Article

Analysis of the Influence of Coating Weight Changes on Metal Surface Protection Effect and Industrial Application Adaptability

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Abstract: This article systematically analyzes the influence of different coating weights on the protective performance and industrial adaptability of metal surfaces, addressing a critical challenge in modern metallurgical engineering and materials science. As industrial demands for durable and versatile materials continue to rise, understanding the precise relationship between coating parameters and material longevity becomes essential. In this study, we conduct a comprehensive investigation by comparing the effects of coating thickness changes on key performance indicators, including corrosion resistance, surface uniformity, and processing adaptability. The experimental framework involves rigorous corrosion tests, such as salt spray and electrochemical impedance spectroscopy, alongside detailed microstructure characterization using scanning electron microscopy and X-ray diffraction. These methodologies are applied across three distinct and widely utilized coating systems: traditional hot-dip galvanizing, advanced aluminum zinc plating, and highly resilient galvanized aluminum magnesium systems. By systematically evaluating these variations, the research identifies optimal coating weight thresholds that maximize structural integrity without compromising formability or increasing manufacturing costs. The results indicate that reasonable control of coating weight can effectively balance the protection life and application requirements under diverse environmental conditions. Furthermore, the findings reveal that the galvanized aluminum magnesium system exhibits superior performance at lower coating weights compared to conventional alternatives. Ultimately, this comprehensive analysis provides a robust, empirical basis for the selection and optimization of industrial coating products, offering valuable insights for engineers and manufacturers aiming to enhance the sustainability and reliability of metal infrastructure.

Keywords: coating weight; corrosion resistance; hot dip galvanizing; metal protection; zinc alloys; industrial adaptability

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1. Introduction

Metal materials are prone to electrochemical corrosion when exposed to environments such as the atmosphere, water, and soil. This corrosion leads to a reduction in structural strength, deterioration in appearance, and loss of functionality. To combat these issues, metal coating protection has been extensively applied across various industries, including construction, automotive manufacturing, household appliances, and steel structures. This method is favored due to its advanced technological development, cost-effectiveness, and reliable protective performance. The protective mechanism of coatings involves sacrificial anode protection and the creation of physical barriers that isolate the corrosive medium from the base metal. The mass of the coating per unit area (g/m^2) directly correlates with the effective thickness of the protective layer, which in turn determines the longevity of the coating's service life. Figure 1 illustrates the relationship between coating mass and durability.

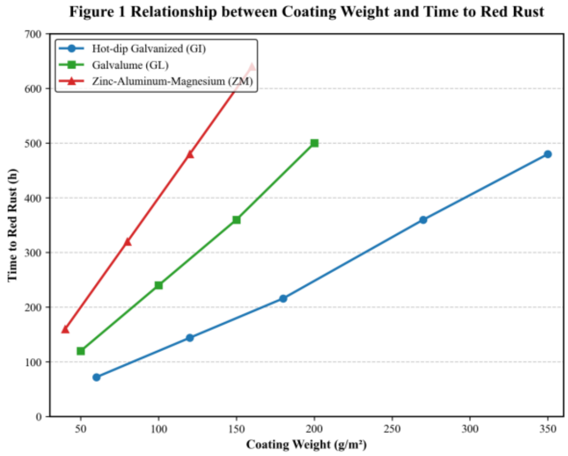

Figure 1. Relationship Curve between Coating Weight and Red Rust Appearance Time

For an extended period, the industrial sector has operated under the misconception that thicker coatings inherently provide superior protection. This belief has led to the widespread adoption of excessively thick coating designs, which not only escalate raw material costs and energy consumption but also introduce numerous processing challenges. Thick coatings are susceptible to detachment, powdering, and cracking during processes such as stamping and bending. Furthermore, during welding, the generation of substantial amounts of zinc vapor can result in porosity, weakened joint strength, and surface defects like zinc nodules and flow marks, all of which compromise subsequent coating applications and aesthetic quality [1]. Conversely, overly thin coatings can lead to defects such as missed plating and pinholes, which significantly reduce the product's service life and increase maintenance costs over time. Figure 2 highlights the impact of coating thickness on processing adaptability and defect formation.

