New Generation Furnace Technology for Copper Rod Production

Introduction

For new investments basically only two different types of copper rod casting processes are considered: *Upwards Casting* for relatively small scale production from 3.000 to about 30,000 t/y and the *SCR™ and Contirod™* processes for up to around 240,000 t/y production capacity. Both types of process start from a copper cathode feedstock. The molten copper is cast either directly for instance, to 8mm copper rod (Upwards Casting), or it is cast as a rectangular bar which is formed to the final rod dimension by an inline hot-rolling mill (SCR™ and Contirod™). Although both types of process produce high conductivity wire rod, the physical and chemical properties of the two products are quite different. Upwards cast copper rod is basically oxygen-free, whereas SCR™ and Contirod™ copper rod has a residual oxygen content of around 200ppm. The differing oxygen levels of the two types of copper rod casting process are inherently necessary for the respective process to work satisfactorily with their very different casting mould designs. Accordingly, the melting process and its related furnace designs have to be optimised to serve the caster with the appropriate melt to assure consistent and optimised product quality.

Furnace Technology for Upwards Casting

In this casting process, the wire is drawn upwards out of a water-cooled graphite mould that is immersed in the copper melt and subsequently formed into coils without further processing, see Fig. 1. In spite of its relatively low casting capacity per strand of only around 120 kg/h, the process is nevertheless profitable in particular thanks to the relatively low investment costs, as evidenced by many plants of this type now in operation worldwide.

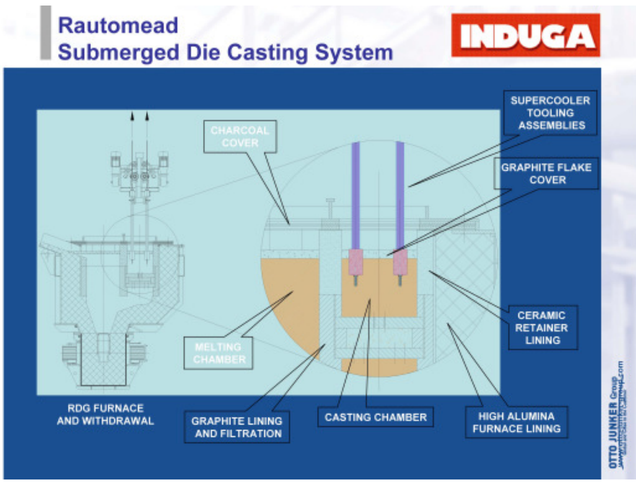

Fig. 1: Submerged die casting system in a double-chamber furnace which is equipped with a melting chamber (left) and a casting chamber (right).

On account of its graphite mould, this process requires the copper to be substantially oxygen-free. This is achieved by using a graphite lining system and/or a heavy layer of graphite flake over the melt. As deoxidisation by phosphorous or other additions would destroy the electrical conductivity and as no oxygen is present to tie up impurities in the copper, it is necessary to use high quality Grade A cathode copper feedstock.

For cathode charging several methods are available which all share some general features: cathodes are typically delivered in packages which are put on a conveyor or arranged around a circular table by crane or forklift. They are then picked up individually using a vacuum lifter and deposited on a tilting table from where the cathode is charged into the melting furnace.

The following description is related to the joint development of Rautomead® and Induga and firstly shows in Fig. 2 two examples of cathode charging: circular arrangement of cathode packages (left) and linear arrangement on a conveyor (right).

