Hot strip mill – from slab to high strength steel

SSAB
SWEDISH STEEL

In the hot strip mill, steel slabs are rolled into strip. The slabs come from our own steelworks in Luleå and from SSAB Oxelösund.

Our strip is produced in several thicknesses and widths. Most of it is delivered as finished product (Domex) directly to customers. Part of the production goes for further processing, such as pickling, cold rolling and/or heat treatment.

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In the coil box, the hot-rolled sheet is wound into a coil for further rolling in the finishing rolling mill.

Our products

SSAB Tunnplåt is the biggest Scandinavian sheet steel manufacturer, and our production is focused on advanced high strength steels. Our products are used in applications such as vehicles, containers and packaging straps.

Our customers are mainly located in Europe, but we also have customers in Asia and America.

We develop, produce and market sheet steel that offers added value to our customers. Hot rolled high strength steels are one example. We are constantly focused on meeting the needs of our customers for quality, reliability of supply and service. Our certification to ISO/TS 16949 is an element in this work.

Hot rolled sheet steel product range

Our hot-rolled product range spans everything from mild steels to advanced high strength steels. The products are delivered as wide coils, slit coils or cut-to-length sheet. The steels are delivered either as-rolled or with a pickled and oiled surface, and also with as-rolled or cut edges. Domex is the brand name of hot-rolled products from SSAB Tunnplåt.

Crane for which high strength Domex MC steel is used.

Truck body made of Domex Wear has good wear resistance.

Domex corrosion resistant steels are used for products such as containers that must withstand exposure to the elements.

Domex high strength steels are used for parts of the Höga Kusten bridge in Sweden.

High strength steels

Domex MC High strength cold-forming steels with excellent formability and good weldability for a wide variety of applications.

Domex Wear Wear-resistant steel with good abrasion resistance that can extend the useful life of most products subjected to abrasive wear.

Domex Weather Resistant Corrosion-resistant steels characterized by good formability, weldability and impact strength, in addition to good resistance to corrosion.

Domex Protect This sheet steel for ballistic protection has a hardness that provides good protection against firearms and other forms of intrusion.

Domex Electrical sheet steel Due to its low content of alloying elements, Domex Electrical sheet steel has good magnetic properties. The sheet steel is used for generators, for which strict demands are made on magnetic and mechanical properties and on flatness.

Domex hardenable steels

Case-hardening steels, high-carbon steels and boron-alloyed steels belong to the group of hardenable steels. High-carbon steels are suitable for applications in which high hardness is essential. Boron-alloyed steels are used as wear steels or high strength structural steels. Case hardening steels are intended for parts that require high surface hardness.

Role of the hot strip mill at SSAB Tunnplåt

The hot strip mill is the first section in the process flow in the SSAB Tunnplåt plant in Borlänge, and is a direct continuation of the artery that begins at the SSAB metallurgical plants.

Slabs are delivered both from the SSAB Tunnplåt metallurgical plant in Luleå and from SSAB Oxelösund.

After hot rolling, the products can be delivered either as coil or in cut-to-length form, or can be processed further in the cold rolling mill. The hot strip mill has undergone vast changes as a result of the Strip 82 and Domex 2000 investment projects.

Investments were made principally on new furnaces and a new roughing mill. The latter investment is part of the SSAB Tunnplåt work on high strength steels.

The process in the hot strip mill begins with loading the slabs in the slab terminal and transporting them to our two reheating furnaces. These are of the walking beam type, and the slabs are heated to around 1 200 °C. The oxide layer, known as millscale, formed on the steel surface at high temperatures is removed in several places. The first time, it takes place in the descaler immediately after the furnaces and is repeated twice–at the roughing mill and before the finishing mill.

In the roughing mill, the thickness of the slab is reduced from about 220 mm to around 30 mm, which is then known as transfer bar. This reduction normally takes place in five passes through the roughing mill. The vertical rolls allow for a certain amount of edging and fine adjustment of the strip width. The transfer bar is then transported to the coil box, where it is coiled because of the limited space available between the roughing mill and the finishing mill.

After the coil box, the transfer bar ends are cut in the crop shears located just before the finishing mill. The strip is rolled in the finishing mill to a thickness of between 1.8 and 16 mm.

All of this is controlled by very sophisticated process control equipment.

After the finishing mill, the strip is cooled in the cooling zone. Temperature control, from the heating temperature in the furnaces, the entry temperature to the finishing mill, and the final rolling temperature of the strip from the finishing mill, to the coiler temperature, is crucial for the mechanical properties of the finished product.

The coiler temperature is measured after the cooling zone and is of major importance to the strength of the strip. The strip can be cooled, normally to 600 °C, with water at high pressure from the top and the underside.

