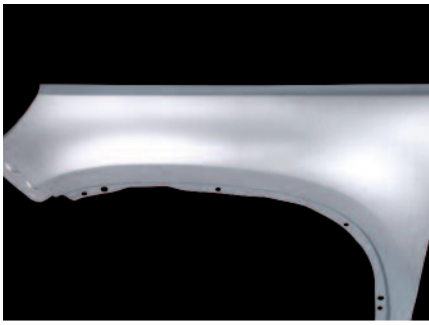
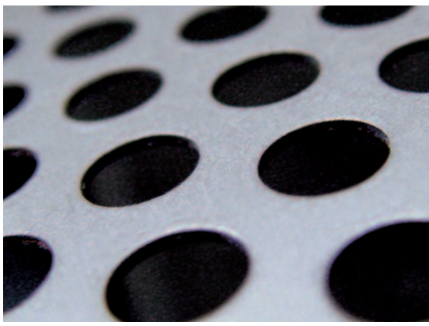
Zinc-Magnesium Coated Steel Sheets

Less is More





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Edition 2013

New Protection for Steel Sheets

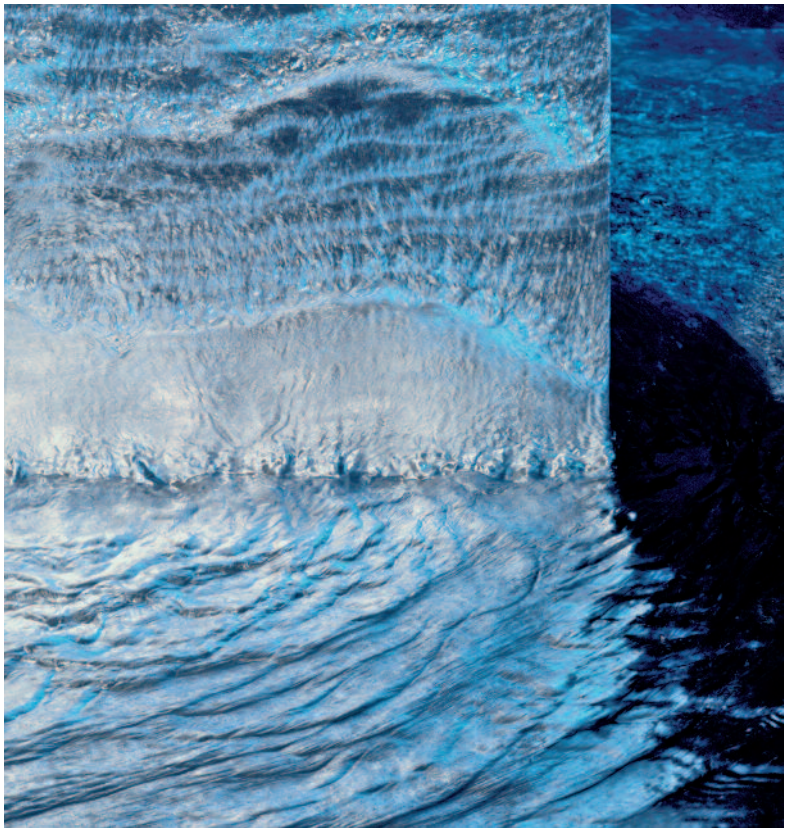
Thinner, more resistant, environmentally friendlier

Steel Sheets made of the strongest grades contribute to light-weight construction while at the same time making design engineering safer – as evidenced in automobile manufacturing, for example. The advantages: on the one hand, less raw material is required for production, while on the other, fuel consumption and CO_2 emissions drop considerably. Significant advances, however, are not only taking place in terms of steel grades – the steel industry is also developing innovative solutions for corrosion protection as well.

With the development of zinc-magnesium (ZM) coatings for commercial use, new levels of performance have been achieved in technical properties, as well as in climate protection, sustainability, and efficient resource utilisation.

Zinc-magnesium coated steel sheets offer notably improved corrosion resistance compared to conventional zinc-coated steel for many applications. In addition, increased protection at cut edges and at scratches is provided by its “self-healing” property. Thanks to these beneficial properties, products manufactured using strip steel coated with zinc-magnesium offer enhanced corrosion protection. Moreover, its excellent characteristics of subsurface migration of paint is noteworthy.

Steel sheets with a zinc-magnesium coating contribute to improving the ecological bottom line of steel products. This is attributable to lower consumption of valuable resources and energy, simplified processing, and extended product life, while the material can be recycled with no loss in quality at the end of each life cycle.



Steel strip exiting the hot-dip bath

Metallic Coatings
A success story

Although zinc-magnesium coatings were first introduced in 2007, the market is growing rapidly – with sales doubling almost annually. In fact, zinc-magnesium coated steel sheets represent the fastest-growing groups of steel products. This is the preliminary peak of a success story that began with zinc coatings about 60 years ago.

