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Causes and Treatment of Hot-rolled Al-Zn Alloy Coated Steel Sheets

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Abstract:

Steel exposure is a major defect of hot-rolled Al-Zn alloy coated steel sheets, which are manufactured on the production line of cold-rolled Al-Zn alloy coated steel sheets, using the United States Steel Corp method. This paper experimentally analyzes morphological features of steel exposure, dusts adhered to furnace roller and degreasing cleaning technology, identifies the main causes of steel exposure, and proposes a method to eliminate the defect, providing a solution to insufficient solder.

***Keywords**: Hot-rolled Al-Zn, Coated steel sheets, Defect of steel exposure.*

I. INTRODUCTION

Hot-rolled Al-Zn alloy coated steel sheets (that is, 55% Al-43.5% Zn-1.5% Si alloy), as an Al-Zn alloy coated product, combine the isolation protection and durability of Al with the cathodic corrosion protection of Zn. The product excels in the resistance to atmospheric corrosion [1]. Its corrosion resistance is 2-6 times that of Galvanized (GL) steel plates of the same coating thickness [2,3]. Thanks to its good corrosion resistance, high temperature resistance, strong thermal reflectivity, and beautiful appearance, hot-rolled Al-Zn alloy coated steel sheets have been widely applied in construction, car making, home appliance manufacturing, and transportation [3-7].

This product is also simple to manufacture, and competitive in the market [8]. In actual production, however, the usage of the product is severely constrained by some urgent issues [9]. In the production process, the most likely problem is defect of steel exposure. The main reason is that AL content in the plating solution is too high, which is close to type II hot-dip AL. The features of Al is high melting point, easy oxidation, large surface tension and not easy to infiltrate on the surface of steel plate, which is the main reason why the production of Hot-rolled Al-Zn is more difficult than that of hot-dip galvanized. Li J.L., Guo T.X. and other teams have made sufficient research on the quality control of GL product production process, summarized the causes of steel strip surface quality defects, and put forward corresponding improvement measures. However, as the hot-rolled Al-Zn products of the project must be produced in the mixed line of the original cold-rolled Al-Zn product production line, the causes of exposed

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steel defects in GL coating are more complex. Compared with the previous production line of pure hot-rolled Al-Zn plating products, new problems may appear in the production process of the project in terms of furnace environment, bath composition and cleaning process. It is necessary to monitor the production process more strictly and analyze the problems in more detail to ensure the product quality.

II. TECHNICAL CONDITIONS

Our project studies the hot-rolled Al-Zn alloy coated steel sheets used in construction. The product is mainly processed in to Z profile steel, U type steel, and C channel steel, which will be made into purlins. The users have proposed specific requirements on the chemical composition, mechanical properties, size allowances, and surface quality of the product. The requirement on surface quality goes: no defect such as insufficient solder and coating peeling is allowed.

According to the technical requirements of users and the production experience of HDG products, the chemical composition, mechanical properties, and dimensional accuracy of hot-rolled Al-Zn alloy coated steel sheets depend directly on the raw material: steel rolls [10-13]. Therefore, the technical difficulty of our project lies in how to ensure the adhesion of the coating, prevent the defect of insufficient solder / steel exposure, and guarantee surface quality.

III. EXPERIMENTAL ANALYSIS

In the light of user demand, the hot-rolled products SD235+AZ (corporate standard) of a steel enterprise were prepared into hot-rolled Al-Zn alloy coated steel sheets, using the United States Steel Corp method. Under the constraint of the production program, the HDG products must be manufactured on the production line of cold-rolled Al-Zn alloy coated steel sheets in the steel enterprise. Thus, it is necessary to adjust the process flow and parameters.

Process flow: Loading materials → Uncoiling → Welding → Looper entry → Strip cleaning → Annealing → Galvanization → Removing excess Zn with air knife → Post-welding cooling → Finishing → Tension leveling → Passivation and anti-fingerprint treatment → Looper removal → Surface quality check → Greasing → Splitting and sampling → Recoiling → Weighting and bundling [14,15]. Among them, strip cleaning consists of multiple stages, including alkali washing, brushing, electrolytic cleaning, and hot water rinsing. The annealing furnace is a large vertical furnace with several international advanced technologies. The zinc pot is an Ajax Tocco Magnethermic moveable induction double zinc pot system. The production system is supported by an advanced vertical roll coater and induction curing furnace, and can produce high-quality anti-fingerprint plates and self-lubricating plates [15,16].