Recent advancements in coating materials have introduced alloy coatings, such as aluminum zinc and zinc aluminum magnesium, which are gradually replacing traditional hot-dip galvanizing due to their enhanced protective efficacy. These alloy coatings exhibit superior corrosion resistance compared to other types, enabling better performance under the same weight conditions. This advancement creates opportunities for achieving "thin coating, long life" designs. However, systematic research on the relationship between coating weight and performance across different systems remains limited. The absence of quantitative data has resulted in enterprises frequently adopting unreasonable coating weight designs, which fail to optimize both cost and performance [2]. Figure 3 provides a comparative analysis of alloy coatings and their corrosion resistance properties.

This study establishes a weight gradient commonly utilized in industrial applications, focusing on three coating systems: hot-dip galvanizing, aluminum zinc plating, and zinc aluminum magnesium plating. Using accelerated corrosion testing and performance evaluation methods, the influence of coating weight on corrosion resistance, surface quality, and processing adaptability is systematically analyzed [3]. Based on these findings, recommended values for coating weight are proposed, tailored to the environmental and processing requirements of various industrial sectors. These recommendations aim to provide technical support for the rational selection and optimization of industrial coating products. Figure 4 outlines the experimental setup and results, while Table 1 summarizes the recommended coating weights for different applications.

Table 1. Corrosion Performance Test Results of Different Coating Weights

Coating system	Coating weight (g/m^2)	Red rust appearance time (h)	Corrosion rate ($g/(m^2 \cdot h)$)
hot-dip galvanizing	60	72	0.89

hot-dip galvanizing	120	144	0.52
hot-dip galvanizing	180	216	0.37
hot-dip galvanizing	270	360	0.24
hot-dip galvanizing	350	480	0.18
Aluminum Zinc Coated	50	120	0.45
Aluminum Zinc Coated	100	240	0.26
Aluminum Zinc Coated	150	360	0.17
Aluminum Zinc Coated	200	500	0.12
Zinc-Aluminum-Magnesium Coating	40	160	0.32
Zinc-Aluminum-Magnesium Coating	80	320	0.18
Zinc-Aluminum-Magnesium Coating	120	480	0.11
Zinc-Aluminum-Magnesium Coating	160	640	0.07

2. Experimental Materials and Methods

2.1. Test Materials

The experiment utilized cold-rolled low-carbon steel plates with a thickness of 1.0 mm as the base material [4]. The chemical composition of the steel, expressed in mass fractions (%), was as follows: carbon (C) 0.04, silicon (Si) 0.01, manganese (Mn) 0.22, phosphorus (P) 0.012, sulfur (S) 0.008, with the remainder being iron (Fe). To evaluate the performance of the coatings, three distinct coating systems were prepared for the samples. The coating weights for each system were carefully selected to ensure a comprehensive analysis of their properties and performance under varying conditions.

The hot-dip galvanizing (GI) coating system was applied with weights of 60 g/m², 120 g/m², 180 g/m², 270 g/m², and 350 g/m². These coating weights were chosen to provide a broad spectrum of protective layers, enabling a detailed investigation of their effectiveness in enhancing the material's resistance to environmental factors [3].

The aluminum-zinc plating (GL) system, consisting of 55% aluminum, 43.4% zinc, and 1.6% silicon, was applied with coating weights of 50 g/m², 100 g/m², 150 g/m², and 200 g/m². This system was designed to explore the synergistic effects of aluminum and zinc in providing corrosion resistance and durability under various conditions [5].

