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GALVANIZING ASSOCIATION

Hot Dip Galvanizing Properties and Process Guide

Issue 2 | September 2025

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The durability of hot dip galvanized steel is particularly important in Australia and New Zealand where 85% of the population live within 50 kilometres of the coast.

Cover photo credit: University of Melbourne Arts West Building, ARM Architecture

Photo credit: Curtin University Yarning Circle, UDLA

Introduction

Hot dip galvanizing protects steel from corrosion by providing a tough metallurgically bonded zinc alloy envelope, which completely covers the steel surface and seals it from the corrosive action of its environment.

The hot dip galvanized coating provides outstanding abrasion resistance. If there is damage or minor discontinuity in the zinc alloy envelope, protection of the steel is maintained by the cathodic action of the surrounding galvanized coating.

The durability of hot dip galvanized steel is particularly important in Australia and New Zealand where 85 % of the population live within 50 kilometres of the coast. Corrosion rates for unprotected structural steel in these coastal regions vary from 1 µm to 1 mm per year, while the hot dip galvanized coating can protect structural steel by providing barrier and cathodic protection for over 50 years close to calm seas and over 30 years when the steel is at least 200 metres from surf beaches. In rural Australia, examples of the original hot dip galvanized overland telegraph poles installed in the 1870's to counter the termites can still be found with their original coating intact and protecting the steel, while on New Zealand's westcoast examples of the Eastbridge system manufactured with bolted connections are still in day-to-day use after nearly 60 years of operation.

The galvanized coating

The galvanizing process produces a durable, abrasion-resistant coating of metallic zinc and zinc-iron alloy layers bonded metallurgically to the steel base and completely covering the work piece.

No other coating for steel matches galvanizing's unique combination of properties and advantages:

1. For most classes of steelwork, galvanizing provides the lowest long-term cost and lowest lifetime carbon footprint. In many cases galvanizing also provides lowest initial cost.
2. The galvanized coating becomes part of the steel surface it protects.
3. The unique metallurgical structure of the galvanized coating provides outstanding toughness and resistance to mechanical damage in transport, erection, and service.
4. The galvanized coating is subject to corrosion at a predictably slow rate, between one-seventeenth and one-eightieth that of steel, depending on the environment to which it is exposed.
5. Galvanizing's cathodic protection for steel ensures that small areas of the basis steel exposed through severe impacts or abrasion, are protected from corrosion by the surrounding galvanized coating.
6. An inherent advantage of the process is that a standard minimum coating thickness is applied.
7. During galvanizing the work is completely immersed in molten zinc and the entire surface is coated, even recesses and returns which often cannot be coated using other processes. This includes all internal surfaces of hollow sections, vessels and containers being coated simultaneously.
8. Galvanized coatings are virtually 'self-inspecting' because the reaction between steel and molten zinc in the galvanizing bath does not occur unless the steel surface is chemically clean. Therefore, a galvanized coating which appears sound and continuous is sound and continuous.
9. Galvanizing is a highly versatile process. Items ranging from small fasteners and threaded components, up to massive structural members can be coated.
10. The mechanical properties of commonly galvanized steels are not significantly affected by galvanizing.
11. Galvanizing provides outstanding corrosion performance in a wide range of environments.
12. 'Duplex' systems of galvanizing-plus- paint or powder coatings are often the most economical solution to the problem of protecting steel in highly corrosive environments. Such systems provide a synergistic effect in which the life of the combined coatings exceeds the total life of the individual coatings if they were used alone.

The nature of corrosion

The corrosion of a metal is a physiochemical interaction between a metal and its environment which results in changes in the properties of the metal. Corrosion of metal results in the degradation of the metal to an oxidized form, for example the conversion of metallic iron to rust. For corrosion to occur it is necessary that the metal is in contact with an electrolyte, typically surface moisture including condensation, rain or ponding water. The electrolyte facilitates the flow of charge and matter and enables the electrochemical reaction to proceed. It is a key requirement for metal corrosion. Electrolytes serve to allow formation of small electrolytic cells on the metal surface, which then results in corrosion.

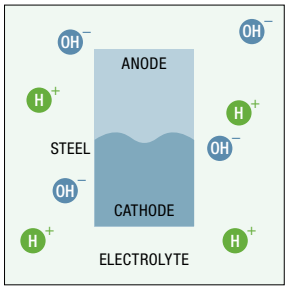
Another factor influencing the corrosion of a metal is the difference in electric potential on the surface of the metal, which can be caused by variations in composition, the presence of impurities, uneven internal stresses, or a non-uniform environment.

Each electrolytic cell comprises a positive electron-producing anode and a negative cathode. Negatively charged electrons flow from anode to cathode. The loss of electrons converts some atoms of the anode to positively charged ions which in turn react with negatively charged ions in the electrolyte. This reaction between anode and electrolyte causes disintegration and corrosion of the anode metal. There is no corrosion of the cathode metal.

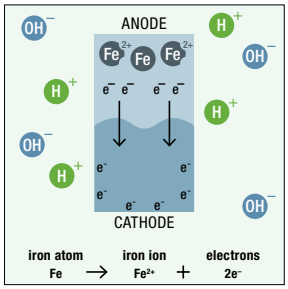
The corrosion of steel is described in more detail in graphics on the following page.

Corrosion of metal results in the degradation of the metal to an oxidized form, for example the conversion of metallic iron to rust.

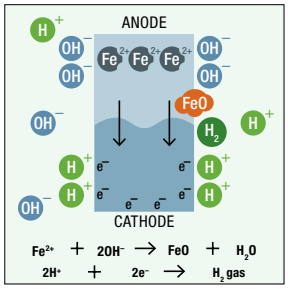
Corrosion of steel



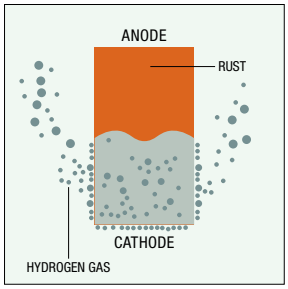
Differences in electrical potential on the steel surface are caused by non-uniformity of the surface composition, by surface moisture or by the electrolyte in which it is immersed. Small electrolytic cells are formed comprising anodes and cathodes.



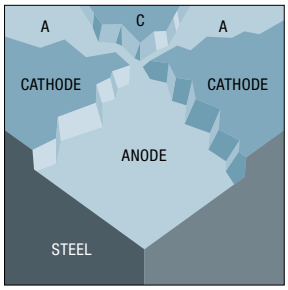
As the result of differences in electrical potential within the cell, negatively charged electrons flow from the anode to the cathode and iron atoms in the anode area are converted to positively charged ions.



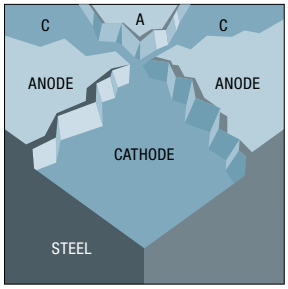
The positive iron ions from the anode attract and react with negatively charged hydroxyl ions in the electrolyte to form iron oxide (i.e., rust). Negatively charged electrons react at the cathode surface with positively charged hydrogen ions in the electrolyte to form hydrogen gas.



Under suitable conditions corrosion occurs at the rate of billions of complete reactions every second and soon results in a layer of rust appearing over the surface of the anodic area.



The anodic and cathodic areas on a piece of steel are microscopic in size. When greatly magnified, the surface might appear as the mosaic of anodes and cathodes visualised here, all electrically connected by the underlying steel. Corrosion occurs in the anodic areas.



As anodic areas corrode new material of different composition and structure is exposed. This results in changes in electrical potentials, causing anodes and cathodes to exchange roles, though not all at once, and areas previously not corroded are now attacked. These processes may continue until the steel is entirely consumed.

Hot dip galvanizing – Protecting steel 3 ways.

