Melting of large steel casting parts in the induction furnace

by **Wolfgang Ertl, Erwin Dötsch**

The voestalpine Group operates in their steel segment a foundry for the manufacture of heavy cast steel with a melt requirement from 1 to 200 t per casting. The melt required in the foundry is acquired for the most part from the LD steelworks sited on the same grounds. The return material with about 50 % occurring with cast steel cannot be employed profitably there; therefore an induction crucible furnace was installed for the melting down of this return flow scrap valuable for the foundry. Its integration into the manufacturing sequence and the operating results prepared in this special employment are described in this contribution.

With 8,000 t good melt per annum, the voestalpine foundry in Linz/Danube, Austria, is the leading manufacturer of high-quality cast steel, mainly for thermal machines such as steam and gas turbines, including compressors, as well as for general mechanical components. The production is aligned to the manufacture of heavy castings as the steam turbine housing shows in **Fig. 1** as an example. Correspondingly, the return material also results in over-sized form. The cast steel return-flow scrap thus occurring has a relatively small value in its diverse alloy composition for the LD steelworks, and likewise on the free market. For the steel foundry, on the other hand, its re-utilization in case of corresponding sorting and preparation has a high economic significance. Therefore in 2007 it was decided in voest to make an investment in a large induction crucible furnace for the processing of the return-flow scrap in the foundry.

In the following text, after representation of the liquid steel supply, the incorporation of the induction furnace into the manufacturing sequence is described, as well as its environmental and process-technical characteristics. The inductive melt sequence and the refractory lining are dealt with in more detail below [1].

PRODUCTION OF THE STEEL MELTS

The steel foundry is located on the grounds of voestalpine-Stahl. This has a great advantage for the foundry that liquid steel can be acquired from the LD steelworks in large units over relatively short paths; it can then be further processed in the foundry to melts ready for pouring. Since 2009 the induction crucible furnace has been additionally available for the production of melts. As can be seen in **Fig. 2** the melt manufacture can now be varied over the following three melt routes:

Route 1: In the first process, the LD converter supplies liquid charges of 110 to 150 t for so-called heavy castings. These heavy pour melts can be further processed to melts ready for pouring directly in the steelworks at the ladle furnace and in a further sequence in the RH process. **Fig. 3** shows the pouring from a 150 t-ladle in the foundry.

Route 2: Here, according to pouring order, 15 to 50 t from the LD converter are diverted for the steel foundry. These partial taps are delivered by rail or special transport and set up then finished on site in the ladle furnace and/or in the VD/VOD station. Route 3: On this path, up to 30 t of liquid steel are delivered from the induction furnace to the ladle furnace or the VD/VOD-station and finished there. The individual routes can also be combined in any type and quantity. The share of the manufacturing methods in the overall production of approx. 16,000 t of melt per annum is represented in **Fig. 4**. According to the economic benefit from the melting of the return-flow scrap, the share of the melts generated in the induction furnace has increased from approx. 12 % in 2010 to meanwhile almost 40 %.

Fig. 1: Steam turbine housing [1]

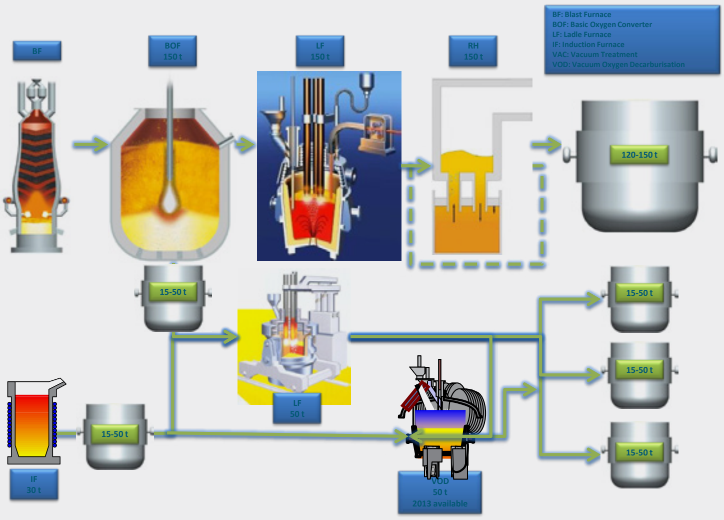


Fig. 2: Melt manufacturing routes (BF – blast furnace, BOF – LD-converter, LF – ladle furnace, RH – Ruhrstahl-Heraeus-plant, IF – induction furnace, VOD – vacuum-oxygen-carburization) [1]