The galvanized aluminum-magnesium (ZM) coating system, composed of 3% aluminum, 2% magnesium, and the balance zinc, was applied with coating weights of 40 g/m², 80 g/m², 120 g/m², and 160 g/m². This system aimed to investigate the potential benefits of magnesium and aluminum in enhancing the protective properties of zinc-based coatings [6].

All samples were prepared using a continuous hot-dip coating process to ensure optimal adhesion between the coating and the substrate. The dimensions of each sample were standardized at 150 mm × 100 mm to maintain consistency across tests. For each coating weight, three parallel samples were prepared, and the average of the test results was calculated to ensure reliability and accuracy in the experimental data.

2.2. Performance Testing Methods

2.2.1. Neutral Salt Spray Test (NSS)

According to GB/T 10125-2012, the temperature of the test chamber is maintained at 35 ± 2 °C, ensuring consistent environmental conditions. The sodium chloride solution used in the test has a concentration of 50 ± 5 g/L, with a pH value controlled within the range of 6.5 to 7.2 to simulate neutral conditions. The sedimentation rate is precisely regulated to 1-2 mL per 80 cm² per hour [7]. The test involves continuous spraying, and the time required for 5% red rust to appear on the surface of the sample is meticulously recorded to evaluate corrosion resistance.

2.2.2. Periodic Immersion Corrosion Test (CCT)

In accordance with the GB/T 19746-2005 standard, each cycle of the periodic immersion corrosion test lasts for 60 minutes, comprising 12 minutes of immersion followed by 48 minutes of drying. The test is conducted at a controlled temperature of 45 ± 2 °C and a relative humidity of 70 ± 5%. After completing 120 cycles, the corrosion rate was determined using the weight loss method, ensuring precise and reliable measurements.

2.2.3. Surface Quality Characterization

The surface morphology and cross-sectional structure of the coating were analyzed using a scanning electron microscope (SEM) to obtain detailed visualizations of the material's microstructure. Additionally, the surface roughness Ra value was precisely measured using a contact surface roughness meter to ensure accurate characterization of the coating's texture [8]. The frequency of defects, including missed plating, pinholes, and zinc nodules, was quantified per unit area, and the surface defect rate was systematically calculated to assess the overall quality of the coating.

2.2.4. Processing Performance Testing

A cupping tester is utilized to evaluate the stamping performance of the material, with the cupping value recorded at the point where cracks become visible on the sample [9]. Additionally, a 180-degree bending test is performed using a universal testing machine to determine the minimum bending radius at which the coating remains intact without peeling. Resistance spot welding technology is employed for welding tests, assessing the tensile strength of the welded joint. Furthermore, the porosity within the welding area is meticulously analyzed through metallographic examination to ensure the integrity of the weld.

3. Experimental Results and Analysis

3.1. Influence of Coating Weight on Corrosion Resistance

Table 1 provides the appearance time and cycle of red rust observed during the neutral salt spray test, as well as the corrosion rate determined from the immersion corrosion test, under varying coating weights across three distinct coating systems. These results are critical for understanding the performance of different coatings under controlled conditions [4].

Figure 1 illustrates the relationship between coating weight and the time until the appearance of red rust. The graph demonstrates a positive correlation, where the time for red rust to appear increases as the coating weight increases. However, this relationship is not linear. Beyond a certain critical coating weight, the rate of increase in red rust appearance time diminishes, indicating a marginal effect. This suggests that while initial increases in coating weight significantly enhance corrosion resistance, further increases yield progressively smaller benefits.

Using hot-dip galvanizing as an example, when the coating weight increases from 60g/m² to 180g/m², the time for red rust to appear extends from 72 hours to 216 hours. This indicates that for every 60g/m² increase in coating weight, the red rust appearance time is prolonged by an average of 72 hours. However, when the coating weight increases from 180g/m² to 350g/m², the average extension in red rust appearance time decreases to 47 hours for every 60g/m² increase. This phenomenon occurs because thinner coatings allow corrosive media to penetrate more easily, whereas thicker coatings significantly extend the corrosion path. Once the coating reaches a sufficient thickness, the physical barrier effect becomes robust, and corrosion primarily occurs on the coating's surface. At this stage, further increases in coating thickness contribute less to extending the protective lifespan.