1. Barrier protection

Barrier protection, as its name implies, works by providing an impermeable barrier between the steel item and its environment. Galvanizing provides barrier protection in two ways: firstly, the galvanized layer provides a protective physical envelope around the steel; secondly, the galvanized layer also develops a **protective patina** on its surface upon exposure to the environment which serves to further extend the life of the galvanized coatings: by limiting oxygen availability.

The barrier protection qualities of galvanized steel are also enhanced by the fact that it is immune to ultraviolet radiation and thus will not degrade on exposure to the harsh environment of Australia and New Zealand. Most other corrosion protection coatings will degrade on exposure to solar radiation. This is usually one of the key limiting factors to the performance of such coatings.

The problem with conventional barrier protection, such as painting, is that it will not prevent corrosion if the base steel is exposed due to mechanical impact damage or abrasion of the coating. In fact, some barrier protection paints allow corrosion to proceed undetected in the form of under-film corrosion.

In the event of severe mechanical damage and exposure of the base steel to the environment, galvanizing also provides **cathodic protection**. Galvanizing performs in a similar way to other sacrificial protection systems, except in this case the sacrificial anode is distributed over the article to be protected and electrical continuity is assured through the metallurgical bond. The cathodic protection characteristics of galvanizing ensure that mechanical damage does not result in concealed under-film corrosion and potential catastrophic failure prevalent in some other protective coatings.

2. Protective Patina

A hot dip galvanized coating exposed to atmospheric conditions naturally responds to the exposure conditions (Figure 1). Upon withdrawal from the galvanizing bath, the molten zinc solidifies, reacts with atmospheric oxygen, and forms a zinc oxide at the rate of 0.01 to 0.02 µm/h. The conversion coating acts to stabilise the coating and assists in resisting the formation of wet storage stain, or zinc hydroxide (ß-$Zn(OH)_2$). In an urban or rural environment, the coating forms a water insoluble and stable zinc hydroxy carbonate patina ($Zn_5(CO_3)2(OH)_6$), developing over three to twelve months exposure. On exposure to a strong marine environment or environmental pollution, the patina converts into alternative stable patinas (see GAA/GANZ Advisory Note AN 05, *Wet storage staining*).

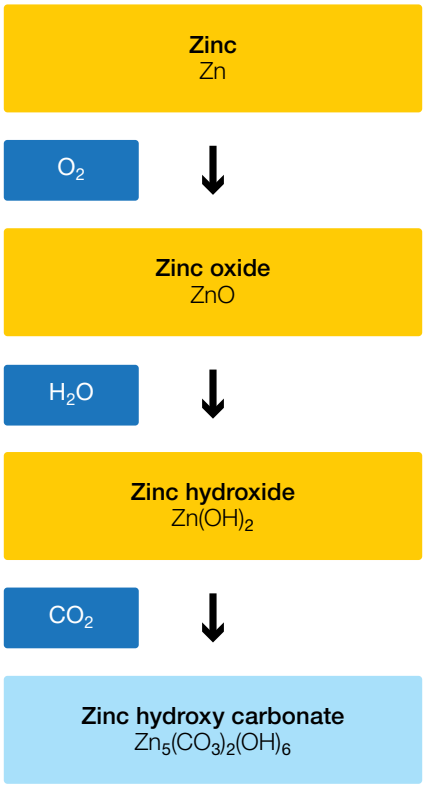
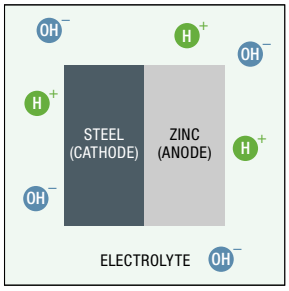


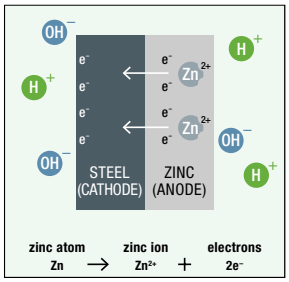
Figure 1: Schematic of zinc patina formation

3. Cathodic protection

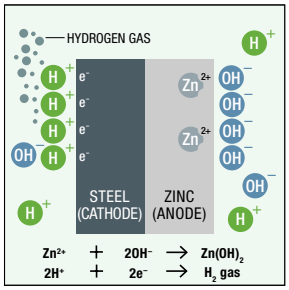
When zinc and steel are in contact in an electrolyte, differences in electrical potential develop and an electrolytic cell is formed. Zinc is more electrochemically active than steel. The zinc therefore becomes the anode in the cell, preventing the formation of small anodic areas on the steel surface.



As a result of the differences in electrical potential within the cell, negatively charged electrons flow from the zinc anode to the steel cathode and zinc atoms in the anode are converted to positively charged zinc ions.



At the cathode surface, negatively charged electrons attract and react with positively charged hydrogen ions from the electrolyte, liberating hydrogen gas. There is no chemical reaction between the steel cathode and the electrolyte. This phenomenon, which prevents corrosion of the cathode, is known as cathodic protection. The positively charged zinc ions at the anode surface react with negatively charged hydroxyl ions from the electrolyte and zinc is slowly consumed, providing sacrificial protection for the steel.

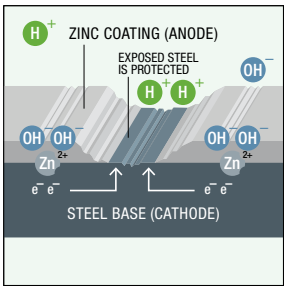


Galvanic series of metals in a sea water electrolyte

Figure 2 shows a series of metals arranged left to right in order of their electrochemical activity in sea water. Metals on the left of the scale provide cathodic or sacrificial protection to the metals to the right. The scale indicates that magnesium, zinc, and aluminium protect steel. In most normal applications magnesium is highly reactive and is too rapidly consumed. Aluminium forms a resistant oxide coating and its effectiveness in providing cathodic protection is limited.

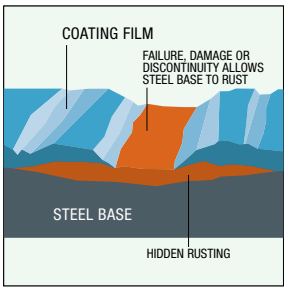
Cathodic protection of damaged areas

Where continuity of a galvanized coating is broken by cut edges, drilled holes or surface damage, small areas of exposed steel are protected from corrosion cathodically by the surrounding coating. Touch up may not be necessary for areas less than 5mm in diameter due to the cathodic protection provided and this sacrificial protection can continue for many years.



In service, zinc corrosion product tends to build up in the coating discontinuities, slowing the rate at which the surrounding coating is consumed to protect a damaged area. A practical example of this cathodic protection phenomenon is the uncoated internal threads of galvanized nuts which are protected from corrosion by the zinc coating on mating bolts and studs.

Most organic coatings and paint films depend on their sealing ability and in some cases anti-corrosive inhibitive pigments to protect steel from corrosion. They offer little or no protection to bare steel exposed by failure, damage, or discontinuity in the coating film. Corrosion starts and spreads rapidly beneath the coating.



When substantial coating damage has occurred to a galvanized coating during handling, fabrication or erection, coating repairs are necessary. See *AN 07 Repair of damaged hot dip galvanized coatings*.

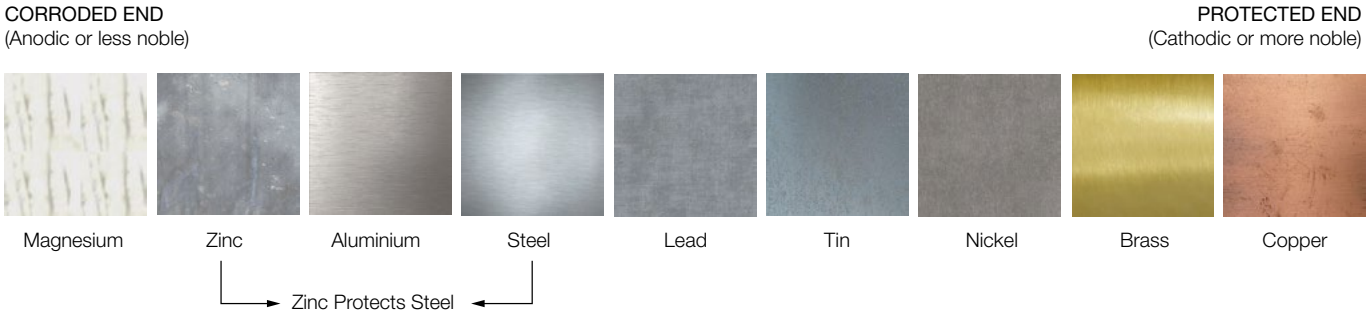


Figure 2: Electrochemical activity of selected metals in seawater showing magnesium, zinc, and aluminium will provide galvanic protection to steel.