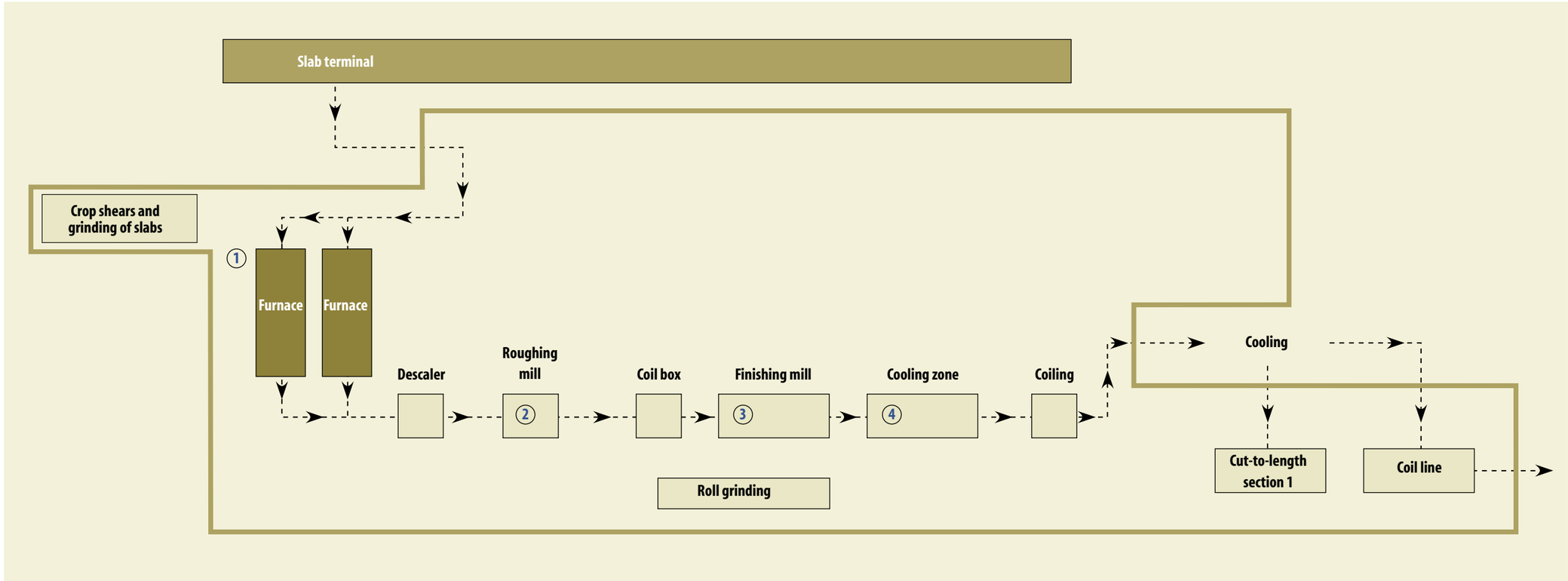
After cooling, the strip is coiled into coils. The coils are strapped, marked and transported out for cooling before being processed further.

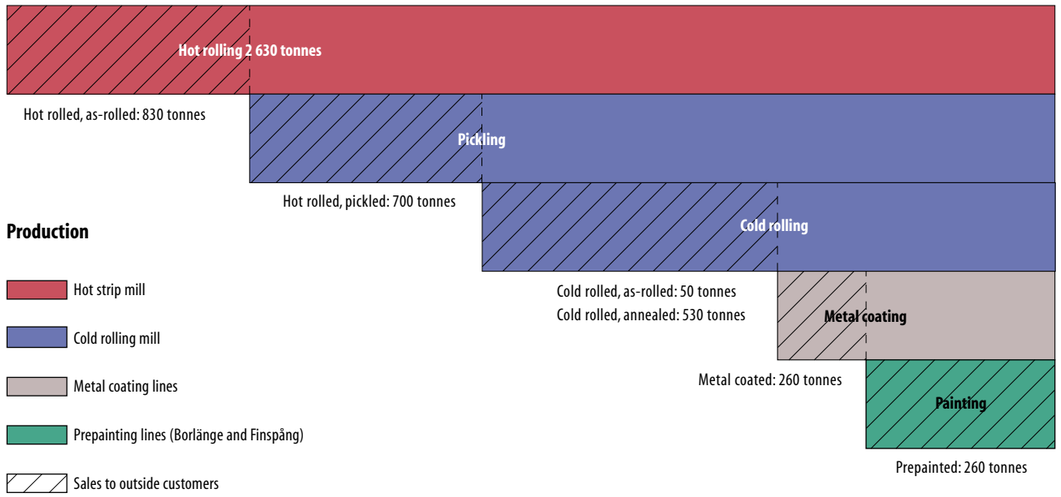
Most of the strip is delivered directly to customers. Some is transferred to the cold rolling mill for pickling, and another part is transferred for cutting-to-length or slitting.

Eskil Johansson
Head of Hot Rolling unit

Eskil Johansson, head of Hot Rolling unit at the Hot Strip Mill.

Flow chart
Hot strip mill





1 Heating
The slabs are heated in the two furnaces to between 1 150 °C and 1 250 °C. Heating takes about three hours.

2 Roughing mill
In the reversing roughing mill, the slabs are reduced from 220 mm to 30 mm thick. This takes places in five passes. The width of the finished strip is also determined in the roughing mill.

