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# Study on Flaking Resistance of Hot-dip Galvanizing Coating

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For the issue of flaking of the hot-dip galvanizing coating during drawing, the microcosmic characteristics of the coatings have been analyzed and experiments have been done to investigate the influence of coating thickness, Al content and steel substrate strength on its flaking-resistance. The results show that the fact of flaking is that the coating partially flaked off at the position far away from interface of steel substrate and coating, and not entirely flaked off from steel substrate because of poor adhesion. The flaking-resistance of coating decreases with the increasing of coating thickness and steel substrate strength, and increases with the increasing of Al content in coating at the same experimental conditions.

***Keywords*** *: hot-dip galvanizing coating, flaking-resistance, formability*

## 1. Introduction

The issue of flaking and powdering of the galvannealing has been concerned widely, and its original causes of formation, influencing factors and the preventive measures have been studyed for a long time.[1)-3)] Long-term practical application show that this issue can also exist during drawing for hot-dip galvanizing steel sheets. It not only affects the surface quality of the formed workpieces, but also decreases the service life of die and increases the clean-up workload because the flaked fragments adhere to the die and then accumulate, which increase the friction between the die and workpieces. Therefore, it is very important for improving drawing formability to study the influencing factors on the flaking-resistance of coating.

## 2. Characteristics analysis

Powdering or flaking often happens on deformation region during drawing when the hot dip galvanizing steel sheets are applied to manufacturing household electrical appliance, shown in Fig. 1. The micromorphology of the flaking shown in Fig. 2, which obtained from deformed region and observed in the SEM of JSM-5600LV. The chemical composition in the flaking micro-area is shown in Table 1, which was analyzed by INCA energy spectrometer. It shows that the main components in the light flaking region are Zn, O and Al, and Al is up to 90% or so. While the main components in the serious flaking region are Zn, O, Si, Fe, P and Al, and Zn is up to 70% or so. Among them, Si and P are the components of surface chemical conversion coating, and S and Cl are the pollutant components.

According to the results of INCA analysis, we shoud see that the flaking area is still covered by zinc coat and the steel substrate is not exposed. It shows that the adhesion between coating and steel substrate is good. The fact of flaking is that the coating partially flaked off at the position far away from interface of steel substrate and coating, and not entirely flaked off from steel substrate.

## 3. Experimentals analysis

In theory, the fact of flaking is that the coating was destroyed by shearing friction stress during drawing. The main influencing factors are structure of coating and the friction conditions between the sheet and die during drawing. Therefore, experiments have been done to investigate the influence of coating thickness, steel substrate

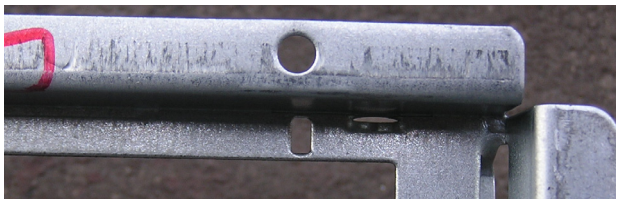

**Fig. 1.** Macromorphology of flaking.

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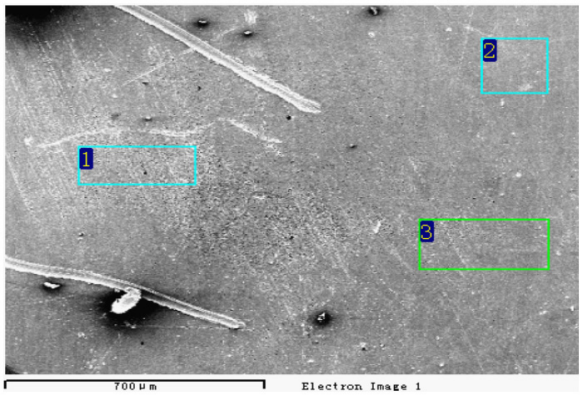
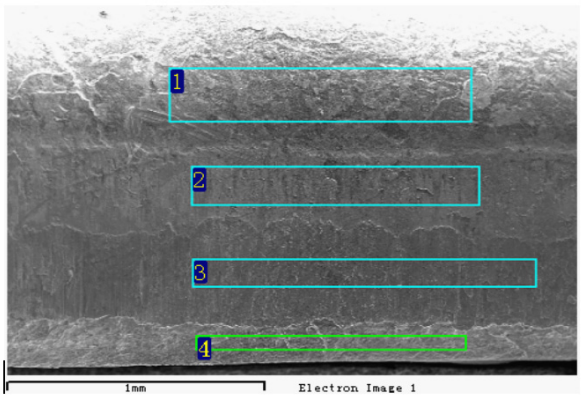