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IV. CAUSES OF STEEL EXPOSURE

4.1 Necessity of Defect Analysis

During the trial production of hot-rolled Al-Zn alloy coated steel sheets, many steel exposure/ insufficient solder appeared in the early phase. The reject ratio of the finished products once surpassed 30%, as shown in Fig 1. Making it necessary to identify the causes of the defect and find preventive measures[17].

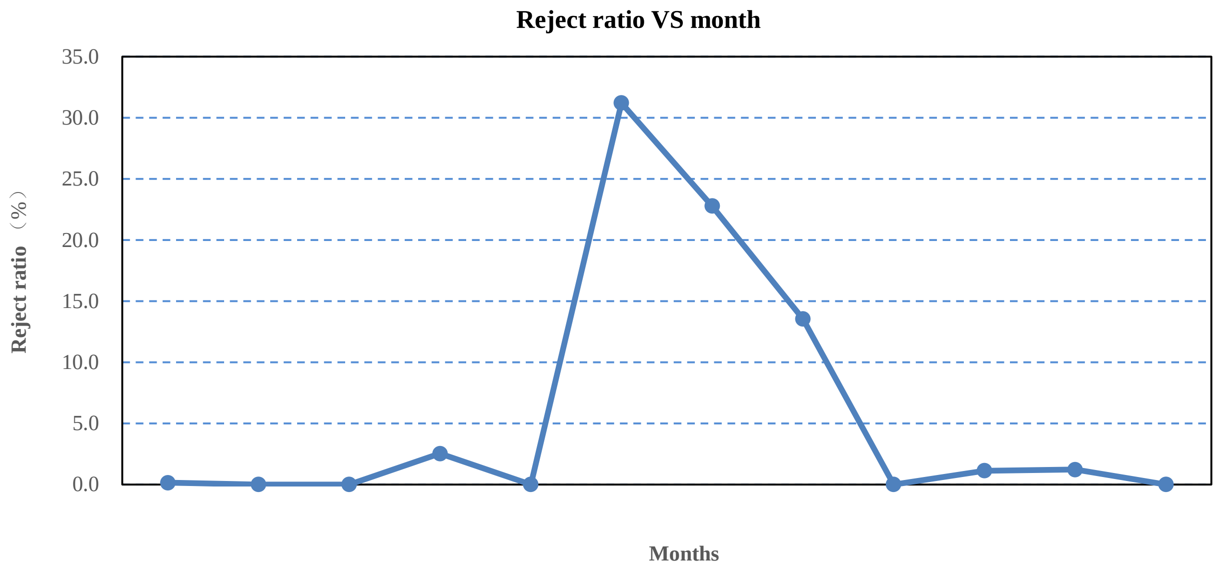

Fig 1: Reject ratio of the finished products

4.2 Morphological Features of Steel Exposure

Follow-up survey shows that steel exposure spread across the plate surface, with no clear distribution law. Fig 2 shows the macro-morphology of the product. The micromorphology and micro-area composition were analyzed with a JSM-5600LV scanning electron microscope (SEM). The results are displayed in Figure 3 and Table 1. The normal areas are mainly composed of Zn, Al, and O, while the steel exposure areas consist of Fe and O. Apart from Fe, O, Zn, Al, Si, and C, the junction between defects and normal areas contains impurities like Ca, S, Na, Cl, and K. These impurity elements might come from the surface inclusions of base steel, the residual degreasing cleaning liquid (water-based), the furnace dusts adhered to roller and brought to the surface of strip steel, the impurities of plating solution, and sample contamination, to name but a few[18-20].