3 Finishing mill
In the finishing mill, the strip is rolled down to a thickness of between 1.8 mm and 16 mm. Rolling must take place at the right temperature to ensure that the strip will have the right mechanical properties. The thickness, profile and width are continuously measured, and fine adjustment is carried out automatically, although adjustment can also be done manually.

4 Cooling zone
The cooling zone comprises 32 top cooling sections and 16 underside water curtains. The task of these is to cool the strip to the temperature necessary to produce the required material properties

5 Coiling
After cooling, the strip is coiled into a coil. Coiling is carried out alternately in two coilers.

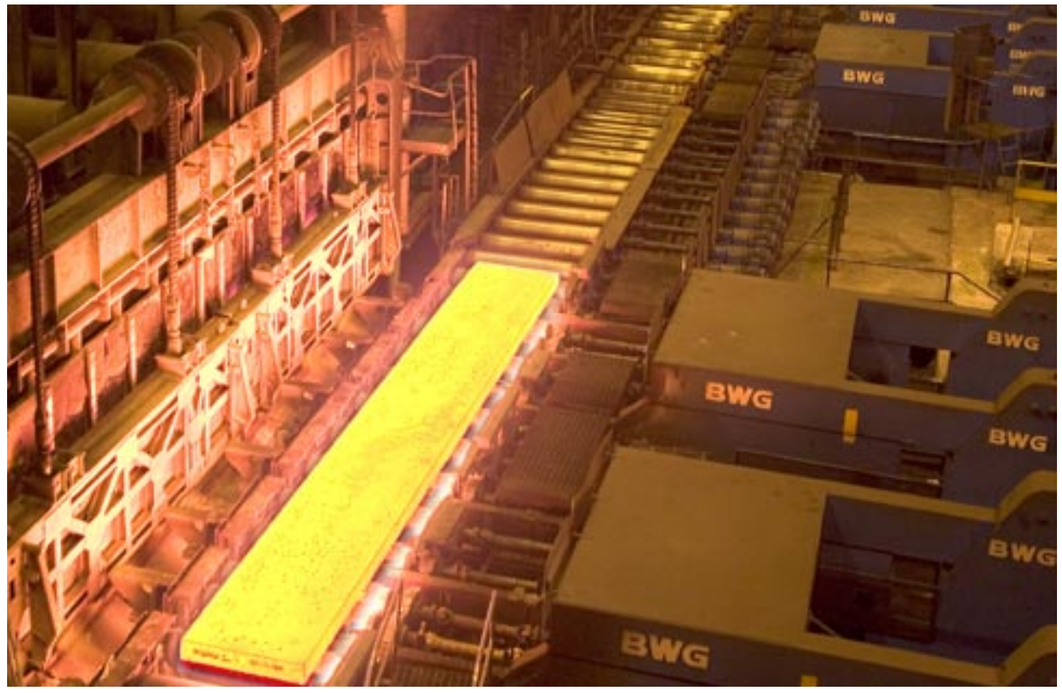
In the coiler, the hot strip is formed into a coil.

Slab handling

Five trains carrying a total of 7 700 tonnes of slabs arrive every day at SSAB Tunnplåt in Borlänge. The slabs arrive from the steelworks in Luleå and Oxelösund.

The slabs weigh an average of 20 tonnes each, and every slab has its own identity number that follows it all the way through the production process. In Borlänge, the slabs are unloaded at one of the two slab terminals. They are then transported by forklift trucks to the furnace hall of the hot strip mill, where they are heated in one of the two reheating furnaces.

Slabs arrive daily at the SSAB Tunnplåt slab stores in Borlänge. A slab weighs an average of 20 tonnes.