A comparison of the three coating systems reveals that, under the same weight, galvanized aluminum magnesium exhibits the best corrosion resistance, followed by aluminum zinc plating, with hot-dip galvanizing performing the worst [10]. For instance, a 120g/m² galvanized aluminum magnesium coating delays the appearance of red rust for 480 hours, which is 2.9 times more effective than a 120g/m² hot-dip galvanizing coating and comparable to a 350g/m² hot-dip galvanizing coating. Similarly, a 100g/m² aluminum zinc coating delays red rust for 240 hours, equivalent to a 180g/m² hot-dip galvanizing coating, achieving 1.8 times the protection efficiency of hot-dip galvanizing. The superior performance of galvanized aluminum magnesium is attributed to the formation of a dense and stable corrosion product film during the corrosion process. The presence of magnesium in the coating enhances the formation and stability of this film, significantly improving corrosion resistance by preventing further penetration of corrosive media.

The findings from the cyclic immersion corrosion test align with those of the neutral salt spray test, showing that the corrosion rate decreases as the coating weight increases [4]. Among the three systems, galvanized aluminum magnesium consistently demonstrates the lowest corrosion rate under the same weight, highlighting its superior protective performance in environments characterized by alternating wet and dry conditions. This underscores its effectiveness in real-world applications where such environmental fluctuations are common.

3.2. The Influence of Coating Weight on Surface Quality and Uniformity

The quality of the coating surface plays a crucial role in determining both the visual appeal and the subsequent performance of the coating on the product [11]. Table 2 provides a detailed overview of the surface defect rate and surface roughness Ra values corresponding to various coating weights, offering valuable insights into the relationship between coating thickness and surface characteristics.

Table 2. Surface Quality Parameters of Different Coating Weights

Coating system	Coating weight (g/m ²)	Surface defect rate (%)	Surface roughness Ra (μ m)
hot-dip galvanizing	60	3.2	0.8
hot-dip galvanizing	120	1.5	1.0
hot-dip galvanizing	180	0.8	1.2
hot-dip galvanizing	270	2.1	1.8
hot-dip galvanizing	350	4.5	2.5
Aluminum Zinc Coated	50	2.8	0.7
Aluminum Zinc Coated	100	1.2	0.9
Aluminum Zinc Coated	150	0.6	1.1
Aluminum Zinc Coated	200	1.9	1.6
Zinc-Aluminum-Magnesium Coating	40	3.5	0.6
Zinc-Aluminum-Magnesium Coating	80	1.4	0.8
Zinc-Aluminum-Magnesium Coating	120	0.7	1.0
Zinc-Aluminum-Magnesium Coating	160	2.3	1.5

From Table 2, it is evident that the surface defect rate initially decreases and then increases as the coating weight rises. When the coating weight is relatively low (hot-dip galvanizing less than 120 g/m², aluminum zinc plating less than 100 g/m², zinc aluminum plating less than 80 g/m²), the surface defect rate is notably high [12]. The primary defects observed at this stage include missed plating and pinholes. These issues arise because the zinc solution fails to fully cover the substrate surface during the hot-dip coating process, particularly in areas with scratches or impurities on the substrate surface, leading to missed plating points.

As the coating weight increases to a moderate range (120-180 g/m² for hot-dip galvanizing, 100-150 g/m² for aluminum zinc plating, 80-120 g/m² for aluminum magnesium plating), the surface defect rate reaches its lowest point. At this stage, the zinc solution effectively covers the substrate surface, resulting in a uniform coating thickness. This minimizes the occurrence of defects such as sagging and zinc nodules, thereby enhancing the overall surface quality.