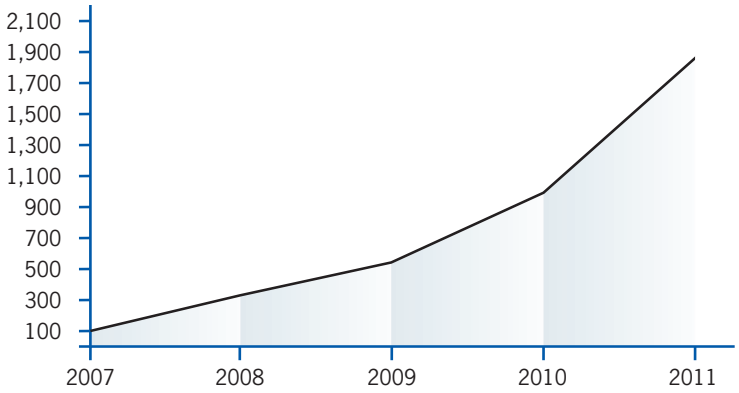
Economic Necessity

Corrosion – colloquially 'rust' – is an economic problem of huge dimensions. Reliable estimates put damage due to rust at about 100 billion Euros annually in Germany alone. The industrialised countries are forced to spend up to four per cent of their gross domestic product combating corrosion damage. Whether massive steel-beamed projects like bridges, or thin-walled components like façades out of steel sheets – without corrosion protection, they would require expensive maintenance and have short life spans. The numbers mentioned make it clear that investments in preventative corrosion protection are meaningful and economically worthwhile.

Continuous Galvanizing

Various grades of steel are used in making steel sheets, depending on the application involved. Different protection systems have been developed to protect the steel from corrosion. In order to protect industrial-scale big quantities of steel sheets from corrosion, one of the most important processes is continuous hot-dipping, also referred to as continuous strip galvanizing. Instead of zinc-plating individual parts, strips are integrally provided with metallic coatings by steel producers.

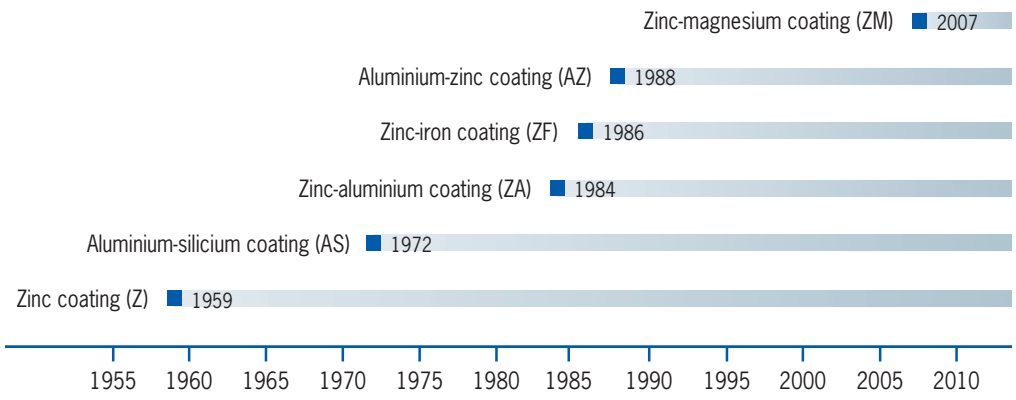
Index of market growth for zinc-magnesium coated steel sheet (2007 = 100)



Tailored Properties

Zinc (Z) as a coating consists of about 99 per cent zinc and was first employed for corrosion protection of sheet steel in 1959. Aluminium-silicon coatings (AS), using an aluminium alloy containing about ten per cent silicon were introduced in 1972 for high-performance thermal applications. Zinc-aluminium coatings (ZA) followed in 1984. In addition to zinc, these contain about five per cent aluminium and possess excellent forming properties. Zinc-iron coatings (ZF), which are produced by diffusion annealing and usually contain eight to twelve per cent iron, providing good weldability, arrived on the market shortly thereafter and have been employed in the automobile industry in particular. Aluminium-zinc coatings (AZ) appeared on the market in 1988. In addition to zinc, these contain about 55 per cent aluminium, as well as small amounts of silicon. Thanks to their even greater corrosion resistance, AZ coatings excel particularly in non-painted condition, as required in roofing and façade applications for example. Zinc-magnesium (ZM) represents the newest advance in metallic coatings (2007) and combines a range of especially advantageous properties.

Coil-stock



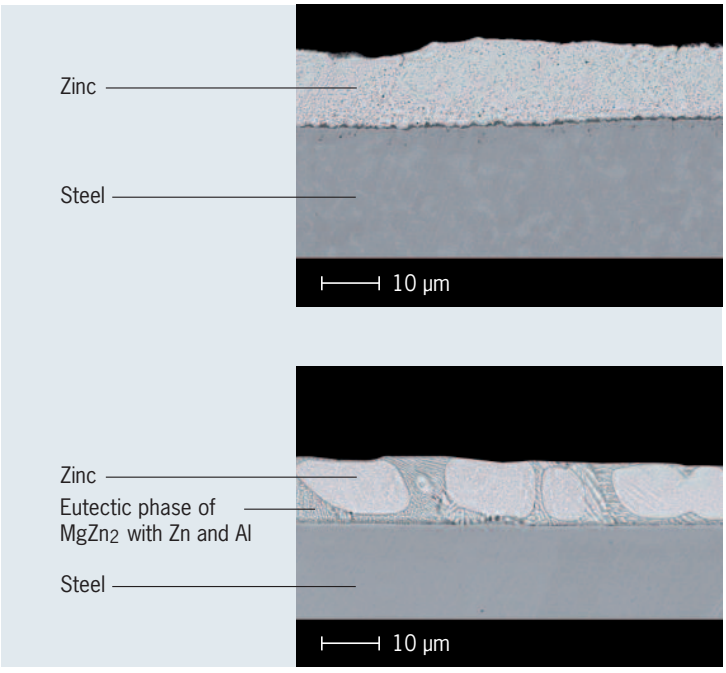
Introduction of metallic coatings in the European markets

