1 Coil coating – principle, market and applications

1.1 Introduction

Coil coating makes use of a simple, but effective principle, i.e. to clean, pretreat and coat flat coils or sheets of steel or aluminium in a continuous operation, before other stages of industrial manufacture\(^1\)-\(^4\). The slogan for this concept is: Finish first – fabricate later!

A conventional process sequence in coil coating consists of:

- Cleaning
- Conversion treatment (including optional post-rinse)
- Drying
- Primer coating
- Top coating
- Foil lamination (optional)

An overview of a large coil coating line is depicted in Figure 1.1.

Figure 1.1: Schematic of a steel coil coating line

Source: Voestalpine
The official definition of the coil coating process is codified in the European Standard EN 10169-1: 2003. It states that coil coating is

- “a method in which an organic coating material is applied on rolled metal strip in a continuous process. This process includes cleaning if necessary and chemical pre-treatment of the metal surface and either one side or two side, single or multiple application of (liquid) paints or coating powders which are subsequently cured or laminated with plastic films”.

### 1.2 Coil coating process

Metal coils are fed into a coil coating line from an entry station, where the coils are reeled off an uncoiler (Figure 1.2), and the beginning of one coil fixed to the end of the preceding coil by welding or stitching. The uncoiler station is usually duplicated, or equipped with twin reels, in order to allow for faster coil changes. The metal strip then enters the active section of the line through a loop accumulator. The large accumulator shown in Figure 1.3a has been emptied during the change of a coil, while feeding the strip length that was stored in it to the continuously running process. It waits to be filled up again to be ready for the next coil change.

The active section comprises a degreasing stage, with a brushing section and rinses; one or more pretreatment stages in either immersion or spray technique, followed by another rinse cascade, and a water dryer. In case of so-called no-rinse pretreatment processes, the strip needs to be dried beforehand, and the treatment solution is applied by a roll-coater (chem-coater), before reacting off and evaporating the water in the dryer. The pretreated strip then enters the primer stage with its roll-coater unit and curing oven, followed by a water quench cooler. Afterwards, the finish coater section is passed which again comprises the roll-coater units and curing oven with subsequent cooling. The finish (topcoat) section often has two coater installations that allow
Coil coating process quicker colour changes. After the topcoat, a lamination with protective foil may follow, before the strip leaves the active section via the exit accumulator. Finally, the strip passes an inspection stand and is taken off the line in an exit unit with a shear and a recoiler.

The entry and exit accumulators are operated to allow a uniform speed throughout the active stages. They are usually dimensioned to provide material for 1 to 2 min of production time stored in them.

Smaller and slower coil coating lines may be equipped with a simpler installation, like the loop pit in an aluminium strip line shown in Figure 1.3b. Similar pits may also be used as an inspection stand.

In high-capacity lines, coils are handled in sizes up to over 2 m width and 2 m diameter. Dimensions in steel lines are usually smaller due to the 3-fold density and weight of steel as compared with aluminium. Still, such a coil weighs up to 20 tonnes.

Figure 1.4 illustrates a roll-coater machine which is used to apply a no-rinse pretreatment. As it does not process any solventborne paint, it needs not be enclosed in a separate compartment that would be necessary to keep the flammable solvent vapours from the working environment. Roll-coaters for pretreatment are also called chemcoaters, as they deal with low-viscosity, aqueous chemical solutions and are adapted to this purpose.

Any roll-coater is designed to pick up an amount of liquid, and transfer it to the moving strip. Usually, there are two- or three-roller arrays. Three-roller coaters may have the rolls mounted in V-shape or with their axes in a line. The nip pressure between the rollers, their relative rotating speed, and their direction of rotation are manipulated in order to obtain a uniform wet film of the desired thickness across and along the strip.