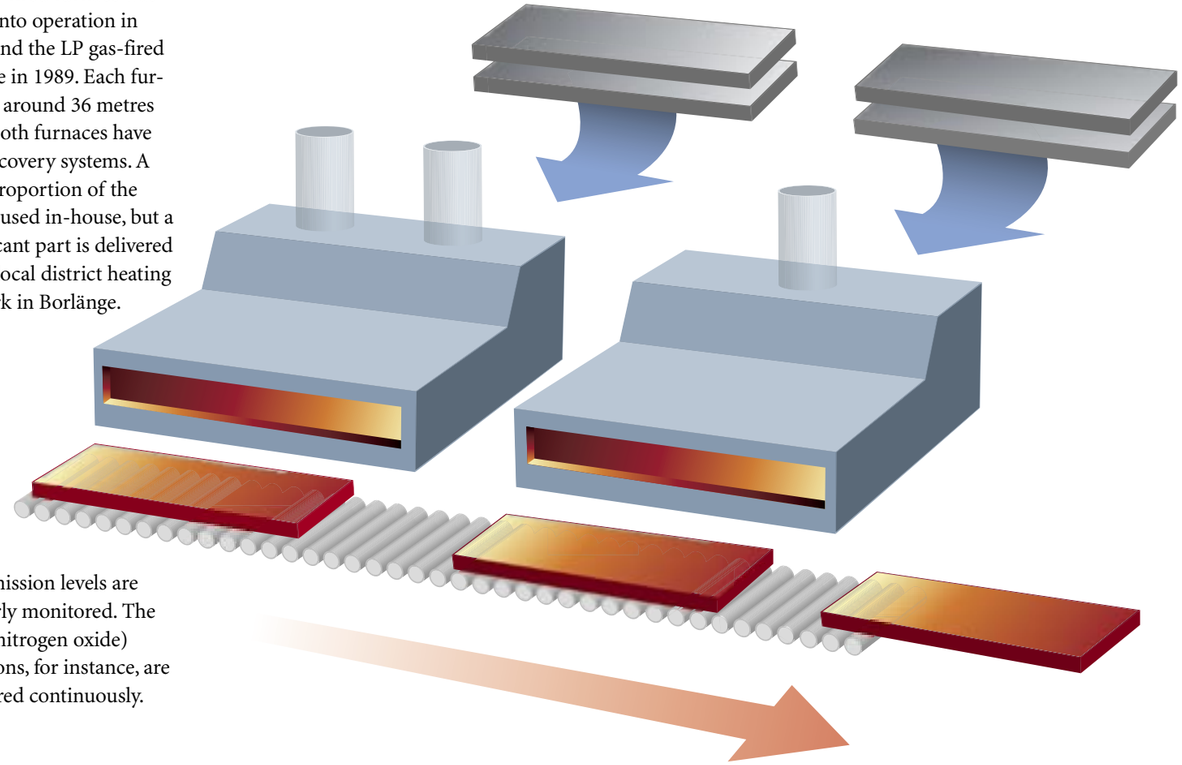
The slabs are heated in the furnace to a temperature of between 1 150 and 1 250 degrees Celsius.

Heating

The 220 mm thick slabs are heated to a temperature of between 1 150 and 1 250 °C. Heating takes about three hours, depending on the slab material and the dimensions to which the slab is to be rolled.

The furnaces are of the walking beam type, and each has a capacity of 300 tonnes per hour. The slabs are advanced through the furnace on steam-cooled rails. Four of the ten rails are movable, and they move the layer of slabs in an up-forward-down-back motion, which is known as the stepping cycle. Every hour, the furnaces consume an amount of fuel oil corresponding to the annual consumption of four oil-heated single-family houses, and LP gas corresponding to 11 000 caravan gas cylinders (P11 cylinders).

The oil-fired furnace was taken into operation in 1981, and the LP gas-fired furnace in 1989. Each furnace is around 36 metres long. Both furnaces have heat recovery systems. A large proportion of the heat is used in-house, but a significant part is delivered to the local district heating network in Borlänge.



The emission levels are regularly monitored. The NOx (nitrogen oxide) emissions, for instance, are measured continuously.

Furnace 301	
Development	
Commissioning date:	1989
Tillverkare:	Chugai-Ro (Japan)
General data	
Max. nominal capacity:	300 tonnes/h
Dimensions	
Length:	34.5 m
Width:	12 m
Slab dimensions	
Max. slab length:	11.2 m
Slab thickness:	220 mm
Temperature range	
Temperature range:	1 150 ° – 1 270 °C
Fuel	
Fuel:	LP gas

Furnace 302	
Development	
Commissioning date:	1981
Manufacturer:	Italimpianti (Italy)
General data	
Max. nominal capacity:	300 tonnes/h
Dimensions	
Length:	36 m
Width:	12 m
Slab dimensions	
Max. slab length:	11.2 m
Slab thickness:	220 mm
Temperature range	
Temperature range:	1 150 °– 1 270 °C
Fuel	
Fuel:	Oil (ASTM Heating Oil No. 6)

Rolling

All slabs arriving at SSAB Tunnplåt in Borlänge pass through the hot strip mill. After heating in one of the two furnaces, the slabs are rolled down from 220 mm thick to between 1.8 and 16 mm thick. Rolling takes place in different steps, and every step is vitally important to the final quality of the material. The quality and properties of the material are carefully controlled throughout the process.