Properties for the Future

More corrosion-resistant and more conserving resources

In the past, there was a simple maxim: the thicker the zinc coating on steel sheet, the better the protection against corrosion. However, the increasing scarcity of raw materials, climbing energy prices, and the rising global requirements for environmental protection led to rethinking. Optimizing of metallic coatings for corrosion protection was needed. The goal was challenging: improve corrosion protection and achieve a broad range of processing properties, while using reduced coating thickness so that the material could be adapted and employed for as wide a range of end products as possible.

Cross-section from samples of zinc and zinc-magnesium coatings



Paradigm Change

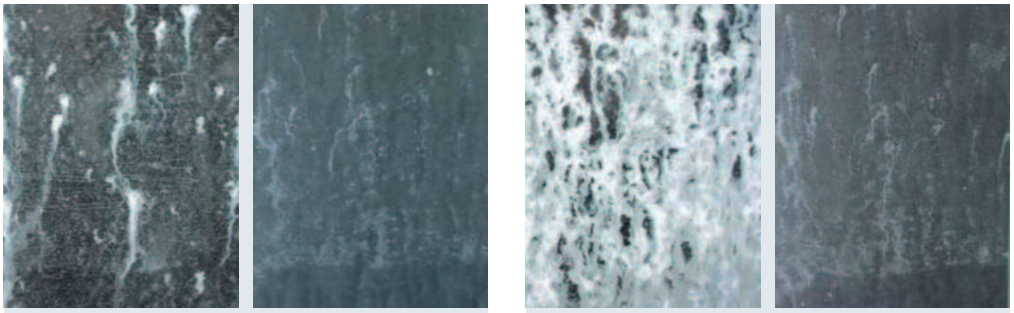
With the development of zinc-magnesium coatings, the steel producers have met these challenges. Despite the reduced amount of material employed and lower energy expenditures in manufacture, improved corrosion protection with a simultaneous reduction in the coating thickness was achieved for many application areas. In addition, excellent downstream processing properties were obtained.

Alloy Composition

The zinc-magnesium alloy used in the coating contains in addition to zinc up to eight per cent magnesium and aluminium in total. A cross-section of samples viewed under the microscope reveals the differences between zinc and zinc-magnesium coatings. The magnesium-aluminium admixture can be recognised as darker phases beside lighter zinc grains. What are the results?

Examination at the Atomic Level

The combined action of oxygen and water is the primary cause of corrosion. The surface of every metal exposed to air is covered by a metal oxide layer. However, the thickness, chemical reactivity, and electrical conductivity of this oxide layer are different for every metal. On alumini-



Zinc and zinc-magnesium coatings in salt spray test

um, for example, this layer is inert and electrically non-conducting. As a result, the aluminium beneath the oxide layer stays protected from corrosion. With iron and certain grades of steel, this layer is electrically conductive. If it comes into contact with oxygen and water in the form of condensation or rain, e.g., oxidation continues unimpeded into the metal beneath the oxide layer. Put simply, rust continues to eat into the material.

Half a Coating Thickness

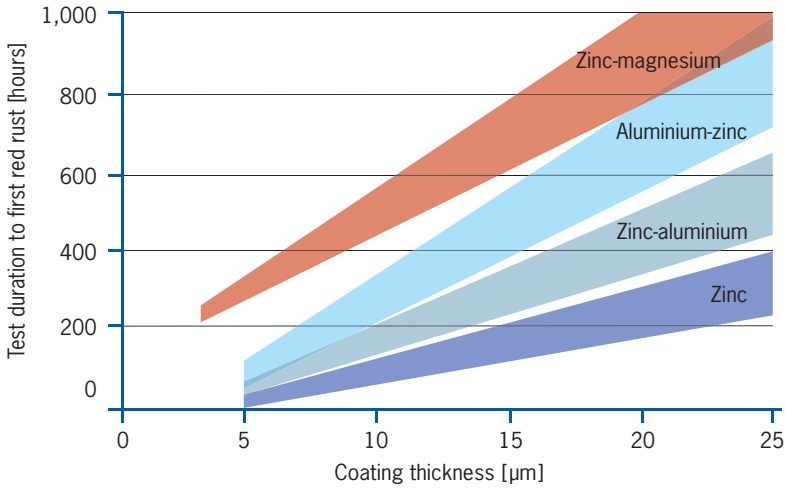
Zinc-magnesium is an optimal anti-corrosion coating for steel. This outstanding protection is based on the effects of two significant mechanisms: cathodic protection and barrier effect.

The general cathodic protection afforded by a zinc-magnesium coating is comparable with that of a conventional zinc coating. However – and this is what makes the difference – the zinc-magnesium-aluminium alloy additionally builds up a very dense and highly ordered oxide barrier layer against corrosion of the coated surface. It displays a significantly improved barrier effect against proceeding corrosion. The result: only half as much coating thickness is required for zinc-magnesium compared to zinc, depending on the kind of corrosive load. In other words, it is a distinctly thinner coating – one that nevertheless displays comparable corrosion resistance especially in salt air environments.