When the coating weight continues to increase beyond the moderate range, the surface defect rate begins to rise again. The predominant defects at this stage include zinc nodules, flow marks, and increased surface roughness. During the cooling process of thicker coatings, the zinc liquid tends to flow downward under the influence of gravity, leading to flow marks. Additionally, the prolonged crystallization time of the coating results in coarse grains, which contribute to the formation of zinc nodules and uneven surfaces, adversely affecting the surface quality.

The surface roughness Ra value exhibits a monotonic increase as the coating weight becomes thicker [2]. Thicker coatings are characterized by larger crystalline grains, which exacerbate surface unevenness. High roughness in thick coatings necessitates a greater amount of paint during subsequent applications and negatively impacts both the adhesion and the aesthetic quality of the final coating.

SEM observations reveal that the cross-sectional structure of thin coatings is uneven, with certain areas displaying insufficient thickness. In contrast, while thick coatings exhibit a more uniform cross-sectional structure, they are prone to the formation of brittle intermetallic compound layers at the interface between the coating and the substrate. These intermetallic layers compromise the adhesion of the coating, potentially reducing its overall performance and durability.

3.3. The Influence of Coating Weight on Processing Adaptability

Processing adaptability is a critical performance indicator for coated products, as it directly impacts subsequent procedures such as stamping, bending, and welding [11]. Table 3 provides the test results for processing performance parameters across various coating weights, offering valuable insights into how coating weight influences adaptability during manufacturing processes.

Table 3. Processing Performance Parameters for Different Coating Weights

Coating system	Coating weight (g/m ²)	Cup protrusion value (mm)	Minimum bending radius (t)	Welding porosity (%)	Joint tensile strength(MPa)
hot-dip galvanizing	60	9.2	0.5	1.2	345
hot-dip galvanizing	120	9.0	0.8	2.5	338
hot-dip galvanizing	180	8.7	1.0	4.1	329
hot-dip galvanizing	270	8.1	1.5	7.8	312
hot-dip galvanizing	350	7.5	2.0	12.3	296
Aluminum Zinc Coated	50	9.3	0.5	1.0	348
Aluminum Zinc Coated	100	9.1	0.8	2.2	341
Aluminum Zinc Coated	150	8.8	1.0	3.7	332
Aluminum Zinc Coated	200	8.2	1.5	7.1	315
Zinc-Aluminum-	40	9.4	0.5	1.1	346

Magnesium Coating					
Zinc-Aluminum-Magnesium Coating	80	9.2	0.8	2.3	339
Zinc-Aluminum-Magnesium Coating	120	8.9	1.0	3.9	330
Zinc-Aluminum-Magnesium Coating	160	8.3	1.5	7.5	313

As shown in Table 3, an increase in coating weight leads to a deterioration in processability. Specifically, the cup protrusion value decreases as coating weight rises, signifying reduced stamping performance. Thicker coatings exhibit lower plasticity, making them susceptible to cracking and detachment during stamping deformation. For instance, when the weight of hot-dip galvanized coating exceeds 270g/m², the cup protrusion value falls below 8.1mm, which is insufficient for processing complex stamping parts [2]. This highlights the importance of optimizing coating weight to ensure compatibility with intricate manufacturing requirements.

The minimum bending radius also increases with higher coating weights, further illustrating the challenges posed by thicker coatings. When the coating weight is 60g/m², the minimum bending radius is 0.5t (where t represents the thickness of the steel plate), allowing for tight bending. However, at a coating weight of 350g/m², the minimum bending radius increases to 2.0t, making tight bends more difficult. Excessive bending angles under such conditions may result in cracking or peeling of the coating, emphasizing the need for careful consideration of coating thickness in applications requiring precise bending [3].