Figure 1.5 shows the schematic of a V-shaped three-roller device in forward operation. This means that the applicator roll is rotated so that its surface moves the same direction as the strip, with only little difference of the surface speed. Liquids with lower viscosities, including aqueous pretreatment solutions, require the applicator to be operated in reverse mode. Since the applicator roll is clad with a rubber or elastomer blanket of adjusted hardness, reverse operation leads to high wear of the roller surface because of the strip edges cutting into it.
The pick-up roll, usually made with a ground stainless steel or hard chromium-plated surface, takes the liquid from a reservoir tray, the wet film is reduced by the metering roll (or, alternatively, a fixed knife, the so-called „doctor blade”), then transferred via the applicator roll onto the strip.

Roll-coaters for the top side of the strip are depicted in Figure 1.6. While on the left (Figure 1.6a), the liquid is fed directly into the nip between the two rolls, the right coater (Figure 1.6b) is operated with a tray from where the paint is taken.

Mounted either above the applicator roll or the support roll, the heads of the gauge control equipment can be seen. They are either fixed to a position across the strip, or they can be moved across statistically or in regular oscillation, to obtain full-area continuous monitoring of the wet film. The measuring principle can be based on infra-red reflection, or electron backscattering induced by a weak radioactive source, krypton-85 ($^{85}$Kr).

The wet, coated strip enters the curing oven immediately after the coater house. Most ovens are operated on hot-air convection with air temperatures up to 400 °C. Some lines are equipped with IR, near-IR or induction ovens.

![Figures 1.6a and b: Top-side paint roll-coaters in operation](Image)

![Figure 1.7: Typical build-up of a coil paint coating](Image)
Liquid paints in coil coating are mostly applied in two layers, i.e. a primer and a topcoat layer. The majority of primers are applied at 5 μm dry film thickness. A normal topcoat system has a gauge of approx. 20 μm (cf. Figure 1.7). For high endurance requirements, however, both primer and topcoat may be used at higher gauges.

There are also single-coat systems available (particularly for uses on Al substrates, and multiple coats may be required for specialist purposes. Backing coats are either applied on a regular primer, or as single coats at typical thicknesses of 10 to 15 µm dry film.

The finished coated coils are taken off the recoiler at the line exit, packed and labelled, and stored prior to transport to the end user, as illustrated in Figures 1.8 and 1.9.

Protective foils are applied optionally as the last step of the coil coating sequence, in order to mechanically protect the finished surface from damages. They are stripped, after the metalworking process, from the end product.

In the case of decorative foils used as the finish coat, these are applied on top of a primer or co-laminated onto an intermediate coating.

PVC films are used for decorative purposes providing particular surface patterns like woodgrain, leather aspect, stone imitations, etc.

Polyethylene terephthalate, PET, or polyester films are hot-laminated onto the last paint layer. Being transparent or coloured and patterned themselves, they allow a multitude of attractive surface finishes, colours, imprints, and gloss grades, in addition to particular technical requirements like high flexibility, scratch resistance, resistance against aggressive environments, detergents, solvents, etc., anti-grafitti features, or foodsafe certification. They are also particularly capable of deep drawing without gloss reduction. Coil coated metal, finished and recoiled, is ready to be formed into the ultimate part by bending, rolling, drawing, punching, etc.
1.3 **Metalworking with precoated coil**

Prepainted metal can undergo numerous processing steps to create the final three-dimensional workpiece that is fabricated. Some examples are depicted in Figure 1.11. The surface being already that of a finished product, the prepainted stock should be handled with appropriate attention. When proper manufacturing techniques are used, prepainted metal is as easily transported, stored and handled as other material. The processing tools need to be adapted, and therefore should be dedicated to prepainted feedstock. For instance, tool surfaces must have smoothly polished and considerably hardened surfaces, in particular when they touch the visible faces of the final item. Feeding must allow traction without skidding, and continuous operation without stoppages, i.e. using a loop feeder with suitable speed regulation.

Usually, prepainted sheet does not require extra lubrication for forming. However, the clearances of the tools, like rollers, dies and cutters must be adjusted to the additional paint film thickness. For all deforming operations, working at temperatures above the glass transition temperature of the coating is advantageous. The forming capability of the prepainted metal can be assessed by standardised simulation methods.