a) light flaking




b)serious flaking

**Fig. 2.** Micromorphology of flaking.

**Table 1. The chemical composition in the flaking micro-area** (mass percent, %)

| spectrum | | O | Al | Si | P | S | Cl | Fe | Zn |
|---|---|---|---|---|---|---|---|---|---|
| a) | 1 | 6.61 | 0.81 | 0.28 | - | - | - | - | 92.31 |
| | 2 | 4.12 | 0.72 | - | - | - | - | 0.90 | 94.25 |
| | 3 | 5.69 | 0.87 | - | - | - | - | - | 93.44 |
| b) | 1 | 34.56 | 0.91 | 2.45 | 1.07 | - | 0.84 | 1.43 | 58.74 |
| | 2 | 26.02 | 0.59 | 1.74 | 1.23 | - | - | 1.20 | 69.22 |
| | 3 | 13.18 | - | - | 0.53 | 0.49 | - | 14.43 | 71.37 |
| | 4 | 15.48 | 0.66 | 1.45 | - | - | 0.77 | - | 81.63 |

strength and Al content of coating on flaking-resistance of coating.

### 3.1 Experimental material and method

The experimental materials were taken from No.A and No.B continuous hot-dip galvanizing line which have different Al content in bath. The steel grades are low carbon aluminum killed steel (DX51D and DX52D) and IF steel (DX53D and DX54D). The coating weight is 80 g/m$^2$~220 g/m$^2$.

The quantity of coating flaking is measured by draw bead test. The sample of 25 mm×300 mm is placed between upper and lower die of the tester, and then the pressing force (300daN) is applied to it. The sample is passed through the dies in the same speed (100 mm/min), which effective length is 100 mm. The quantity of coating flaking is evaluated by weight-loss method.

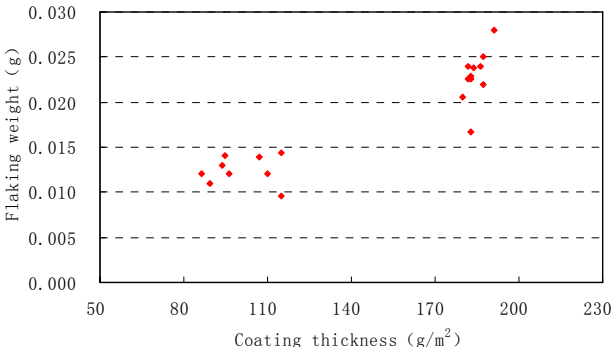
The coating weight is measured according to China standard GB/T 13825 (Metal Coatings-Determination of the mass for hot dip galvanizing coating on ferrous materials-Gravimetric Method). The coating is cleaned up by hydrochloric acid and then evaluated by weight-loss method.

The coating aluminum content: The coating is flaked according to GB/T 13825, and then test the aluminum content of flaked coating by ICP spectrometer.

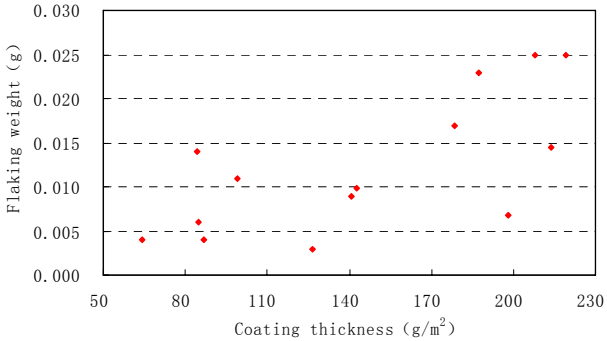
### 3.2 Results and discussion

#### 3.2.1 Influence of coating thickness on its flaking-resistance

The relationship between coating flaking quantity and its thickness is shown in Fig. 3. It shows that the flaking-resistance of coating increases with the decreasing of its thickness.