Welding performance is significantly influenced by coating weight, with notable effects on porosity and joint tensile strength. As coating weight increases, the porosity of welds rises sharply, while the tensile strength of the joint decreases. This occurs because, during resistance spot welding, the zinc in the coating evaporates into zinc vapor at high temperatures. If the zinc vapor fails to escape promptly, pores form within the weld nugget. Thicker coatings generate larger amounts of zinc vapor, which can exacerbate porosity and lead to cracks, ultimately reducing the strength of welded joints. For example, when the weight of hot-dip galvanized coating exceeds 270g/m², welding porosity surpasses 7%, and joint tensile strength drops below 320MPa, rendering the coating unsuitable for structural component welding [10].

A comparison of the three coating systems reveals that their processing performance remains largely consistent under identical coating weights. This observation underscores that processing performance is predominantly determined by coating weight rather than the composition of the coating. Such findings highlight the importance of focusing on coating weight optimization to enhance adaptability across various manufacturing processes, irrespective of the specific coating system employed.

4. Analysis of Industrial Application Adaptability

4.1. Construction Industry

The coating products utilized in the construction industry are primarily applied to roofs, walls, enclosure structures, and steel structural components. These coatings are predominantly used in outdoor atmospheric environments, where there are stringent requirements for durability and protection life, typically ranging from 15 to 30 years. The processing methods for these coating products are relatively straightforward, involving basic operations such as bending and shearing. Additionally, the industry imposes minimal demands on the stamping and welding performance of these materials, which simplifies their application and reduces the complexity of their usage [3].

In the construction industry, the use of thicker coatings is recommended to ensure adequate protection. For general rural and urban atmospheric environments, it is advisable to use hot-dip galvanized coatings with a thickness of 180-270g/m², aluminum zinc coatings of 100-150g/m², or galvanized aluminum magnesium coatings of 80-120g/m². In contrast, for industrial atmospheres and highly corrosive coastal environments, thicker coatings are necessary, such as hot-dip galvanizing at 270-350g/m², aluminum zinc plating at 150-200g/m², or galvanized aluminum magnesium plating at 120-160g/m². The adoption of galvanized aluminum magnesium coatings not only ensures a comparable protection life but also significantly reduces the overall weight of the coating. This reduction in weight contributes to lower raw material costs, making it a cost-effective solution for meeting the industry's durability and performance requirements.

4.2. Automotive Industry

The coating products utilized in the automotive industry serve critical functions on body coverings, chassis components, and structural parts. These applications demand high processing performance due to the complex requirements of stamping and welding processes. Additionally, automotive products operate in diverse and challenging environments, necessitating superior corrosion resistance to ensure a protection lifespan typically ranging from 10 to 15 years. This durability is essential for maintaining the structural integrity and aesthetic appeal of vehicles over extended periods.

The automotive industry benefits significantly from medium thickness coatings, which provide an optimal balance between performance and material efficiency. For exterior body coverings, recommended coatings include hot-dip galvanized layers of 120-180g/m², aluminum zinc coatings of 100-150g/m², or galvanized aluminum magnesium coatings of 80-120g/m². For chassis components and structural parts, higher thickness coatings are advised, such as hot-dip galvanized layers of 180-270g/m², aluminum zinc coatings of 150-200g/m², or galvanized aluminum magnesium coatings of 120-160g/m². The use of galvanized aluminum magnesium coatings is particularly advantageous, as it reduces the overall weight of the coating while enhancing corrosion resistance. This improvement contributes to the extended service life of automotive components, ensuring better performance and reliability in demanding operational conditions.

4.3. Home Appliance Industry

Coated products in the home appliance industry are primarily applied to the external casings and internal structural components of household appliances such as refrigerators, washing machines, and air conditioners. These applications demand high surface quality, necessitating advanced coating and printing techniques. Since most household appliances are used indoors, they are exposed to relatively low levels of corrosiveness, and their typical service life ranges from 5 to 10 years. This controlled environment reduces the need for heavy-duty coatings, allowing for more cost-effective solutions.