In many cases, **roll-forming** is employed to form corrugated or grooved panels, profiles of any shape, or tubes.

**Bending and flanging** are common ways to fold up sheet ends or to join two panels together. As any cut edge of precoated metal is inadvertently left unprotected, bending and flanging is often used to retract these edges from the surrounding.

**Deep-drawing** must consider the material flow including the flexibility of the paint to ensure the deformation limits are not exceeded.

**Forming corners** from a precoated sheet is a particular design task. For small deformations, corners can be made by deep-drawing. In other cases they are obtained by folding operations. According to the design and quality requirements, the folding can be done to result in open, diagonal, or mitred corners. The latter involves both flanks of the bent sheet to be folded in so none of the cut edges are left open to view.

*Figures 1.10a to c: Examples of roll-formed and deep-drawn goods made from precoated coil*  
*Source: a, b) ThyssenKrupp Steel Europe, c) ArcelorMittal*
Cutting and punching of pre-coated metal requires properly sharpened tools. If possible, the cut or punch should be performed from the coated side.

There are a variety of ways for fastening and joining of pre-painted metal. Adhesive bonding is often chosen when it comes to combination with other materials. Mechanical fastening with screws, bolts or rivets is a more obvious method that however bears in it the disadvantage of drilling holes through the sheet material first. Integral joining by clinching or stitching provides a more elegant way. Clinching requires somewhat thicker sheets to be joined, as it involves the material of the overlapping sheets to flow and form the interlocking buckle and cavity. It can be performed so that the joint is invisible from the outer surface.

Panels are bent and flanged together to form fold-up seams that are either visible (like a standing seam) or retracted from sight.

Even resistance welding is possible, providing the coating does not insulate too much. It needs either applying the coating only on one side or using thin or special conductive coatings. With the proper conditions, welding can be performed on the reverse of a sheet without leaving traces on the visible outer face.

### 1.4 Inherent benefits of coil coating

Coil coating provides a lot of benefits when compared to post-finishing.

First of all, the quality of the paint finish is consistently high, because the process is run continuously and highly automated. All along and across the coated strip, the coating will have a uniform thickness and appearance within narrow tolerances. Gauge variations are in the range of <1 µm. Regarding durability in terms of adhesion, corrosion and weathering resistance, there are architectural products available with lifetime warranties up to 40 years. To avoid mechanical damages of the prefinished metal during onward processing, protective foils can be applied. These stay on the coil until after the metalworking and mounting and are stripped afterwards.

For the user of precoated coil, it is important that the design of end products is easy and flexible, once some principles for the processing of the prefinished feedstock are adopted. Choice can be made from an abundance of colours and finishes. Prepainted metal also protects areas that would go uncovered by post-finishing. Working with prefinished metal produces much less pollution and waste than a post-finishing concept.
Benefits also translate to the **economy and ecology** of the process.

Coil coatings are applied with an optimised consumption of materials, and to almost all customary sheet dimensions.

The user of prepainted stock enjoys multiple savings just because he does not need to operate the pretreatment and painting process. This means there is a lot less of consumables and waste, there is lower investment, floor-space, inventory and energy consumption. There are no concerns about waste and effluent treatment and disposal, and no emissions of volatiles. There is less, and safer, labour, because no hazardous or inflammable materials need to be handled, and finally, this also results in lower insurance cost.

Precoated sheet and coil is entirely recyclable, and there is a functioning infrastructure in place to collect and recycle metal scraps.

All in all, coil coating, as an automated, well-controlled and low-impact process, has a built-in safety, for the manufacturer, the operator, the user, as well as for environment.

### 1.5 Coil coating market in Europe

Looking at the coil coating market in Europe[^5] nowadays, 1.1 billion m² of mostly galvanised steel and 220 million m² of aluminium strip are precoated. These figures must be understood as the dimensions of the metal, while the actually coated surface is double, since top and reverse sides have to be considered. It should also be mentioned that, by definition, these figures do not enclose the production of coated steel and aluminium for food and beverage packaging uses, which in terms of the process technology are very similar.