Metallic zinc coatings for steel

There are a variety of zinc coatings used for corrosion protection, each having its own unique characteristics and performance.

Zinc coatings are applied to steel surfaces by hot dip galvanizing, electroplating, sherardizing, mechanical plating, painting with zinc-rich coatings and zinc thermal spraying (metallizing). Of these, the HDG process is by far the most widely used.

Following is a brief explanation of each type of zinc coating.

Batch hot dip galvanizing is a process where prepared items are galvanized by immersing them in molten zinc. The surface of the work is completely covered, producing a uniform coating of zinc and zinc-iron alloy layers whose thickness is determined principally by the thickness of the steel being galvanized. This is an important advantage of the batch galvanizing process as a standard minimum coating thickness is applied automatically regardless of the operator.

The molten zinc in the galvanizing bath reacts with and covers corners, welds, seals edges, and can penetrate recesses to give complete protection to areas which would be potential corrosion spots with other coating systems. The galvanized coating is slightly thicker at corners and narrow edges, giving greatly increased protection compared to organic coatings which thin out in these critical areas. Complex shapes and open vessels may be protected by hot dip galvanizing inside and out in one operation.

Articles ranging in size from small fasteners to structures hundreds of metres high may be protected. Large galvanizing baths, in conjunction with consideration of modular design or progressive dipping techniques (also known as “double dipping”) allow almost any structure to be galvanized, with greatly reduced maintenance costs and extended service life.

Small items can be dipped into the molten zinc in a container which is spun or centrifuged after withdrawal. This aids in removing excess zinc from threads and edges and provides a smooth, albeit thinner coating than other batch dipped items.

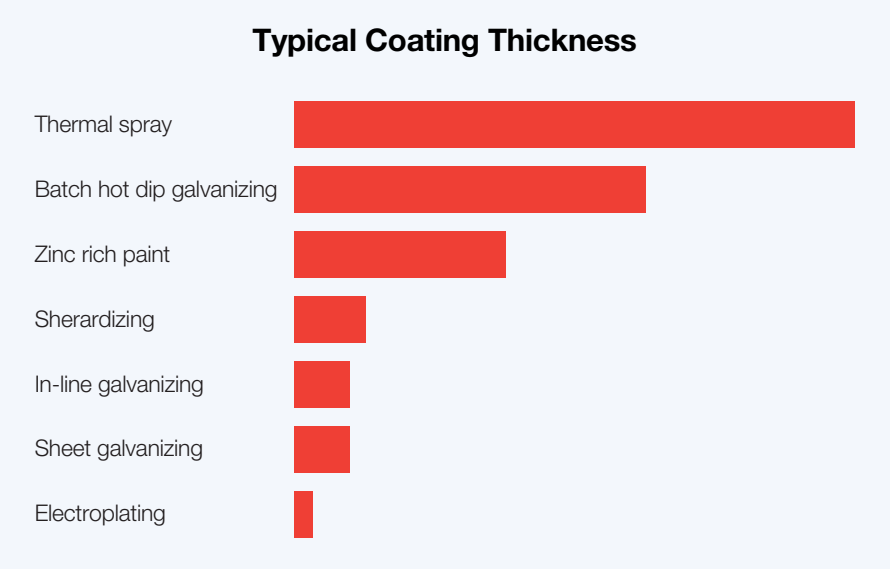


Figure 3: The typical relative thickness of common zinc coatings. The thickness of the coating is generally proportional to the durability of the article.

Continuous galvanizing or in-line galvanizing processes are used to coat steel sheet, pipe, and wire in specially developed galvanizing lines. These processes are widely used and typically allow accurate control of coating thickness, ductility, and other characteristics of the zinc coating, producing a broad range of products to suit the varying requirements of subsequent fabrication and end usage.

These products should not be confused with batch hot dip galvanized articles. In-line galvanized articles always produce thinner coatings than batch hot dip galvanizing for the same steel thickness and therefore offer less corrosion protection when exposed to the same environment.

Continuous galvanized products can usually be further processed by bending or roll forming, for example as purlins and girts, without damaging the coating. In addition, welded hollow sections formed from pre-galvanized strip are in wide use. Welds, cut ends, cut edges, and drilled or punched holes may need repair to restore the corrosion protection, depending on the application and environment.

Thermal spray or metallizing is the process of spraying semi-molten zinc, other metals or their alloys onto fabricated items using wire or powder heated by a flame, electric arc or plasma heat source. The process produces a slightly porous coating relative to hot dip galvanizing and does not form an alloy with the base steel.

Zinc spraying has the advantage that zinc coatings up to 250 µm thick, equivalent to approximately 1600 g/m^2 due to the lower density of the sprayed coating, can be applied on any steel, by either manual or mechanized methods and the process can be carried out in the factory or field. Thermal spray coatings adhere to the steel substrate through a mechanical bond. The steel surface must be prepared by abrasive blasting, and the coating cannot normally extend very deeply into any internal cavities. In addition, it is more susceptible to mechanical damage and application can be restricted at sharp edges, tight corners, holes and when there is poor surface preparation. The resulting zinc coating provides both barrier and cathodic protection for the underlying steel in the same way as a galvanized coating.

In most cases thermal spraying is more expensive than batch hot dip galvanizing for the equivalent section, but these processes are complementary and can be used in tandem on large structures.

Electroplating is a versatile, and effective method of applying a protective coating to small steel components. It is the most widely used method of applying metallic zinc coatings to small fasteners, particularly those with fine threads. However, fasteners used with batch hot dip galvanized articles should have comparable corrosion protection and composition to avoid bimetallic corrosion.

There is, in general, an economic upper limit to the zinc coating thickness which can be applied by electroplating, resulting in thinner coatings than other zinc application methods, and therefore electroplated zinc coatings are normally not used for outdoor exposure without supplementary coatings.

Sherardizing is a thermal diffusion coating process in which ferrous articles are heated in the presence of zinc dust which may also include additional elements to aid the process.

It is performed in closed, slowly rotating drums at temperatures ranging from 300 °C to 500 °C, but usually below the melting point of zinc (419 °C) where the zinc reacts with the ferrous surface to form zinc-iron alloy layers.

Sherardizing is most effective for small articles – typically those with fine threads, although the article size is limited only by the rotating drum size. The process also precludes hydrogen embrittlement, and it can therefore be used safely for very high strength steels above 1000 MPa.

Coating thickness can vary from 20 µm to 120 µm, although items are most commonly coated in the 20 µm to 50 µm range. The coating thickness is typically dependent on the time in the rotating drum and zinc availability, not on the steel thickness.

Mechanical plating or peen plating is an 'electroless' plating method used to deposit coatings of ductile metals onto metal substrates using mechanical energy and heat. It is used to plate zinc (sometimes alloyed with tin) onto steel parts, particularly threaded components and close tolerance items. The coating thickness is similar to electroplated items, although with porosity up to 40 %. It is possible to create thicker coatings, sometimes comparable with spun galvanized coatings. This method is often used for self-drilling screws used to fasten metal roofing and join roll-formed sections in housing.

As with electroplated coatings, care should be taken to ensure bimetallic corrosion is avoided through the use of compatible materials or suitable isolation techniques.