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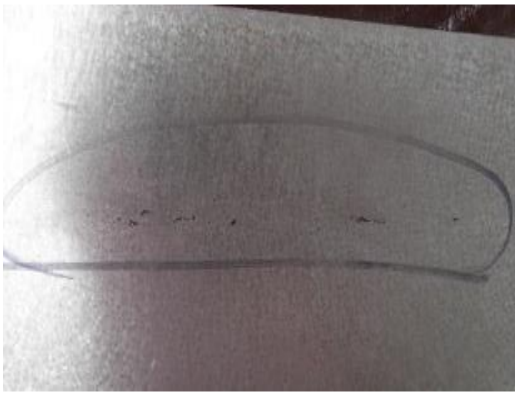
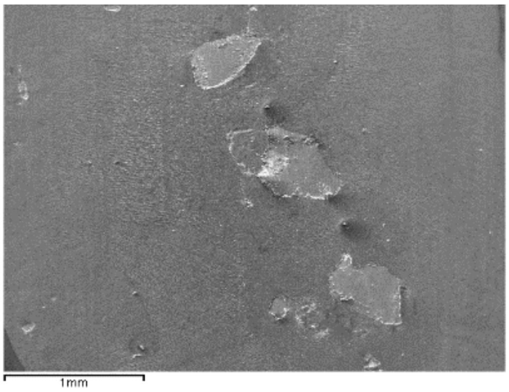
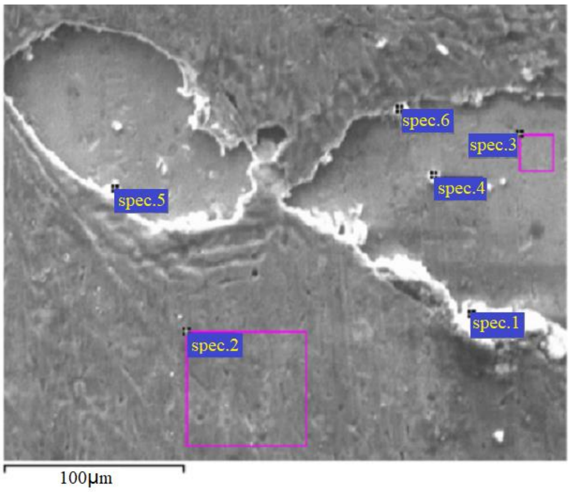