Fig. 3: Pouring from the 150 t-ladle [1]

CHARACTERISTICS OF THE INDUCTION FURNACE

Since longer times the induction crucible furnace, because of its environmental, workplace and process advantages, has been more and more replacing the electric arc furnace, at least in smaller and medium-sized steel foundries [2]. Also in case of the project planning of the large-scale melting aggregate with voestalpine, the induction furnace (**Fig. 5**) has been preferred over the electric arc furnace, basically for the following reasons:

- Low fumes emission, correspondingly low expenditure for extraction and filtration.
- High yield from the metallic component, particularly of alloy materials.
- High flexibility: fast start-up with full performance. No liquid steel is necessary for the start; this enables a cold start and frequent alloy changes.
- Inductive agitation. The high level of bath movement leads to the fast appropriation of the alloy materials and to a uniform melt.
- Low floor space requirement.
- Simple and automatable operation.
- Better workplace conditions: less noise emission and lower levels of heat radiation.

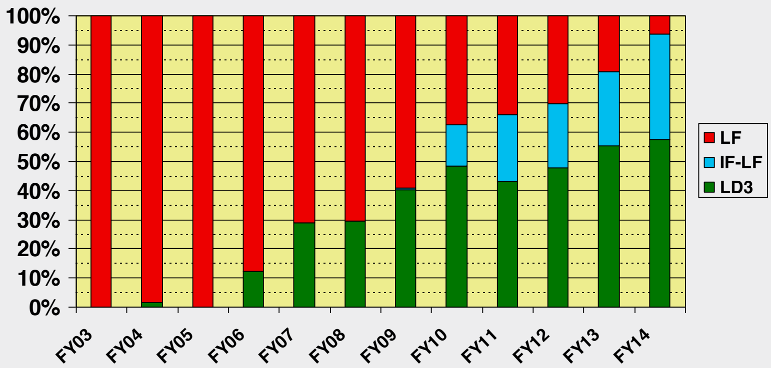


Fig. 4: Share of melt manufacturing routes from 2003 to 2014 (LD3 – Heavy castings directly from steelworks, LF – Melts diverted from LD-converter, IF-LF – Melts from induction furnace) [1]

Disadvantages are the susceptibility of the refractory lining and the reduced possibilities for metallurgical work: The refining is not as effective as in the electric arc furnace, the dephosphorization and desulfurization are limited so that materials used with low levels of contamination are required, which the induction furnace, as a remelting aggregate, processes to the different alloys.

THE INDUCTIVE MELTING PLANT

In **Table 1** the identifying data of the induction furnace are listed. In the so-called batch operation, non-alloy, low-alloy and high-alloy steel melts with average tapping weights of 27.5 t are melted.

Table 1: Identifying data of the induction furnace

Type	ABP-IFM 9
Year of manufacture	2008
Maximum capacity (to spout area)	38 t
Nominal version	30 t
Rated frequency	250 Hz
Connected load	16,000 kW
Specific energy consumption	530 kWh/t
Refractory material consumption	10 kg/t
Average tapping temperature	1,720 °C