Zinc rich paint coatings consist of metallic zinc dust in organic or inorganic vehicle/binders. Surface preparation by abrasive blast cleaning or by using power tools to expose bare steel with a profile is necessary, and coatings may be applied by brush or spray. Zinc rich coatings are barrier coatings which also provide cathodic protection to small, exposed areas of steel, provided the steel surface is properly prepared and the paint conforms to the relevant Standard, e.g., AS/NZS 3750.9 or AS/NZS 3750.15. Suitable zinc rich paint coatings also provide a useful repair coating for damaged or worn galvanized coatings.

These products have the advantage over hot dip galvanizing in that they can be applied in the field and to any sized article. Some products can be applied with thicker coats or otherwise top coated to provide extra protection. The disadvantages of these products are susceptibility to transport and field damage, curing times, and cost for equivalent corrosion protection (usually as part of a system).

Comparative properties of selected coatings

The following tables provide a useful assessment of the properties and characteristics of various coatings for steel in a range of applications and environments.
(Ref: Thomas, R., *Rust Prevention by Hot Dip Galvanizing*, Nordic Galvanizers Association, 1980.)

Table 1

	Key	Hot dip galvanizing	Zinc spraying	Electro-plating	Zinc-rich paints	Mechanical plating
Alloying with base steel	(1)	A	D	D	D	D
Durability of coating	(1)	A	A	D	C	B
Cathodic protection	(1)	A	A	A	C	B
Resistance to mechanical damage	(1)	A	B	C	C	A
Resistance to abrasion	(1)	A	B	C	C	A
Piece size limitations	(2)	B	A	C	A	C
Risk of deformation	(2)	B	A	A	A	B
Ease of inspection	(1)	A	B	A	C	A
Initial costs	(3)	A	B	B	B	B
Maintenance costs	(3)	A	A	D	B	C
Suitability for painting	(1)	B	B	B	B	B

Key

(1)
A Very good
B Good
C Poor
D Very poor

(2)
A None
B Little
C High
D Very High

(3)
A Very Low
B Low
C High
D Very High

The galvanizing process

In Australia and New Zealand, hot dip galvanized coatings are generally applied to structural steel sections, beams and columns, fabricated steel assemblies, castings, steel reinforcement and miscellaneous steel components using AS/NZS 4680, *Hot dip galvanized coatings on fabricated iron and steel articles – Specification and test methods*, while threaded fasteners are hot dip galvanized using AS/NZS 1214, Fasteners – Hot dip galvanized coatings. Continuous, semi-continuous or specialised plants are used to apply the hot dip galvanized coating to semi-finished products such as wire, tube or sheet and coil and these processes and Standards are not covered here.

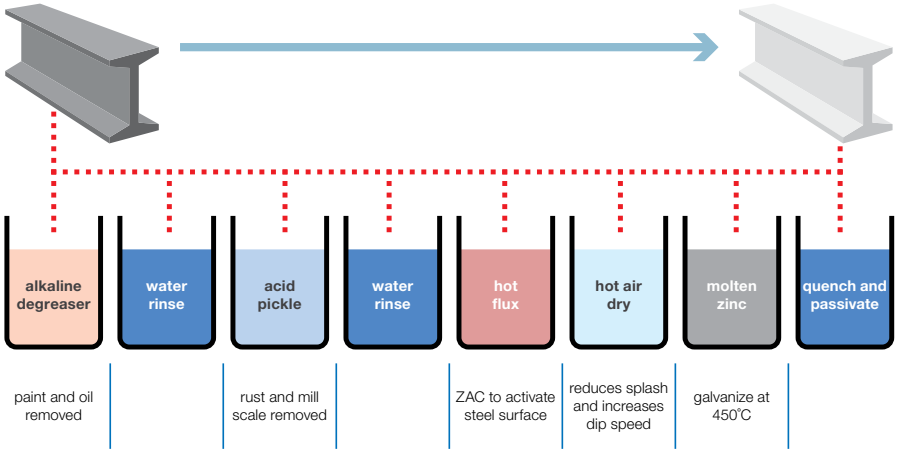


Figure 4: The galvanizing process is a simple, factory-controlled procedure which delivers consistent outcomes.

Pre-treatment

Pre-treatment of the steel is required to provide a chemically clean steel surface that can be presented to the molten zinc in the galvanizing bath, so that the metallurgical alloying reaction and bonding of the zinc coating to the steel can occur. For this to be achieved it is necessary to remove any organic surface contamination, such as oil and paint, so that the pickling process, using mineral acids, can be effective in removing surface oxidation or mill scale.

Abrasive blast cleaning

Abrasive blast cleaning is not normally used to prepare steel fabrications prior to galvanizing although there are times when it will be recommended for coating quality purposes.

Abrasive blast cleaning may be used to remove lacquers or varnishes, sand and other surface contamination that cannot be removed by the standard chemical methods. It is not always possible to blast internal surfaces and weld areas, and these areas especially should be visually inspected before galvanizing.

Abrasive blast cleaning is also used to prepare malleable and grey iron castings for galvanizing as adherent moulding sand is not readily removed by pickling.

Blasting with steel grit or garnet can be used to increase the surface profile of the steel in cases when a thicker zinc coating than the Standard is specified in the contract, to increase the service life of the product. See also *AN 02, Thicker galvanized coatings for specialised applications*.

Degreasing and paint removal

In Australia and New Zealand, the first step in preparing the steel surface is for the steel to be dipped into an alkali degreasing solution, generically known as 'caustic'. Hot caustic solutions are usually operated at about 10% sodium hydroxide (NaOH), at 70°C – 90°C though ambient temperature caustic solutions are also used.

Immersion times in this solution can vary, depending on the nature and degree of the contamination and the temperature and chemistry of the bath, and although immersion time can be less than 5 minutes, it can sometimes take longer than 24 hours to remove heavy grease or oil, paints, lacquers, and varnishes, particularly finishes encountered on some larger diameter pipe products.

Often it becomes more economical to pre-remove such adherent contamination by mechanical cleaning, and it is usual for the galvanizer to recommend that abrasive blast cleaning be employed for this purpose.

Alkali degreasing is usually followed by a rinsing step, to minimize carryover of the caustic solution to subsequent treatment processes.

Acid Pickling

During the acid pickling process, contaminants such as rust and scale are removed without attacking the underlying steel. Hydrochloric acid (HCl) is the most commonly used acid, although sulfuric acid (H_2SO_4) is also used. The H_2SO_4 pickling is slower, more likely to lead to pickling defects and forms sludge more readily than HCl but is consumed slower and is less volatile. The concentration of HCl will vary through its life, but will typically be within the range of 6 % to 14 % and is normally operated at ambient temperature. Most galvanizing plants have multiple acid baths of varying strengths. HCl is also used to strip faulty galvanized coatings from defective articles.

Some plants, including those with enclosed pickling systems or located in cooler climates and during winter months, heat the acid to 25 °C – 35 °C, as these higher temperatures can increase the pickling rate and lower iron solubility.

The required pickling time and result will depend on the condition of the steel received; the previous processing of the steel (e.g., prior blasting or painting); the amount of rust and mill scale (it will take longer to remove if thick); whether there are acid inhibitors or accelerators used; and the working conditions such as agitation of the parts. Pickling time can vary from as short as 10 to 20 minutes for articles which are otherwise 'clean' to several hours for heavily rusted articles.

Fluxing

The flux process is designed to activate the pickled and rinsed articles to ensure a fast and consistent reaction with the molten zinc when the product enters the bath.

The most common method for fluxing is achieved by dipping articles into an aqueous solution of zinc ammonium chloride, called pre-fluxing. Pre-flux tanks normally operate at 50 °C to 70 °C and at concentrations of 200 g/L to 300 g/L. If possible additional drying of the pre-fluxed work in a drying pit or tunnel, prior to dipping can be advantageous to galvanized quality, zinc and zinc byproduct reduction and reduced fume emissions.

Dipping

On immersion into the galvanizing bath the steel surface is wetted by the molten zinc and reacts to form a series of zinc-iron alloy layers. To allow formation of the coating the work remains in the bath until its temperature reaches that of the molten zinc, in the range of 445 °C to 465 °C. The temperature range is usually tightly controlled by the galvanizer as excessive variation leads to rapid wear of the kettle which is expensive and time consuming to replace or repair.