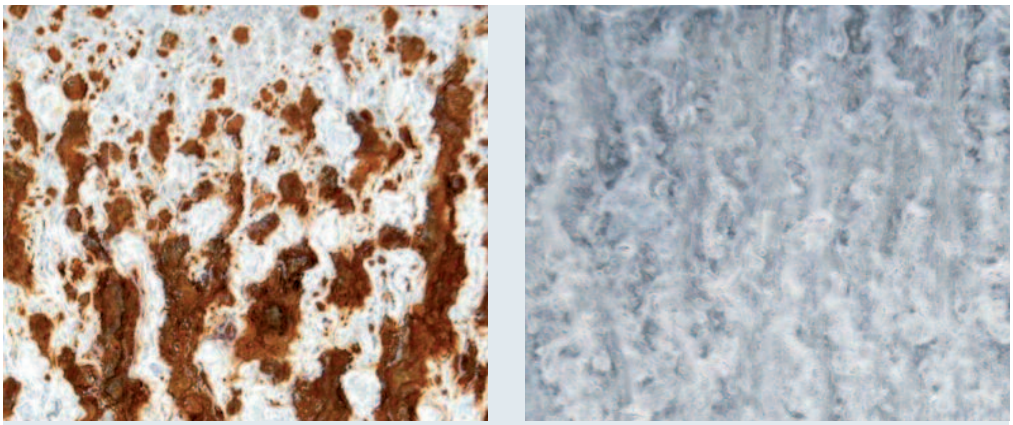
Considerably Higher Corrosion Resistance

In order to test the corrosion resistance of materials, they are exposed to extreme conditions in the laboratory. These conditions, however, cannot exactly simulate all environmental conditions. In the salt spray test, galvanized steel sheet samples are sprayed with a solution of table salt. Differences are readily apparent to the naked eye. While the zinc-coated samples are almost completely covered in white rust after 48 hours, those with the zinc-magnesium coating remain almost unchanged in appearance. The first red rust appeared in the zinc coating after

Various metallic coatings in salt spray test



Bright corrosion of zinc and zinc-magnesium coatings



Zinc (coating thickness: 10 µm) | Zinc-magnesium (coating thickness: 7 µm)

336 hours

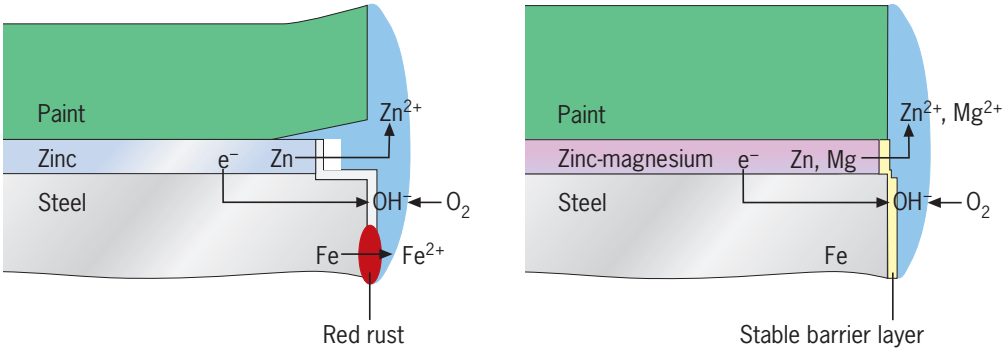
72 hours. In contrast, the samples with zinc-magnesium coating lasted 500 hours. That means the zinc-magnesium coated steel sheet samples exhibited about seven times higher corrosion resistance in the salt spray test for the same coating thickness.

Excellent Barrier Effect

Zinc-magnesium coatings offer an additional important advantage in the unpainted as well as in the painted condition. The zinc-magnesium complex reacts at cut edges or in scratches by forming a solid barrier layer. The result is that the reaction of oxygen and iron is slowed. Damages to the surface get in effect "healed". For painted surfaces, the subsurface migration, e.g. around scratches, is considerably reduced.

The improved corrosion protection of zinc-magnesium can already meet the increasingly strict EU guidelines. Approvals for Class III corrosion protection of materials in accordance with DIN 55928-8 and Corrosivity Category C3 in accordance with DIN 55634 have been issued.

Schematic representation of the corrosion reaction



Galvanized steel sheet with organic coating

Zinc-magnesium coated steel sheet with organic coating

Super-Thin Coating
Big Advantages

Users gain a wealth of advantages with zinc-magnesium coatings – for almost consistent converting process. Depending on the purpose and employment of the end product, different variants and new combinations of them are available to processors.

The Same Barrier Performance with Thinner Coating

For products with sufficient barrier protection already, zinc-magnesium coatings allow lower coating thickness.

At the same time, a zinc-magnesium coating of the same thickness as a conventional zinc coating enjoys significantly higher corrosion resistance. This permits processors to offer products with extended lifetime.

Products with Greater Stiffness

With the reduced coating thickness matched by the same good corrosion protection properties, processors can choose strip with a thicker steel substrate for the same coil weight. This means the product stiffness is enhanced for the same product thickness.