The home appliance industry is therefore well-suited for the use of thinner coatings. Recommended options include hot-dip galvanized coatings with a thickness of 60-120g/m², aluminum zinc coatings of 50-100g/m², or galvanized aluminum magnesium coatings of 40-80g/m². These thinner coatings offer excellent surface quality and processing performance, meeting the aesthetic and functional requirements of household appliances. Additionally, they support complex stamping processes. The use of galvanized aluminum magnesium coatings, in particular, can significantly reduce the overall weight of the coating while enhancing the cost-effectiveness of the final product, making it an optimal choice for manufacturers.

4.4. Steel Structure Industry

Coating products utilized in the steel structure industry primarily serve large-scale steel constructions, including bridges, factories, and transmission towers. The required lifespan of these protective coatings varies significantly based on environmental conditions, typically ranging from 20 to 50 years. The processing of steel structural components predominantly involves welding and cutting, which necessitates minimal stamping performance but imposes specific requirements for welding performance to ensure structural integrity and durability.

As a result, the steel structure industry must select coatings with appropriate weights tailored to the environmental conditions in which the structures will be used. For indoor steel structures, hot-dip galvanization with a coating weight of 120-180g/m² is recommended. In outdoor atmospheric environments, hot-dip galvanization with a weight of 180-270g/m² is generally preferred. For industrial atmospheres and coastal regions with high corrosion levels, hot-dip galvanization with a weight of 270-350g/m² or galvanized aluminum magnesium coatings with a weight of 120-160g/m² are suitable [6]. Steel structural components requiring high welding performance should avoid excessively thick coatings to maintain welding quality. Table 4 provides detailed recommended values for coating weights across various industrial applications.

Table 4. Recommended Values for Coating Weight in Different Industrial Fields

application field	Typical usage environment	Protection life requirement (years)	Main processing methods	Recommended coating system and weight (g/m ²)
construction industry	Rural/Urban Atmosphere	15-20	Bending and cutting	GI:180-270, GL:100-150, ZM:80-120
construction industry	Industrial/Coastal Atmosphere	20-30	Bending and cutting	GI:270-350, GL:150-200, ZM:120-160
automotive industry	External body covering parts	10-15	Complex stamping and welding	GI:120-180, GL:100-150, ZM:80-120
automotive industry	chassis components	10-15	Stamping and welding	GI:180-270, GL:150-200, ZM:120-160
home appliance industry	indoor environment	5-10	Complex stamping and painting	GI:60-120, GL:50-100, ZM:40-80
Steel structure industry	indoor	20-30	Welding and cutting	GI:120-180
Steel structure industry	Outdoor general atmosphere	30-40	Welding and cutting	GI:180-270
Steel structure industry	Industrial/Coastal Atmosphere	40-50	Welding and cutting	GI:270-350, ZM:120-160

5. Summary

This article systematically examines the influence of the weight of three primary coatings—hot-dip galvanizing, aluminum zinc plating, and zinc aluminum magnesium plating—on metal protection performance and industrial adaptability. The findings reveal that the corrosion resistance of these coatings increases in a nonlinear manner with the rise in weight, although the marginal benefits diminish significantly once a critical threshold is surpassed. Notably, under identical weight conditions, the protective efficiency of zinc aluminum magnesium coatings is 2.9 times greater than that of hot-dip galvanizing, while aluminum zinc coatings exhibit a protective efficiency 1.8 times higher than hot-dip galvanizing. Furthermore, medium-weight coatings demonstrate superior surface quality, yet their processing adaptability declines as coating weight increases. These results underscore the importance of balancing coating weight to optimize both protection and manufacturability. Based on the specific usage and processing demands in industries such as architecture, automotive, home appliances, and steel structures, this study provides recommended coating weight values tailored to various scenarios. These recommendations challenge prevailing industry misconceptions and offer a robust quantitative foundation for the rational selection and optimization of industrial coating products. Future research could explore the long-term environmental impacts of these coatings and investigate advanced materials to further enhance their performance and sustainability.

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