Induction furnaces in the aluminium industry

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For 53 years, the Marx Group in Germany with its approximately 100 employees has been working in the furnace industry. The company's activities include planning and manufacturing of induction furnace plants, engineering, development, renovation, modernization and retrofitting of induction furnace plants, service and customer support. The company has thus gained extensive experience in working on almost all types of induction furnaces. Nearly every type of furnace has been serviced, repaired, retrofitted or modernized in its facilities. The company's sites in Iserlohn, Hennigsdorf, Donauwoerth, Germany, and in Youngstown, Ohio, USA provide well-aimed proximity to their customers in Europe and the US.

Marx gives an overview of the different types of induction furnaces being used for melting, holding, and holding/casting of aluminium. Applications of the induction equipment will be described. The advantages of using an induction furnace, such as high melt quality, high flexibility, environmentally friendly, high power density, quick melting, homogeneous melts, etc. will be explained.

Basically two different kinds of induction furnaces are used for melting, holding and casting of metals: the channel-type induction furnace and the coreless type induction furnace.

The channel-type induction furnace consists of a refractory lined furnace body made of steel, onto which one or several channel-type inductors are flanged for heating the metal. For reasons like thermal conductivity and buoyancy of the hot melt, in most cases the channel-type inductor is flanged to the bottom of the channel-type furnace body, resulting in the typical design of a small to medium-sized channel-type melting furnace like that shown in Fig. 1.

Depending on the function of the furnace in the production line, the design may put the channel inductor and furnace body in other positions. Channel-type induction furnaces are used for aluminium and aluminium alloy melting, as the aluminium is sensitive to hydrogen pick-up, and channel-type furnaces combine a smooth bath surface with a sufficient bath turbulence inside the melt to homogenise the melts in regards to chemical analysis and temperature, and so can minimize and hydrogen and oxygen pick-up at the bath surface. Channel induction furnaces are also used for holding/casting furnaces for aluminium and its alloys.

These furnaces have a higher electrical efficiency than coreless furnaces, but in case of frequent alloy change, the and consequently with the need to empty the furnace on a regular basis and to accentuate stirring activity inside the melt, then the coreless furnace is the preferred choice for a melting or holding/casting furnace (Fig. 2).

A version of induction heating is a so-called 'coreless inductor'. Coreless inductors were already being used at the beginning of the 1980s for heating holding furnaces in the aluminium and copper casting industry (Fig. 3).

Typically holding furnaces in continuous casting lines were equipped with such inductors which consume more energy than a channel-type inductor, but which offer much higher lifetime and allow for emptying the holding furnace on a regular basis. The following picture reflects the development in design of coreless inductors. The 250 kW inductor on the left side was put into operation in the end of the 1990s, heating a three-chamber holding/casting furnace for copper alloys. It has no inductor case, in contrary to the 340 kW inductor on the right side, which has been used

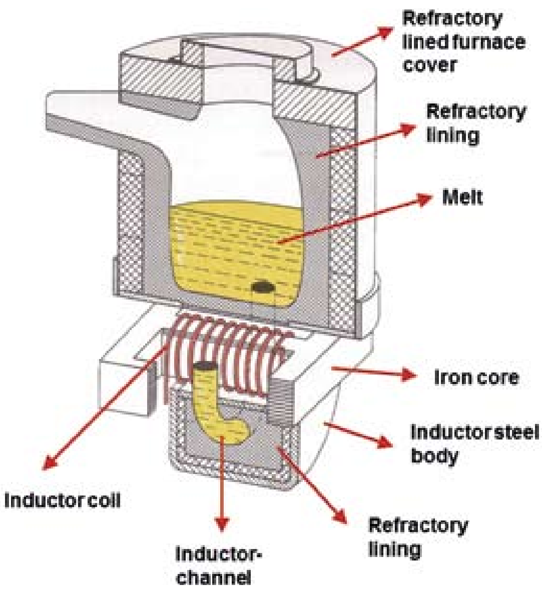

Fig. 1: Channel-type furnace

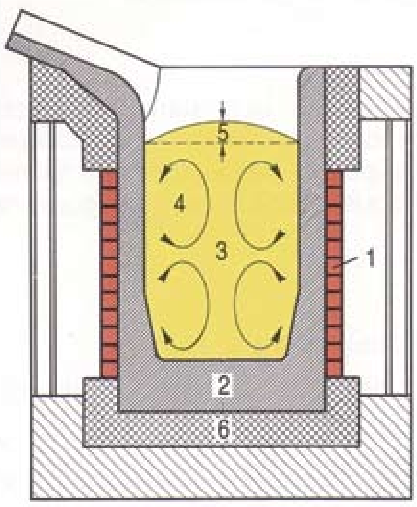

Fig. 2: Coreless furnace – 1 Inductor coil, 2 Refractory lining, 3 Melt, 4 Bath circulation/stirring effect, 5 Meniscus/Melt dome