More Square Meter of Steel Sheets for the Same Tonnage

For products that do not have to meet regulatory approvals, a second variant is to maintain the same gauge of steel substrate. The total thickness of sheet is less due to the reduced coating thickness – and this means more square meter of steel sheets for the same tonnage. In the case of common sheet gauges, this area advantage can run up to four per cent.

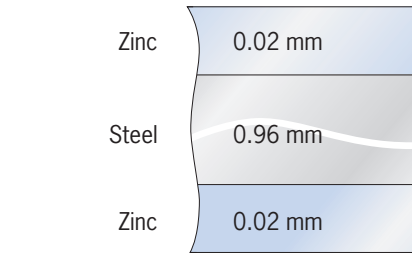
Visually Attractive as well

Zinc-magnesium coated steel sheets possess a homogenous, metallic, semi-matte to gloss surface.

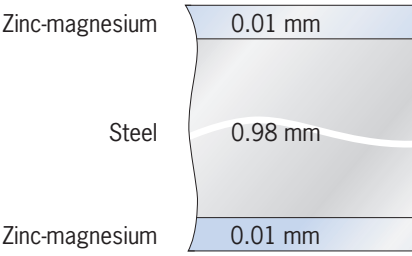
Overview of Advantages

- Excellent corrosion performance, especially in salt air environments
- Greater flexibility in product designing and product properties with respect to corrosion resistance
- Savings in material for the same corrosion performance
- “Self-healing” ability at cut edges and around scratches
- Stronger surface with reduced abrasion, thereby much better formability
- For roll forming on a case-by-case basis, abstaining from lubricants, reducing clean-up effort of tools and minimising waste disposal
- Longer lifetime and useful lifetime of products
- Conservation of valuable resources
- Environmentally-friendly and energy-efficient production

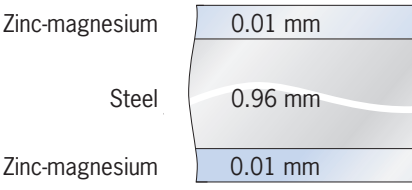
Examples of the same level of protection



Standard steel sheet



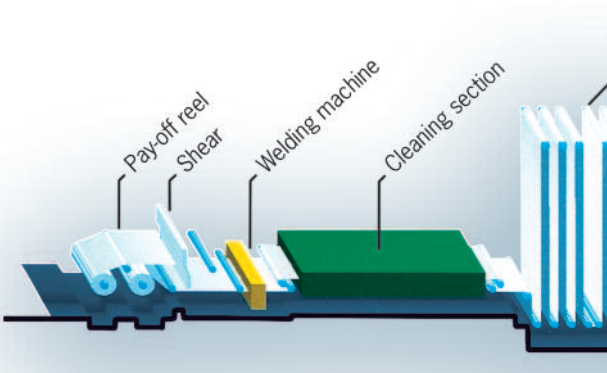
Variant 1:
higher stiffness for the same total sheet thickness



Variant 2:
more square meter per ton of steel for the same stiffness

High-Precision Production
Finishing continuously

Zinc-magnesium coated steel sheets are manufactured in continuous hot-dip coating lines using the same process as conventional metallic coatings.



Hot-dip coating plant for manufacturing steel sheet with zinc-magnesium coating

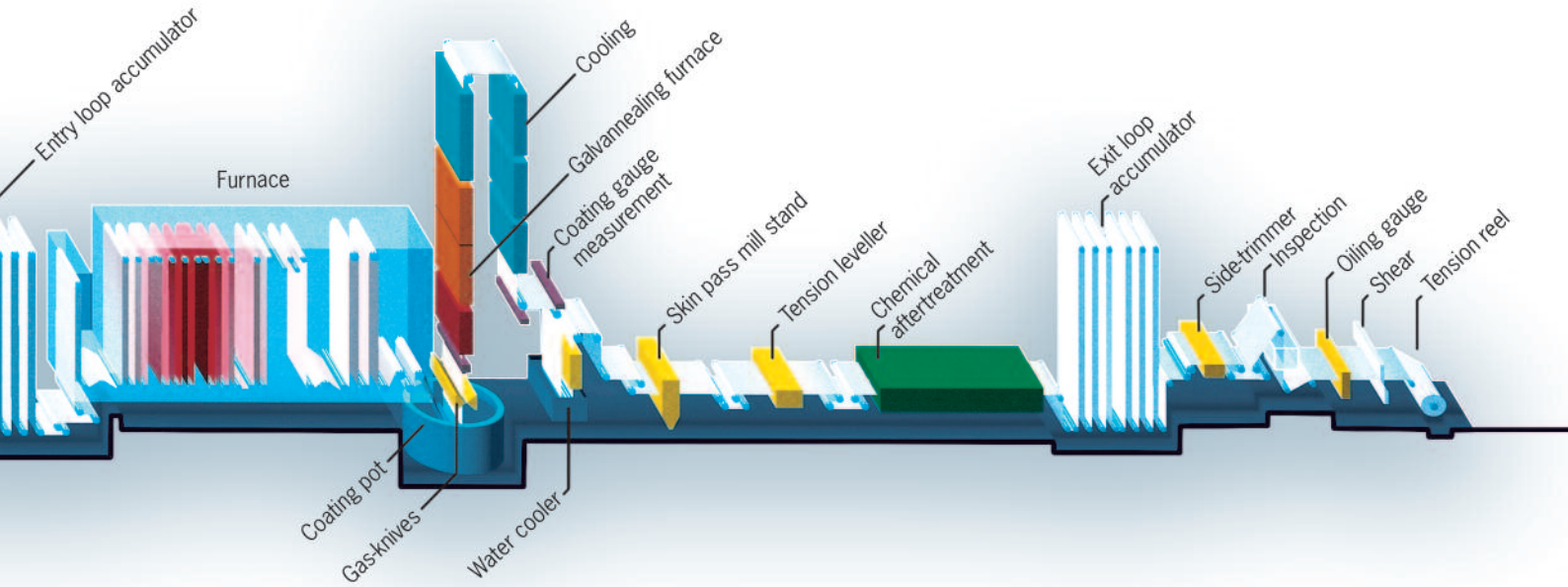
Continuous Strip
The steel strip is delivered in coils. It is joined by a welding machine into one continuous strip that runs through the entire coating line and is cut again into the individual coils afterwards.