Descalers

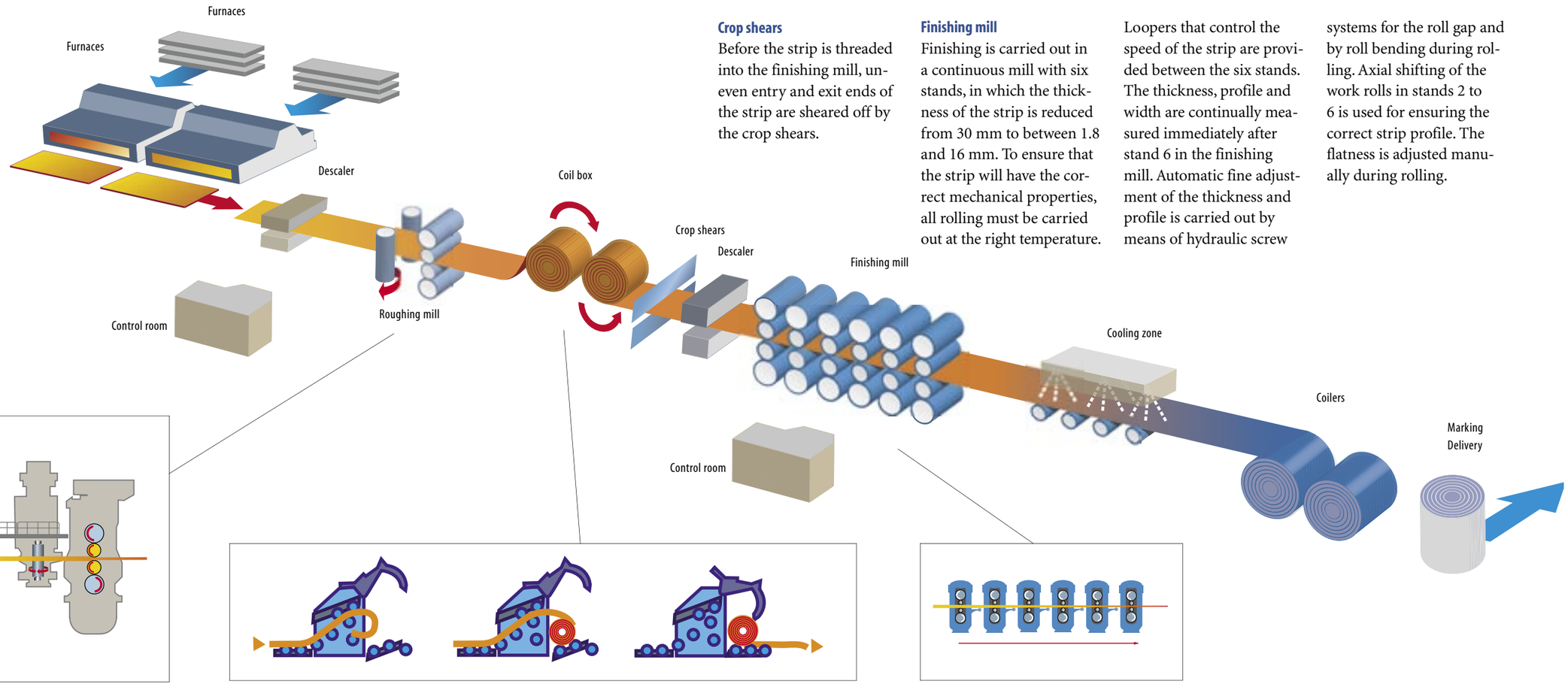
When hot steel comes into contact with air, a layer of oxide is formed on the surface of the steel. In order to avoid problems with the surface of the finished product, the oxide layer - known as millscale - must be removed. In the hot strip mill, this is done in several places by descalers, in which the millscale is flushed away with water at a very high pressure. The millscale formed in the furnace is coarser and is removed just outside the furnace.

Roughing mill

In the reversing roughing mill, the slabs are rolled in five passes to the correct width and a thickness that is suitable for further rolling to the finished product in the finishing mill. The thickness is reduced from 220 mm to 30 mm. The roughing mill is the only place in the hot strip mill where the width of the finished strip can be changed by edging with the vertical rolls.

Coil box

In the coil box, the strip is coiled to enable the next strip to be rolled in the roughing mill during threading into the finishing mill. The temperature of the strip is also equalised and maintained in the coil box. This allows for a greater reduction in the finishing mill and thus a thinner final gauge and closer thickness tolerances.



Roughing mill

General data

Date of manufacture:	1998
Type:	Reversing four-high mill with vertical rolls
Max. roll force:	5 000 tonnes

Rolls

Back-up rolls	ø 1 550 x 2 090 mm
Work rolls	ø 1 225 x 1 900 mm
Edging rolls	ø 1 100 mm

Motor

Motor:	AC motor from ABB
Rating:	2 * 8 800 kW

Finishing mill

General data

Year of manufacture, stands 1–5:	1961
Year of manufacture, stand 6:	1997
Modernized:	1982–1988
Type:	Continuous four-high mill

Hydraulic loopers between all stands.

Rolls

Number of stands:	6
Back-up rolls:	ø 1 300 mm
Work rolls:	ø 696 mm
Max. roll force:	2 800 tonnes

Electromagnetic roll gap adjustment in stands 1–6.
Hydraulic roll gap presetting in stands 2–6.

Motor

Motor:	7 250 kW DC motor from ASEA
Speed:	15 m/s

In the finishing mill, the thickness of the strip is reduced from 30 mm to between 1.8 and 16 mm.

Crop shears

Before the strip is threaded into the finishing mill, uneven entry and exit ends of the strip are sheared off by the crop shears.