a) Unaided view

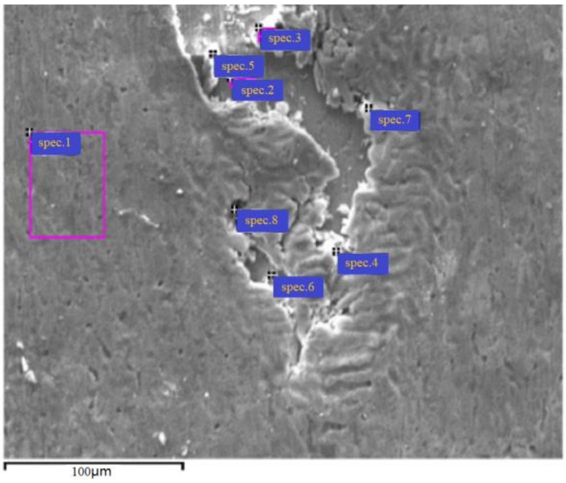


b) SEM view

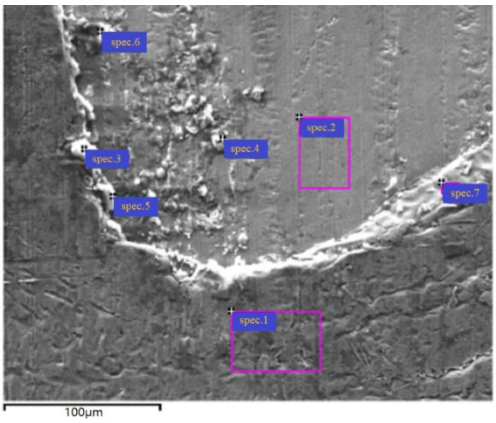
Fig 2: Macro-morphology of the product



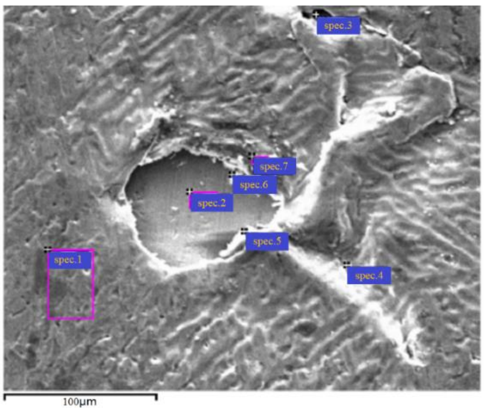
a) Sample 1



b) Sample 2



c) Sample 3



d) Sample 4

Fig 3: Micro-morphology of the product

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Table I. Micro-area composition analysis of steel exposure areas (%)

Micro-area		C	O	Na	Mg	Al	Si	S	Cl	K	Ca	Ti	Fe	Zn
Sample 1	1	49.79	28.17	---	---	3.68	1.60	1.04	2.22	---	1.01	---	7.02	5.47
	2	17.67	3.28	---	---	37.43	---	---	---	---	---	---	---	41.62
	3	---	13.37	---	---	---	---	---	---	---	---	---	86.63	---
	4	17.43	22.60	---	---	0.73	---	0.52	---	---	---	---	56.88	1.84
	5	32.35	34.34	---	---	6.88	1.18	1.13	3.89	---	2.26	---	7.87	10.10
	6	---	35.17	---	---	12.94	16.99	2.80	---	5.34	3.38	---	14.93	8.45
Sample 2	1	18.69	5.16	---	---	35.87	---	---	---	---	---	---	---	40.28
	2	7.00	12.00	---	---	0.64	---	---	---	---	---	---	80.35	---
	3	---	30.31	---	---	52.01	---	---	---	---	1.84	---	10.41	5.43
	4	32.15	30.22	---	---	8.56	0.85	0.72	2.66	---	1.35	---	3.57	19.90
	5	37.00	20.82	1.87	---	---	---	---	0.51	---	---	---	39.80	---
	6	---	1.31	---	---	0.86	---	---	---	---	---	---	92.66	5.17
	7	16.44	---	---	---	43.98	---	---	---	---	---	---	1.78	37.80
	8	---	1.28	---	---	2.36	---	---	---	---	---	---	34.75	61.61
Sample 3	1	---	7.52	---	---	39.63	3.13	---	---	---	---	---	2.09	47.62
	2	---	13.78	---	---	---	---	---	---	---	---	---	86.22	---
	3	---	49.57	1.58	---	19.81	21.50	---	---	6.03	---	---	1.50	---
	4	15.84	37.70	1.60	---	0.64	---	0.67	---	---	---	---	43.54	---
	5	---	41.08	2.46	8.02	5.78	20.63	---	---	0.67	7.82	1.97	11.56	---
	6	8.91	1.90	---	---	---	---	---	---	---	---	---	89.19	---
	7	13.50	2.92	---	---	41.37	---	---	---	---	---	---	2.69	39.52
Sample 4	1	---	7.82	---	---	47.18	---	---	---	---	---	---	---	45.00
	2	---	10.19	1.52	---	---	---	---	---	---	---	---	88.29	---
	3	25.95	15.82	---	---	10.00	2.56	1.43	---	---	3.87	---	27.61	12.77
	4	---	1.81	---	---	40.12	---	---	---	---	---	---	2.45	55.62
	5	---	12.51	---	---	1.05	0.89	---	0.71	---	---	---	84.84	---
	6	---	---	---	---	---	---	---	---	---	---	---	94.81	5.19
	7	19.23	16.73	---	---	10.74	---	---	2.86	---	0.92	---	2.44	47.08

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The previous studies have shown that the plating solution indeed has a certain number of Ca-containing impurities, as it etches the refractory materials in the zinc pots. However, these impurities will not cause steel exposure, but create convex granules. Besides, the defected sample was cleaned by ultrasonics before being observed. The contaminants were basically removed from the sample. Therefore, the Ca, S, Na, Cl, and K detected on the defected sample could not originate from plating solution impurities or sample contamination.