Annealing
Initially, the strip must be warmed in an annealing oven in order to set the desired mechanical properties of the substrate during re-crystallisation. The cold rolled hardened strip – the strip has been cold rolled before hand – acquires a softer structure. Simultaneously, the surface composition is altered and allows better wetting in the subsequent galvanizing process.

Galvanizing
Here, the strip proceeds through the zinc pot containing the molten coating alloy. The strip is led through the zinc-magnesium bath via guide rolls and leaves it vertically. The coating thickness can be set by high-precision gas knives. Integrated control systems assure uniform coating.

Cooling and Temper Rolling
The strip is cooled down in multistage air and water cooling zones. Subsequently, it can be cold rolled in a skin-pass mill stand for setting the desired material properties and surface structure. E.g., the coated strip can be provided with a pre-defined surface roughness, giving improved forming and painting properties lateron.

Surface Treatment
The strip can be oiled, sealed, chemically passivated or gets a subsequent organic coating. Finally, it is cut at the previous weld joins and wound again into individual coils.



Available Dimensions

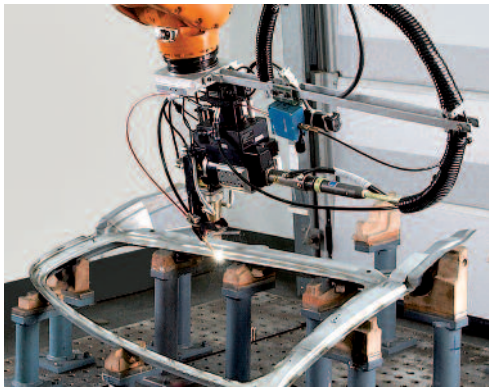
Zinc-magnesium coated steel sheet is usually offered in thicknesses of 0.4 to 3.0 mm. The available coatings run from 70 to 350 g/m^2, corresponding to thicknesses of approximately 5 to 25 µm per side. The range of steel grades extends from low carbon steels that can be well deep drawn to steels with high proof strength. The provisions contained in the German Steel Iron Materials (SEW) Datasheet 022 in conjunction with DIN EN 10346 apply to hot-dip steel sheet with zinc-magnesium coating.

Strip after leaving the coating pot and passing the gas-knives

Processing Options

Multi-purpose and Highly Efficient

Test set-up: laser beam welding an automobile inner door panel of zinc-magnesium coated steel sheet



The processing properties of zinc-magnesium coated steel sheet are superior to those of the standard galvanized version in many ways. In particular, this includes minimised abrasion during forming, as the zinc-magnesium coating possesses a higher surface hardness than conventional zinc coatings. That reduces the expense of cleaning the facility and extends the useful lifetime of the machines.

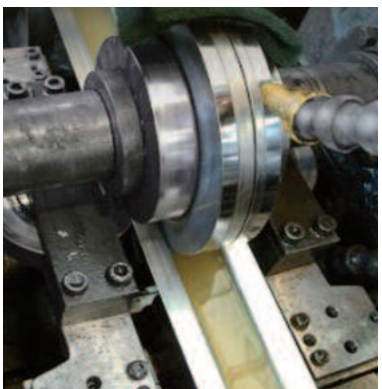
Forming

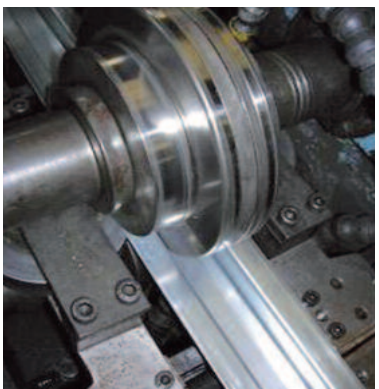
The coefficient of friction influences the forming behaviour of a material. Investigations have shown that the coefficient of friction for zinc-magnesium is similar to or better than that of zinc. The commonly used forming processes require correspondingly just small adaptions on the tooling for zinc-magnesium.

The reduced coating thickness offers processors an important advantage: thinner coatings allow easier forming. A further benefit: in multi-stage forming processes, there is no cold shut between the material and the forming tool thanks to the greater surface hardness of zinc-magnesium coated material.