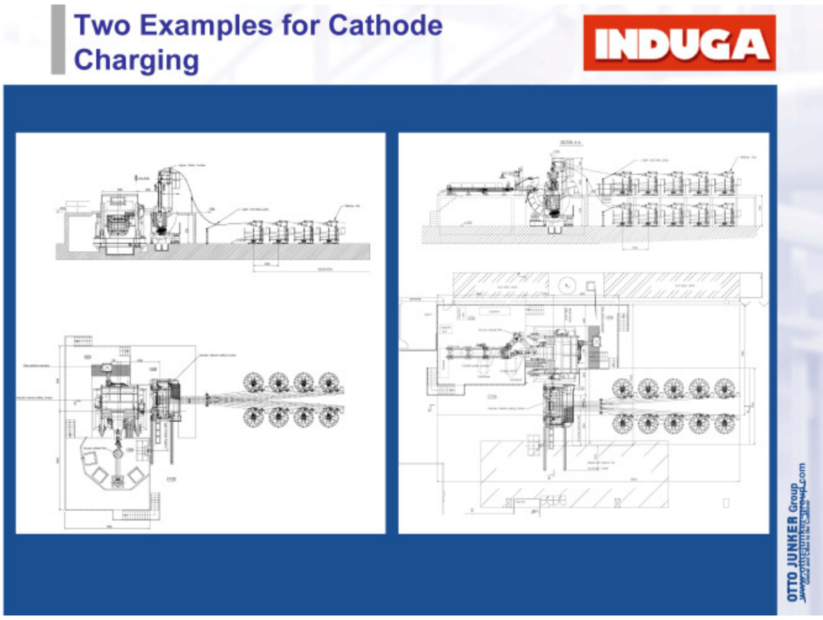

Fig.2: Two different rod casting line designs with different cathode charging concepts: left - a circular arrangement, right - a linear one.

For small scale melting, a combined melting/casting furnace is used as already shown in Fig. 1. It has two separate chambers and is equipped with a double-loop channel inductor that heats up the melting and the casting chamber of the furnace simultaneously.

For higher melt rates, a separate melting furnace is used. First option is a channel-type furnace with syphon discharge, see Fig. 3. Second option is a drum-type melting furnace. This is used for melt rates up to 3.5 t/h. The advantage of this furnace shape, shown in Fig. 4, lies in its easy sealing possibilities, which is important for consistent and low oxygen content. Moreover, such a furnace can be equipped with purging plugs offering active deoxidising features, which are superior to the conventional dwell time-based passive deoxidising practice, using only charcoal protection.

