EFFICIENT PRODUCTION
OF TINPLATE PACKAGING
MATERIAL OUT OF COLD-STRIP
Product Portfolio, Technology & References
SMS group covers all tinplate production processes with innovative technologies for an efficient production of packaging material out of cold-strip. All necessary processing lines can be supplied completely from one source including mechanical and process equipment, furnace technology, electrics and automation as well as production know-how. All facilities are equipped with modern technologies which lead to considerable economic, ecologic and process advantages.

This brochure gives a comprehensive overview about all our plants and technologies for tinplate production as well as some information about our references. Furthermore, it especially emphasizes on the operational advantages our plants and processes provide.
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100% RECYCLABLE VERSATILE PACKAGING MATERIAL

Electrolytically tinned ultra-thin sheet (usually termed “tinplate”) is a cold-rolled, recrystallization-annealed and in some cases reduced thin sheet of carbon steel, upon which a tin coating has been applied by an electrolytic process, adhering firmly to the surface of the steel strip. The tin coating protects the base material against corrosion and, furthermore, acts as an excellent primer for subsequent painting, provided that proper surface-treatment has been carried out. Tinplate thus combines the strength and formability of steel with the corrosion-resistance and good visual appearance of tin.

Tinplate is also known as “packaging steel” in view of its chief utilization. The main areas of application lie in the fields of tin cans for foods and beverages and for animal foods. It is also used for the manufacture of packagings for chemical industry products and spray cans for aerosols. Furthermore, closures such as lids and bottle tops are often made from tinplate. It is not only the corrosion-resistance and the attractive visual appearance that are the main advantages in the use of tinplate but also the high degree of re-usability. It is 100% recyclable, and it can be re-used several times without loss of quality.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Hardness [Rockwell]</th>
<th>Yield strength [N/mm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>T 1</td>
<td>&lt; 49 ± 3</td>
<td>230</td>
</tr>
<tr>
<td>T 2</td>
<td>&lt; 52 ± 3</td>
<td>245</td>
</tr>
<tr>
<td>T 2.5</td>
<td>&lt; 55 ± 3</td>
<td>260</td>
</tr>
<tr>
<td>T 3</td>
<td>&lt; 57 ± 3</td>
<td>275</td>
</tr>
<tr>
<td>T 4</td>
<td>&lt; 62 ± 3</td>
<td>340</td>
</tr>
<tr>
<td>T 5</td>
<td>&lt; 67 ± 3</td>
<td>435</td>
</tr>
<tr>
<td>DR 7</td>
<td>&lt; 67 ± 3</td>
<td>490</td>
</tr>
<tr>
<td>DR 8</td>
<td>&lt; 73 ± 3</td>
<td>550</td>
</tr>
<tr>
<td>DR 9</td>
<td>&lt; 76 ± 3</td>
<td>620</td>
</tr>
<tr>
<td>DR 10</td>
<td>&lt; 80 ± 3</td>
<td>700</td>
</tr>
<tr>
<td>Typical applications</td>
<td>Typical thickness [mm]</td>
<td>Remark</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td><strong>SR-Grades</strong> (Single Reduced)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical application, eg. oil filter housing</td>
<td>0.3 – 0.5</td>
<td>Very good deep drawing characteristics, high flexibility</td>
</tr>
<tr>
<td>Two-part beverage can (top made of steel or aluminum)</td>
<td>0.2 – 0.4</td>
<td>Good deep drawing characteristics, good stiffness</td>
</tr>
<tr>
<td>Two-part beverage can (top made of steel or aluminum)</td>
<td>0.25</td>
<td>Good deep drawing characteristics, good stiffness</td>
</tr>
<tr>
<td>Crown corks, fruit and veget. cans (top, wall and bottom)</td>
<td>0.18 – 0.24</td>
<td>Increased stiffness to prevent buckles</td>
</tr>
<tr>
<td>Fruit and vegetable cans (top, wall and bottom)</td>
<td>0.18 – 0.24</td>
<td>For high strength requirements</td>
</tr>
<tr>
<td>Fruit and vegetable cans (top, wall and bottom)</td>
<td>0.18 – 0.24</td>
<td>For highest strength requirements</td>
</tr>
<tr>
<td><strong>DR-Grades</strong> (Double Reduced)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish cans</td>
<td>0.2</td>
<td>For high strength requirements</td>
</tr>
<tr>
<td>Mineral water and beer cans</td>
<td>0.14</td>
<td>For high strength and rigidity requirements</td>
</tr>
<tr>
<td>Lids and bases for mineral water and beer cans</td>
<td>0.11</td>
<td>For higher strength and rigidity requirements</td>
</tr>
<tr>
<td>Special applications</td>
<td>0.11</td>
<td>For highest strength and rigidity requirements</td>
</tr>
</tbody>
</table>

This table gives a brief overview about the most common tinplate grades and their characteristics. Some characteristics may differ depending on process routes, special customer requirements or other conditions. Furthermore, there are many more applications.
MATERIAL FLOW

In general there are two different process routes to produce tinplate out of cold rolled steel strips. In one route the strips get cleaned in an electrolytic cleaning line, annealed in a batch annealing furnace as well as tempered and rolled in an offline mill.

In the other route – which is commonly used for higher capacities – all this processes take place in one tinplate continuous annealing line with an inline DCR (double cold reduced) and temper mill.

Finally, in both routes the material is tinned in an electrolytic tinning line.

The SMS group offers innovative technical solutions at all steps of the production of tin plate.
A tinplate continuous annealing line substitutes three single plants and makes the production process more efficient.

The electrolytic tinning process is the heart of every tinplate production works.
ELECTROLYTIC CLEANING LINE

CLEAN SURFACES AND LOW MEDIA CONSUMPTION

Strip cleaning systems by SMS display an optimum symbiosis between high efficiency and careful utilization of resources. The design of each individual machine guarantees maximized overall cleaning performance. The balancing and optimization of the media flows assure minimized media and energy consumptions.