The formation of zinc filaments is significantly reduced when roll forming zinc-magnesium finished sheet steel compared to zinc, also thanks to the harder surface. The material can therefore be processed for many applications without rolling emulsion and thus without the subsequent clean-up of the production line. That is more economical, reduces operating and maintenance costs, and protects the environment.

Roll forming: galvanized steel sheet with lubricant (left) and zinc-magnesium coated sheet steel without (right)





Welding

Resistance spot welding and laser beam welding are the main joining techniques for the initial stages of automotive bodyshell work. The weldability of zinc-magnesium is comparable to zinc for both techniques.

Comparison of the properties of steel sheet with zinc and with zinc-magnesium coating

	Zinc	Zinc-magnesium
General properties		
• Superior surface	■	■
• Suitable for varnishing	■	■
• Resistance to acids	■	■ a)
• Resistance to bases	■	■ a)
• Temperature resistance	■	■
Corrosion behaviour		
• Without varnish		
– Surface without deformation	■	■
– Bending shoulder	■	■
– Cutting edge	■	■
• Varnished, coil coated		
– Surface without deformation	■	■
– Bending shoulder	■	■
– Cutting edge	■	■
Forming properties		
• (Micro) cracking	■	■
• Abrasion	■	■
• Best formability requested	■	■
Joining		
• Spot welding	■	■
• Soldering	■	■
• Bonding	■	■ b)
• Mechanical joining	■	■

Note:
The information given in this table characterizes the present level of experiences and apply for comparable product thicknesses and coating masses. It should be considered that the use of ZM coating offers the application of reduced coating masses.
The given classification is not valid for all kinds of application. In cases of doubts, the manufacturer should be consulted for advice.

a) For use in sour or basic media, a specific test is required for lower coating masses considering, that depending on the requirement or test conditions the classification into a better or worse class may be possible.

b) Due to excentric load path at high load level, mild grades and/or thin steel sheets tends to lower portions of cohesive failure mode.

Legend:
■ = especially recommended
■ = recommended
■ = standard
■ = less appropriate
■ = still to be clarified

Phosphating and painting

A well-formed phosphate layer facilitates good adhesion of the subsequent paint layer. Zinc-magnesium coatings can be easily pre-treated with typical standard phosphating used in the automobile industry. The paintability is identical to that of a standard galvanized surface.

Application examples
Convincing in Practice

Zinc-magnesium coated steel sheet can be employed in practically all application areas. The product advantages of zinc-magnesium are essential especially in a corrosive environment or for increased protection requirements.

Construction Components Without Organic Coatings

Due to their excellent factory-provided corrosion resistance, zinc-magnesium products are suitable for use in construction areas not requiring painted substructures. They can therefore be employed for façades, solar installations, roof drainage, scaffolding planks, pipe ducting and insulation, as arms and rollers in awnings and blinds as well as for fencing. Profiles for drywall framing made of zinc-magnesium coated steel sheet can even be inserted directly into moistly concrete. A good example of its capability is a roll-formed steel beam for the construction industry that is manufactured from 1.5 mm thick steel sheet with the grade S250GD and with a zinc-magnesium coating of 120 g/m^2. It offers a convincing combination of corrosion protection, cathodic protection, and scratch resistance. The steel beam thus has properties that otherwise can only be obtained by additional coating processes.

Construction Components With Organic Coatings

Zinc-magnesium alloy coatings can be coil coated with all the common organic coating systems. Thanks to the high specific corrosion resistance the coating thickness of zinc-magnesium steel sheet, being organically coil coated, can be sharply reduced in comparison to traditional zinc coatings. ZM-coated substrates that are to be used for organic coated structural components employ coating weights of 70 to 140 g/m^2 as a rule. The reduced use of zinc in this case conserves its resources, as normally a layer of 275 g/m^2 is used. The insulation panels at India's Bharati Research Station in the Antarctic are an example of the extreme capability of resistance. At temperatures down to minus 45 °C, extreme performance requirements are presented to S320G+ZM140 with an organic coating.

Tubular steel beams of zinc-magnesium coated steel sheet

India's Bharati Research Station just prior to completion: insulation panels of zinc-magnesium coated steel sheet with organic coating fulfil the most demanding requirements, even at temperatures down to minus 45 °C.

Vehicle Manufacturing

In automotive construction, zinc-magnesium coated steel sheet can be employed for diverse components of the body-in-white that are subject to highly corrosive, salt-bearing loads. Practical examples are demonstrating the advantages: in a joint research project, a steel producer and automobile manufacturer are developing a mud guard with a zinc-magnesium coating. The investigations confirm that the weldability and behaviour of the paint are as excellent as with zinc coatings used up to now. Instead of electrolytically galvanized steel, zinc-magnesium coated steel can be used for the mud guards in future, offering improved properties for the product.

The driver compartment, mud guards, and roof hoops are typical applications in utility vehicles. In addition, steel sheet with a zinc-magnesium coating is suited for use in trailers and motor homes.

Mud guard with zinc-magnesium coating: weldability and paint behaviour are as excellent as they are with conventional zinc coatings.

Hi-rise rack storage: supports and shelves of steel sheet with zinc-magnesium coating

Industrial and Housekeeping-Related Applications

Steel sheet with zinc-magnesium coating is ideal for industrial hi-rise racks and other shelving systems. In these applications, the material is exposed to heavy mechanical loading every day and meets these high demands for robustness thanks to its enhanced abrasion resistance. If minor surface damages occur, such as scratching, however, “self-healing“ by the zinc-magnesium coating reduces the risk of progressive corrosion damage and thereby increases the lifetime of the rack.