a) sample from No.A CGL




b) sample from No.B CGL

**Fig. 3.** The relationship between flaking weight and coating thickness.

With the increasing of coating thickness, the contact area and friction force between coating and die increase obviously during drawing, and then the flaking quantity of coating increase notably because the hot-dip galvanizing coating is very soft. For the influence of steel substrate strength and structure and hardness of coating, the flaking-resistance appears some difference when the coating thickness has little difference.

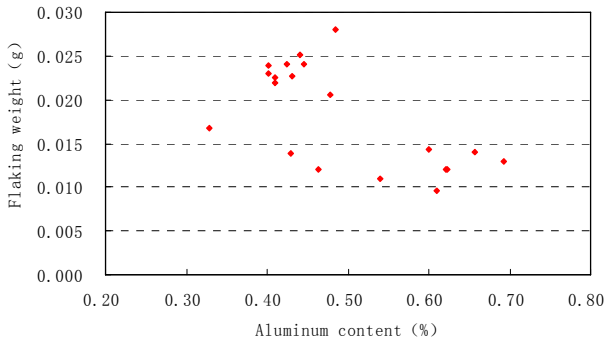
### 3.2.2 Influence of coating aluminum content on its flaking-resistance

Fig. 4 shows the relationship between the flaking weight and aluminum content of coating. It shows that the flaking-resistance increases with the increasing of aluminum content of coating.

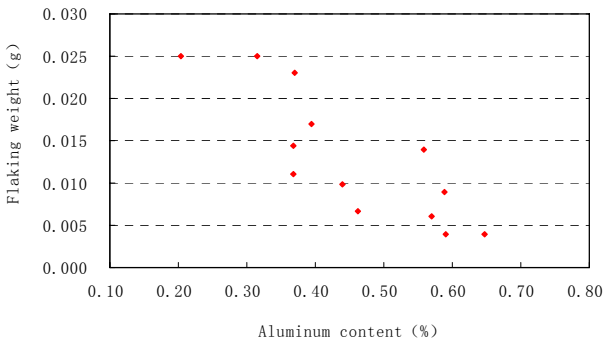
The aluminum content of hot-dip galvanizing coating composes of three parts as follows: ① reacting between the steel substrate and aluminum in the bath and forming Fe-Al interface layer during galvanizing, which brings out a great deal of aluminum from the bath; ② forming of pure zinc layer, which brings out the same proportion of aluminum as that of the bath; ③ the intermetallic compounds or dross particles containing aluminum in the bath goes into coating, which brings out some gathered aluminum. The practice shows that the aluminum content of Fe-Al interface layer is much higher than that of bath. The aluminum content of coating depends primarily on that of Fe-Al interface layer. The pure zinc layer thickness increases with the coating thickness. Therefore, with the increasing of coating thickness, aluminum content of coating decreases (shown in Fig. 5) and flaking-resistance reduces.

The Fe-Al interface layer will not form completely if the effective Al content in bath or entry temperature of sheet is much lower, or galvanizing time is shorter, which result in decreasing aluminum content of coating and poor adhesion and then decreasing flaking-resistance.

In addition, the practice shows that the flaking-resistance of coating from No.A CGL is worse than that from No.B CGL althrough the Al content of No.A CGL is higher than that of No.B CGL at the same coating thickness, as shown in Fig. 5. In fact, the Al content controlling of No.A CGL is slightly lower than that of the No.B CGL. Furthermore, the Fe-Al interface layer of No.A CGL is normal, and the adhesion between coating and steel substrate is excellent. So we conjecture that some intermetallic compounds or dross particles containing aluminum in the bath goes into the coating of No.A CGL, which makes the Al content higher and results in worse flaking-resistance.

