Publication

Single-billet induction heaters meet the most exacting demands

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OTTO JUNKER GmbH is the only equipment manufacturer to offer both gas-fired heaters (GBE/ KombiGAS) and induction heaters (IBE) for reheating extrusion billets. This paper presents the available range of induction-type billet heaters and their advantages. The description is supplemented by a review of the handling systems employed from the billet or log feeding station to the point of billet transfer to the extrusion press. Calculations of operating costs and CO₂ emissions are given for diverse materials and key European countries, and some current reference projects are mentioned to round out this presentation.

Induction billet heater (IBE)

In a heater of this type, the part responsible for heating the extrusion billet consists of a water-cooled coil wound in multiple layers. The shape of this coil is adapted as closely as possible to the billet geometry for maximized efficiency, Fig. 1. Energy is transferred as the magnetic field produced by the coil induces a current in the aluminium billet and thereby heats it. In a single-billet heater, more than 1000 kW of electric power can be transferred per m² of product surface, irrespective of the billet surface condition (as-cast skin / scalped).

Fig. 1 Front view of a taper-heating plant built in 2012 for SAPA Bolzano to replace their HTS heater
As a result of these features, this heater is characterized by high heat-up rates and comparatively low space requirements for the heating unit, i.e., the coil. On the other hand, the electric power supply and the indispensable cooling system need additional space which must be taken into account in layout planning. Temperature control quality depends on the number of control zones; OTTO JUNKER warrants a reproducibility of the heating process to within +/- 5K, Fig. 2. The temperature measurement carried out for this purpose is performed in the 12:00 o’clock position; this prevents the billet from moving upon application of the thermocouples and ensures a defined contact configuration. Wear of the thermocouple tips needs to be addressed by maintenance personnel at regular intervals of time. OTTO JUNKER has significantly increased these intervals by the so-called "blind heating" approach whereby the thermocouples are applied only in the critical phases, i.e., at the start and end of the heating cycle. All additional information is calculated via a mathematical model coupled to the IGBT frequency converter.

**Fig. 2:** Power-controlled heating of an aluminium billet to 530 °C ± 5K at a maximum temperature head of +20K

Since only a single billet is heated at a time and the high power density mentioned earlier leads to short heating times, the IBE system exhibits the highest flexibility among all other known billet heaters. As virtually no heat is stored in the system, temperature changes in either direction may be effected at any time, and the minimum contract lot size becomes "1" from a heating point of view. Another major advantage of an induction heater lies in its ability
to apply an axial temperature profile ("taper") to each billet. Induction heaters of OTTO JUNKER design achieve this goal, again, with a reproducible temperature accuracy of +/-5K, Fig. 3.

Fig. 3: Result of the check-up measurement, conducted before the aluminium extrusion press, of a linear taper set to 50 K/m

Such taper heating is employed chiefly in direct aluminium extruding applications. Direct extrusion means that friction forces will be acting on the press container enclosing the billet. The friction work needed to overcome these forces is fully converted into heat, most of which goes into the billet. Consequently, the billet temperature and hence, the temperature of the extruded semi-finished product will rise as extruding proceeds at a constant speed. However, since the dimensional stability, surface quality and microstructural properties of an extruded semi-finished product are essentially a function of temperature, the aim is to keep the temperature of the extruded product constant throughout the process. In order to achieve this, either the extrusion speed (and hence, press throughput) must be progressively reduced or else it needs to be ensured that the billet already exhibits an opposed temperature profile, the so-called taper, beforehand. Today, tapers of up to 100 K per m of billet length can be
realized. It is state-of-the-art practice to calculate the necessary taper with the aid of mathematical models integrated into the extrusion press and to redefine it, from one billet to the next, on the basis of measurement readings. These calculations may even call for a non-linear taper, which can likewise be produced with an induction heater.

The energy efficiency attained in the induction heating process depends on the magnetic and electrical properties of the material to be heated. The underlying physical interrelationships are too complex to review in this context. However, as an engineering "rule of thumb", it may be stated that the energy efficiency of an induction heater operating at a constant frequency will be the better, the lower the thermal conductivity of the charge material, Table 1. The use of variable power and frequency IGBT (insulated gate bipolar transistor) converters is now state-of-the-art.