The European market comprises some 200 coil coating lines, of which approx. 60 are high-capacity lines with tonnages of 200,000 t/a and over.

Fourteen steel lines are coupled with a galvanising installation, two Al lines have an annealing section upfront. Many of the smaller lines are small-strip installations that produce,
Coil coating market in Europe for instance, packaging strip or venetian blinds. Currently, powder paints are used in thirteen coil coating operations; the vast majority of lines use liquid paints.

In Europe, most coil coating lines are owned by the large steel or aluminium producers who usually operate several of them in different locations. But there are also medium-sized enterprises.

Average dimensions in a steel coil coating line are a width of 1.6 m, and a metal thickness of 0.5 mm. A typical line speed is 100 m/min, with an upward trend. Dimensions for Al lines are typically larger, with widths of 2 m and speeds going up to 200 m/min.

Major paint suppliers are the large groups that operate worldwide, however also here, some smaller companies participate in the market.

Overall, the potential paint usage is almost 200 kt/a, translating to a value of almost 1 billion €/a, including topcoats, primers, backing coats and some specialty coatings. The major target markets are architectural uses, transport and the domestic appliance industry. Precoated strip is also sold for a large variety of general industrial uses.

The graph (Figure 1.11) shows the historical development of shipments of precoated steel since 1970 in Europe. It should be mentioned that the tonnages of steel grew at a lower rate, because of the long-term trend to use thinner, stronger material.

While the recession of 2008 clearly took its toll, the market has largely recovered, but seems to stabilise, and not return to its former growth rates, 5 to 8% year-on-year. The steel shipments have achieved a level of 1.1 billion m² again, although some of the recent growth might be attributed to stockbuilding. Over the past two decades, a considerable shift of demand to Central and Eastern Europe has taken place since the fall of the Iron Curtain in 1990, and it should be noted also that, since about 2005, imports from China, Korea, India and Taiwan have taken a share of approximately 15% in the competition. Worldwide figures for the coil coating market are about 4 times the European data.

Table 1.3: Key data of the coil coating market in Europe

| Volume | 1.1 billion m²/a steel (approx. 95 % galvanised)  
|        | 220 million m²/a aluminium  
|        | approx. 200 lines, hereof approx. 60 large lines (200 kt/a), 14 integrated galvanising, 13 powder |
| Operators | ArcelorMittal, Norsk Hydro, Tata Steel, ThyssenKrupp Steel Europe etc. |
| Ave. dimensions | approx. 1.60 m width, 0.5 mm thickness  
| | 100 m/min line speed |
| Paint chemistry | Polyester/melamine, polyurethane, PVdF, PVC |
| Market size | 180 to 200 kt/a (approx. 900 million €/a)  
| | (topcoats, primers, backing coats, specialties) |
| Target markets | Architecture, transport, appliance, gen. industry |

Figure 1.11: Historical development of shipments of precoated steel in Europe. Blue line: Annual shipments; orange line: Moving average

1.6 Applications of precoated metal

1.6.1 Overview

A closer look at the uses of precoated metal and the discussion of some examples will demonstrate the versatility of coil coating. As mentioned, the major target industries are the architectural sector with interior and exterior applications, the transport and the domestic appliances markets. General industry like the manufacture of metal furniture, climatisation equipment, teletronics and other domestic electrical gear also takes a considerable share.

Figure 1.12a shows the distribution of precoated steel uses per application. Architecture takes by far the largest share of over 70%. A part of precoated material is distributed via service centres and stockists. The final destination and end-use for this material is therefore unknown, however it is safe to expect a similar distribution of this material as for the big rest.

An analogous view on precoated Al (Figure 1.12b) shows an even stronger segment dedicated to the buildings market. This includes production of roller shutters and sunblinds. The market for precoated aluminium semis is currently declining. In 2012, it suffered shrinkage of 8 to 9% versus the previous year.