The work is then withdrawn at a controlled rate and carries with it an outer layer of molten zinc, which solidifies to form the relatively pure outer zinc coating.

The period of immersion in the galvanizing bath varies from a few minutes for relatively light articles, to 10 minutes or longer for larger structural members.

Galvanizing fasteners and small components by centrifuging

Fasteners and small components are loaded into perforated cylindrical baskets. After degreasing, acid pickling, and pre-fluxing, baskets are lowered into the galvanizing bath. After withdrawal from the molten zinc, baskets are raised without delay and spun or centrifuged at high speeds for 15 to 20 seconds. Excess zinc is thrown off, providing a smooth, uniform coating, and also maintains the integrity of any threaded items.

Threaded fasteners and washers are galvanized to AS/NZS 1214 and have the same coating thickness requirements as AS/NZS 4680 threaded and centrifuged articles (see Table 5).

Progressive Dipping (commonly known as “Double Dipping”)

Progressive dipping is a term used to describe the process of galvanizing an item which is longer, wider or deeper than the relevant available bath dimensions. In this procedure, the item is lowered into the bath so that half or more of its ‘over dimension’ is immersed in the molten zinc pool. When the galvanized coating has been achieved on the immersed section, the item is withdrawn from the bath and adjusted in handling so that the ungalvanized portion can be immersed in the bath.

In this procedure an overlap of zinc coating will occur, and this will normally have to be addressed in the case of visually obvious structural elements. Progressive dipping increases the possibility of dimensional instability (distortion) of fabricated items. Guidance in these cases should be sought from the galvanizer at the design stage.

Quenching and Passivation

Upon extraction from the galvanizing bath the item is then usually quenched, i.e. cooled in a tank of water, which may contain an inhibitor to provide added initial passivation of the zinc surface to prevent early oxidation. After quenching, any sharp points are removed by fettling and the galvanized item is ready to use. Unlike painted steel surfaces, there is no curing time required.

The resulting galvanized coating is tough and durable, usually comprising a softer, relatively pure zinc outer layer and a series of tough, hard zinc-iron alloy layers metallurgically bonded to the underlying steel, that completely cover the article and provide excellent resistance to abrasion.

An important advantage to the galvanizing process is that visual inspection shows the work is completely protected and gives an excellent guide to coating quality.

A summary of the coating thickness requirements of articles galvanized to AS/NZS 4680 are listed in Tables 3 and 4, while the requirements for centrifuged articles are shown in Table 5.

Hot dip galvanized coatings are generally applied to structural steel sections, beams, columns steel fabrications, rebar, and fasteners.

Metallurgy of galvanizing

When the cleaned and fluxed steel surface contacts the molten zinc of the galvanizing bath the protective flux layer is removed leaving a clean steel surface which is immediately wetted by the zinc. This results in a reaction between molten zinc and steel with the formation of zinc-iron alloy layers.

The photomicrograph below shows a section of typical galvanized coating which consists of a progression of zinc-iron alloy layers bonded metallurgically to the base steel, with the relatively pure outer zinc layer. Depending on the chemistry and surface condition of the article being galvanized, the structure of the coating can vary and create different appearances. See the section on *Appearance* for more details.

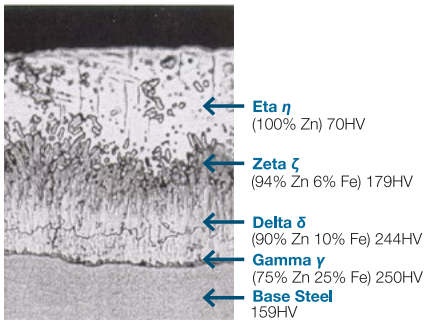


Figure 5: Typical galvanized coating showing the pure zinc outer layer, with zinc-iron alloy layers.

The structure of the galvanized coating and the relative thickness of its zinc-iron alloy layers have little or no effect on the protective life of the coating. Protective life depends on total coating thickness.

Galvanized coatings differ from paint coatings in that sharp edges are always fully coated, due to the way the zinc and steel react in the galvanizing bath.

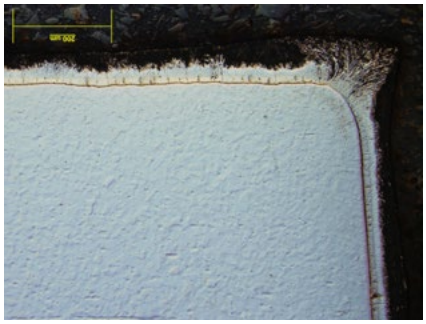


Figure 6: Galvanized coatings are slightly thicker at corners and edges as shown, an important advantage over most organic coatings which thin out in these critical areas.

Abrasion resistance of galvanized coatings

The photomicrograph (Figure 5) shows that the zinc-iron alloy layers are harder than the base steel, resulting in galvanizing's outstanding resistance to abrasion and mechanical damage. Abrasive or heavy loading conditions in service may remove the relatively soft eta layer of zinc from a galvanized surface, but the very hard zeta alloy layer is then exposed to resist further abrasion and heavy loading.

Abrasion tests show that if abrasion resistance for epoxy zinc-rich primers and most other conventional paints is taken as unity, polystyrene zinc-rich primers are 5 times better, zinc silicate primers 50 times better and hot dip galvanized steel 400 times better. This comparison was made by comparing the weight of silicon carbide (in grams) to erase 100µm of coating using a Taber Abraser, with results shown below.

Table 2

Coating	Weight of silicon carbide (g)	Relative performance
Epoxy zinc-rich primer	0.05 – 0.06	1
Polystyrene zinc-rich primer	0.2 – 0.3	5
Zinc silicate primer	2 – 3	50
Galvanized steel product	20 – 25	>400

The toughness of a galvanized coating makes it particularly suitable in situations where abrasion could be a problem either in assembly or in use. Conveyor systems, including buckets for quarried material and hoppers for coal wagons, are well suited. Galvanizing also limits the damage when spanners or other tools slip or when nuts turn on a galvanized surface during tightening. While the toughness of the galvanized coating does greatly simplify the handling of large, heavy sections and reduces potential remedial work, even when the base steel is exposed, the sacrificial properties of the galvanized coating will protect any small, exposed areas and help prevent unsightly and damaging rust.

Galvanized coating thickness

During the first minute of immersion in the galvanizing bath, zinc-iron alloy layers grow rapidly on the surface of the steels which are most commonly galvanized. The rate of alloy layer growth then diminishes and is finally very slow. When the work is withdrawn from the bath an outer layer of relatively pure zinc is also carried out. The total hot dip galvanized coating thickness formed depends on the mass and thickness of the steel being galvanized and on the chemistry and surface condition of the steel.

AS/NZS 4680 now specifies the minimum average coating thickness for normal and ultra-low reactive articles and for those articles that are centrifuged.

Table 3: Requirements for normal steel articles and castings that are not centrifuged

Article and its thickness	Nominal coating mass, g/m²	Minimum average coating thickness, µm
Steel: < 1.5 mm	320 g/m²	45 µm
Steel: ≥ 1.5 mm to ≤ 3 mm	390 g/m²	55 µm
Steel: > 3 mm to ≤ 6 mm	500 g/m²	70 µm
Steel: > 6 mm	600 g/m²	85 µm
Castings: < 6 mm	500 g/m²	70 µm
Castings: > 6 mm	570 g/m²	80 µm

Table 4: Requirements for ultra-low reactive (ULR) steel articles that are not centrifuged

Article thickness	Nominal coating mass	Minimum average coating thickness
≥ 1.5 mm to ≤ 3 mm	320 g/m²	45 µm
> 3 mm to ≤ 6 mm	390 g/m²	55 µm
> 6 mm	500 g/m²	70 µm

AS/NZS 1214 specifies the average coating thickness for threaded fasteners.

