows the wear width results measured after the abrasion test before applying the molybdenum flame spray to the high-strength brass casting. Mean wear width after abrasion tests before applying the molybdenum flame spray to the high-strength brass casting was approximately 534.93 ㎛, and the figure verified that the wear width was slightly increased according to the applied load.

Fig. 10 shows the wear width results after the abrasion test after applying the molybdenum flame spray to the high-strength brass casting. Mean wear width after abrasion tests after applying the molybdenum flame spray to the high-strength brass casting was approximately 443.51㎛. The wear width was not clearly revealed at the tested loading condition. This was due to the surface hardness effect due to the molybdenum flame spray. In addition, the figure also verified that not only surface wear but also surface peeling occurred in the abrasion test after the molybdenum flame spray. The comparison of before and after applying the molybdenum flame spray to the high-strength brass casting verified that the wear width was reduced in the abrasion test after the molybdenum flame spray, which was due to the effect of the molybdenum flame spray.

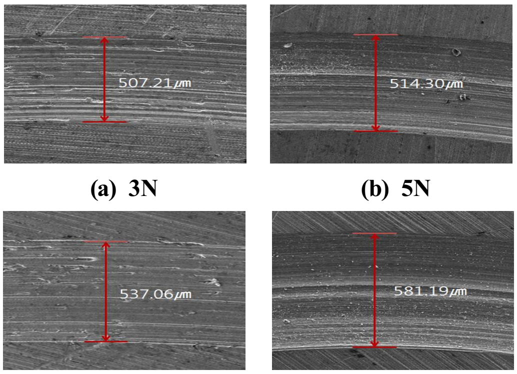
3.5 Surface composition after abrasion tests

In relation to the wear width in Section 3.4, the surface compositions in Mo and Cu at the wear track portion after the abrasion test after molybdenum flame spray were analyzed.

Fig. 11 shows the analysis results. In the wear track of 3N-applied load, only Mo component was detected, and in the wear tracks of 5N, 8N, and 10N-applied loads, Mo component was slightly reduced while Cu component was slightly increased. The above results imply that the molybdenum coating layer was slightly worn as the applied load increased. As described in the results in Section 3.2, wear was slightly increased with increase in applied load within the range of the tested applied load due to the thickness of the molybdenum coating layer.

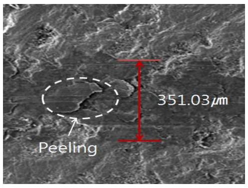
3.6 Micro hardness and surface roughness

The surface roughness of the specimens was measured five times before and after molybdenum flame spray on the high-strength brass casting using a Vickers hardness tester(MHK-H1, Akashi), and the means were taken as measurements. Fig. 12 shows the results as a graph. The micro hardness values before the molybdenum flame spray on the high-strength brass casting was approximately 256.8Hv, and the micro hardness value after the flame spray was 749.5Hv.

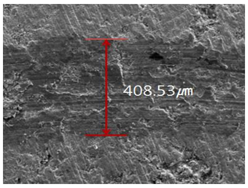


(a) 3N **(b) 5N** **(c) 8N** **(d) 10N**

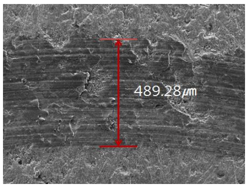
Fig. 9 Wear width(Non-coating)



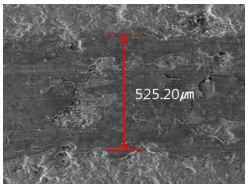
(a) 3N



(b) 5N

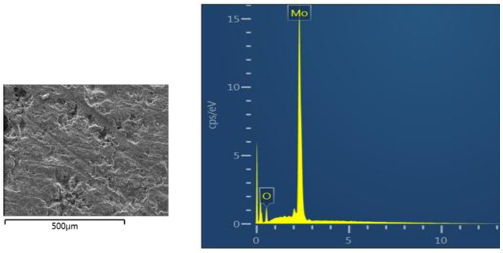


(c) 8N

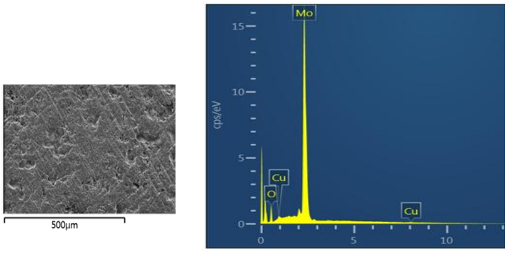


(d) 10N

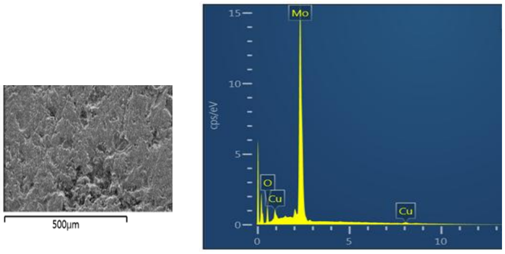
Fig. 10 Wear width(Mo coating)



