Boosting Productivity and Quality

Induction Heating in Hot Rolling Mills

Integrated minimill concepts for the production of hot strip have been in successful operation for many years. All the plant components, from the vertical casting machine through the roller hearth furnace right up to the compact rolling mill are installed in line to enable a continuous process from the liquid steel phase right through to the coiled hot strip. Increasing demands on productivity and the quality of the rolled goods can be met today by integrating flexible induction units into these lines.

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Increasing Demands on Productivity and Quality

New demands are currently leading to a further development of the traditional minimill concept with the following benefits: [1]

- Higher production up to 4 million t/a
- More stable thin strip rolling down to < 1 mm as substitution for cold rolling (endless process)
- Production of high-strength, cryogenic strips for tube production in the thickness range 0.5 – 1 inch

Within these innovative minimills, there is a need for an intelligent temperature increase at various points. Induction heating is used for this, hence creating an added value for the end customer that is reflected directly in an improved product quality with lower production costs – and that with a sustainably environmentally friendly, CO_2-free method of operation.

One advantage of induction heating is that a large amount of energy can be introduced into the material to be heated within a very short time. This physical phenomenon allows the plant to be built compactly and with a small footprint. The inductor can be selectively employed where a temperature increase or temperature adjustment is necessary.

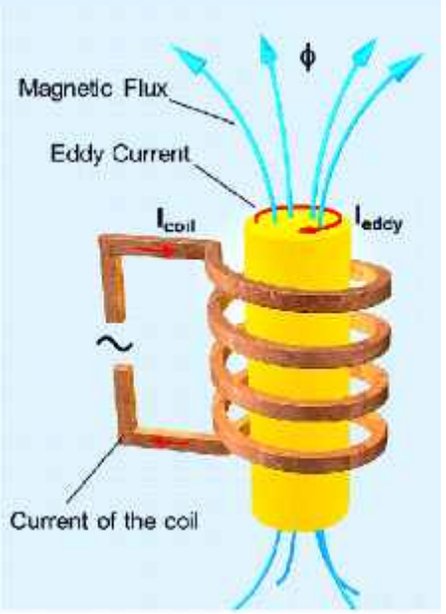
Induction Heating Method

With the induction technology, the metal workpiece is generally surrounded by a coil in which electricity flows and induces a magnetic flux in the workpiece.

This magnetic flux in turn generates an eddy current in the workpiece which generates heat in the workpiece due to the specific resistance of the material.

As a result, a contact-free temperature increase can be achieved in the workpiece thanks to the flow of electricity. Depending on the power and frequency of the electricity, the temperature in the workpiece can be very precisely influenced. [Fig. 1]

FIG. 1: THE PRINCIPLE OF INDUCTION HEATING



In hot rolling lines, different coil forms are used, depending on the slab or strip thickness. [Fig. 2]

During longitudinal-field heating, the workpiece is completely surrounded by the coil. The resulting eddy currents flow at the current penetration depth along the slab surface. It is to be recommended

upstream or downstream of the roller hearth furnace or downstream of the roughing stand where there is still a sufficient strip thickness.

Thanks to their simple construction, these longitudinal-field inductors are very sturdy and suitable for use in rolling mills and can therefore be easily integrated into the process.

Transverse-field heating, on the other hand, is used for thin strips. A special coil construction ensures that the induced currents do not neutralise one another on the upper and lower sides of the thin strip. As even very thin strips can be heated in this way, this method is employed between the last finishing stands. There they can be moved into or moved out of the process very flexibly.

The advantages of induction can be summarised as follows:

- Energy consumption only during effective production
- High power density over a short process length
- Competitive price (investment and life cycle costs)
- Independent of gas and oil as fuel
- Uniform heating of the slab with short heating time and reduced scale formation