Table 5: Requirements for articles that are centrifuged

Article thickness	Nominal coating mass	Minimum average coating thickness
Articles with threads	355	50
> 6 mm diameter	360 g/m²	50 µm
≤ 6 mm diameter	180 g/m²	25 µm
Other articles (including castings)		
≥ 3 mm	390 g/m²	55 µm
< 3 mm	320 g/m²	45 µm

Factors influencing coating thickness.

The thickness, alloy structure and finish of galvanized coatings are influenced by:

1. Steel thickness
2. Surface condition of the steel
3. Composition of the steel

Increasing the period of immersion in the galvanizing bath in the normal galvanizing temperature range will generally not increase coating thickness by any significant amount.

Thickness of the steel: The easiest way to increase the coating thickness is to increase the thickness of the steel, as shown in Table 3 and Table 4. Very thick steels usually produce coating thicknesses significantly more than the minimum required in AS/NZS 4680 which provides additional durability benefits.

Surface condition of steel: Galvanizing is unique in that the coating appearance largely reflects the starting surface condition. Steel that is heavily rusted (pitted) or contains roll marks will usually show these features after galvanizing. Similarly, the quality of the weld, especially porosity and overlap, will show after galvanizing.

Abrasive blasting steel before galvanizing roughens and micro-hardens the blasted surfaces, producing thicker coatings. Application of abrasive blasting to achieve thicker coatings is generally limited by practical and economic considerations. Abrasive blasting of steel to achieve thicker coatings is covered in GAA/GANZ Advisory Note AN 02, *Thicker galvanized coatings for specialised applications*. Where increased service life or reduced maintenance is required, the use of a duplex (galvanizing-plus-paint) systems may also be an acceptable alternative.

Composition of steel: Both the silicon and phosphorous content in the steel have effects on the structure, appearance, and properties of galvanized coatings. This relationship, known as the Sandelin Curve, is based on decades of extensive research from around the world and is also published in AS/NZS 2312.2 in tabular form.

Thicker coatings can result from increased reactivity of the steel with molten zinc and rapid growth of zinc-iron alloy layers on the steel surface. In extreme cases, coatings can be very thick and more susceptible to handling damage, especially on the edges and these steels are known as reactive steels. These steels are not recommended for duplex coatings requiring sweep blasting due to the increased risk of delamination. Thinner coatings than the requirements in the Standard result from decreased reactivity of the steel with molten zinc, primarily due to very low silicon levels in the steel and sometimes from very smooth surfaces from machining, cold forming or cold rolling.

Normal steels and ultra-low reactive steels are now separately identified in AS/NZS 4680 with ultra-low reactive (ULR) steels defined as those with a silicon content of ≤ 0.01 %. All other steels are considered by AS/NZS 4680 as normal steels, however the coating thickness, alloy structure and appearance vary depending on the silicon and phosphorus content.

Table 6 and Figure 7 show typical galvanized coating characteristics based on steel composition and the reactivity relationship is described below.

- When the silicon content is ≤ 0.01 %, the steel has been deoxidised with aluminium, resulting in a higher aluminium content than normal steels. These steels are described as ultra-low reactive (ULR) to the galvanizing process and will produce coatings that are slightly thinner than those produced for normal steels of the same thickness (see Table 4). The appearance of the coating will be a typically bright metallic finish. These galvanized coatings are usually seen in ‘laser plate’ type flat sections (for example, BlueScope Steel’s Xlerplate Lasercut 250 plate). Some hollow sections also use ULR steels.
- When the silicon content is 0.01 % < Si ≤ 0.04 % and P < 0.02 %, the appearance will typically be a bright metallic finish and the coating thickness is normal. When present in combination with silicon, phosphorous can have a disproportionate effect, producing excessively thick galvanized coatings. The effect of phosphorous varies depending on the silicon content and reference should be made to Table 6 as a general guide to the effect.

- If the silicon content is 0.04 % < Si ≤ 0.14 %, very thick coatings may develop, which can sometimes lead to instability in the coating adhesion and cohesion. Galvanized coatings on these steels can be dull grey or patchy grey in colour with a rougher finish than usual. The coatings may be more easily damaged in handling if there is a strong zinc-iron alloy layer growth. These steels will usually require best practice venting and edge treatment design to be used successfully. Coating service life is proportional to the increased thickness and is unaffected by appearance, provided the coating is sound and continuous.
- When the silicon content is 0.14 % < Si ≤ 0.25 % the coatings are normally bright, although they tend to be mottled as the steel thickness increases. The coating thickness is usually always more than the requirements in Table 3 of AS/NZS 4680 and many hot rolled steels are in this category.
- When the silicon content exceeds about 0.25 %, the coating often tends to be grey in colour, increasing in thickness as the silicon content increases, and is always thicker than Standard requirements. This means the coating is more susceptible to damage, especially at the edges when chained for transport or otherwise roughly handled with fork trucks. However, in most cases, a silicon content above 0.25 % will be acceptable due to the increased durability benefits to the user. In some applications when a very long durability is desired, such as bridges, a higher silicon content is useful.

The thickness, adherence, and appearance of galvanized coatings on reactive steels are outside the control of the galvanizer. See also GAA/GANZ Advisory Note AN 35, *Steel composition and the effect on hot dip galvanized coatings*.

Assessment of the coating thickness for acceptance inspection is discussed in GAA/GANZ Advisory Note AN 37, *Acceptance inspection methods for hot dip galvanized coating thickness*.

Appearance

A galvanized coating is normally smooth, continuous, and free from gross surface imperfections and inclusions. However, it cannot be compared with the smooth surface of continuously galvanized sheet or coil since these are produced by a process which permits close control of coating thickness and appearance.

Over 30 different types of typical surface conditions that can occur on batch hot dip galvanized articles are discussed in detail in the Hot Dip Galvanizing Inspector Program, which has been run by the ACA in partnership with the GAA and GANZ since 2016.

These surface conditions include everything from ash deposits to zinc splatter, but by far the most common point of contention is the initial appearance or colour of the galvanizing. Irrespective of the initial lustre and colour of galvanized coatings, it does not affect the corrosion protection offered by the coating and over time the appearance of the galvanized coating will change to a light grey as it naturally weathers due to its patina formation.

Initial Appearance

From the batch galvanizing process, there are four different initial appearances a coating can develop based on its formation; bright, spangled, dull and mottled. Some galvanized articles may even develop more than one of these appearances across their surface.

Galvanized steel with a **bright** appearance is the most commonly seen and has become what people expect to see when looking at newly galvanized steel (Figure 8). This bright appearance is created by the solidification of unreacted zinc on top of zinc-iron alloy layers when it is withdrawn from the zinc bath (Figure 5).

Figure 8: Typical initial bright appearance of hot dip galvanizing

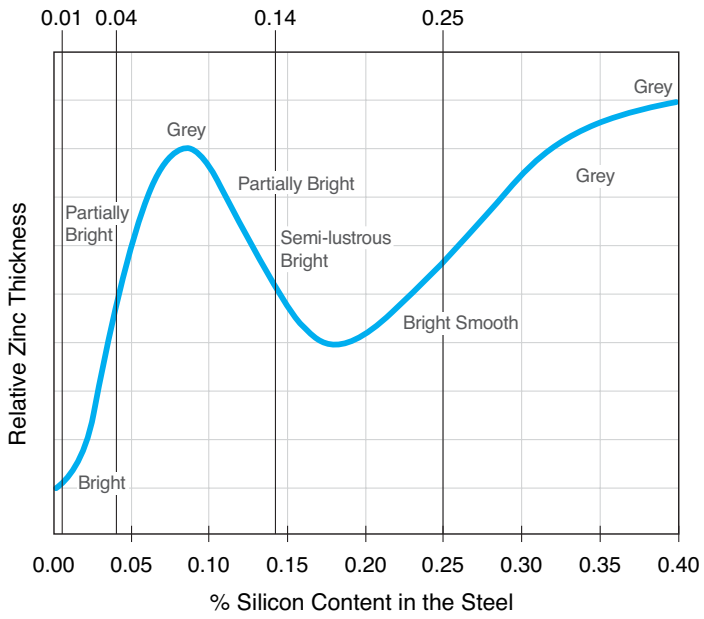


Figure 7: The Sandelin Curve showing the relationship with silicon and galvanizing coating thickness