on several holding furnaces in the aluminium semi-fabricating and casting industry for many years now (Fig. 4).

The following table (Table 1) compares important features of channel-type furnaces and coreless furnaces. Some of these features or combinations of these features are the basis for the decision to use induction furnaces in a production process.

There are typically various reasons for using induction furnaces in the aluminium industry. Important reasons to choose an induction furnace are high melt quality, a good melt bath circulation, low metal losses due to burn off, small heat losses from the furnace, quick melting, minimized gas pick-up and small footprint. Other reasons might be the historically grown production structures, or simply the availability of larger amounts of gas or electricity in the area of the production plant.

A good melt circulation results in homogeneous melts in regards to analysis and temperature. It can produce high-alloyed aluminium melts even when charging larger amounts of pure metals like silicon into the aluminium basic melt. The ratio of bath surface to metal volume is typically very low, in particular for coreless furnaces and smaller channel-type furnaces, which means that the bath surface of big induction furnaces is relatively small in relation to the melt volume and especially in comparison with gas fired hearth furnaces. Small melt surfaces mean lower heat losses by open radiation and less metal oxidation and gas pick-up.

Table 1 **Comparison: Channel furnace – Coreless furnace**

Features	Channel furnace	Coreless furnace
Structure / Design	Various furnace body designs	Typically cylindrical
Electrical efficiency	high: approx. 85-90%	lower: approx. 60-70%
Energy consumption	lower	higher
Flexibility / Alloy change	poor, no emptying	good, simple emptying
Refractory lining	Bricks, dry ramming, castables	Pre-manufactured crucibles made of ceramicor graphite, dry ramming
Refractory change	Channel inductor: simple Upper furnace: complex	simple and cheap

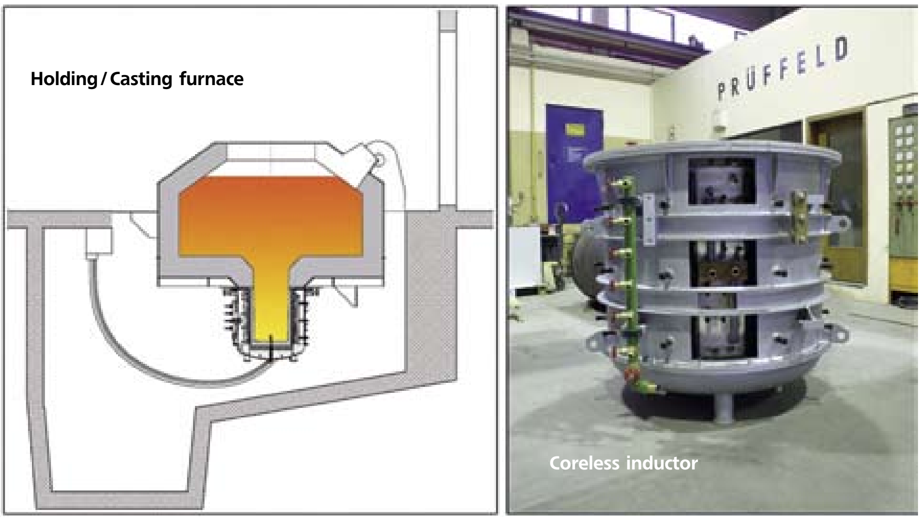

Fig. 3: Different types of induction furnaces – Furnace heated by coreless inductor

Fig. 4: Coreless inductor designs

Compared to cylindrical gas fired furnaces, which heat the metal indirectly through a graphite or silicon carbide crucible wall, the heat directly generated inside the melt by induction offers much quicker melting, resulting in higher productivity and cleaner, oxide inclusion-free melt. Shorter melting times also benefit refractory lifetimes, particularly if the aluminium alloy is aggressive and erodes or infiltrates the refractory. Also typical superheating damage to areas in the refractory wall above the melt surface, which are observed in gas-fired hearth furnaces, are no topic with induction furnaces.