The cleaning sections for tinplate production contain vertical process tanks for spray cleaning and electrolytic cleaning, each followed by cleaning with brushes. 4-stage-cascade rinsing and hot-air drying complete the process. This design allows achieving a maximum exposition time with a minimum line length.

Special sealing systems at the roll openings limit the escape area for fumes, steam and liquids to the necessary level. The exhaust system is effective right at the escape points, thus minimizing exhaust volume and reducing energy consumption. The tank hoods are equipped with a water seal to avoid external air being drawn in. The connections of the tanks are equipped with special systems to avoid any escape of liquids and fumes. Furthermore, operation costs are kept low by an intelligent media management.

Typical set-up of an electrolytic cleaning section for tinplate production:
The strips are introduced from two pay-off reels (1) and are joined by a stitcher (2). In the multi-stage cleaning section (3), iron residues, cold rolling oil, and other contaminants are removed from the surface. Finally, a cross-cut shear (4) divides the strip and a coiler (5) winds it into coils.
SPRAY CLEANING

Vertical spray cleaning involves spraying a hot alkaline solution onto the strip. That has both a mechanical effect due to the spray pressure as well as a chemical effect from the alkaline solution. It’s a process that not only cleans but also pre-heats the strip with the hot solution. The vertical design allows the media to flow down by gravity without building up a considerable film thickness.

ELECTROLYTIC CLEANING

The electrolytic cleaning tank ensures that also finest impurities will be removed and an excellent surface quality will be reached. The principle behind electrolytic cleaning is the electrolysis of water. Vital here is the electric current directed from the electrode at one side of the tank through the alkaline solution via the strip to the electrode at the other side of the tank again through the alkaline solution. That breaks down the water into hydrogen and oxygen. The gas develops in the form of small bubbles directly on the metal surface underneath the layer of soiling. As the bubbles rise, they lift the dirt off the surface, which then dissolves in the degreasing solution or forms an emulsion. The vertical design of the electrolytic cleaning section realizes optimum flow properties for the electrolyte. The flow direction from the bottom to the top of the cell supports the gas release of hydrogen and avoids gas nests in the process tank.

BRUSH CLEANING

The brush machines mechanically remove oil and dirt residues. The surface is cleaned by a combination of pressure and rotation movement. To achieve even more effective cleaning, the brushes move counter to the strip travel direction.
BATCH ANNEALING FURNACES

DISCONTINUOUS ANNEALING

After cold rolling the steel strip is hard and brittle. To be used as packaging material it has to pass a recrystallization annealing process to achieve the necessary ductility for the later cold forming process.

Batch annealing furnaces (also called bell-type furnaces) serve to anneal and cool the cold rolled and already cleaned tinplate material in the batch mode. Depending on the required capacity numerous annealing bases with several heating and cooling hoods are installed in a tinplate production plant. The heat treatment process for each hood takes between one and two days depending on the batch size and material grade. Each hood can process several coils at once. The coils are stacked one on the other using intermediate convector plates for strip edge protection and to increase the heat transfer. The coil stack is covered with an inner cover to ensure an oxygen-free protective atmosphere. A heating or cooling bell is put over the inner cover depending on the current process phase.

SMS uses modern batch annealing technology which is based on the use of 100% hydrogen atmosphere to increase the heat transfer and prevent the strip surfaces from oxidation. The heating bell serves for the heat-up of the annealing furnace up to temperatures around 650°C. For the cooling process special cooling bells are used with a combined air/water cooling technology.

Batch annealing furnaces offer the highest flexibility when it comes to different material grades with different strip dimensions. This is because every annealing base works independently. The size of the whole plant – i.e. the number of the annealing bases – is always adapted to the required production rate. Of course, it is easily possible to add some bases to an existing plant when necessary. The biggest installations for tinplate productions consist of around 60 annealing bases. In modern tinplate works normally annealing bases with a useable diameter of 2,100 mm are used. Stacking height and charging weight are limited to approximately 4,600 mm and 110 t due to the characteristics of tinplate material.
Batch annealing furnaces serve to anneal and cool cold strip coils in the batch mode and are able to process several coils simultaneously. Each for cooling and heating different bells are used, while the coils remain in the inner cover under 100% hydrogen atmosphere.
OFFLINE AND INLINE DCR & TEMPER MILL

DOUBLE REDUCED MATERIAL WITH TAILORED PROPERTIES

A special feature of the tinplate production process is the second rolling for thickness reduction after annealing. In addition, a temper rolling process prepares the strip for further surface-finishing and coating.

Two-stand DCR temper mills (Double Cold Reduction) combine reduction in the first stand with skin-passing in the second stand. This enables the material properties and the surface roughness to be set in a very carefully targeted manner for tinplate and guarantees trouble-free further processing.

SMS group provides DCR mills in CVC® plus design. In combination with proven technical features, like our new enhanced bending system for an extremely large roll gap setting range, multizone-cooling and Dry Strip system (DS system), excellent strip quality is ensured. For tempering, the mill can be operated with both systems: wet and dry skin passing.

Depending on the required capacity and the product mix, SMS group offers DCR mills for batch as well as for continuous inline operation in a tinplate production line.
The design concept of an offline DCR mill is shown beside. The offline DCR mill is able to cope with a wide product range. The annealed strip is carried to the coil preparation station (1) by coil car. After removal of the first windings, the coil passes the sleeve handling station (2) and is carried to the pay-off reel (3). Rolling and tempering takes place in the CVC® plus mill stands (4). Roll change is carried out fast and automatically by using the change cars (5). The finished strip is safely wound in coils at the tension reel, supported by a belt wrapper (6). The coil passes the weighing and strapping machine (7) and is removed from the mill section by coil car. The whole process control and monitoring takes place in the main pulpit (8). Environmentally friendly mill operation is ensured by the fume exhaust system (9) as well as other facilities.
TINPLATE CONTINUOUS ANNEALING LINE

FAST PROCESSING OF THIN STRIPS

The annealing of the cleaned strip followed by reduction and surface treatment provides the material in the annealing line with the material and surface properties necessary for tinning and subsequent processing.