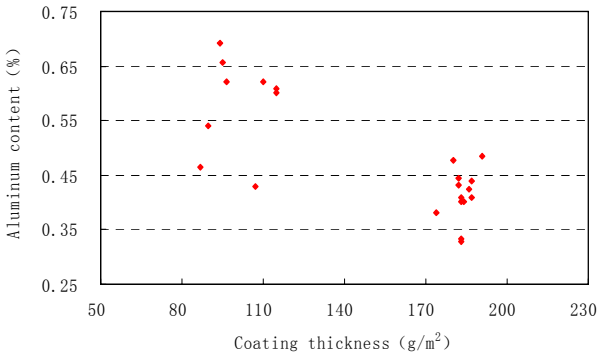



a) sample from No.A CGL

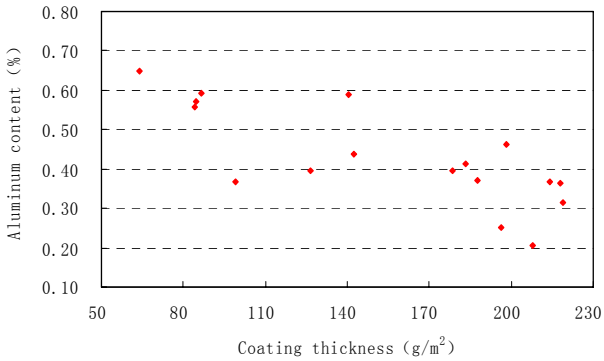



b) sample from No.B CGL

**Fig. 4.** The relationship between flaking weight and aluminum content of coating.

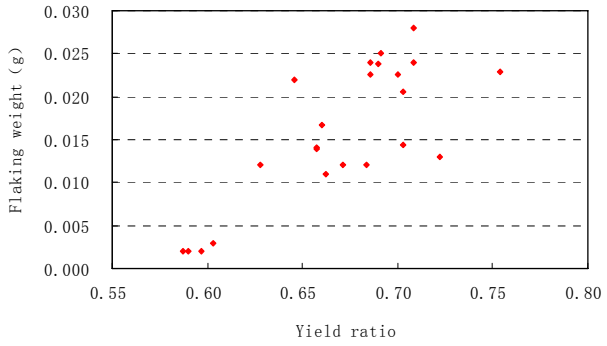



a) sample from No.A CGL

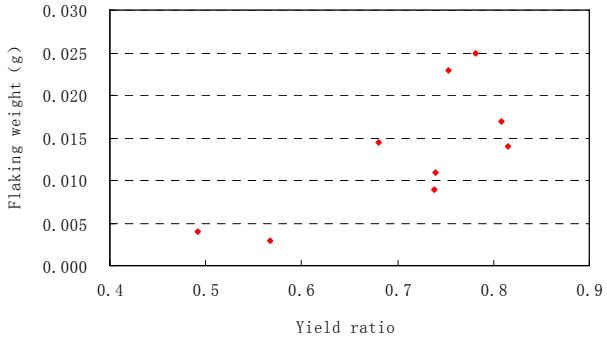



b) sample from No.B CGL

**Fig. 5.** The relationship between coating thickness and its aluminum content.




a) sample from No.A CGL




b) sample from No.B CGL

**Fig. 6.** The relationship between flaking-resistance and steel substrate strength.

### 3.2.3 Influence of steel substrate strength on coating flaking-resistance

The relationship between coating flaking-resistance and the yield ratio of steel substrate is shown in Fig. 6. It can be seen that flaking-resistance decreases with the increasing of yield ratio.

The internal reason of coating flaking during drawing is that the coating quality is poor, and the external reason is that the friction between the steel sheet and die is larger. With the increasing of steel substrate strength, the friction force between the sheet and die increases and flaking weight increases.

## 4. Conclusions

1) The flaking of hot dip galvanizing coating is that the coating partial flaked off at the position far away from interface of steel substrate and coating, and not entirely flaked off from steel substrate because of poor adhesion.

2) The flaking-resistance of coating decreases with the increasing of coating thickness and the yield ratio of steel substrate, and increases with the increasing of Al content in coating at the same experimental conditions.

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