In some cases induction furnaces were installed many years ago when the costs of electricity and gas were not so different as they are today. And nowadays the customer has gained good experience in operating the furnace in an optimum way, which closes the gap of the operation costs due to different energy costs.

Hearth furnaces for aluminium melting, being heated by one or several channel inductors, were installed in the 1960s and 1970s, and are still in operation at numerous production lines for aluminium slabs, billets and rod (Fig. 5).

A newer furnace of the same kind was installed 2004 at a semi-fabricator plant in Belgium. This furnace has a total holding capacity of 70 tonnes and a useful capacity of 52 tonnes. It is equipped with four 1,500 kW water-cooled channel inductors and has a melting rate of approx. 11-12 t/h. It is top-loaded and still constitutes an important melting aggregate in the customers vertical slab casting line today.

Channel-type melting furnaces of 2-tonne capacity (Fig. 6) have been in operation at a Scandinavian motor producer for more than ten years now. Three of these furnaces are equipped with a one-piece 200 kW channel inductor and they melt pure aluminium. The aluminium melt is then transferred to downstream electrically heated holding / dosing furnaces, which dose the melt into high-pressure die casting machines. These lines produce motor housings. →

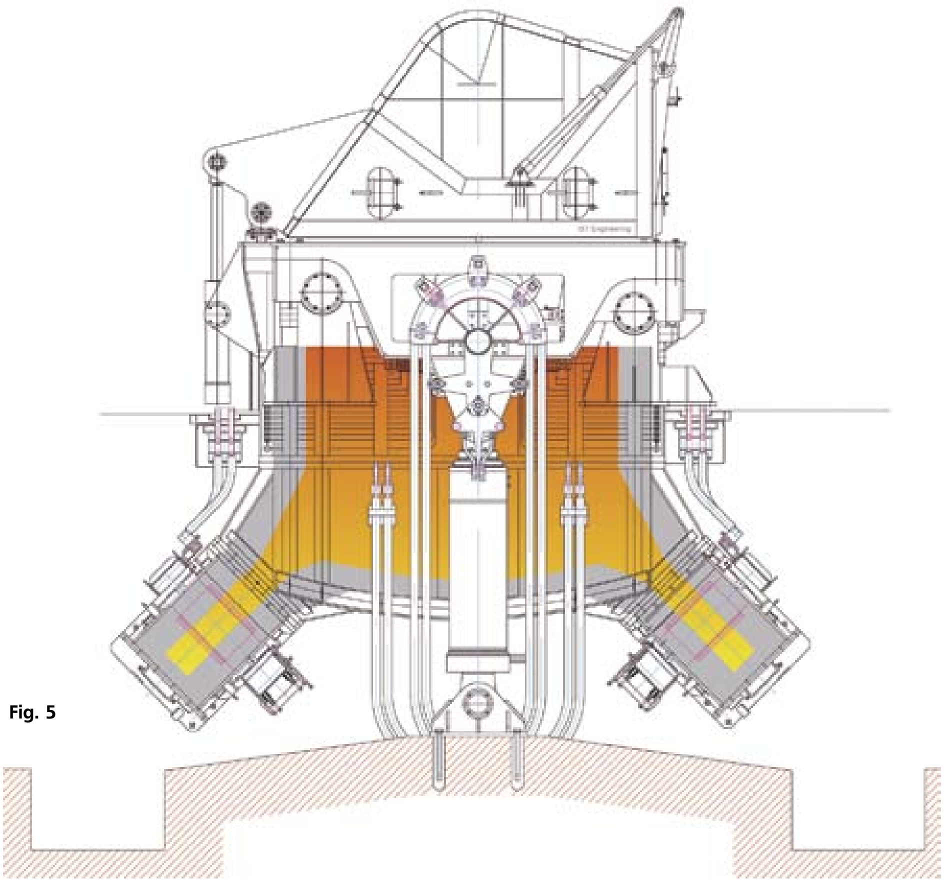

Fig. 5

Channel-type holding furnaces (Fig. 7) are operating in many semi-fabricator plants in Europe. According to the old foundrymen's philosophy 'melting by gas – holding with electricity', they are used for micro-alloying and for homogenizing the melt coming from the gas-fired melting furnaces, and for pouring the melt into multi-strand vertical casting machines.

