Effects of Sandblasting on Adhesion Resistance of PVD Films

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Al and Zn-coated steel sheets are widely used as automobile parts. During the press processes, coating materials are used to prevent wear and adhesion to the dies. DLC films, which have excellent adhesion and wear resistance, are widely used. However, the DLC film has a problem that peeling occurs when a large surface pressure is applied. By using a PVD film with excellent adhesion, peeling due to surface pressure can be suppressed. By improving wear resistance and adhesion resistance to Al and Zn, it can be applied to molds for these steel sheets. It is necessary to understand the basic tribological properties of PVD films for Al and Zn. Besides, in recent years, it has been reported that tribological properties are improved by introducing micro-roughness to sliding surfaces and friction surfaces.

In this study, we evaluated the adhesion resistance of PVD films on blasted substrates to Al and Zn. For comparison, samples without blasting were also evaluated. In the PVD method, TiN, TiCN, CrN, AlTiN, and AlCrN were respectively deposited. A ball-on-disk friction tester was used to evaluate adhesion resistance. After the friction test, the wear marks of the specimen and the ball were observed with an optical microscope. The presence or absence of adhesion was determined by optical micrographs.

In the Al ball, the surfaces were roughened by blasting, which made adhesion more likely. The average friction coefficient of TiCN film without blasting treatment was as low as about 0.2, but the average friction coefficients of the other specimens were as high as about 0.6 to 0.7 due to the occurrence of adhesion. In the case of Zn balls, TiN, TiCN, and AlCrN showed excellent adhesion resistance regardless of blasting treatment. For CrN and AlTiN, blasting treatment improved the adhesion resistance to Zn.

Keywords: *Sandblastings, PVD, adhesion resistance, Al, Zn*

1. Introduction

In recent years, the automotive industry has demanded improved fuel efficiency by reducing the weight of vehicle bodies. Furthermore, owing to the increasing need for collision safety, there is a need for frame parts with higher strength [1)]. High-tensile steel is attracting attention as a promising lightweight and high-strength material for automobile parts, and its usage rate is increasing, especially in the body frame of automobiles [2, 3)]. Furthermore, hot-dip aluminum plating and hot-dip galvanizing were applied to the high-tensile steel to prevent rust and corrosion. In particular, alloyed hot-dip galvanized steel is actively used in sand sills and members that require corrosion resistance [3)]. In addition, because aluminum-coated steel sheets have superior heat resistance compared to ordinary hot-dip galvanized steel sheets, their application in automobile exhaust system materials and automobile fuel tank materials is spreading [4)]. Most automobile frame parts using high-tensile materials are formed by press working, and are coated to prevent the wear and adhesion of the mold. In the press working of aluminized steel sheets and galvanized steel sheets, since aluminum and zinc are soft, aluminum and zinc tend to adhere to the mold during press forming, which may impair press formability [5, 6)]. Therefore, it is necessary to apply a coating with excellent adhesion resistance to these press molding dies.

Typical surface treatments applied to extend the life of molds include Physical Vapor Deposition (PVD) and Chemical Vapor Deposition (CVD) [7)]. For soft materials such as aluminum and zinc which easily cause adhesion, DLC is formed by plasma CVD, which has a low coefficient of friction and excellent adhesion resistance [8, 9)]. However, the DLC film on the mold surface peels off because of the large surface pressure applied to the DLC film during cold-press working [9)]. Therefore, cold press dies are required to have a coating that not only has adhesion resistance and wear resistance but also has excellent adhesion and can withstand high surface pressure. PVD films, which can be treated at relatively low temperatures, have high adhesiveness [10)], and can be applied even under conditions of high surface pressure load by combining them with nitriding [11)]. Currently, the PVD method is widely used to deposit hard ceramic films based on Ti- and Cr-based nitrides. Typical Ti-based films include TiN films [12)], which have excellent wear resistance and corrosion resistance, TiCN films [13)], which have better wear resistance than TiN and AlTiN films [14)], which have excellent heat and oxidation resistance. Examples of Cr-based films include CrN films [15)] with excellent wear and corrosion resistance and AlCrN films [16)] with excellent heat resistance.

If these types of films can improve in adhesion resistance and wear resistance to aluminum and zinc, they can be applied to dies for processing aluminized steel sheets and galvanized steel sheets. In addition, in recent years, it has been reported that tribological properties are improved by introducing micro-roughness into sliding surfaces and friction surfaces [17)]. Sandblasting can control the surface shape of the projection material. By performing blasting with different blasting materials, we can clarify the conditions that can improve the tribological characteristics of sandblasting.

In this study, the adhesion resistance and friction properties of PVD films on substrates blasted with Al and Zn are investigated.