The very thin material (up to 0.1 mm) is processed at very high speeds (up to 750 m/min). The product range comprises all grades and also contains the qualities T2.5, T5 and DR 10, which cannot be produced by batch annealing.

The strip cleaning section has efficient process components including spray and electrolytic cleaning cells.

The radiant tube furnace is the heart of the plant and is recognized for its low resource consumption. Due to precise furnace control, the process follows the specified annealing curve exactly.

Two 4-high skin-pass mill stands are integrated for post-treatment. The first skin-pass mill stand adjusts the mechanical-engineering characteristics of the strip by a thickness reduction. The second creates a defined strip surface structure.

PROCESS SEQUENCE

The line is provided with strip by two pay-off reels (1). A welding machine (2) joins the strip ends to form an endless strip. A creep looper (3) makes sure the strip does not stand still in the cleaning section (4) during the welding process. This ensures clean quality of the strip surface for the subsequent processes. In the cleaning section, abraded iron particles as well as oil and rolling emulsion residues are dissolved in an alkaline solution. Another strip accumulator (5) continuously supplies the furnace (6). During the annealing process, the strip is heated up and cooled down according to a given temperature curve. The exit strip accumulator (7) acts as a buffer for the strip coming out of the furnace. It enables failsafe operation of the furnace when rolls are being changed in the downstream reducing and skin-pass...
mill or when coils are being removed in the exit section. In the two-stand inline mill (8) for reduction and skin-passing, the strip can be rolled with a degree of reduction of up to 42 percent and be provided with a defined roughness structure. The vertical inspection accumulator (9) makes it possible to stop the strip in the inspection stand (10) to visually check its surface structure. The next step is an electrostatic oiler (11) for applying a protective oil film to the sensitive surface. Subsequently, the strip is cut up by a flying shear. Winding is alternately carried out by two coilers (12). The strip is thus perfectly prepared for electrolytic tinning.
DREVER RADIANT TUBE FURNACE

The full radiant tube furnace by Drever International is the heart of the annealing line. During the annealing process, the strip is treated in the individual furnace sections according to defined annealing curves. This serves to remove strain hardening. First, the strip is heated up to about 750 °C.

After the soaking section, in which this temperature is held for a certain time, the material is cooled down fast to some 100 °C, which sets the desired microstructure of the material. In the following overaging zone carbides are eliminated from the steel which minimizes the risk of aging. Finally, cooling units lower the temperature of the strip to about 40 °C.

A protective gas atmosphere with hydrogen content of 5% or less prevents oxidation on the strip surface in the heating zones. A constant slight overpressure in the furnace keeps out the ambient air so that no oxygen can get in.

HIGHLIGHTS

- Low resource consumption
- Precise following of the heating curve
- Mathematical model with speed control
- Experience in heating very thin strips up to 750 °C
- Special roll profile design
- Rapid cooling with temperature transversal control (edge damper)
The material is annealed in a very environmentally friendly way in a full-radiant tube furnace with atmosphere control and special designed rolls.

Drever furnace in the continuous annealing line for tinplate production which was erected by SMS for the Shagang Group.
ELECTROLYTIC TINNING LINES

PRECISE APPLICATION OF A THIN TIN LAYER

The significant process steps in an electrolytic tinning line are cleaning, leveling, pickling, tinplating, remelting and passivating. All of these process steps must fulfill high requirements in order to guarantee the surface quality of the end material. SMS offers various innovative technologies for tinning lines, which increase the ecological and economic efficiency of the plant (see following pages).

PROCESS SEQUENCE

Two pay-off reels (1) unwind the strip, which is joined by a welding machine (2) and side trimmed (3) subsequently. Then it is fed into the strip accumulator (4). During the electrolytic pre-cleaning with rinsing (5), dirt is removed from the strip surface. The tension leveler (6) guarantees the strip’s high flatness, contributing to reliable strip travel and thus to a high-quality end product. The electrolytic pickling section (7) follows, in which all corrosion residues are removed from the strip surface. Before the strip is tinned, it passes through a preconditioning cell (8). The strip then runs into the electrolytic tinning section (9) with several vertical coating cells. All processes in the line are conducted and regulated automatically, involving evaluation of the data from numerous measuring systems. After coating, the MSA solution containing tin is
removed from the strip surface in a cascade rinsing unit (10). The dissolved tin and the rinsing water are recovered in an evaporator and returned to the process. To prepare the strip for the following reflow process, it is treated with a hydrochloric acid-based fluidizing agent in a flux tank (11). Two pairs of squeezer rolls and a strip dryer follow. The tinned strip is then introduced into the inductive reflow-unit (12).

The last major processing section is the passivation with chrome (13) for protecting the strip surface. This happens in two tanks. Here also, an evaporator recovers the chrome and the rinsing water. The rinsed and dried strip runs into a strip accumulator (14). An inspection stand (15) follows as well as a flying shear (16) to separate the strip and finally two tension reels to coil up the material (17).
ELECTROLYTIC TINNING LINES – TINNING PROCESS

ELECTROLYTIC TINNING WITH SOLUBLE ANODES

In an electrolytic tinning line, the tin is applied to the strip surface by electrochemical precipitation, while the strip runs through an acid electrolyte. The electrolyte acts as an ionic conductor because chemical processes occur due to the directed movement of the ions at the electrodes during the transfer of the charge.

To start the electrolytic tinning, an electrical voltage is applied to the strip and to the tin ingots immersed in the solution. In this case, the tin is situated at the positive pole (anode) and the strip at the negative pole (cathode). As soon as a direct electrical current flows from the anode to the cathode, tin ions are dissolved from the anode and then become deposited on the strip surface via the electrolyte by means of reduction. The strip surface thus becomes coated uniformly with tin.