The previous studies have also demonstrated that the surface inclusions of the base steel could reduce platability, which in turn brings steel exposure, and the resulting defect areas would include elements like Ca, S, Na, Cl, and K. Nevertheless, empirical evidence suggests that the steel exposure induced by inclusions should appear as intermittent dots and lines, accompanied by many convex strips. These defects should have been noticeable before plating. Hence, it is preliminary judged that the inclusions of the base steel are not a major cause of steel exposure.

4.3 Dusts Adhered to Furnace Roller

Semi-quantitative analysis was carried out on the few dusts adhered to the furnace roller. The analysis results are listed in Table II.

The furnace dusts contain such elements like Ca, S, Na, Cl, K, Co, Cr, Mn, and Ni. Preliminary analysis shows that a high content of Co, Cr, Mn, and Ni should be detected in defect areas, if the steel exposure is resulted from the falling platability, which is driven by the furnace dusts adhered to roller and brought to the surface of strip steel. However, these impurity elements were not discovered in the previous micro-area composition analysis. Thus, the furnace dusts could not be the main cause of steel exposure.

Table II. Semi-quantitative analysis on furnace dusts

Component	**Content （%）**	**Component**	**Content （%）**	**Component**	**Content （%）**
ZnO	53.8	Al_2O_3	1.88	CuO	0.0597
Na_2O	13.8	SiO_2	0.928	MgO	0.0534
Co_2O_3	12.3	K_2O	0.463	TiO_2	0.0531
Cr_2O_3	4.69	MnO	0.435	P_2O_5	0.0172
Cl	4.33	NiO	0.413	Br	0.0094
SO_3	3.59	CaO	0.246	MoO_3	0.0045
Fe_2O_3	2.67	PbO	0.176	ZrO_2	0.0039

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4.4 Degreasing Cleaning Technology

The authors surveyed the free alkalinity of the pre-degreasing tank and degreasing tank, and the conductivity of the cleaning tank in the hot-rolled Al-Zn alloy plating unit. The results are shown in Fig 4 and 5.

As shown in Fig 4 and 5, the free alkalinity of the degreasing tank remained normal, but the conductivity of the cleaning tank surged up when the reject ratio caused by steel exposure was high (as shown in Fig 1). The upsurging conductivity could be attributed to the high free alkalinity of the degreasing tank, or the entry of alkaline liquor into the cleaning tank due to the insufficiency of rinsing water; the poor quality of cleaning water in the degreasing tank, which contains lots of electrolytes.