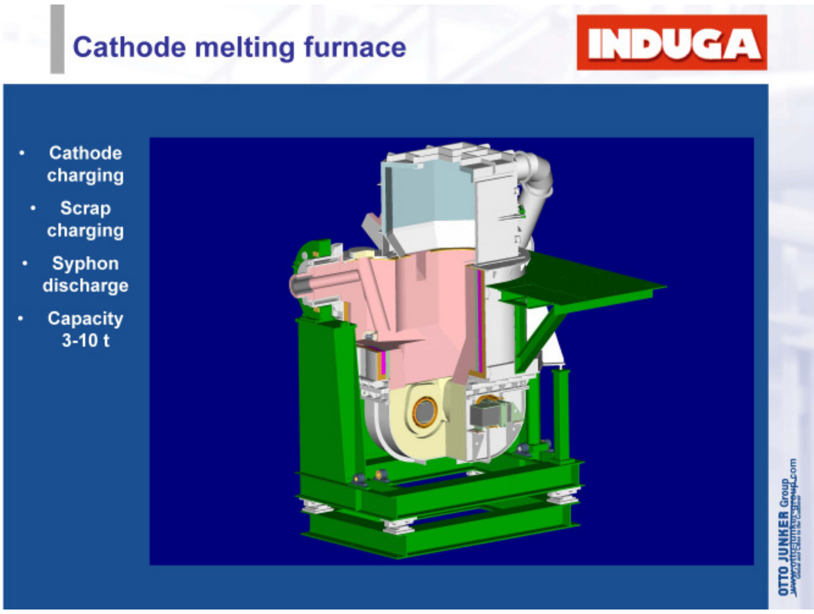

Fig. 3: Melting furnace with fixed spout discharge

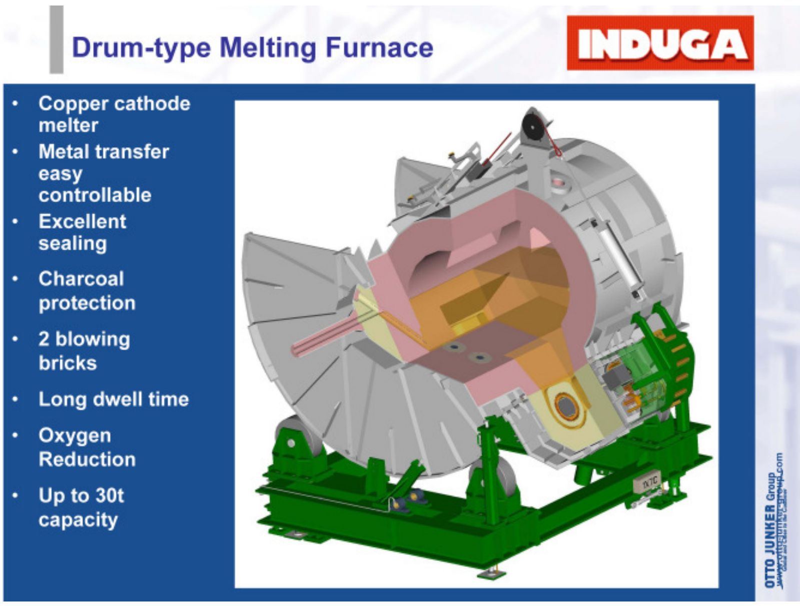

Fig. 4: Melting furnace with fixed discharge axis

For a small casting furnace, reference is again made to where the casting chamber is part of the single furnace used in that process. But higher casting capacities need a separate casting furnace because the relatively large number of coolers require a certain surface area to be arranged and also the temperature has to be kept space-wise constant over the whole area. To get the required OFC grade of max. 3 ppm residual oxygen, the melt surface is completely covered by carbon flake.

In Fig. 5 a complete production line with 32 strands is shown as an example. This line has an annual capacity of 30,000 tonnes. As can be seen, here the casting furnace is divided into two casting sections separated by a central filling chamber. Each casting section has its own inductor and it is separated by a weir from the refilling chamber of the furnace. This arrangement offers easy access to the rod coolers from both sides of the furnace.

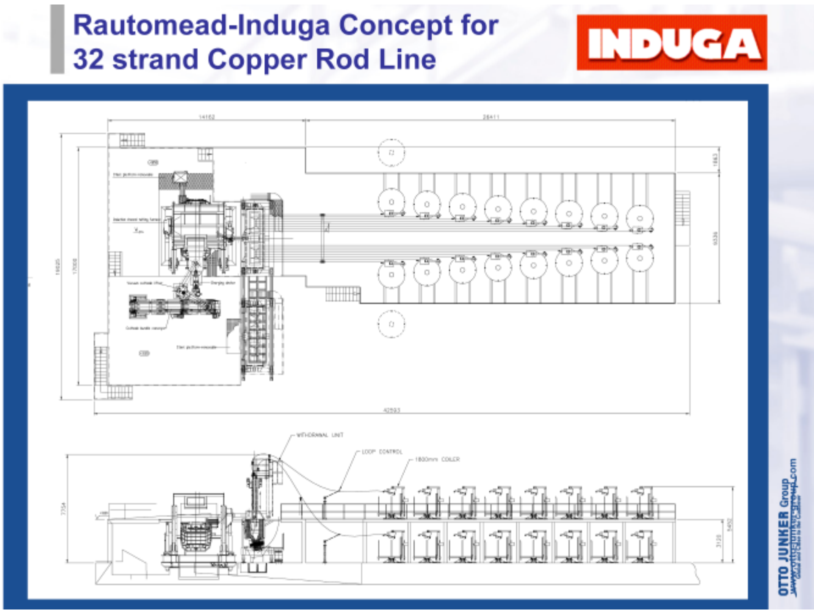

Fig. 5: Complete rod production line with 32 coilers on two levels

Furnace Technology for the SCR™ and Contirod™ Processes

The lion's share of copper wire rod is produced today in continuous cast-and-roll plants of the SRC™ or Contirod™ designs, equipped with travelling moulds. They differ primarily in the type of mould used. The continuously cast wire bars from both processes have cross-sections of 3600 mm² or more and are hot-rolled down to typically 8 mm wire rod that is then pickled, waxed and formed into coils.
The conventional furnace concept of these wire lines is based on a shaft-type furnace for melting, a first transfer launder with an integrated deslagging box, a gas-fired holding furnace and a second transfer launder with stopper-controlled discharge into the tundish of the caster. This concept has been successful for years and is employed in most wire production lines, see Fig. 6.