VERTICAL TINNING CELLS

The coating itself takes place in several vertical cells. Each strip enters the vertical cells of an electrolytic tinning line by moving vertically downwards. It is deflected by a sink roll, runs out vertically upwards and is then deflected by a conductor roll in such a way that it runs into the next cell by again moving vertically downwards.

WITH-ADJUSTABLE ANODE BANKS

While moving upwards and downwards the strip always travels between two anode banks (one for each side of the strip). Thus, each cell is equipped with four banks with soluble tin anodes. Depending on the strip width, the anode banks are fitted with up to 18 tin bars, each with a width of 70 mm (for maximal strip width of 1,260 mm). This arrangement is particularly suitable for the reliable and uniform application of very thin tin layers. No strip edge masks are needed because the anode width is always adjusted.

The surface of an ultra-thin carbon steel strip gets coated with a thin tin layer by an electrolytic process in a vertical tinning cell.
to the strip width. In one cell, one pair of anode banks is equipped with insoluble anodes, thus enabling compensation of any excessive dissolved tin. The location at which the insoluble anodes can be inserted is variable.

PRECISE APPLICATION OF THIN LAYERS

The thickness of the tin layer can very easily be adjusted via the magnitude of the electric current and via processing time, which depends directly on the strip speed. Depending on the strip width and speed, the quantity of current is set in conformity with Faraday’s law such as to enable the desired layer thickness to be applied. Each anode stand has its own rectifier, which is connected with the anode carrier and with the conductor roll. Very thin layers of just a few µm can thus be applied very precisely. Depending on requirements, differing layer thicknesses can also be applied to the strip sides. Altogether, the material consumption is extremely low thanks to the very precise application of very thin layers, which proves to be an essential advantage of the process over the hitherto customary hot-dip tinning, i.e. coating by immersion in liquid tin.

ELECTROLYTE WITH HIGH CONDUCTIVITY

Owing to its higher conductivity, methanesulfonate acid (MSA) is used as the electrolyte in the tinning tanks of SMS lines, resulting in reduced energy costs and in the achievement of greater flexibility due to the higher current density. Since the MSA electrolyte is for the most part biodegradable, it can be disposed of in an environment-friendly manner.
HIGH COST EFFICIENCY THROUGH THE USE OF SOLUBLE ANODES

The use of soluble anodes leads to major economic advantages compared to lines with insoluble anodes. Only because of less tin losses due to tin sludge and the lower price for tin ingots it is possible to save 2.7 million Euros per year*. More savings are generated due to the fact that no costs for recovering the anodes or oxygen for tin dissolving are required. One further advantage are stable tinning conditions in a parallel anode arrangement where the width of the anode bank can be adjusted to the strip width in order to prevent edge over coating without the use of edge masks. An anode monitoring system serves for a continuous supervision of the anode conditions.

The electrolytic tinning process can also be operated with insoluble titanium anodes, in which case the electrolyte then has to be continuously enriched with tin ions to enable the tin to be deposited on the strip surface. For this, however, a system is required in which the tin granulate is dissolved by using oxygen. A serious economic disadvantage is the higher price of tin granulate, which is 5 to 10% higher than that of the tin bars used for the production of soluble anodes. Moreover, at least 4% of the dissolved tin is lost because when the granulate is being dissolved with the aid of oxygen, not only the required tin (II) is generated but also a large quantity of tin (IV). In combination with iron, this forms tin sludge from which the tin can no longer be regained.

In addition, the active surfaces of the anodes, which are provided with a special metallic coating, have to be restored in an elaborate process at least once each year. The insoluble anodes also require edge masks in order to enable the anode width to be adapted to the strip width in cases where smaller strips are used. This is necessary so as to prevent any overcoating at the edges of the strip surface.

ADVANTAGES COMPARED TO INSOLUBLE ANODE TECHNOLOGY

- Less tin losses due to less sludge (< 1% vs. 4-8%)
- Up to 10% lower prices for ingots (soluble anodes) compared to pellets (insoluble anodes)
- Stable tinning conditions in parallel arrangement
- No edge over coating
- No edge mask necessary
- No recovering costs for anodes
- No costs for oxygen for dissolving tin

*Calculation based on: 225,000 t/a capacity, 7,000 h/a, 1,000 t tin consumption per year, 24,000 €/t tin ingots, 24,969 €/t tin pellets (needed for insoluble anodes), losses due tin sludge 1% (soluble anodes) and 8% (insoluble anodes).
PRECONDITIONING CELL

Directly before entry into the first tinning cell, the strip runs through a preconditioning cell filled with diluted sulphuric acid, in which the strip is once again activated and the last few iron hydroxide particles are removed. The strip is thus able to be coated directly when running into the first tinning cell. In addition, it is ensured that the iron content in the electrolytes remains at a stable low level (approx. 5 to 6 g/l). In conventional tinning lines without this preconditioning cell, the strip is activated in the first tinning cell and cleansed of iron hydroxide, whereupon the iron concentration in the electrolyte may rise up to 20 g/l and the electrolyte will finally become unusable.

Furthermore, the material is kept wet and protected against corrosion between cleaning and tinning section. Most of the time it travels through a special channel, in which diluted sulphoric acid is sprayed on the surface. Later on, this liquid is collected and reused in the preconditioning cell. Another special item is the steering roll which is located in the channel.

This way a smooth travel of an already activated and clean material is ensured as well as efficient tinning.

CONDUCTOR ROLLS WITH TUNGSTEN CARBIDE COATING

In SMS tinning lines all conductor rolls are coated with tungsten carbide. Due to this special coating the rolls have a three times higher service live than in case of conventional coatings. The coating lasts for approximately nine months.
ELECTROLYTIC TINNING LINES – THICKNESS CONTROL AND ANODE MONITORING

PARALLEL ANODE ALIGNMENT

In the tinning lines with soluble anodes by SMS, all of the bars of an anode bank are changed simultaneously and therefore all of the bars in a bank always have the same thickness. This so-called parallel alignment of the anodes means that on the one hand continuously high-quality and uniform coating conditions are ensured and, on the other hand, the endangering of the strip travel due to defective anodes is avoided. Of course, the anode change happens during operation and doesn’t effect the production process.