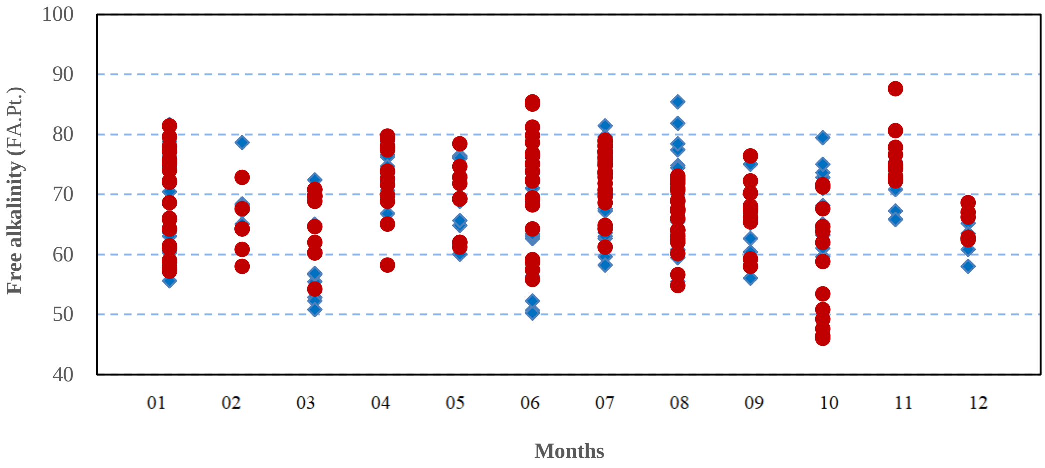

Fig 4: Free alkalinity of degreasing tank

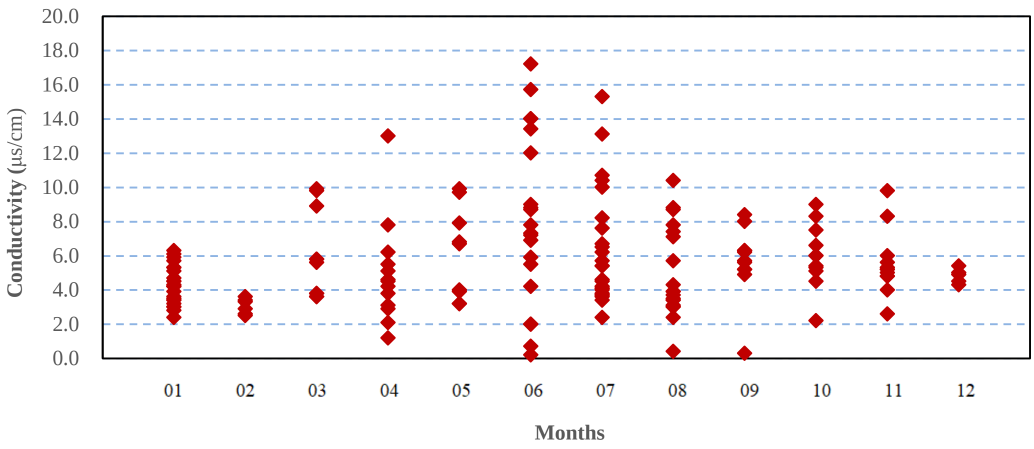

Fig 5: Conductivity of cleaning tank

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V. TREATMENT MEASURES OF STEEL EXPOSURE

The survey on degreasing and cleaning technologies shows that: when the reject ratio caused by steel exposure was high, the free alkalinity of the degreasing tank remained normal, but the conductivity of the cleaning tank surged up. Therefore, there is a problem in the quality of the desalted water used for degreasing and cleaning. Since the previous defect feature analysis concludes that the defect areas contain Ca, S, Na, Cl, and K, it can be deduced that the content of calcium ions, sulfate ions, and chloride ions in the rinsing water increases, and some of these ions remain on the surface of the strip steel; the ensuing reduction in platability causes the defect of steel exposure / insufficient solder.

In general, the hot-rolled Al-Zn alloy plating unit should be degreased and washed with desalted water, whose hardness is about 0.1mg/L and conductivity is about 0.1μs/cm. To clean the front panel, the conductivity of the cleaning tank must be controlled below 10μs/cm. Hence, we stepped up the monitoring of the water quality of the desalted water, keeping it within the range specified in the relevant technological procedures. In this way, the reject ratio induced by steel exposure was effectively controlled (as shown in Fig 1).

VI. CONCLUSIONS

In this project, the original cold-rolled Al-Zn product production line is used to produce hot-rolled Al-Zn products. In view of the exposed steel defects on the surface of the strip steel, the project team analyzed the factors such as the quality of the original plate, degreasing cleaning solution, furnace roller adhesion dust, plating solution impurities and sample pollution. According to the appearance characteristics of the defects, defect composition, changes of cleaning process parameters, etc. The decisive factors of exposed steel defects were found, and the products meeting the requirements of customers were successfully prepared by adjusting the process parameters. This method can also be used for reference to solve the actual production problems encountered in the process of preparing GL products by other production processes.

For this project, the causes of exposed steel defects and specific solutions are as follows:

(1) The main reason for the defect of steel exposure / insufficient solder is the abnormal water quality of the water used for degreasing and cleaning. The content of calcium ions, sulfate ions, and chloride ions in the water increases. Some of these ions remain on the surface of the strip steel; the ensuing reduction in platability causes the defect of steel exposure / insufficient solder.

(2) Stepped up the monitoring of the water quality of the desalted water, keeping it within the range specified in the relevant technological procedures (conductivity≤10μs/cm). Then, the reject ratio induced by steel exposure was effectively controlled.

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