Finishing mill

Finishing is carried out in a continuous mill with six stands, in which the thickness of the strip is reduced from 30 mm to between 1.8 and 16 mm. To ensure that the strip will have the correct mechanical properties, all rolling must be carried out at the right temperature.

Loopers that control the speed of the strip are provided between the six stands. The thickness, profile and width are continually measured immediately after stand 6 in the finishing mill. Automatic fine adjustment of the thickness and profile is carried out by means of hydraulic screw systems for the roll gap and by roll bending during rolling. Axial shifting of the work rolls in stands 2 to 6 is used for ensuring the correct strip profile. The flatness is adjusted manually during rolling.

Cooling

The cooling zone is more than 55 metres long and comprises 32 top cooling sections and 16 underside water curtains that cool the material to the right temperature.

The strip must be carefully cooled to ensure that it will have the required mechanical properties.

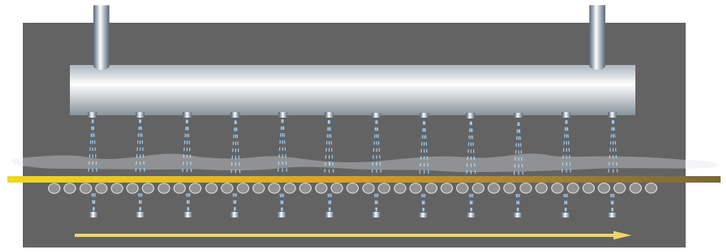
The cooling zone is more than 55 metres long and comprises 32 top cooling sections and 16 underside water curtains that cool the strip to the right temperature.

The temperature of the strip material is measured before the cooling zone and just before coiling in order to enable the cooling rate to be controlled. The cooling water flow is about 8 000 cubic metres per hour.

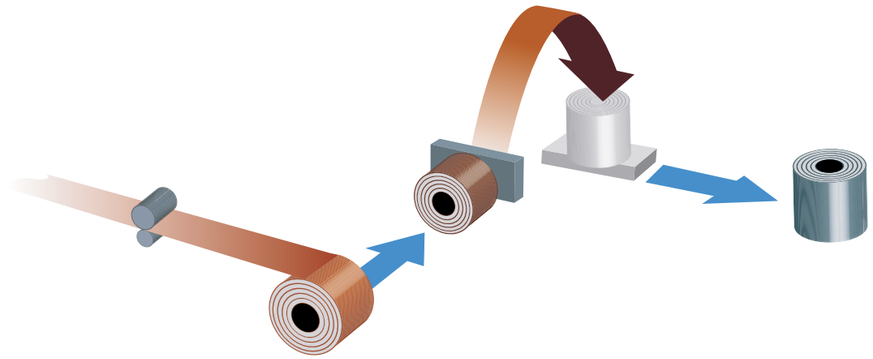
Certain steel grades require rapid quenching, whereas others must be cooled slowly, such as hardenable steel grades that would harden if cooled too rapidly.

Cooling zone

General data	
Length	55 m
Type	
Laminar cooling of the top of the strip with 32 sections. Water curtains on the underside of the strip with 16 sections.	
Max. water flow	
Top	4 000 m³/h
Underside	4 000 m³/h



Coiling



After cooling in the cooling zone, the strip is coiled alternately in the two coilers H3 and H2. The maximum coiling temperature is 800°C.

The guide bars ahead of the coilers are used for guiding the strip, and a feeder draws the strip to the coiler. Three pinch rolls form and secure the first end of the strip to the mandrel of the coiler.

Before the coil is removed, the mandrel is ”collapsed” so that its diameter is reduced to make it easy to remove the coil.

The inside diameter of the coil is 763 mm, the maximum outside diameter is 2 100 mm and the maximum weight is 30 tonnes.

The coil then undergoes:

- Strapping: A strap is wrapped automatically around the outside of the coil to keep it together.
- Tipping: The coil is tipped to an upright position, with the coil sides at the bottom and top to ensure that the coil will not be deformed by its own weight and become oval during the initial part of cooling in air.
- Inspection: Quality is very important. The coil is examined for possible defects, such as mechanical damage or defects in the coil appearance.
- Clearing: In the event of minor damage, the coil can be lifted out of the production line to receive immediate attention in simple equipment in the coiler area.
- Weighing: Every coil is weighed and its weight is recorded.
- Automatic marking: The periphery and the upper end are marked with the identity and destination.
- Cooling: A conveyor transports the coil, which is cooled by the surrounding air during transport. It takes about two hours for the coil to reach the end of the conveyor. The total cooling time is two to three days.
- Transport: The coil is transported by forklift truck to the next line via the raw strip stores for further cooling.

Coiling

Number of coilers	2
Coiler 3	
Type:	MDS 1986, 1.5–16.0 mm ”Step control”
Motor:	690 kW
Max. coil weight:	30 tonnes
Coiler 2	
Type:	SACK 1974, 1.5–13.0 mm
Motor:	690 kW
Max. coil weight:	30 tonnes
Diameters	
Inside diameter:	762 mm
Outside diameter:	2 100 mm

The finished coil is tipped to an upright position.