Table 6: Typical coating characteristics related to steel composition

Category	Si & P relationship	Appearance	Resistance to mechanical damage	Thickness of coating
ULR	Si ≤ 0.01 % Si+2.5P ≤ 0.09 %	Typically bright	Excellent	Thinner than normal steels. See Table 4
A	Si ≤ 0.04% and P < 0.02% and Si+2.5P ≤ 0.09%	Typically bright	Excellent	Normal. See Table 3
B	0.14% < Si ≤ 0.25%	Typically bright, can tend to mottle or become grey with increasing steel thickness	Good	Always thicker than for normal steels (Table 3)
C	0.04 % ≤ Si ≤ 0.14%	Can be dark and coarse	Reduced	Much thicker than for normal steels (Table 3)
D	Si > 0.25%	Can be dark and coarse	Reduced	Coating increases in thickness as the Si content increases

Note: For category ULR and category A steels this applies for hot rolled sections. When galvanizing cold rolled steels in this category, the formula Si + 2.5P ≤ 0.04% should be applied.

A **spangled** appearance (Figure 9) has the same general coating structure and lustre as the bright appearance, with the only difference being how the zinc solidifies. For spangle to form, certain types of additional elements must be present in the zinc to allow the crystalline pattern to form. The concentration of these elements and the cooling rate of the article influence the size and shape of the crystal formation.

Figure 9: Shiny spangled appearance

Dull-grey coatings on newly galvanized steel are seen by some as an inferior coating, but this is an inaccurate assumption. A dull-grey colouring as an initial appearance is due the coating structure being entirely made of zinc-iron alloy layers, with no top layer of zinc.

While there is always zinc pulled up on top of the zinc-iron alloys when an article is withdrawn from the bath, it does not always just solidify in place as with bright and spangled appearances. Sometimes, the zinc will continue to react with the base iron and be totally converted, leaving only zinc-iron alloy at the coating's surface (Figure 10 and Figure 11). These coatings are usually thicker than their bright or spangled counterparts and in-turn will have a longer service life when placed in the same environment.

Figure 10: Hot dip galvanized coating on pipe changing to dull appearance while still being withdrawn from the molten zinc.

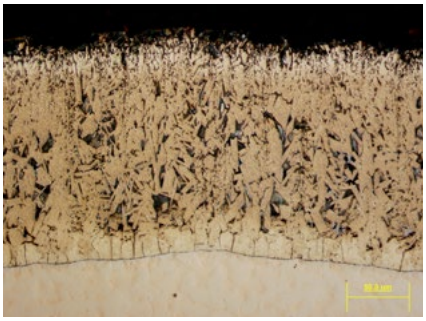


Figure 11: Micrograph of a dull hot dip galvanized coating with no outer zinc layer

A **mottled** appearance consists of a dull-grey circular type pattern around areas with a bright finish (Figure 12). It is also described as a cellular, web (spider web), or mechanical scale pattern and is often mistaken to be the result of cracks in the coating. This appearance occurs due to a partial presence of zinc-iron alloy layers at the surface of the galvanized coating (Figure 13), with the pattern believed to be due to the alloys being created at grain boundaries only and the remaining zinc solidifying without reacting. The appearance may occur in a localised area or extend over the entire surface of an article.

Figure 12: Mottled appearance of a newly galvanized pipe

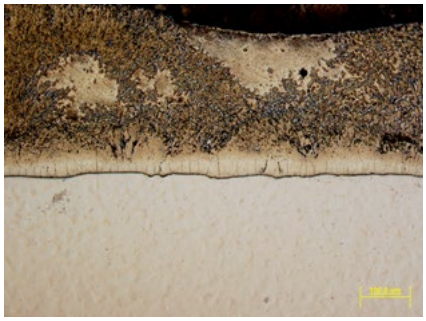


Figure 13: Mircograph showing part of the structure of a part dull, part shiny galvanized coating

Factors Influencing Initial Appearance

Why can't I specify the appearance I want? A simple question with a complicated answer. The commonly seen differences in initial appearance can rarely be controlled by the galvanizer, as it is highly dependent on the metallurgical reaction that occurs while the steel is immersed in the molten zinc. There are numerous factors that influence how a galvanized coating forms on any given piece of steel with the four main factors affecting the initial appearance being: steel composition (or chemistry), the surface condition of the article, its cooling rate and its design and fabrication, including venting and draining.

1. Steel composition (chemistry)

Certain elements in the steel, in particular silicon (Si) and phosphorus (P), affect the reactivity of the iron with molten zinc. The extent of the reactivity is dependent on the concentration of each element and this relationship was first described by Sandelin in 1940 (Figure 7).

The compositions that cause a prolonged or faster rate of reaction between the iron and molten zinc while the steel is submerged are known as 'reactive steels.' These steels usually result in mottled or dull appearances as well as having thicker coatings.

2. Surface condition

The condition of the article's surface contributes to the initial appearance of galvanizing. On a macro level, the surface of the galvanized coating typically matches or amplifies the article's contours. A good example is if the steel suffered from pitting corrosion before being galvanized, the coating will follow the pitted surface. On a micro level, the surface profile affects the reactivity of the steel with the zinc. A rougher surface with a higher surface area will generally result in increased reactivity and higher potential for dull or mottled appearance, while smoother surfaces are less reactive and more likely to have a bright appearance.

3. Cooling rate

The thickness of the steel will affect the cooling rate of the article when it is withdrawn from the molten zinc, with thicker steel retaining heat longer. This retained heat can allow the diffusion of the zinc to continue, creating more zinc-iron alloy and hence mottled or dull coatings are more likely to develop.

4. Design and fabrication, including venting and draining

The influence of design and fabrication on appearance generally relates to the adequacy of the venting and draining along with variations in section thicknesses and fabrication methods.

If vent and drain holes are small, it will take more time for the zinc to flow around or into the article, or both, when being dipped as well as more time to flow out during withdrawal compared to when the vent and drain holes are relatively larger. This also influences the time taken to cool the article and in turn can affect the surface appearance.

Ideally, thickness variations in fabrications should be minimised to help avoid distortion and this also helps to limit variations in initial appearance due to different cooling rates.

Another factor related to design and fabrication that affects appearance is when steels of significantly different chemical composition are used in the one article (Figure 14). This can lead to completely different initial appearances between adjacent areas, despite the whole article being dipped at the same time.

Assessment of the appearance of hot dip galvanized coatings for acceptance inspection is discussed in AN 52, *Acceptance inspection for hot dip galvanized appearance*.

Figure 14: Dull appearance on one section of the a fabricated handrail

Appearance Over Time

All metals, with the exception of noble metals like gold, oxidise in the atmosphere forming chemically stable corrosion products. In some cases these corrosion products create a passive film on their surface. For zinc, this natural passivation process results in a noticeable change to its appearance and generally occurs in three stages, as shown in Figure 1. The result of this process is generally the formation of a relatively insoluble zinc hydroxy carbonate film, known as the patina, which has a matte, light grey colouring. Everyday examples of commonly galvanized objects where this light grey appearance of the patina may be observed include handrails, street signposts, roadside guardrails, and light poles.

The development of the zinc patina happens over time and the speed of change will vary depending on the exposure environment. At the extremes, it can happen in as little as a couple of days or take as long as a few years, but for most common exposures in Australia and New Zealand it will develop over a few weeks or months.

Another appearance one may come across, usually on older galvanized coatings, is what's commonly referred to as bronzing. For a typical bright coating (whose structure is shown in Figure 5), bronzing will start after the eta layer is consumed and corrosion of the first alloy layer (zeta) starts. As there is a small percentage of iron in the alloy layers, small amounts of iron oxide (rust) are formed on the surface coating, creating a 'bronze' or 'rusty' appearance. This appearance can be confused with rusting of the base steel, however there is always a significant amount of galvanized coating remaining on top of the base steel when bronzing occurs. One method for determining the difference between bronzing and corrosion of the base steel is to take coating thickness measurements of the area.