In the home, zinc-magnesium profiles can be employed in humid areas as well as for domestic appliances that are constantly exposed to high moisture levels, such as washing machines or dryers.

Advantages of zinc-magnesium for gardening tools not only include longer storage life of the end products, but also advantages during their manufacture. E.g., wheelbarrow baskets can be produced from a simpler grade of steel such as DX54D+ZM140 (zinc-magnesium) instead of from DX56D with an aluminium-zinc coating. Additionally, material coated with zinc-magnesium shows less friction in the forming tool and requires considerably less drawing oil. The previous material type had to be heavily oiled to avoid cracking of the sheet during deep drawing.

Wheelbarrow basket of deep-drawn sheet steel: a simpler grade of steel can be used thanks to the zinc-magnesium coating

Possible application for steel sheet with zinc-magnesium coatings

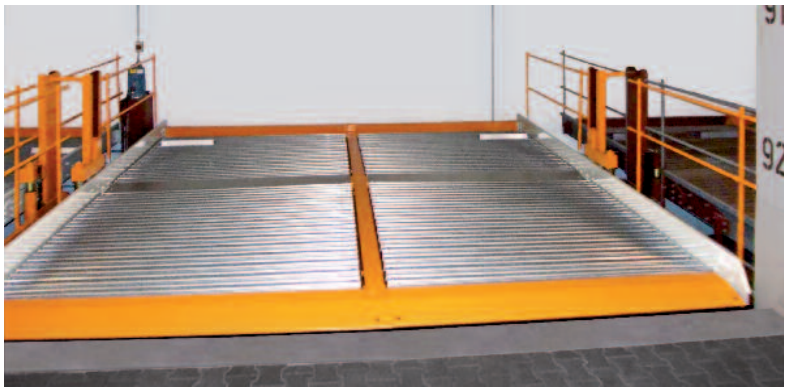
- Architecture and construction
  - Trapezoidal and panelled profiles as well as insulation panels
  - Window frames
  - Industrial and garage doors
  - Scaffolding planks
- Vehicle manufacturing
  - Automobiles
  - Utility vehicles
  - Trailers, motor homes
- Motorway equipment
  - Guard rails
- Domestic appliances
- Engineered homes
  - Cable and ventilation ducts
  - HVAC
  - Solar installations
- Storage engineering
- Device engineering
  - Wheelbarrows
- Agriculture
  - Silo construction

Trapezoidal profile for industrial buildings

Ventilation pipes

Guard rails

Parking systems



Exemplary Environmental Protection

Durable and 100-per-cent Recyclable

Steel provides a significant contribution in meeting the challenges and achieving the ambitious goals of environmental and climate protection. Through economic sense and ecological responsibility, the consumption of resources in steel production has been significantly reduced over the past years. In addition, steel can be recycled as often as desired with no loss of quality and it thereby fulfils the requirements for a closed material cycle.

High-strength steel grades facilitate for example light-weight automobile construction techniques that reduce vehicle weights. At the same time, new steels allow higher engine efficiencies. Both of these contribute to reducing fuel consumption and CO_2 emissions of vehicles.

Innovative metallic coatings such as zinc-magnesium help to expand this positive ecological balance. The lifespan of products manufactured from steel sheet is increased and the consumption of the respective alloying elements reduced. Of course, zinc-magnesium coated steel sheet is absolutly recyclable.

Zinc-magnesium coatings contain no hazardous materials and thus conform to European REACh chemical regulations (Registration, Evaluation, and Authorisation of Chemicals).

Greenhouse: profiles of zinc-magnesium coated steel sheet form the supporting construction

Zinc-Magnesium Coated Steel Sheet
Less is More

As the newest generation of metallic coatings, zinc-magnesium coated steel sheets (ZM) possess considerably improved corrosion protection. This permits coating thicknesses to either be significantly reduced, respectively structural components can be realised which exhibit extended corrosion protection, thereby conserving resources and protecting the environment. Improved processing properties help reduce manufacturing costs.

Specific information about availability and usage is offered by technical representatives in the customer service departments of steel producers.

Frames made from organic coated zinc-magnesium steel sheet for mounting photovoltaic elements

Standards/Directives

The following standards and directives apply:

- DIN 55634: Paints, varnishes and coatings – Corrosion protection of supporting thin-walled building components made of steel
- DIN 55928-8 (replaced by DIN 55634): Corrosion protection of steel structures by paints and coatings – Part 8: Corrosion protection of supporting thin-walled building components (withdrawn)
- DIN EN 10143: Continuously hot-dip coated steel sheet and strip – Tolerances on dimensions and shape
- DIN EN 10346: Continuously hot-dip coated steel flat products – Technical delivery conditions
- SEW 022: Continuously hot-dip coated steel flat products – Zinc-magnesium coatings – Technical delivery conditions

The following publications of the Stahl-Informations-Zentrum contain further information:

- Characteristic Properties 093 – E: Continuously Organic Coated Steel Flat Products
- Characteristic Properties 095 – E: Continuous Hot-Dip Coated Steel Strip and Sheet

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