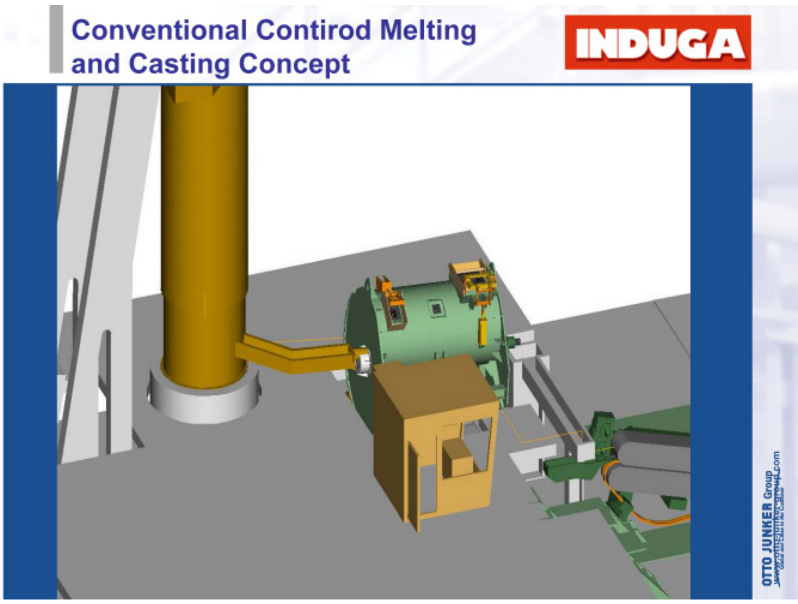

Fig. 6: Layout of a typical furnace line for the Contirod™ process

Although this furnace concept does its job, there are some natural limitations concerning its process capabilities:

- Deslagging is not 100% especially during start-up or if a significant portion of return scrap is used.
- The superheating power of the holding furnace is relatively poor.
- Temperature control during start-up is sometimes difficult.
- The holding furnace function is more or less limited to a buffer function for start-up and stop. There are no metallurgical or thermal dwell time functions.
- Precise control of residual Oxygen is difficult.

Fig. 7 shows an overview of an improved furnace concept which has been first implemented in the MKM Contirod™ line as it is in operation since 1999 in Hettstedt, Germany. Besides the well known shaft melting furnace it is equipped with three induction heated furnaces: one deslagging furnace, a holding furnace and a casting furnace.