In conventional lines, the bars are pushed through from one side to another, causing a wedge arrangement. As a result both, new and highly abraded bars are used within one anode bank what can lead to quality problems.

The parallel anode alignment used by SMS ensures uniform coating conditions over the whole strip width.

Wedge alignment as used in conventional lines can cause quality issues since anode quality varies within one bank.
CLOSED-LOOP LAYER THICKNESS CONTROL

More than 200 measuring units are installed along a typical tinning line by SMS. In combination with real-time measurement of the tin layer thickness, the line is operated in the so-called closed-loop mode. This makes it possible to constantly monitor and set all line parameters to guarantee an optimized production process. The thickness is measured online via x-ray fluorescence principle, which allows a direct observation of the cross-section of the layer. Depending on the required layer thickness and taking into account all other parameters the electric current is adjusted fully-automatically.

The system was developed based on the long term experience of SMS and is essential for fast start-up, production efficiency and product quality. Up to 5 percent of tin are saved due to less over tinning. As result, operational cost of up to 1.2 million Euro per year* can be saved.

ANODE-MONITORING SYSTEM

The condition of the anodes is continuously recorded and displayed by a monitoring system. The anodes are changed at full process speed after they have become dissolved to a maximum of 50%. To determine the condition of the anodes at all times, the electric current flowing through the anodes is continuously counted.

The anodes are manufactured in the direct vicinity of the lines in an anode casting machine in which the residues of utilized anodes are used in addition to new tin ingots.

*Calculation based on: 225,000 t/a capacity, 1,000 t tin consumption per year, 24,000 €/t tin ingots.
ELECTROLYTIC TINNING LINES – REFLOW TECHNOLOGY

VERTICALLY ADJUSTABLE REFLOW UNIT

In the reflow unit, the coating is heated inductively beyond the melting point of the tin up to 250 °C, thus giving the strip a shiny surface and forming an alloy layer (0.2 – 0.8 g/m²) which enhances the corrosion protection and the adhesion of the tin layer on the strip surface. The heat treatment makes it possible to combine the advantages of electrolytic coating (very thin layers) and of hot-dip tinning (formation of an alloy layer).

Thanks to the use of high-frequency technology (150 to 200 kHz) the heat treatment can take place completely via induction. Unlike in the case of resistance heating or a combination of resistance and induction heating, no conductor rolls are necessary on the strip surface, which could otherwise lead to surface defects. The inductive heat treatment also avoids all risk of the formation of so-called “wood grains” on the surface.

Particularly worth mentioning is the highly efficient, simple and precise control of the induction unit, in which the position of the unit in the strip travel path can also be altered (height-adjustable). The time interval between the induction unit and the subsequent water-cooling system can be set as a function of the strip speed so as to enable the desired iron-tin-alloy layer to be formed.

The heat treatment exposition time is decisive for the tin adherence and it is defined by the strip speed and the distance to the water quench tank. By means of the vertically movable inductor, the exposition time can be adjusted to the right value under all production conditions.
FLUX TANK

In preparation for the reflow process, the strip is treated with a hydrochloric acid-based fluidizing agent in a vertical tank. This is followed by two pairs of squeezer rolls and a strip dryer.

WATER QUENCH

In the water cooling section downstream of the reflow unit the strip is cooled down from 250 °C to atmosphere temperature. Water cooling takes place both by immersion in water and via controlled nozzles, which can be adjusted flexibly in three dimensions. Thus, the intensity of the cooling can be precisely controlled according to the required cooling demands. It is made sure, that no water-stains on the surface occur and steam bubbles are prevented as well.
ELECTROLYTIC TINNING LINES – ENVIRONMENTALLY FRIENDLY EVAPORATOR TECHNOLOGY

EVAPORATOR TECHNOLOGY FOR TINNING AND POST TREATMENT

A certain drag-out of electrolyte into the rinsing sections after tinning and post treatment cannot be fully avoided. Even if the amount is rather small, the costs for (tin enriched) electrolyte and contaminated rinsing water put this drag-out to a large scale. Therefore, SMS uses special evaporator systems for separation into concentrate (electrolyte) and distillate (rinsing water). By means of the closed-circuit system, the resulting concentrate is each reused in the active bath whereas the distillate is returned to the rinsing bath. The recovery of chrome and tin electrolytes follows the same evaporation principle. Operating costs are significantly reduced by the closed-circuit design. Thus, up to 250 t of tin, 3,500 m³ of electrolyte and 42,000 m³ of DI-water are recovered each year. This adds up to operational savings of more than 4 million Euros per year*.

ADVANTAGES:
- No loss of tin, chrome and electrolyte
- Reusing condensate as demi water
- Saving of waste water and waste disposal

The evaporator system ensures a 100% recovery of dragged out electrolytes and thus a closed-circuit of resources. For the recovery, two evaporator systems for each tinning line are used. The plants serve to treat the rinsing water, while simultaneously recovering tin and chrome electrolytes. To protect the tin-electrolyte solution, which is highly sensitive, the rinsing water is treated under vacuum at temperatures of up to 45 °C. The treatment of rinsing water for the chrome electrolyte takes place in the same way.

*All given calculations are based on the following parameters: 225,000 t/a capacity, 7,000 h/a, 24,000 €/t tin ingots, 500 €/m³ MSA electrolyte, 5 €/m³ DI-water
The loaded rinsing water is guided evenly into the pipes below via a liquid distributor (1). The fluid film wets the inner side of the pipes. This makes so-called falling-film evaporation possible. The pipes are heated from the outside by means of specially generated steam out of the process. As a result the water on the inside evaporates (2) and, in accordance with the concurrent-flow principle, is discharged towards the bottom with the liquid. The concentrate is collected at the bottom (3) and the steam is transferred into a separator with demister (4). Here, the last droplets of concentrate are separated from the steam and collected (5). Subsequent, the steam is heated up via vapor compression (6) and is used to heat the pipes. After the heat exchange the steam condensates and is fed back into the process as rinsing water (7).
ANODE CASTER

The anode caster serves for casting of tin anodes without any tin losses at a continuous casting temperature of 360 °C. The continuous process produces perfectly shaped and high-purity tin anodes made of tin ingots and anode remnants. The plant configuration and control technology from SMS are harmonized in all processes: From the casting operation right through to the anode transport to the electrolytic tinning line, all steps are performed automatically.