FIG. 3 : PRINCIPLE CIRCUIT DIAGRAM OF AN INDUCTION HEATING UNIT

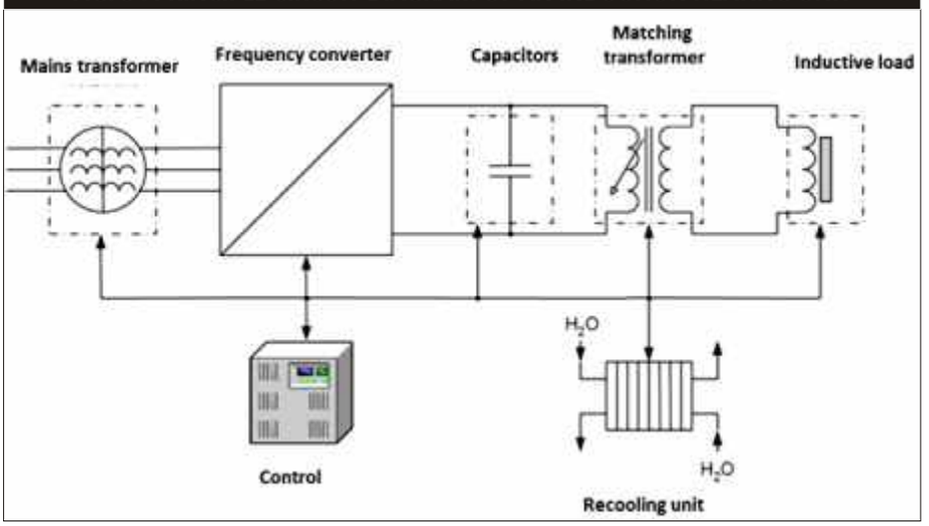
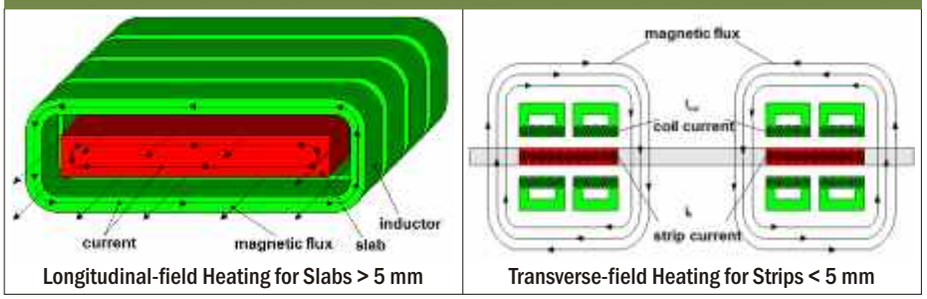


FIG. 2 : FUNCTION OF LONGITUDINAL-FIELD AND TRANSVERSE-FIELD HEATING



Longitudinal-field Heating for Slabs > 5 mm

Transverse-field Heating for Strips < 5 mm

Basic Configuration of an Induction Heating Unit In A Rolling Mill

The induction heating unit consists of the following modules [Fig. 3]

- Mains transformer
- Frequency converter
- Capacitors
- Inductor
- Recooling system
- Open-loop and closed-loop control unit

The function of the mains transformer is to transform the mains voltage into the operating voltage of the frequency converter. The mains transformer acts as the link between the customer's mains power supply and the induction heating unit. The voltage supplied by the mains transformer is a 3-phase AC voltage. By the frequency converter this AC voltage is first transformed into DC voltage, and then converted into single-phase AC voltage with the required operating frequency.

The capacitors serve as a capacitive energy accumulator and form the oscillating circuit together with the inductor, in other words the inductive load. The inductor is a coil which generates the magnetic field and hence transports the alternating current from the oscillating circuit into the workpiece. The inductor proper is water-cooled as it is not only heated by the high currents, but is also exposed to the heat radiated by the workpiece.

The busbars and power cables have to transport currents up to 10,000 A and higher. These high currents also generate heat in all the current-carrying components. This heat is compensated by the recooler which is designed according to the process, water temperature and ambient conditions. It coordinates the amount of cooling water required during operation. The main components of the recooler are the heat exchangers which transfer the heat loss to the works water [2].