In the individual case with charges > 38 t, work is also carried out in heel operation. The furnace is supported on load cells, so that the melt sequence can be checked over a melt processor. The furnace content, its theoretical temperature and the time requirement up to the reaching of a specified melt temperature are displayed on the screen as definitive ongoing variables. By means of these variables, the operator charges by means of magnetic crane in regular sequence on average about 30 % steel scrap, mainly in the form of laminated sheet packages, and approx. 70 % return-flow scrap of the foundry. In this case, approx. 1 t of sheet metal scrap is set for the care of the crucible base initially, then the laminated sheet packages and the large-format return-flow scrap, which, after cutting with oxygen burner and subsequent cleaning by means of sandblast unit, are present in the form represented in **Fig. 6**. With the melting of these approx. 500 kg heavy metal parts, the kinetics of the melting process must be considered. With the start-up of the furnace filled with this melt stock, the first melt is formed in the lower crucible after a relatively short time, to which the electromagnetic field is coupled with preference. In a furnace of high power density, then the danger exists that more energy will transfer to the melt inductively than can be given out on the solid matter through heat transfer. The result is bath overheating which leads to premature lining wear. The processor does not detect this overheating since the temperature is determined here on the basis of a balance consideration, without taking the kinetics into account.

The diagram in **Fig. 7** enables the estimation of the melt duration of plate- or ball-shaped solid parts in the characteristic melt, depending on the difference between the melt and the liquidus temperature [3]. If it is presupposed that, for the care of the refractory lining, the overheating of the melt should be limited to 150 K above the liquidus, then the melt-down time of the approx. 40 cm thick return parts is accordingly 15 to 20 min. Experience shows that the overheating is held within the described limits when, in the first part of the melt period, up to a content of approx. 14 t, only half the rated power is applied in the furnace

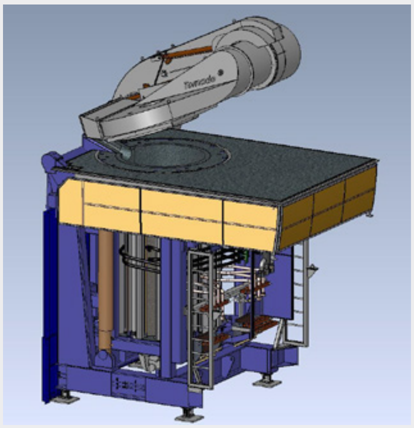
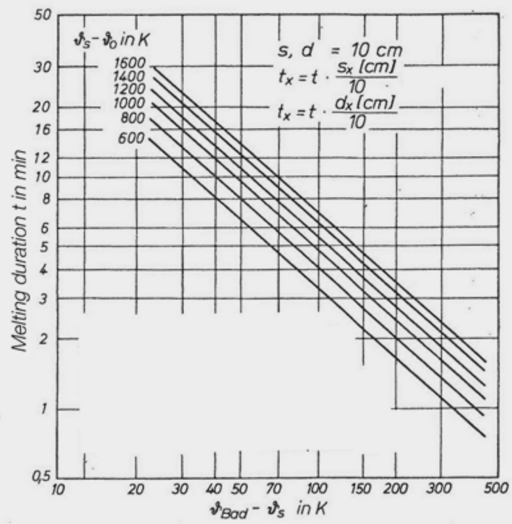


Fig. 5: ABP-induction furnace, Type IFM 9 [1]

Fig. 6: Return scrap after cutting and cleaning [1]



ϑ_{Bad} = melt temperature s = plate thickness
ϑ_S = liquidus temperature d = cylinder or balldiameter
ϑ_0 = start temperature

Fig. 7: Melting duration of 10 cm thick return pieces in dependence of the difference between the actual and the melting temperature for several charging temperatures [3]