Roll grinding

Rolls with different crowns and of different materials must be available for rolling different steel grades. The rolls wear quickly and are changed about once every shift, i.e. three times per 24 hours. So rolls are changed 370 times a week. A roll can be reused between 80 and 170 times, depending on the grade of material being rolled. There are always 120 rolls in stock.

In addition to having the right diameter, newly-ground rolls must also be correctly profiled.

There are two types of horizontal rolls - work rolls and back-up rolls. In addition, there are vertical work rolls in the roughing stands.

The profile of the rolls vary from a shape similar to a Coca-Cola bottle, to more or less straight rolls. This is known as CVC and Sinusoidal crowning (form).

Before the rolls can be machined, they must be cooled and washed. Hydraulic machines rotate the bearings into the right position to enable the roll to be placed in the grinding machine without the need for removing the bearings.

The roll grinding machines are automatic and grind the rolls in accordance with preset values. Between 0.5 and 0.7 mm of the roll diameter is ground away every time to restore the roll surface and form. Grinding takes just over half an hour. Major damage to the periphery of the roll is removed by turning before grinding.

A grinding wheel is usable from a diameter of 940 mm to 670 mm. About seven grinding wheels a week are needed for the grinding operations. The grinding wheels are cooled by grinding coolant in a circulating system, and the coolant is changed twice a year.

The accuracy of grinding is as follows:

- Roll conicity: 0.02 mm
- Roll profile deviation: 0.02 mm
- Max. roll diameter deviation in roll stand: 0.25 mm

After machining, the rolls are subjected to crack detection and ultrasonic testing. The bearings are then lubricated.

The bearing housings of the back-up rolls are changed after every grinding operation. On the other hand, the bearing housings of the work rolls are removed at the end of the useful life of the rolls or if the roll has been damaged.

The rolls sustain heavy wear and are reground in a roll grinding machine. Every roll can be used between 80 and 170 times, depending on the material grade.

Roll grinding

Diameters of roughing mill rolls (cast)

Back-up rolls	1 350–1 550 mm
Work rolls	1 100–1 225 mm
Vertical rolls	1 000–1 100 mm

Weights (with bearings) of roughing mill rolls

Back-up rolls	86 tonnes
Work rolls	61 tonnes

Diameters of finishing mill rolls (cast or forged)

Back-up rolls	1 165–1 300 mm
Work rolls	630–696 mm

Weights (with bearings) of finishing mill rolls

Back-up rolls	47 tonnes
Work rolls	13 tonnes

Machines

Four numerically controlled roll grinding machines, two of which can be adapted for grinding different/all rolls. A roll lathe and two roll storage places for work rolls and back-up rolls are also provided.

Finishing

In the finishing phase, the rollers can be cut and aligned, as well as trimmed and packaged for onward transport to the customer.

The finishing unit is located in the same building as the hot strip mill and has several tasks. Hot rolled strip from the coils is cut to length and levelled. Coils are trimmed and packed. Then the packed material is loaded for onward transport to the customer.

Cut-to-length line 1

Cut-to-length line 1 cuts and straightens strip from the hot-rolled coils and pickled coils to produce cut-to-length sheet. Thickness: 3–16 mm. Width: 640–1 600 mm. Length: 1 600–13 000 mm.

Packing

Depending on the method of transport and the destination, the sheets from the cut-to-length line are packed in accordance with the specified code.

Adjacent to the cut-to-length line, the automatic packing line wraps the sheets in cling film. Manual packing on pallets and with paper wrapping is carried out in two stations in the vicinity of the cut-to-length line.

Delivery

The packages are stored and loaded on to railway wagons and trucks from the adjacent hall.

Coil finishing

In coil finishing, the coils are trimmed, and samples are then taken for quality inspection. The coils are weighed and strapped in accordance with the specified packing code in an automatic circumference strapping machine and an axial machine for strapping through the centre of the coil.

The coils are then labelled before being stored in the hall.

After approved quality inspection, the coils are loaded mainly onto railway wagons for transport to customers.

Testing of material for cut-to-length lines 1 and 3 is also carried out in coil finishing.

Focus on the environment

Society is making growing environmental demands on our production system and also on our products. It is therefore vital for environmental matters to be included in all elements related to our operations.

The environmental management system is our tool for organizing the environmental work in the company, creating involvement, and increasing the effectiveness in environmental matters. We have decided to work along predetermined guidelines, and we therefore follow the ISO 14001 environmental standard.

We have received environmental certification in 2002 and we regularly register new improvements in the field of the environment, including those emerging during periodic environmental audits.

The environment is gaining in importance in the development of products and production processes. Safety, material recovery and conservation of resources are the guidelines in this development work.

Steel is an excellent material, since it can be recycled time after time for use in new products. Our high strength steels, for instance, enable structures and products to be made lighter. This reduces the consumption of raw materials and lowers the fuel consumption during transport. Work on high strength steels thus goes hand in hand with a better environment and sustainable development.

For further information, visit www.ssabtunnplat.com.