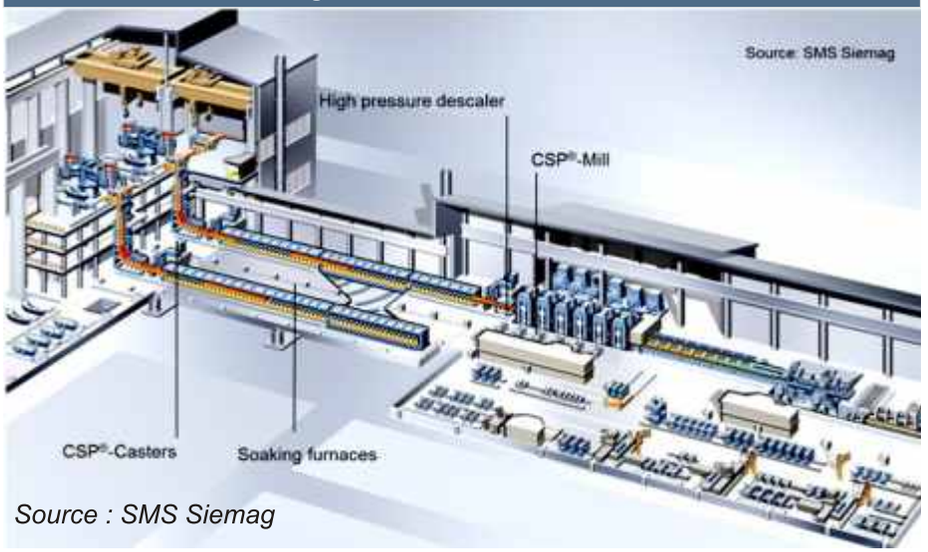
The open-loop and closed-loop controller performs the online commutation of the required power, depending on the strip speed, strip inlet temperature and the demanded strip outlet temperature. Furthermore this unit monitors the actual temperatures, all control and monitoring functions of the medium-frequency converter and the complete periphery, including the recooler.

Use of Induction Heating in Hot Rolling Mills

The solidified slab from the thin slab caster enters the roller hearth furnace with an inlet temperature of around 1000°C and leaves it again at around 1150°C. For some special applications, e.g. thin strip rolling or for certain materials such as silicon steel, however, higher slab temperatures are an advantage. The slab thickness is then reduced in the following hot rolling mill. The figure [Fig. 4] shows a CSP® hot rolling mill.

Thanks to its compact design, the heating unit can be employed anywhere

Fig. 4. CSP® HOT ROLLING MILL



Source : SMS Siemag

in the line where a temperature increase is required – for example at the inlet or outlet of the roller hearth furnace, between the roughing stand and the first finishing stand of the mill, or between the last finishing stands.

Use Upstream or Downstream of the Roller Hearth Furnace

In modern minimills, the roller hearth furnace can only be used for holding and buffering of the temperature. An induction heating facility arranged upstream allows the active heating zone of the roller hearth furnace to be eliminated. This makes the furnace shorter, hence directly reducing gas consumption and consequently also the CO_2 emissions.

Of the roller hearth furnace, an induction heating facility can raise the slab temperature and flexibly adapt the ingoing temperature into the rolling process to an optimum level so that special processes such as thin strip rolling are also possible.

The temperature gradient caused by the non-uniform cooling of the slab when the leading end is already in the rolling mill, while the trailing end is still in the roller hearth furnace is also compensated by intermediate induction heating. An additional benefit of induction heating downstream of the roller hearth furnace: The furnace can be operated at a lower temperature. Apart from the sustainable reduction in the consumption of fossil fuels, this also results in a longer service life of the refractory material and of the transport rollers in the roller hearth furnace. A lasting reduction in the maintenance costs and times for the conventional roller hearth furnace can be achieved.

The fact that with induction the heat is generated directly in the slab and that very fast results in a significant reduction in scaling of the slab surface. Less scale is formed due to the short dwell time at the necessary temperature, leading not only to a higher metallic yield but also to less wear of the rolls as scale is very abrasive.

The optimum energy efficiency of the whole process is thus achieved by the intelligent combination of roller hearth furnace and induction heating unit. As already explained above, the roller hearth furnace is operated at lower temperatures and the material and application-specific optimum rolling temperature is provided flexibly be induction.

Furthermore, at temperatures of around 1120°C in the roller hearth furnace, "dry rolls" can be used to guide the slab through the furnace. At these temperatures their service life is not limited and no localised heat loss occurs as would be the case with the water-cooled rolls that would be absolutely essential at furnace temperatures of above 1200°C. The gas consumption is significantly reduced.