Two furnaces (1) compensate for temperature fluctuations and make sure, that the casting temperature is constant for the continuous production process. The liquid tin flows into the casting mold (2), where it is distributed homogeneously. The complete anode is produced in a single cast. On its way through the plant, which is arranged as a carrousel (3), the high-purity tin cools down and solidifies to form the finished anode, which then can be utilized without any further processing. Upon ejection from the mold (4), the cast head is removed automatically. After removal from the casting mold, the anode is automatically conveyed into a transport and removal container and stacked (5). From here, the complete anode sets, which are now ready for use, are directly conveyed to the removal position on the plant next to the tinning cells.
The tin bars are made of tin ingots and anode remnants and are ready to be used in the plant after ejection from the mold. The high-purity tin bar cools down and solidifies while it is transported to a conveyor belt via rotation of the carousel.
SMS group has supplied numerous plants for tinplate production in the last decades. For example, the first tinning lines which were erected at ThyssenKrupp Rasselstein, Germany, in the 1960s were delivered by SMS. Today, Rasselstein is one of the three largest packaging steel producers in Europe and operates several SMS-built plants (4 ETLs, CAL, DCR-Mill). Furthermore, several continuous annealing lines for tinplate have been delivered all around the world, starting with a line for Hoogovens in the Netherlands (today TATA Steel), which was also built in the 1960s. Over the years, many major tinplate producers from all around the world ordered tinplate production plants from SMS. Some examples are given in the following pages.
The newest tinning line of ThyssenKrupp Rasselstein, Germany, is still one of the world’s most modern plants. Even though SMS group erected and commissioned this line already in 2005. Here the benefits of a perfect interaction between process technologies, mechanical and electrical equipment and automation systems can be seen. The line went into production only two years after the contract was signed. The commissioning too was done in record time. Full production capacity was already reached after 42 days. This was made possible by perfect coordination of process technologies, mechanical and electrical engineering and automation – all from one source.

An essential element here was the Plug-and-Work concept. Already before commissioning, the electrical and automation equipment was installed in a test center. Everything was tested in a realistic manner with a sophisticated simulation system. The operating concept was optimized and the operator team trained, ensuring perfect readiness for the start of production.

**CONSTANT APPLICATION OF THIN TIN LAYERS**

In the line the strip is joined to an endless strip in a laser welding machine. The strip cleaning unit uses an alkaline solution to degrease the surface. In the pickling section, the final corrosion residues and degreasing agents are removed completely. In the tinning section, tin layers of 1.0 to 5.6 g/m² can be deposited. If requested, even in different thicknesses on both sides of the strip. ThyssenKrupp Rasselstein uses soluble anodes due to the advantages concerning process technology and operational costs. The whole process takes place at a strip speed of 600 m per minute. This corresponds to 36 km per hour, with an ultra-thin and yet always constant tin coating being deposited over the entire strip surface. The strip gauge, the tin coating thickness, the surface quality and the strip speeds are measured continuously and automatically. A total of 260 measuring devices are installed.
SOPHISTICATED CONTROL SYSTEMS

The anode consumption rates are measured and displayed. The line’s yield is thus optimized by the well-planned, timely exchange of the anodes. The switchgear cabinets and converters for the drive engineering control the drives, 185 altogether. They must run 100% synchronously in all operating modes and under changing plant conditions. The power supply to the rectifiers with the copper connection conductors is installed underneath the line. The advantage for Rasselstein is that electrification concepts have been implemented which lead to significant productivity increases.

To ensure that the tin coating adheres more strongly to the strip surface, it is melted at 235 °C in the reflow unit and quenched directly with water. The chemical post-treatment improves the resistance to corrosion. The final production steps and quality assurance measures are monitored at the exit control pulpit. Parallel to this, the strip is subjected to a thorough visual check at the inspection stand. Any possible defects are entered directly into the control pulpit. The data are likewise recorded by the material tracking system to ensure complete and unimpeded quality documentation. The process is completed with a shear unit and a recoiler group. A coil of high-grade tinplate leaves the tinning line.

TECHNICAL DATA

of the newest electrolytic tinning line of Thyssen-Krupp Rasselstein.

<table>
<thead>
<tr>
<th>Electrolytic tinning line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual capacity</td>
</tr>
<tr>
<td>Strip thickness</td>
</tr>
<tr>
<td>Strip width</td>
</tr>
<tr>
<td>Entry speed</td>
</tr>
<tr>
<td>Process speed</td>
</tr>
<tr>
<td>Exit speed</td>
</tr>
<tr>
<td>Steel grades</td>
</tr>
</tbody>
</table>

Starting with the mechanical equipment and extending to the complete electrical and automation systems, supply facilities, pollution control and acid regeneration systems, everything comes from one single source at ThyssenKrupp Rasselstein.
TINPLATE PRODUCTION AT SHOUGANG JINGTANG

Tinplate has been produced at the Shougang Jingtang works on Caofedian Island, China, since October 2013. SMS erected a tinplate annealing line with an inline DCR rolling mill, an offline DCR rolling mill, and two electrolytic tinning lines on the artificially created island off the coast of the Chinese province Hebei. A total of almost 500,000 t of high-grade tinplate can be produced in order to fulfill the growing demand for packaging material in China.