Such furnaces are used in slab or billet casting lines, and they have capacities from a few tonnes up to 40 tonnes. They are heated by either channel inductors or coreless inductors (Fig. 8), depending on the dross-generating tendencies of the alloys to be held. The typical heating power of these furnaces is in the range of 60 kW up to 400 kW, depending on total holding volume and inductor type.

Coreless induction furnaces are often used for melting of swarf or UBC scrap because of their advantages recycling, and for producing high-alloyed aluminium melts, e.g. in piston foundries or at master alloy producers, and for other special applications. Sometimes they are used as back-up for gas fired melting furnaces and for in-house recycling of special aluminium melt grades.

Existing melting furnaces for swarf melting in European semi-fabricator plants typically have total holding capacities of 12 tonnes or more. They are used for remelting UBC scrap, swarf or turnings in larger amounts. These furnaces are usually operated with a liquid metal heel (sump) so that the small turnings can be quickly and effectively melted inside the liquid metal, thus reducing metal burn-off oxidation and gas pick-up, which tends to happen in other melting furnace types due to the large surface these materials expose. The scrap material charged into such coreless induction furnaces usually is pre-dried, and UBC scrap is treated in a special pre-heating process in order to burn off the varnish from the cans.

Fig. 7: Channel-type holding furnace

Fig. 6: Channel-type melting furnaces of 2-tonne capacity

A special coreless induction furnace for producing an aluminium alloy with higher tin amounts has been installed in Austria three years ago (Fig. 9). This furnace has a total holding capacity of one tonne, and it operates at a frequency of 1,000 Hz with a pre-manufactured ceramic crucible, and melt temperatures of up to 800 °C.

It feeds the aluminium-tin alloy into a downstream holding furnace from which the melt is dosed onto a steel belt. The final product is used to produce bearings for heavy-duty vehicles and trains.

The piston producers and master alloy producers use the stirring activity generated

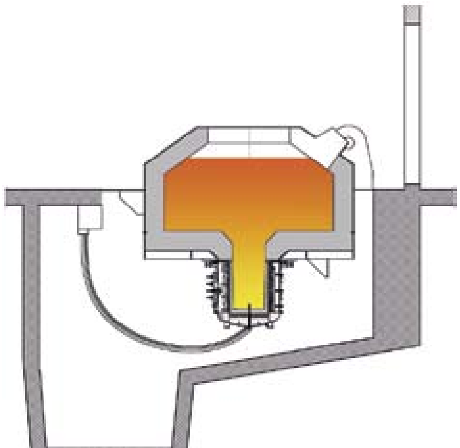

Fig. 8

in coreless induction furnaces for producing high-alloyed, homogeneous aluminium melts either to produce pistons with high material strength, or to make master alloy ingots. These ingots are used in smaller aluminium foundries for easy alloying of the melt in gas or resistance-heated furnaces, which do not ensure a stirring effect inside the melt. In producing pistons or master alloys the stirring effect inside the melt is of great importance. Therefore often coreless induction furnaces are used which can be operated at different frequencies. Melting of the alloys uses higher frequencies, e.g. 100-200 Hz, while homogenization of the melt or alloying of the basic aluminium melt achieves higher stirring effect by switching to lower frequencies which penetrate further into the melt. Other ways of operation are to switch furnace coils separately in the upper and lower zones of the coreless furnace. Switching coils alternately or simultaneously can control the melt movement in certain areas of the furnace.

Fig. 9: Special coreless induction furnace for producing an aluminium alloy with higher tin amounts

There are certainly more applications for coreless induction furnaces in aluminium productions than can be described in this overview. Finally, we mention metal pumps using the induction principle to pump liquid aluminium between furnaces or between furnace chambers.

Conclusions

Although induction furnaces are not the most common type of furnaces in daily aluminium production, there are several applications where such furnaces have important advantages over gas fired ones for the production process. The decision to choose a gas fired furnace or an induction heated one should be based on the production process and the required features of the final product. Before deciding, the investor should get an overview through discussions with both gas fired furnace suppliers and induction furnace suppliers. He can then choose the right furnace technology for his product and production process. Daily operation costs, handling of high off-gas volumes, and the availability of gas or electricity in larger amounts are further aspects which influence this decision.

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