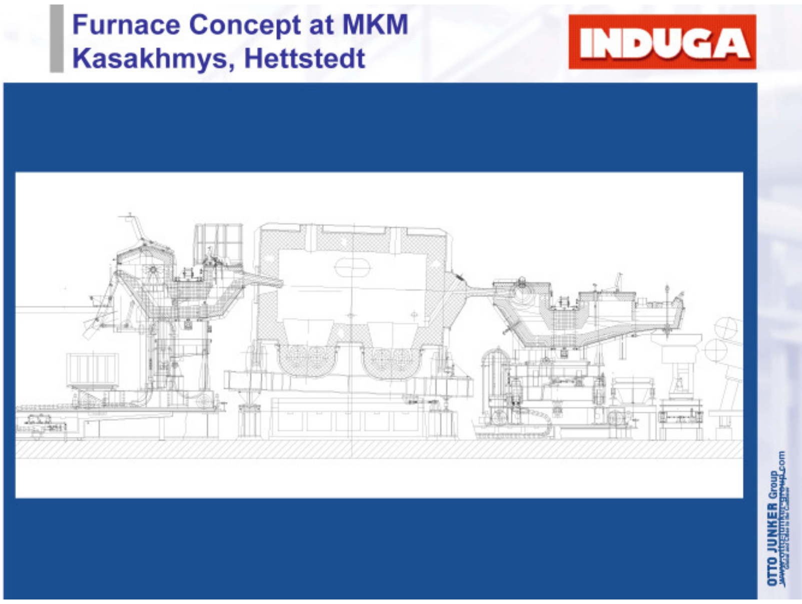

Fig. 7: Schematic side view of the MKM Contirod™ line. The (right hand sided) casting furnace is actually arranged 90 degrees backwards

Fig. 8 shows the design of a corresponding deslagging furnace with a capacity of 6 tonnes and an integrated inductor connecting the two furnace chambers by means of a syphon. The molten copper enters the furnace via a launder and flows continuously into the slag collecting chamber. This chamber can be opened by a hydraulically actuated cover for skimming which is easily done during operation from the rear of that furnace.

From the deslagging chamber the copper enters into a transfer chamber from which it flows through a tube into the holding furnace. On its way the copper has to pass three submerged inductor channels which have a total heating capacity of 250kW. They are used to compensate for heat losses and to allow a small temperature increase from about 1100 to 1120 degrees C. For this, the furnace power is controlled by a submerged thermocouple.

Concerning its deslagging, capability this furnace is superior to a conventional deslagging box because when entering the chamber the metal flow speed is slowed down significantly due to the relatively big volume. In addition the position of the connecting channel is deep under the melt level. Both features guarantee a 100% separation of the shaft furnace slag from the line under all operational conditions. Depending on cathode quality, skimming is necessary about 2-3 times per shift for high and about 5 times per shift for lower grade cathodes.

On the other hand, the only opening of the transfer chamber is the overflow tube guiding the slag-free and slightly heated molten metal into the holding furnace. Therefore the atmosphere can be easily controlled and any contact with air is safely avoided. As a result this furnace clearly works as a separator between the more-or-less open melting part and the closed buffer and casting part.

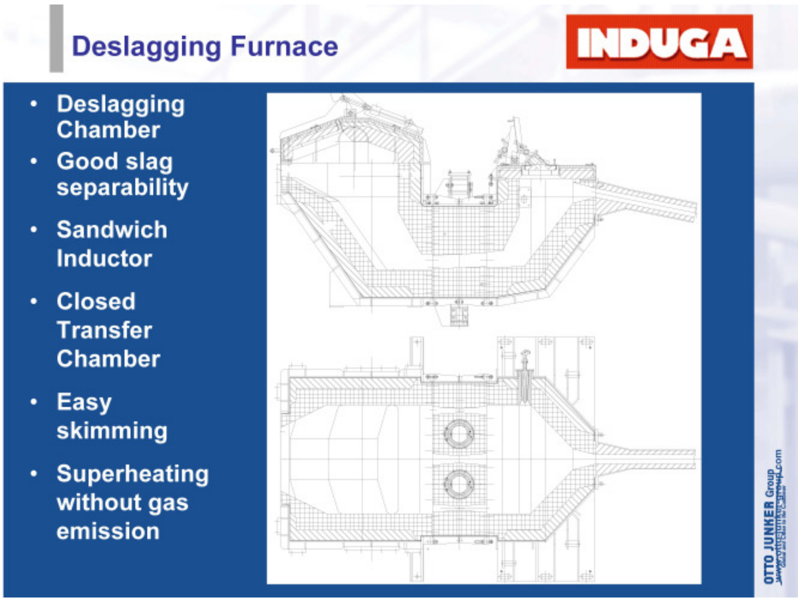

Fig. 8: Deslagging furnace with syphon and transfer tube

The overall shape of the MKM holding furnace is very similar to the conventional gas-fired holder, offering a continuous and controllable outflow independent of the flow rate of the incoming metal. Instead of gas burners, it is heated by two channel type inductors and the syphon-type outflow picks up the metal well underneath the bath level, avoiding any open spout area. Both features are state-of-the art in OFC production lines where practically the same furnace type is used as a melter of cathodes, see Fig. 4.