2. Experiment

2.1 Specimens

The specimen was a commercial alloy tool steel SKD11 (13×15×6 mm). After quenching at 1303K, the tempering was performed at 803K. Subsequently, the surface of the

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specimen was mirror-finished. To investigate the effect of sandblasting, sandblasting with alumina, SiC, or glass was performed. For comparison, specimens without sandblasting were also prepared. In the PVD method, TiN, TiCN, CrN, AlTiN, and AlCrN are deposited using an arc ion plating method. The film properties are listed in Table 1. The thickness of each coating was ~ 3 μm. After the PVD treatment, the droplets on the surface layer were removed by aero-wrap polishing.

Table 1 Characteristics of various hard thin films.

Film	TiN	TiCN	CrN	AlTiN	AlCrN
Hardness (HV)	2500 (±400)	2800 (±400)	2300 (±300)	2900 (±400)	3000 (±300)
Oxidation resistance temperature , T/ K	823 (±50)	723 (±50)	923 (±50)	1073 (±50)	1372 (±50)

2.2 Friction wear test

A ball-on-disk type friction tester was used for the friction tests. Table 2 lists the conditions of the friction tests. A load of 1 N and a sliding radius of 3 mm were set. The humidity was adjusted by sealing the friction test space with a container and blowing dry air into it. The test was conducted under 50 % humidity. Pure Al and hot-dip galvanized balls were used as ball materials. The Al ball has a diameter of Φ8 mm. The Zn ball has a diameter of Φ8.2 mm, and the SUJ2 ball is coated with Zn with a film thickness of 0.1 mm. Each average friction coefficient was calculated for 3000-5400 cycles. The abrasion marks on the specimens and balls after the friction test were observed using an optical microscope. The presence or absence of adhesion was determined using optical micrographs.

Table 2 Condition of friction.

Ball	Al, Zn
Normal load (N)	1.0
Radius of rotation (mm)	3.0
Number of rotations (rpm)	300
Cycle	5400
Sliding speed (m/s)	0.09
Temperature, T / K	291~296
Humidity (%RH)	50

3. Results and Discussion

Figure 1 shows the friction test results of each coating on Al and Zn balls. In the friction test, the friction coefficient is stabilized, and the thin film worn out due to the friction. In addition, it has been reported that the friction coefficient suddenly increases and the variation width changes by the intrusion and discharge of wear debris on the friction surface [18,19]. Also in this experiment, these factors are thought to cause the rapid increase and fluctuation range of the friction coefficient. At the initial stage of sliding, a large change in the friction coefficient was observed. After that, it tended to stabilize. In the Al ball, the friction coefficient of TiCN without sandblasting showed the lowest value of about 0.2. On the other hand, the friction coefficient of the sandblasted TiCN was high at about 0.6. In the friction test with Al ball, the friction coefficients of all the sandblasted coatings were almost the same. Therefore, it was possible that adhesion of Al occurs in all sandblasted specimens.

In the Zn ball, the friction coefficients of the sandblasted specimens tended to be less prone to large fluctuations than the non-sandblasted specimens. Due to variations in the friction coefficients, adhesion of Zn may not have occurred in some specimens. In specimens without sandblasting, it was considered that the friction coefficient fluctuates due to the intrusion and ejection of wear debris from the friction