Mechanical properties of galvanized steels

Strength and Ductility

Extensive research has shown the galvanizing process has no effect on the strength and ductility of the structural steels commonly galvanized.

Embrittlement

For steel to be in an embrittled condition after galvanizing is rare. The occurrence of embrittlement depends on a combination of factors. Under certain conditions, some steels can lose their ductile properties and become embrittled. Several types of embrittlement may occur but of these, only strain-age embrittlement is aggravated by galvanizing and similar processes. The following information is given as guidance in critical applications.

Susceptibility to strain-age embrittlement. Strain-age embrittlement is caused by cold working of certain steels, mainly low carbon, followed by ageing at temperatures less than 600°C, or by warm working steels below 600°C.

All structural steels may become embrittled to some extent. The extent of embrittlement depends on the amount of strain, time at ageing temperature, and steel composition, particularly nitrogen content. Elements that are known to tie up nitrogen in the form of nitrides are useful in limiting the effects of strain ageing. These elements include aluminium, vanadium, titanium, niobium, and boron. In Australia and New Zealand, these elements (excluding boron) are commonly included in structural steels.

Cold working such as punching of holes, shearing, and bending before galvanizing may lead to embrittlement of susceptible steels. Steels less than 3mm thick are unlikely to be significantly affected.

Hydrogen embrittlement. Hydrogen can be absorbed into steel during acid pickling but is expelled rapidly at galvanizing temperatures and is not a problem with components free from internal stresses.

Certain steels which have been cold worked and/or stressed can be affected by hydrogen embrittlement during pickling to the extent that cracking may occur before galvanizing.

Work by the GAA in 2017 showed that Bisalloy Grade 700 high strength steel to AS 3597 can be successfully hot dip galvanized. Like all steels to be hot dip galvanized, care should be taken with the edge treatment and thermal cut edges should be ground back to remove the thin oxide layer for best results. For these steels, the best results are achieved by abrasive blasting to a Sa 3 level of cleanliness prior to galvanizing and omitting the acid cleaning step to eliminate the risk of hydrogen embrittlement. The chemistry of this grade usually encourages a thick but adherent coating, providing exceptional durability compared to other grades.

High strength bolts to grade 8.8 and 10.9 are successfully hot dip galvanized all over the world.

Grade 8.8 bolts are not affected by hydrogen embrittlement and no change in process is required. Best practice with 10.9 bolts usually includes minimal or no exposure to the acid pickling step, requiring the bolts to be cleaned by blasting or rumbling to Sa 3 level of cleanliness prior to galvanizing. (See the *Bolting Guide* for more information)

The galvanizing process involves immersion in a bath of molten zinc at about 450°C. The heat treatment effect of galvanizing can accelerate the onset of strain-age embrittlement in susceptible steels which have been cold worked. No other aspect of the galvanizing process is significant.

Liquid metal embrittlement (LME) occurs when a combination of steel characteristics, fabrication detailing, and galvanizing processing variables create conditions for brittle cracking of a steel article during galvanizing. Such a combination of factors rarely occurs in practice. Control of the design (e.g., location of stress concentrations) and detailing of the component (e.g. steel quality, levels of residual stress, quality of welding, and position and finishing of drilled or punched holes and flame-cut surfaces), and the galvanizing conditions (e.g. pre-treatment conditions, dipping speed and zinc melt additives) can eliminate the risk of this condition occurring. If design and fabrication is carried out to the requirements of AS 4100 or NZS 3401.1 and AS/NZS 5131, then LME will not occur as all members of the GAA and GANZ carry out hot dip galvanizing practices that fully conform to the requirements of AS/NZS 4680.

The galvanizing process has no effect on the strength and ductility of the structural steels commonly galvanized.

Recommendations to minimise steel embrittlement

Where possible, use a steel with low susceptibility to strain age embrittlement. Following the requirements of AS 4100, NZS 3401.1 and AS/NZS 5131 will eliminate all embrittlement. Where cold working is necessary the following limitations must be observed:

1. **Punching.** The limitations specified in AS 4100 and AS/NZS 5131 on the full-size punching of holes in structural members must be observed. Statically loaded members and connections in fatigue must not have punched holes in steel thicker than 12mm. Material of any thickness may be punched at least 3mm undersize and then reamed or be drilled. In CC1 and CC2 categories of AS/NZS 5131, holes may be punched full size in material where f_y is up to 360MPa and where the thickness does not also exceed ($5600/f_y$) mm.
2. **Shearing.** AS/NZS 5131 does not permit steel thicker than 16mm to be sheared unless it is stress relieved prior to galvanizing, although typically, steel thicker than 16mm is thermally cut. Sheared edges to be bent during fabrication should have stress raising features such as burrs and flame gouges removed to a depth of at least 1.5mm. Before bending, edges should be radiused over the full arc of the bend.
3. **Bending.** Susceptible steels should be bent over a smooth mandrel with a minimum radius 3 times material thickness. Where possible hot work at red heat. Cold bending is unlikely to affect steels less than 3 mm thick.
4. **Critical applications.** It is better to avoid cold work such as punching, shearing, and bending of structural steels over 6mm thick when the item will be galvanized and subsequently subjected to critical tensile stress. If cold working cannot be avoided a practical embrittlement test in accordance with ASTM A143 should be carried out. Where consequences of failure are severe and cold work cannot be avoided, stress relieve at a minimum of 650°C before galvanizing. Ideally, in critical applications structural steel should be hot worked above 650°C in accordance with the steelmaker's recommendations.
5. **Edge distances of holes.** AS 4100 does not permit holes to be closer than 1.75 the fastener diameter from sheared or flame cut surfaces, 1.50 from the fastener diameter for machine cut, sawn or planed edges of rolled plate, flat bar or sections and from 1.25 the fastener diameter for the rolled edge of a rolled flat bar or section. The minimum hole distance can also be affected by Clause 9.3.2.4 (ply in bearing) of AS 4100.

Fatigue strength

Research and practical experience show that the fatigue strength of the steels most commonly galvanized is not significantly affected by galvanizing. The fatigue strength of certain steels, particularly silicon killed steels may be reduced, but any reduction is small when compared with the reductions which can occur from pitting corrosion attack on ungalvanized steels and with the effects of welds.

For practical purposes, where design life is based on the fatigue strength of welds, the effects of galvanizing can be ignored. Fatigue strength is reduced by the presence of notches and weld beads, regardless of the effects of processes involving a heating cycle such as galvanizing. Rapid cooling of hot work may induce microcracking, particularly in weld zones, producing a notch effect with consequent reductions in fatigue strength. Section 11 of AS 4100 provides for details of fatigue design of steel structures.

In critical applications, specifications for the galvanizing of welded steel fabrications should call for air cooling rather than quenching after galvanizing to avoid the possibility of microcracking and reductions in fatigue strength.

This is one of a series of Technical Guides on the durability, sustainability, application, design, process, bolting, welding and painting of galvanized steel. We also offer a range of free Advisory Notes on various aspects of hot dip galvanizing, along with a Durability Estimator App.

To download the Technical Guides, Advisory Notes and access the Durability Estimator App, go to https://gaa.com.au/technical-publications/

This content, and more, is also available as web content at our dedicated Design Manual website https://designmanual.gaa.com.au/

We provide trusted information on all aspects of galvanizing. A hub for engineers, architects, specifiers, fabricators, and consultants looking for information on the superior protection and unmatched advantages of adding a galvanized coating to steel.

By protecting steel from corrosion, hot dip galvanizing performs an invaluable environmental service. Hot dip galvanizing significantly prolongs the life of steel, contributing to the preservation of our natural resources.

We're here to help

Are you looking for more information or advice on the durability, sustainability, application, design, process, bolting, welding or painting of galvanized steel? Want advice on a specific situation or issue? You're in the right place! We would love to hear from you.

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