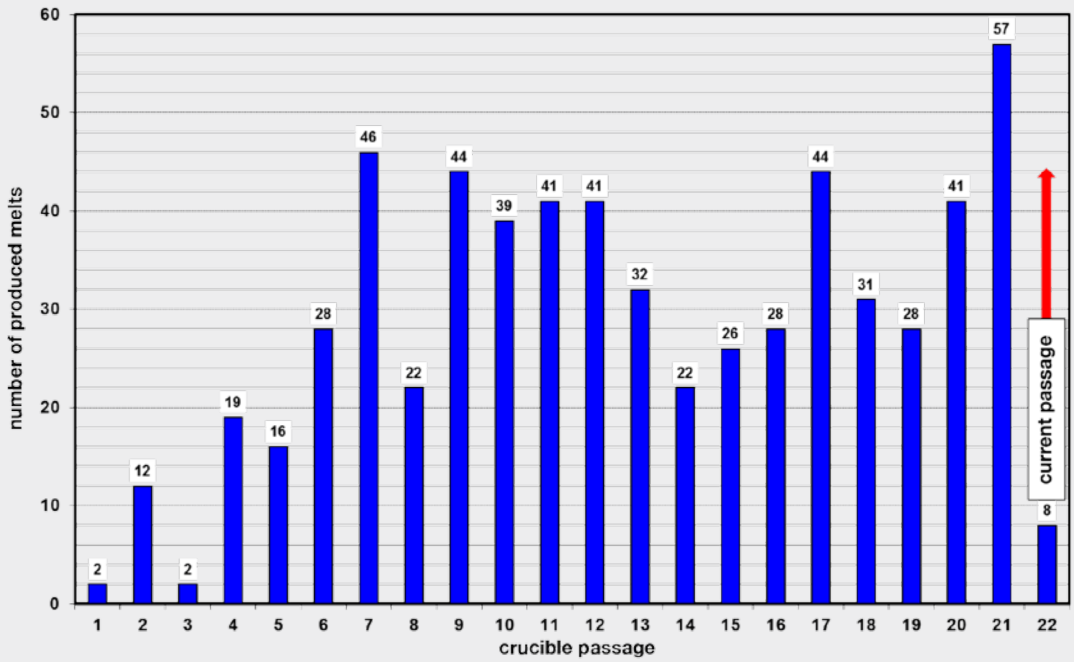
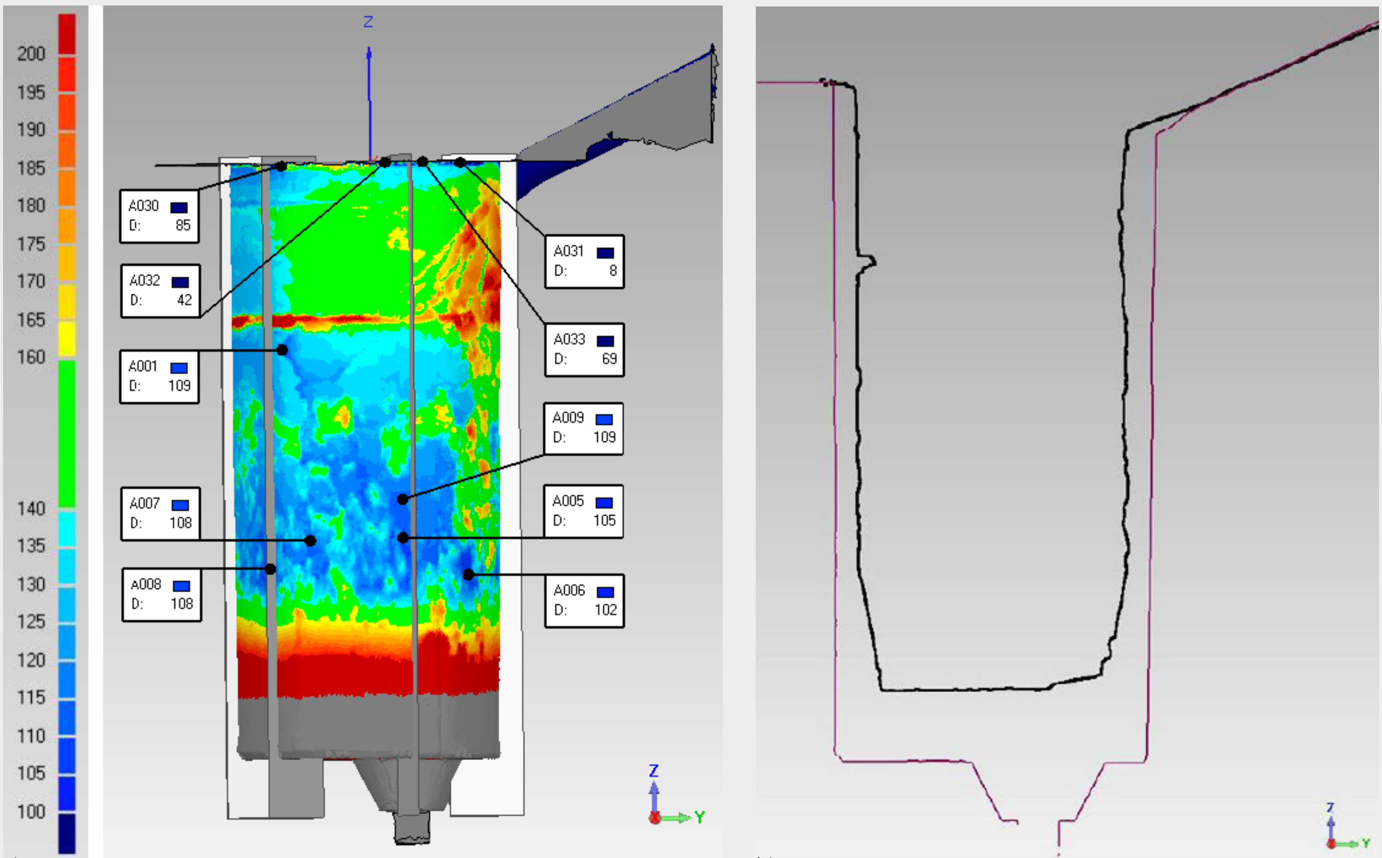