Despite the size of the coil coating market, and the undisputed benefits of the technology, there is still a large portion of potential end users left unpenetrated. Looking at the total market of galvanised steel coil that is produced in Europe (Figure 1.13), apparently only 20% hereof actually are channelled through a coil coating process. Another 20% are altogether left uncoated. 30% are delivered to automotive OEMs with their specialist batch coating lines for car bodies, truck cabins and parts. The remainder of 30%, however, is sold to manufacturers who produce single workpieces from coil or sheet blanks and have the painting of these goods either done inhouse or at job coaters.

A good part of this potential might indeed be penetrable for the coil coating technology. Reasons why coil coating did not yet enter may be manifold, from historical to processing to economic motivations. The latter often has to do with the economy of size resulting in supply restrictions and small-order surcharges for precoated metal.

1.6.2 Building applications

Uses in both indoor and outdoor architecture form the most important market. Precoated products are used for wall cladding and roofing of buildings. Almost traditional applications are large industrial halls and plant buildings, and agricultural buildings like stables, barns and sheds. With the grown acceptance and appreciation, nowadays also large administra-
Applications of precoated metal

and office buildings are made of precoated metal, their design taking advantage of the manifold possibilities in forms and surface aspects. Domestic building is a more recent market to be tackled. External applications also comprise garage doors, roller shutters and blinds, as well as composite panels with thermal or noise insulation.

Wall cladding is very commonly done with precoated metal on large industrial, agricultural or administration buildings, regardless whether the material is mounted in long strips of corrugated or V-groove panels, or used to fabricate single cassettes built into curtain walls. The photographs of Figure 1.14 show some examples.

Roofing with precoated metal in standing seam or tile fashion is popular in the domestic building market in some countries, while in others, the traditional ceramic or concrete tiles
prevail. Figure 1.15 shows a variety of uses for roofing. Corrugated or standing seam appearance is often found on the traditional industrial or rural buildings, while in domestic housing, they imply an individual design touch. Tile-formed metal sheet is used in more conventional buildings, where it proves particularly convenient for roof repair systems.

To complete a metal-clad roof, metal flashings are obvious. Finally, precoated metal is also used for gutters, sinks and drains. Two other examples of outdoor building applications of precoated metal are shown in Figure 1.16. Roller shutters and sunshades traditionally are a domain of precoated aluminium.

**Indoor applications** include partitioning, wall panels, ceiling and flooring panels.

### 1.6.3 Transport applications

Precoated metal is also used in the **transport** sector. Typical products include sheet and panels for containers, caravan and mobile home sidings and interior, van and trailer bodies, insulated boxes, road and railway coaches (cf. Figure 1.17). Also small parts like license plates, wiper assemblies and trim are among the applications.
A specialist use is the preprimed sheet that goes into passenger car bodies. A zinc-rich paint is applied on pretreated electro-galvanised steel. This coating, by its nature, provides improved corrosion resistance and compatibility with the processes in car body production that involve resistance welding and cathodic electro-dip painting. The enhanced corrosion protection is particularly important in critical areas of a car body, like seams, box sections or flanges, where a pretreatment is geometrically difficult to apply and may therefore be faulty, or the electro-dip paint is only insufficiently deposited due to shielding effects.

1.6.4 Applications in appliance and general industries

Another important use of precoated metal is the manufacture of domestic appliance equipment. Here a particularly demanding set of requirements applies, as the precoated feedstock needs to be extremely formable, scratch resistant, humidity and temperature resistant, and resistant to domestic cleaners and detergents, as well as aggressive food ingredients. All kinds of large appliance are produced from precoated stock, like refrigerators and freezers, washing machines, dishwashers or ovens, but also smaller items as microwave ovens, ranges or fume hoods (Figure 1.18).

Also, smaller electrical articles, HVAC equipment (heating, ventilation, air-conditioning) and teletronics are made using prefinished sheet. These items sometimes appear in the