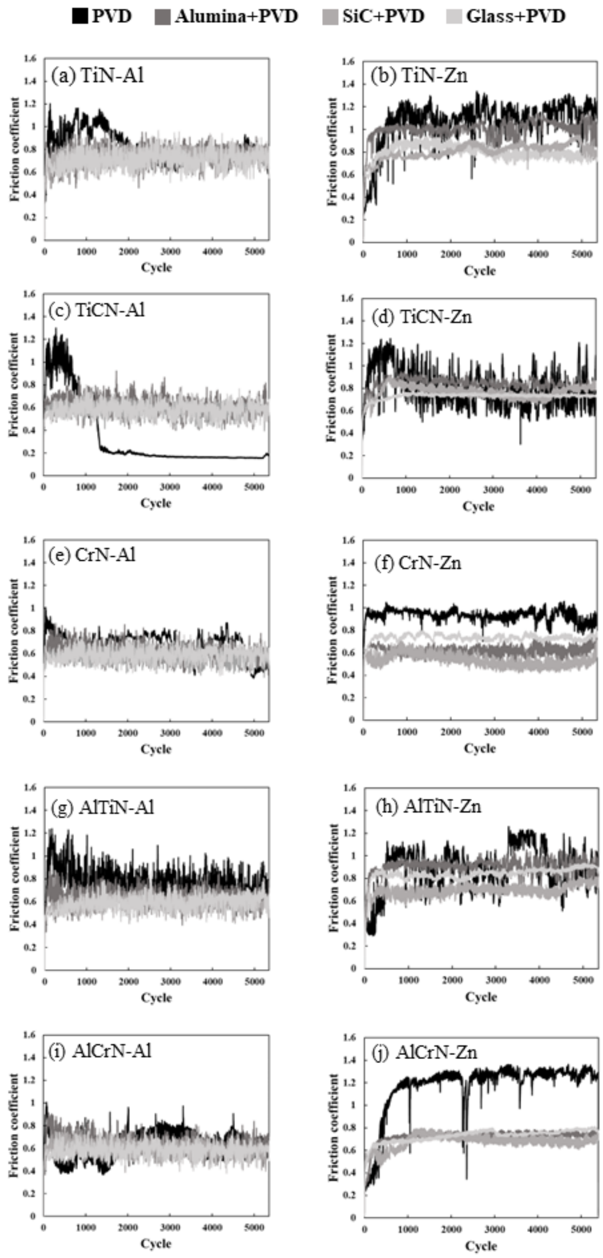

Figure 1 Friction test results for each coating on Al and Zn balls. (a)TiN-Al, (b)TiN-Zn, (c)TiCN-Al, (d)TiCN-Zn, (e)CrN-Al, (f)CrN-Zn, (g)AlTiN-Al, (h)AlTiN-Zn, (i)AlCrN-Al, (j)AlCrN-Zn.

surface. If there was unevenness on the surface due to sandblasting, wear debris enters the grooves on the surface, and it may be difficult for wear debris to enter the friction surface.

Figures 2 and 3 show the average friction coefficients of each specimen for Al and Zn balls. The presence or absence of adhesion is indicated by symbols below the graphs. The presence or absence of adhesions were determined by optical photography.

In the Al ball, adhesion of Al did not occur in TiN, TiCN and AlCrN without sandblasting. TiN, TiCN, and AlCrN are considered to have high adhesion resistance to Al. On the other hand, the adhesion resistance of CrN and AlTiN to Al was low. Moreover, sandblasting caused adhesion on all films. In the case of soft materials such as Al, it has been reported that adhesion starts when Al was scraped at the edge due to surface irregularities [20]. In this experiment as well, it is thought that the presence of unevenness on the surface due to sandblasting made it easier for Al to adhere. When the mating material was Al under no lubrication, it was found that the specimens without sandblasting had better tribological properties.

In the Zn ball, since the surface was greatly roughened by sandblasting with SiC, adhesion occurred in all specimens. For TiN, TiCN, and AlCrN without sandblasting, adhesion of Zn did not occur. In addition, even after sandblasting with alumina and glass, adhesion did not occur in these film types. TiN, TiCN, and AlCrN were considered to have high adhesion resistance to Zn. In CrN and AlTiN, where adhesion occurred without sandblasting, the adhesion did not occur by sandblasting with alumina before PVD treatment. Since Zn has higher hardness than Al, it is considered to be more difficult to scrape off than Al. Furthermore, it is possible that the adhesion of Zn could be suppressed by making it difficult for wear debris to enter the friction surface due to the unevenness.

By adding unevenness to the surface by sandblasting before PVD treatment, the adhesion resistance to Zn was improved in the friction test under no lubrication.

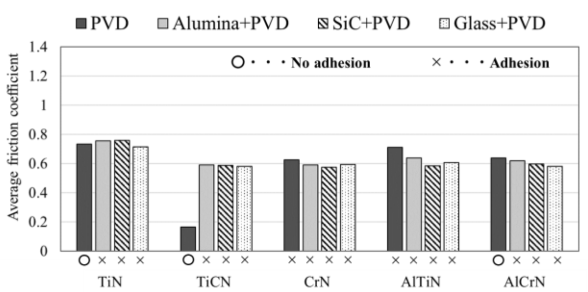

Figure 2 Average friction coefficient with Al ball.

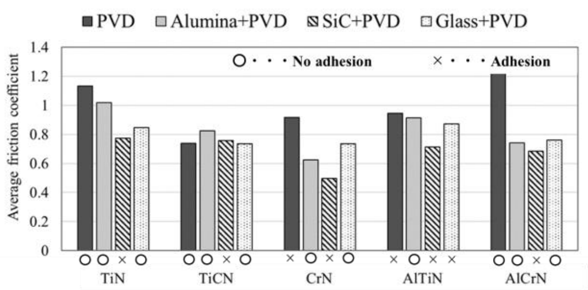

Figure 3 Average friction coefficient with Zn ball.

4. Conclusions

For TiN, TiCN, and AlCrN without sandblasting, adhesion of Al and Zn did not occur, indicating high adhesion resistance. In the Al ball, adhesion of Al occurred in all films by sandblasting. When adhesion of Al occurred, the average friction coefficients were about 0.6 to 0.7. In the case of Zn ball, CrN and AlTiN, on which adhesion occurred without sandblasting, have improved adhesion resistance to Zn by sandblasting with alumina or glass. By adding unevenness to the surface by sandblasting before PVD treatment, the adhesion resistance to Zn was improved in the friction test under no lubrication.

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