ANNEALING LINE WITH REDUCING/SKIN PASS MILL

The tinplate annealing line has a capacity of more than 435,000 t/a. An outstanding feature of the line is that it can reliably process very thin strips (down to 0.12 mm) under stringent quality demands and at very high speeds (up to 750 m/min). A component of the annealing line is an inline DCR mill (Double Cold Reduction), which consists of two 4-high millstands, with CVC® plus and other tried-and-tested technologies, such as work roll bending, multi-zone cooling and DS system.

This skin-pass rolling mill combines a thickness reduction of up to 42% in the first stand with skin-passing in the second mill stand. The flexible and technically fully equipped plant can be used either for wet or for dry skinpassing. In the exit section of the line, an electrostatic DUMA-BANDZINK oiler provides the strip with a preserving oil film.

A total of almost 500,000 t of high-grade tinplate can be produced by the two tinning lines for the manufacturing of packaging material.
OFFLINE REDUCING/SKIN PASS MILL

In order to further reduce and skin pass annealed material in a batch process, SMS delivered an offline CVC® plus DCR mill with equivalent technical equipment to that of the inline DCR rolling mill. On this line, not only tinplate but also strip made of standard steel, are re-rolled and skin-passed. The yearly capacity of the offline DCR rolling mill amounts to more than 420,000 t.

ELECTROLYTIC TINNING LINE

With a total yearly production capacity of 475,000 t, the two identical electrolytic tinning lines can tinplate all the material from the previously mentioned plants. In both electrolytic tinning lines, tin is distributed on the strip surface by means of an electro-chemical precipitation process, while the strip moves through an electrolyte in nine vertical tinning cells. Shougang Jingtang decided to use soluble anodes due to the economic advantages offered by them. Furthermore, all the modern equipment for tinning lines that SMS supplies, is integrated in to the line, such as a preconditioning cell, an evaporation unit, anode casting equipment and a vertically traversable reflow unit.

TECHNICAL DATA

<table>
<thead>
<tr>
<th></th>
<th>Tinplate annealing line</th>
<th>Offline DCR</th>
<th>Electrolytic tinning lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual capacity</td>
<td>436,000 t</td>
<td>420,000 t</td>
<td>237,500 t</td>
</tr>
<tr>
<td>Strip thickness</td>
<td>0.12 - 0.55 mm</td>
<td>0.12 - 0.55 mm</td>
<td>0.12 - 0.55 mm</td>
</tr>
<tr>
<td>Strip width</td>
<td>700 – 1,280 mm</td>
<td>700 – 1,280 mm</td>
<td>700 – 1,280 mm</td>
</tr>
<tr>
<td>Entry speed</td>
<td>1,000 m/min</td>
<td></td>
<td>750 m/min</td>
</tr>
<tr>
<td>Process speed</td>
<td>750 m/min</td>
<td>1,800 m/min</td>
<td>600 m/min</td>
</tr>
<tr>
<td>Exit speed</td>
<td>1,100 m/min</td>
<td></td>
<td>750 m/min</td>
</tr>
<tr>
<td>Steel grades</td>
<td>CQ, T1, T2, T2.5, T3,</td>
<td>T1, T2, T2.5, T3,</td>
<td>CQ, T1, T2, T2.5, T3, T4,</td>
</tr>
<tr>
<td></td>
<td>T4, T5, DR7M, DR8, DR9,</td>
<td>T4, T5, DR7M, DR8,</td>
<td>T4, T5, DR7M, DR8, DR9,</td>
</tr>
<tr>
<td></td>
<td>DR10</td>
<td>DDQ, EDDQ, CQ, DO</td>
<td>DR10</td>
</tr>
</tbody>
</table>

These products serve to meet the growing demand for packaging material on the Chinese market.
Shagang Group, China, has successfully commissioned its new annealing line and the electrolytic tinning line both supplied by SMS group in 2014. Being a systems provider, SMS supplied all components including electrical and automation equipment.

In March, 2014, the first strips were processed on Shagang Group’s new tinplate annealing line. The electrolytic tinning line which serves to coat the annealed and skin-passed strips with a thin layer of tin followed in April, 2014. Since that time, the new cold rolling mill in Zhangjiagang City in the eastern Chinese province of Jiangsu has been producing tinplate as starting stock for packaging material. The mechanical equipment, processing and furnace technologies as well as electrical and automation systems for both lines were supplied completely by SMS.

CONTINUOUS ANNEALING LINE

The annealing line provides the strip with the required material and surface properties by annealing and subsequent reduction plus surface treatment. In a powerful Drever radiant tube furnace, the strip is processed according to an exactly defined annealing curve. Two four-high skin-pass mill stands are integrated for post-treatment. The first skin-pass mill stand serves for setting the mechanical-technological strip properties by thickness reduction whereas the second one creates a defined strip surface texture.
ELECTROLYTIC TINNING LINE

In the electrolytic tinning line the strip is plated with a thin layer of tin whose thickness can be precisely controlled also in the case of very thin tin layers. Due to the use of soluble tin anodes which are produced in an anode caster also included in the supply package, the operating company benefits from considerable economic advantages including reduced expenses for tin. A special process component is the preconditioning cell which activates the strip immediately before tinning and removes iron hydroxide particles. Tin-plating takes place in eight vertical cells. The position of the vertically movable reflow unit in relation to the running strip is adjusted flexibly to achieve the desired alloy layer. The electrolyte which is dragged-out into the rinsing sections of the tinning and passivation processes, is regenerated via two evaporator systems. The plants serve to treat the rinsing water, while simultaneously recovering tin and chrome electrolytes.

TECHNICAL DATA

of the tinplate production facilities which SMS erected for Shagang Group.