Thanks to this combination of roller hearth furnace with dry rollers and induction heating, up to 10% of the energy consumption can be saved, depending on the product mix.

Use in the Vario Rolling Mill

In Vario rolling mills, induction heating is employed between the roughing stand and the first finishing stand.

This is an innovative technology for the production of micro-alloyed steel grades in API quality, i.e. for high-quality tube steels.

The induction heating ensures a uniform temperature level between these two mill stands so that a higher relative thickness reduction is achieved. The high temperature level allows higher degrees of forming to be attained.

Furthermore, the as-cast microstructure is completely eliminated and a very homogeneous microstructure is obtained thanks to recrystallisation – even in up to 20 mm thick slabs. The following figure [Fig. 5] shows the metallurgical effect [3].

One example shows the two retractable induction units between the roughing stand and the finishing stand for a high production capacity of up to 4 million tonnes of API steel grades, e.g. API X70. [Fig. 6]

Use of the Endless Rolling Process

The endless rolling process is outstandingly suitable for stable production of thin strips down to < 1 mm and can thus replace cold rolling in some cases. The maximum rolling speed, however, is limited to 8 m/s. During the rolling process, the strip continuously loses heat. If a given temperature now has to be reached at the last mill stand for either metallurgical or process reasons, this can only be achieved by selective induction reheating between the last two or three intermediate stands. [Fig. 7]

In the example, a temperature of around 950°C is necessary at finishing stand 6. Since, due to the relatively slow rolling speed, this temperature is already reached behind finishing stand 3, three integrated induction heating

FIG. 5. : METALLURGICAL EFFECT OF RECRYSTALLISATION

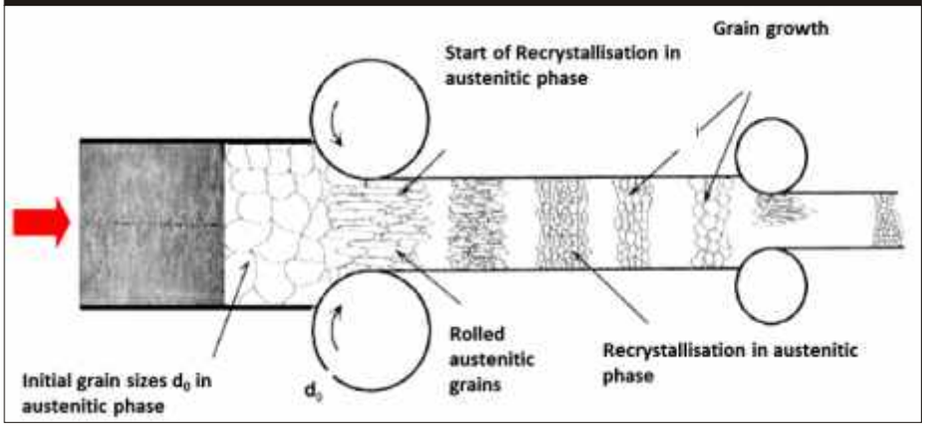
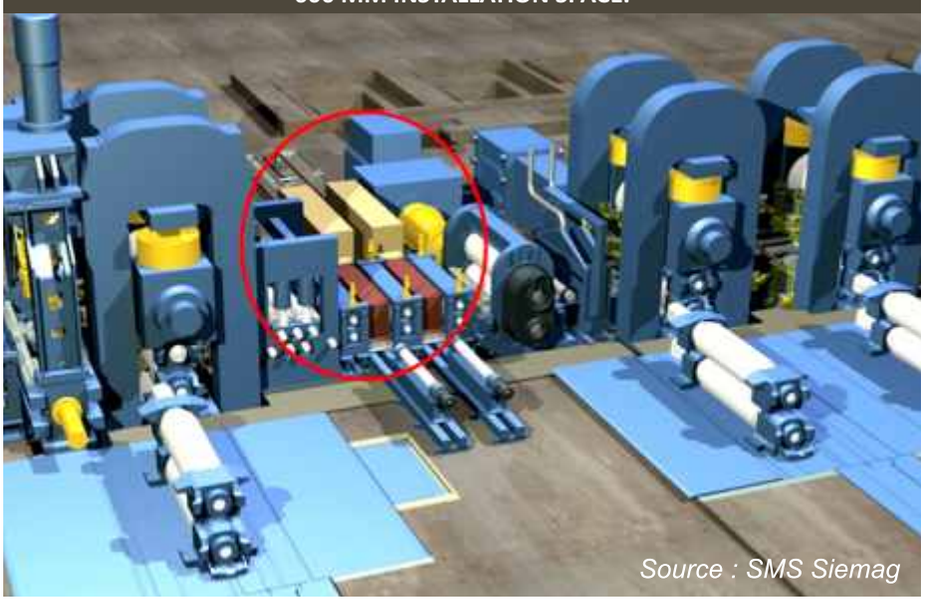