Energy consumption

Oil and LP gas are the primary energy sources for heating the slabs in the hot strip mill. Advanced techniques and well trained personnel enable high precision to be achieved in the plant, which lowers the energy consumption and improves the conservation of materials.

The energy efficiency is so high that the hot strip mill is among the better plants of its type in an international comparison. Excess heat from the furnaces is sufficient for meeting the whole of the space heating demand of the SSAB Tunnplåt industrial site. In addition, excess heat from the furnaces also supplies a large proportion of the heat for the local district heating system.

Settling pond for cleaning the cooling water from the process.

The environment

Development

The 1970s
Local emissions. Treatment plants with operation and inspection within specified permits and emission conditions.

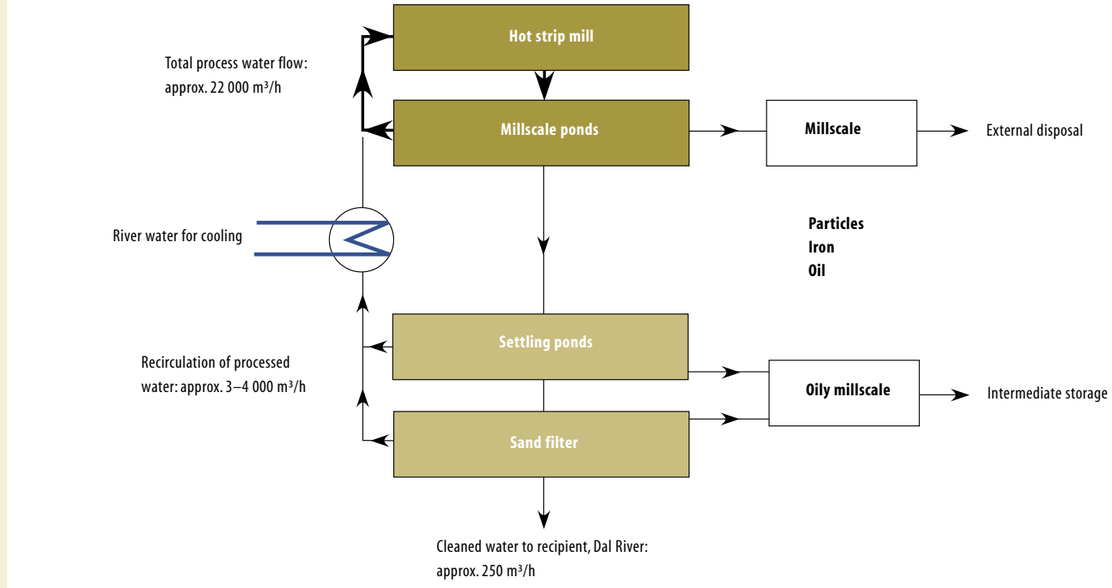
The 1980s
Energy consumption. Process development towards reduced energy consumption.

The 1990s
Focus on the product. Development of environmentally friendly products with a minimum of harmful substances.

The 2000s
Sustainable development. Focus on safety, recovery and conservation of resources.

Energy and environmental data for furnaces

Specific energy consumption	830 kWh/tonne
Nitrogen oxide emissions	190 mg/MJ



Water treatment plant of the hot strip mill
Hot rolling demands large quantities of water for cooling the furnaces, rolls and materials. The hot strip mill is provided with a comprehensive water system in which millscale, oil and grease are recovered. The system also includes treatment systems for separating impurities from the water before the water is returned to the process. A minor part of the water is discharged to the Dal River, but about 99 percent of the water is recirculated.

Materials testing

The mechanical properties of the materials produced are tested at the laboratory. The personnel are on shift work and testing is carried out around the clock.

The most common test is the tensile test, in which properties such as the yield strength and tensile strength of the material are determined. More than 250 000 tests are carried out every year.

Other properties that can be determined include bendability, impact strength, hardness and surface roughness. The internal purity of the material can also be checked. The laboratory also issues yearly around 80 000 test certificates that accompany the deliveries.

The quality inspection work includes thickness measurement.

SSAB Tunnplåt AB is the largest Scandinavian steel sheet manufacturer and the leader in Europe in the development of advanced high strength steels.

SSAB Tunnplåt is a member of the SSAB Swedish Steel Group, has a turnover of SEK 12 billion, and employs 4 000 persons in Sweden. We manufacture annually around 2.6 million tonnes of sheet steel.

We have an environmental policy that involves continual improvements to the efficiency of processes and environmental plants, and the development of the environmental properties of our products from the life cycle perspective.

We manufacture the following steels in our modern, high-efficiency production lines and rolling mills for strip products:

DOMEX®
Hot rolled steel strip

DOCOL®
Cold rolled steel sheet

DOGAL®
Hot-dip galvanized steel sheet

PRELAQ®
Prepainted steel sheet

We assist our customers in selecting the steels that are best able to improve their competitiveness. Our strength lies in the quality of our products, our reliability of supply and our flexible customer service.

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