Fig. 8: Produced melts per lining of the crucible campaigns since 2009 [1]



a) b)

Fig. 9a/b: Wall thickness measurements per laser scan [1] with maximum 10 MW. Correspondingly the charge time, including de-slagging and finishing, is about 3 hours. Per day (Tuesday to Friday) on average one to two charges (4 charges are an exception) are melted, currently up to 20 charges monthly.

REFRACTORY LINING

Spinel-forming dry mass, which basically consists of 82.5 % Al_2O_3, 15 % MgO und 0,5 % SiO_2 is employed. The wall thickness is 150 mm. After inserting the crucible base, a sinter template 12 mm thick is installed and centered. Then the dry mass is inserted and compacted mechanically. The subsequent sintering is implemented with liquid steel as follows:

- Approximately 1 t of small-sized sheet steel scrap is batched for the care of the furnace floor.
- With a gas burner, template and melt stock are heated up with 200 K/h to an internal temperature of 1,100 °C.
- The temperature is maintained for up to 2 hours.
- The liquid steel is filled in one charge at 1,650 °C.
- After that the furnace is switched on with approx. 3 MW, so that the melt is brought to 1,720 °C and is held at this level for approx. 5 hours.

After completion of the melt charge, in the case of no further melt activity on the subsequent day, the hot crucible is allowed to cool down slowly to ambient temperature with closed cover and without any additional auxiliary cooling. In case of restart of operation, the crucible is then heated up to 1,100 °C with gas burner according to the same method as during the sintering, it is then filled with the first molten metal for the next charge and started again as described before. The service life of the crucible is represented in **Fig. 8** in the form of produced melts per crucible passage since the operational startup in 2009. With the evaluation of the relatively low number of 30 to 40, a maximum of 57 charges per lining, the above described operating methods with continuous cooling and reheating are to be considered. The breaking out of the worn-out crucibles is implemented mechanically with a hydraulic crucible press-out equipment.

The monitoring of the crucible wear is implemented with the earth leakage indication described in another section [4] and with the known Saveway system. Meanwhile, the wear measurement is additionally implemented by laser scan. **Fig. 9a** and **Fig. 9b** indicate as examples the results of measurement, by means of which the wear status of the crucible can be reliably assessed.

CONCLUSION

The voestalpine steel foundry in Linz/Danube has operated since 2009 a 38 t/16 MW induction crucible furnace for the melting down of the return material occurring in the foundry. The manufacture of heavy castings has as consequence that the return-flow scrap, also after cutting with oxygen burner, is present in large format. Correspondingly the performance setup of the induction furnace is to be adapted to the kinetics of the melting process. The reinstatement of the alloyed return material is of great economic significance for the steel foundry. It is therefore planned that a second crucible furnace will be installed for TwinPower operation, so that the connected load can be used fully for melt charges up to 70 t.

LITERATURE

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