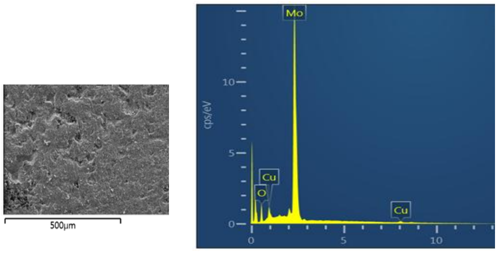
(a) 3N(Mo:83.7Wt.%)



(b) 5N(Mo:83.7Wt.%, Cu:1.10Wt.%)



(c) 8N(Mo:80.36Wt.%, Cu:3.33Wt.%)



(d) 10N(Mo:79.68Wt.%, Cu:4.04Wt.%)

Fig. 11 Variation of chemical composition after wear test

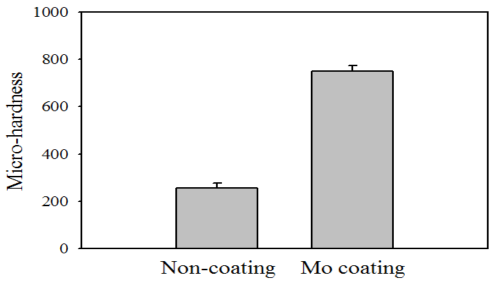
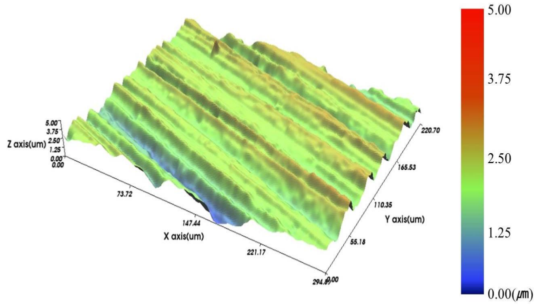


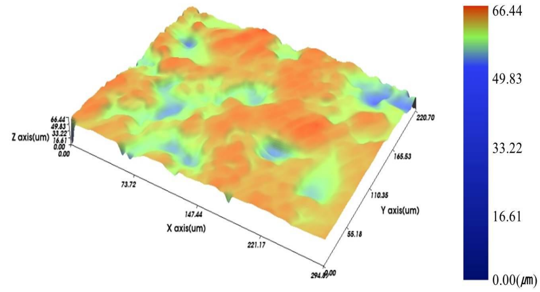
Fig. 12 Comparison of micro-hardness

The micro hardness value was increased by 65.7% compared to that before the molybdenum flame spray on the high-strength brass casting.

To verify the surface roughness before and after molybdenum coating on the high-strength brass casting, the surface roughness in about 300×300 squared micrometer area was measured using a three-dimensional(3D) optical surface profiler. Fig. 13 shows the surface roughness results before and after molybdenum coating on the high-strength brass casting. As shown in the figure, the surface roughness value before coating was up to 5.00㎛, and the maximum surface roughness value after molybdenum coating was 66.44㎛. As revealed in the results, the surface roughness was rapidly degraded after molybdenum flame spray. The reason for this was that the uneven deposition of molybdenum particles in the surface of the high-strength brass casting and the size of molybdenum particles affected the surface roughness.



(a) Non-coating



(b) Mo coating

Fig. 13 Comparison of surface roughness

4. Conclusions

This study analyzed surface characteristics quantitatively according to molybdenum flame spray on high-strength brass casting that is used as a transmission clutch material for small ships. The following conclusions were made.

1. The molybdenum coating layer was created with a thickness of 375.74㎛, and the frictional coefficient was increased by approximately 0.112μ after molybdenum flame spray treatment.

2. The wear width was slightly increased according to the applied load, but more peeling occurred than that in the normal wear in the molybdenum coating layer.

3. The micro hardness value in the molybdenum coating layer was increased by approximately 65.7% after flame spraying, and the surface roughness value was degraded by approximately 92.5%.

Acknowledgment

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