As a result, the following features can be attributed to this holding furnace concept:

- The inductors provide excellent mixing and efficient heating.
- The metal temperature can be precisely controlled and refers to the complete furnace content.
- The furnace offers a real mass and heat buffer.
- Mixing results in partial degassing due to charcoal contact.
- Width to height ratio is not critical.
- Atmosphere control is easy.
- Environmental improvements are obvious.

In general, this furnace stabilizes the whole process a lot and assures a consistent and stable metal quality.

The casting furnace, Fig. 9, is the final furnace in the line and has a forehearth which extends above the casting machine and from which the metal is poured into the caster. The flow rate is controlled by a stopper using the mould level signal from the caster. The curved shape of the forehearth has been chosen to provide an excellent view on the mould metal level inside the caster.

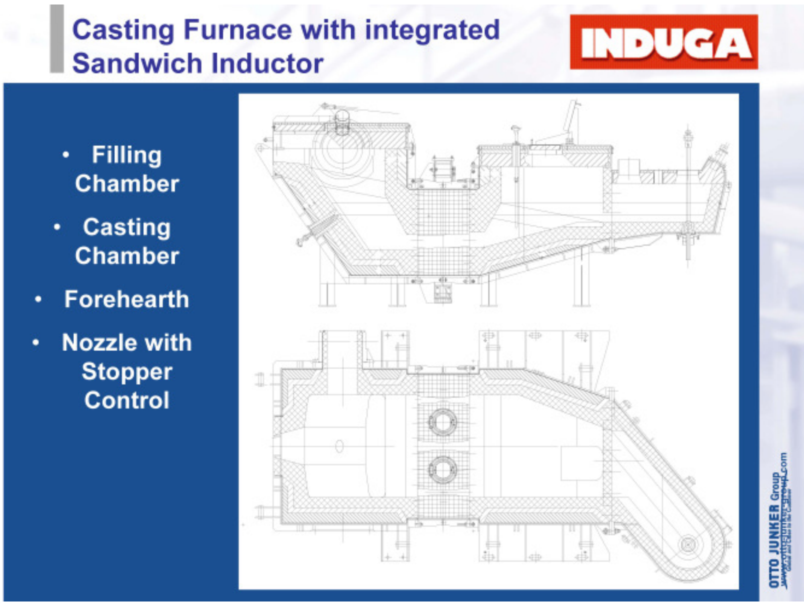

Fig. 9: Twin chamber casting furnace with integrated inductor

Compared with a conventional casting launder, the forehearth flanged directly to the furnace has the advantage that it does not have to be additionally heated with gas burners during casting, as the heat losses are compensated for by the direct contact with the metal heated by the inductor. The forehearth merely has to be heated up automatically approx. 15 minutes before the start of casting. Furthermore, the metal arrives at the stopper without the casting stream otherwise necessary, thus significantly reducing contact with the atmosphere.

At the end of casting, the furnace is tilted back to empty the forehearth into the furnace and to expose the nozzle. On the rear of the furnace is a deslagging opening through which the furnace can also be completely emptied.

The metal supply from the holding furnace enters the casting furnace directly through the tilting axis via a runner. This charging situation was chosen so that the furnace can be continuously charged with metal in both tilted positions, i.e. before the start of casting, and in working position as well.

In addition to the features known and proven for years in conjunction with forehearth furnaces, this casting furnace is also equipped with a weighing device. The cells are located between the furnace vessel and bogey in order to allow the furnace weight to be monitored continuously during the whole casting process. This incorporation of weight monitoring into the furnace control concept prevents both overfilling and excessive discharging of the furnace, assures a continuous and pre-determined metal flow to the caster, and so represents a further step towards a fully automated casting line.