FIG. 6. : RETRACTABLE INDUCTION UNITS BETWEEN ROUGHING STAND AND FINISHING STAND. EACH UNIT HAS A MAXIMUM OUTPUT OF 4.5 MW WITH 600 MM INSTALLATION SPACE.



units between the last three finishing stands can ensure the necessary temperature of 950°C at the end of the rolling process. [Fig. 8]

Summary

Induction heating is an energy-efficient process with a high specific power density over short process lengths and can thus be outstandingly integrated into or even retrofitted in innovative minimill production lines.

A downstream induction temperature booster allows the conventional furnace to be shortened and operated at lower temperatures. This helps to maximise the service life of the refractory material and of the furnace rollers. Furthermore, it enables the use of non-cooled dry rollers which, with a given production mix, allows an energy saving of around 10% compared with operation with cooled transport rollers.

At the same time the use of induction sustainably reduces the gas consumption of the roller hearth furnace, and hence the CO_2 emissions. The flexible temperature control of the induction heating permits optimum inlet temperatures into the rolling mill.

The higher temperature level between the first two mill stands permits a larger thickness reduction, the complete elimination of the as-cast structure and re-crystallisation of the microstructure.

FIG. 7 : INDUCTION REHEATING BETWEEN THE FINISHING STANDS FOR SELECTIVE TEMPERATURE INCREASES DURING THE ROLLING OF THIN STRIP GRADES.

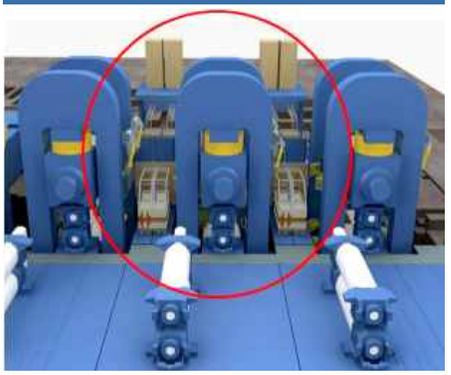
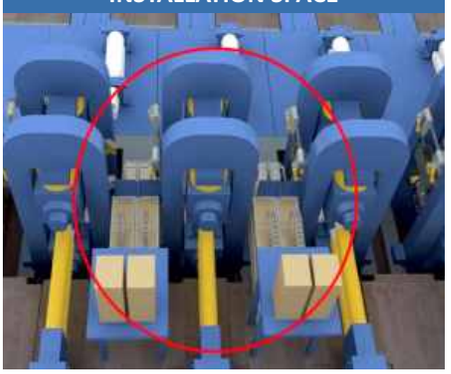


FIG. 8 : FLEXIBLE TRANSVERSE-FIELD MODULES WITH A MAXIMUM OUTPUT OF 3.2 MW WITH 550 MM INSTALLATION SPACE



In the endless rolling process for very thin strip grades or silicon steels, compact, integrated induction units between the finishing stands compensate the temperature loss and guarantee the right temperature level at the end of the finishing mill.

Overall, induction heating in minimills offers the operators a wide range of new possibilities which further increase their competitiveness and permit the production of particularly lucrative steel grades.

Bibliography

[1] Newsletter Metec special edition June 2011

[2] Development and evaluation of inductive reheating concepts in the hot rolling mill [Vogt: Elotherm; Master thesis 2011]

[3] Newsletter SMS group 3/2011