<table>
<thead>
<tr>
<th></th>
<th>Tinplate annealing line</th>
<th>Electrolytic tinning line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual capacity</td>
<td>418,100 t</td>
<td>202,500 t</td>
</tr>
<tr>
<td>Strip thickness</td>
<td>0.18 – 0.55 mm</td>
<td>0.12 – 0.55 mm</td>
</tr>
<tr>
<td>Strip width</td>
<td>700 – 1,250 mm</td>
<td>700 – 1,250 mm</td>
</tr>
<tr>
<td>Entry speed</td>
<td>1,000 m/min</td>
<td>650 m/min</td>
</tr>
<tr>
<td>Process speed</td>
<td>720 m/min</td>
<td>520 m/min</td>
</tr>
<tr>
<td>Exit speed</td>
<td>1,100 m/min</td>
<td>650 m/min</td>
</tr>
<tr>
<td>Steel grades</td>
<td>T2,5, T3, T4, T5</td>
<td>T2,5, T3, T4, T5; DR7M, DR8, DR9, DR10</td>
</tr>
</tbody>
</table>

In April 2014, Shagang Group produced its first tin-plated strip.

The SMS-team was responsible for smooth commissioning.
TOSYALI TOYO ORDERS A CUTTING-EDGE TINNING LINE WITH SOLUBLE ANODES

Tosyali Toyo (Tosyali Toyo Steel Co. Inc.), the Turkish-Japanese Joint Venture between Tosyali Holding and Toyo Kohan, has awarded SMS the contract for the supply of an electrolytic tinning line. This line will be a key element of the new steel mill for the production of packing materials to be constructed in Osmaniye, southern Turkey. From late 2016, 255,000 t of very thin steel sheet per year will be coated with tin layers ranging from 1.0 to 11.2 g/m².

Tosyali Toyo has selected SMS as supplier because the line will be supplied from one single source featuring outstanding technology. The line features a great number of high-performance equipment units, which impress with their environmental compatibility and economic efficiency as well as their reliability in operation, flexibility and product quality.

In the entry section, a side trimming shear with scrap baller is integrated. Prior to tinning, the strip is prepared in a cleaning, tension leveling and pickling section. The tin coating section itself contains preconditioning and six electroplating cells. The applied tin layer is subsequently treated in a fully inductive heating system, in order to enhance the surface quality. Finally the strip is passivated and dried.

PRECISE TIN COATING AND HIGH QUALITY

Along the tinning line, various measuring units are installed to ensure constant process supervision and control. In combination with the tin layer thickness measurement, the best possible product quality and production efficiency is achieved.
Rinsing water from the tinplating and the passivation process will be reconditioned in an advanced evaporation system. In this way, further operational expenses are saved.

A separate anode caster is used to cast the anodes without tin losses and at a steady temperature. The fully automated casting process produces perfectly shaped, high-purity tin anodes from the anode remnants and tin ingots.

Tosyali Toyo has decided in favor of a line with soluble anodes due to its economic, ecological and process technology-related benefits.

TECHNICAL DATA
of the electrolytical tinning line for Tosyali Toyo.

<table>
<thead>
<tr>
<th>Electrolytic tinning line</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual capacity</td>
<td>255,000 t</td>
</tr>
<tr>
<td>Strip thickness</td>
<td>0.12 – 0.6 mm</td>
</tr>
<tr>
<td>Strip width</td>
<td>700 – 1,270 mm</td>
</tr>
<tr>
<td>Entry speed</td>
<td>650 m/min</td>
</tr>
<tr>
<td>Process speed</td>
<td>450 m/min</td>
</tr>
<tr>
<td>Exit speed</td>
<td>650 m/min</td>
</tr>
<tr>
<td>Steel grades</td>
<td>T1, T2, T2.5, T3, T4, T5, DR6, DR7, DR8, DR9, DR10</td>
</tr>
</tbody>
</table>

FAST START-UP
WITH PLUG & WORK TEST
In the Plug & Work integration test, the complete control and automation equipment is installed in a test field and subjected to a plant simulation prior to commissioning. In this procedure, the control- and automation systems are tested and optimized under true-to-life conditions. The operating personnel are also trained at the same time, so that they are already familiar with the control system and achieve a steep run-up curve upon actual commissioning.
SMS group provides integrated solutions including electrics and automation for all tinplate production facilities. They will be jointly designed to implement the advanced technology required for the production of the envisaged first class tinplate material.

Therefore the electrical and automation team is integrated in all activities regarding engineering, commissioning or research and development. The same models which are used to design the line are within the process automation used to operate the line. This is an essential benefit for our customers especially with regard to after sales service and for future product development.

X-PACT® MODULAR AUTOMATION PACKAGES

Electric and automation is a crucial success factor in the realization of complex plants. This is where everything comes together for controlling, monitoring, checking, evaluating, and coordinating the plant. As a holistic electrics and automation package, X-Pact® makes sure all plant parts mesh with each other and work smoothly together: from energy supply and distribution through drive technology, instruments and automation, and production planning.

All electrical and automated functions included in X-Pact® are performed by globally available components of modular design. That ensures standardized solutions for all tasks – carefully worked out according to international standards. This guarantees maximum reliability, service, and independence in production. And furthermore, it helps to make any necessary adjustments in next to no time.

The X-Pact® production planning and control system provides all the tools which are needed for effective planning and quality assurance of the processes in tinplate production plants.

SOLUTIONS FOR TINPLATE PROCESSING

- Line drive control
- Basic automation
- Coating control
- Tension leveler model
- Technological control system
- X-Shape flatness measuring and control system
- Elongation control system
- Level 2 control system

The customer staff is trained under realistic conditions prior to commissioning.

The compact cabinets with the CPU’s handle the data and ensure the process control operations.
Plug & Work Integration Test

The Plug & Work test leads to a steep start-up curve. Prior to commissioning on site the automation is built up in a test field where all production sequences are simulated. By doing this it is possible to test and optimize the automation software under realistic conditions and train the customer’s staff.
"The information provided in this brochure contains a general description of the performance characteristics of the products concerned. The actual products may not always have these characteristics as described and, in particular, these may change as a result of further developments of the products. The provision of this information is not intended to have and will not have legal effect. An obligation to deliver products having particular characteristics shall only exist if expressly agreed in the terms of the contract."