

## **4. Hot Rolling, Cold Rolling, Coating**

### **4.1. Hot Rolling**

Slabs are first reheated in reheating furnaces. There are two types of reheating furnaces: pusher furnaces and walking beam furnaces. They differ mainly in the way the slabs are transported through the furnace. In the pusher-type furnaces, the charging machine pushes the slabs transversely through the furnace. In the walking beam furnaces, water-cooled walking beams move the slabs longitudinally through the furnace. The slabs are ready to be rolled when they have reached a temperature of 1200 °C.

Prior to rolling, the scale layer of oxides formed on the slabs during reheating in the furnace has to be removed. This is done by the scale breaker, which cleans the top and underside of each slab with a water jet. After this, the slab is transported by the roller table to the roughing stand and then onto the finishing mill. Just in front of the finishing train there are cropping shears that remove the head and the tail of the sheet. After the cropping shears, the sheet passes through a second scale breaker, which removes the oxide scale that has again been formed on the steel. Each stand in the finishing mill reduces the thickness of the sheet until the final thickness required has been attained.

Because the sheets get progressively thinner, the strip speed increases from stand to stand. After rolling, the strip is cooled with water until the right temperature has been reached and finally it is coiled. After further cooling, the product can be sold as hot rolled coil or sheet (mill finish or unpickled), or sent to the cold rolling mill.

### **4.2. Cold Rolling**

After hot rolling, the strip carries a layer of oxide scale. This scale consists of a chemical compound of iron and oxygen and it is hard and brittle. To prevent these oxides being pressed into the sheet during subsequent processing, they have to be removed prior to cold rolling. This is done by pickling, during which the strip is passed through a warm acid bath. Some mills use hydrochloric acid and some sulphuric acid. Immediately after pickling, the steel strip is carefully rinsed and dried.

Pickling requires continuous and even contact between the pickling acid and the treated material. This means that the strip has to move through the pickling baths at as constant speed as possible. Coils are therefore joined head to tail at the entry to the pickling shop to produce a continuous strip. The join is made by means of a butt weld, whereby both ends are heated and then butted together. Subsequently the weld is planed to remove the excess thickness. The strip is then passed to the entry loop accumulator, which acts as a storage buffer between the discontinuous entry section and the continuous pickling section. After pickling, there is an exit accumulator to accommodate speed differences between the pickling process and the downstream treatment.

After pickling, rinsing and drying, the strip can be cut to the required width by the side trimmer. Subsequently, the strip is oiled, cut and coiled. The oil not only served as a protection against rust, but also acts as a lubricant during subsequent cold rolling. The shears cut the strip when the coil has reached the required size. The strip can be cut at the weld, or another location to obtain the required coil weight. The pickled coils can be sold as coils or sheets or can be passed on for further cold rolling.

In the cold rolling section, the tandem mill reduces the strip to the thickness requested by the client. The further reduction in thickness is achieved by a combination of compression and tensile forces: pressure on the rolls and tension between the roughers. After leaving the last roll stand, the strip is coiled again.

Some mills operate an integrated pickling and tandem process, meaning that the coils can go straight on to be cold rolled immediately after pickling, without interruption.

Although the cold rolling in the tandem mills reduces the sheet to the required thickness, the steel has become hardened and cannot be further processed in this “full hard” state. The steel therefore has to be subjected to a thermal treatment, and this takes place in the annealing furnaces.

### **4.3. Annealing**

Steel acquires the desired mechanical properties through annealing in an inert atmosphere at a temperature of about 700°C. There are two possibilities: the coils are either annealed in the batch annealing furnace (BAF) or in the continuous annealing and processing line (CAPL).

In the batch annealing section, the steel coils are positioned on furnace supports. Up to four coils are stacked on top of each support. The stack is protected from the atmosphere by a protective cover around which the actual annealing hood is positioned. The air present inside the protective cover is replaced by a reducing gas (pure hydrogen or a mixture of hydrogen and nitrogen) to protect the sheet and prevent it from rusting during the annealing process. The gas also acts as a heat transfer medium. The annealing temperature depends upon the steel grade required, but will be about 700 °C. After annealing, the hood is removed and replaced by a cooling hood with a ventilator at the top, which cools the steel. The entire process takes several days.

The continuous annealing process is designed as a fast method of providing the steel with homogenous and uniform heat treatment that should generate steel properties that are at least as good as of those resulting from the conventional batch annealing process. As implied by the term “continuous annealing and processing line”, the process entails more than just annealing: within ten minutes, a cold rolled coil is degreased, annealed, tempered in the skinpass mill, inspected and finished according to the requirements of the customer. In addition to the time saved by the continuous annealing process, there are also certain steel grades that can only be produced by continuous annealing.

In the continuous annealing line, the coils are welded to each other by a mesh seam weld so that a fully continuous strip can pass through the entire installation. First of all, the strip is completely degreased. After rinsing and drying, the strip arrives in the accumulator linking the discontinuous entry section and the continuous furnace section. In the furnace, the strip is heated to a temperature of about 700 - 800 °C, depending upon the metallurgical

requirements. This annealing temperature is maintained for a short period only. In the first cooling stage, the temperature is reduced to approx. 400 °C and the strip is held at this temperature for a fixed period of time. This constitutes the accelerated ageing or over ageing of the steel. Finally, the strip is cooled down further. The entire annealing process only takes a few minutes. After the exit accumulator, the strip passes through a temper rolling stand or skinpass mill where it acquires the required elongation, surface roughness and flatness. The side trimmer trims it to the required width. After inspection, oiling and stamping, the strip is cut to the required weight by the cropper shears and coiled.

The annealed coils from the batch annealing section still have to obtain their elongation, surface roughness and flatness in the skinpass mill. Cropping shears in front of the coiler cut the strip to the correct coil weight, and the welds made prior to the skinpass mill are also removed at this stage.

If necessary, the cold rolled coils can be transported to the inspection line. The main purpose of these inspection lines is an additional control of the strip surface. At the same time as the edges are trimmed, the strip is marked and oiled and if necessary, the weight of the coil can be adjusted by cutting or welding.

The annealed cold rolled steel is packaged to protect it during transport and storage. After packaging, a label with the relevant data is attached. Now the material is ready to be dispatched to the customer.

#### **4.4. Coating**

For many applications, the customer requires coated material. This may be electrolytic coating, hot dip coating or organic coating.

For hot dip coating, full hard cold rolled coils or hot rolled coils are used. For electroplating, completely finished, annealed cold rolled coils are used. Organic coating can be applied to annealed cold rolled coils or to coils with a metallic coating

#### **Points to remember:**

- Prior to hot rolling, slabs are reheated in reheating furnaces. There are two types of reheating furnaces: pusher furnaces and walking beam furnaces.
- During hot rolling, hot slabs are rolled into thin sheets; their heads and tails are cropped and coiled.
- Hot rolled coils can be subsequently cold rolled. Prior to cold rolling, scales are removed during pickling.
- After cold rolling, coils are in a “full hard” state.
- Annealing in an inert atmosphere helps cold rolled coils to acquire the desired mechanical properties.
- There are two types of annealing: Batch annealing and Continuous annealing

**Glossary:**

<b>English</b>	<b>Czech</b>
Annealing	Žihání
Butt weld	Tupý svar
Coiling	Svinování do svitků
Pickling	Moření
Planed	Zarovnaný
Rolling stand	Válcovací stolice
Rolling train	Válcovací trať
Roughing	Předválcování
Scales	Okuje
Tempering	Popouštění
Walking beam furnace	Kroková pec

mill finish – přírodní hrany

Rougher – předválcovací stolice