OTTO JUNKER, benefiting from synergy effects gained in the manufacture of induction-heated coreless melting furnaces, has been using a proprietary IGBT converter technology that has proven its merits in over 100 installed systems since 2004. Like the induction heater itself, every IGBT converter cabin is built – without exception – at the Lammersdorf factory and subjected to testing and adjustments together with the induction heater before shipping so as to reduce the commissioning effort at the customer's site.

OTTO JUNKER's range of products

Naturally, apart from these billet heaters, OTTO JUNKER also supplies all billet handling equipment tailored to on-site conditions, from the billet or log feeding station to the point of billet transfer into the extrusion press. Always included in the basic scope of supply is a product tracking capability that supports documentation and archiving of all production data (target & actual) so that the requirements of modern quality management will be fulfilled.

At this point, special mention should be made of several devices which have been enjoying brisk demand of late and are often supplied along with the billet heater:

Especially when processing aluminium logs, it has remained a challenge to minimize the amount of scrap produced by the sawing or cutting operation. By combining a log welder with a cold saw, it is possible to avoid the formation of scrap altogether, except for the inevitable sawing swarf.

Before the welding operation, the log ends are moved flush against each other and clamped in such a manner that no air gap remains and zero radial offset is obtained, if at all possible. In this way, air inclusions are avoided to the maximum possible extent, Fig. 4.

At the customer's request, test welds can be carried out to make trial extrusions which can then be evaluated in preparation of an investment decision.
The „narrow cut“ design of OTTO JUNKER's twin-blade cold saw helps to reduce losses in the form of low-value swarf substantially. Due to the saw blade thickness of only around 3 – 4 mm, a very thin cut is obtained compared to conventional single-blade saws. The two saw blades are mounted in a common frame and can be individually adjusted so that no undesirable steps will form on the sawn surface, Fig. 5.
Ideally, the logs supplied to the saw are taken from a vertical log magazine, **Fig. 6.** Its log storage capacity, with a strict separation between material grades, is much larger than that of a horizontal magazine. Needless to say, logs withdrawn for production may also be put back into storage, e.g., if a job is to be aborted, and re-used at some later date. The requisite software is developed and commissioned by our engineers.

**Fig. 6:** A typical vertical magazine installed in 2012 for SAPA of Offenburg

**Operating costs and emissions**

From the operator's viewpoint, the only disadvantage of an induction heater lies in the operating costs to be factored into the payback calculation. These are higher than for a system relying on fossil energy. However, the drawback of higher CO$_2$ emissions tends to be relevant only at the national level as the specific electricity mix of a given economy needs to be considered here. For Germany as an industrial location, it remains to be seen how specific CO$_2$ emissions will develop in the next few years in view of the recently adopted phase-out of nuclear power and the country's shift in focus towards regenerative energies, **Table 2.**

As regards electricity prices, their direction appears clear: regenerative energy is currently more costly than nuclear power, and fossil energy costs can hardly be expected to come down in the long run if only because of the limitation of resources. This makes it more difficult to justify the use of electrical (instead of fossil) energy in extrusion technology from an economic viewpoint, to say nothing of the significant operating cost drawbacks which already emerge today when comparing the German situation to countries with similarly high labour costs (e.g., France or Sweden), **Table 3.**
In calculating investment payback periods it is therefore recommended to consider not just the energy demand of the induction heater per tonne of heated aluminium but to relate this energy consumption to the actual product output obtained downstream of the extrusion press. The higher yield will then justify the use of an induction heater. Key arguments in favor of the induction billet heater include the following:

- fewer quality defects through accurate, reproducible temperature control, i.e., fewer rejects
- low number of billets in the system at any given time, i.e., if a job is aborted, only one excess billet will be heated (contrary to the situation with a multi-billet heater).

### Specific energy consumption

<table>
<thead>
<tr>
<th></th>
<th>Aluminium</th>
<th>Brass</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final temperature without taper</td>
<td>480°C</td>
<td>800°C</td>
<td>950°C</td>
</tr>
<tr>
<td>Specific enthalpy of charge material</td>
<td>130 kWh/t_{Al}</td>
<td>99 kWh/t_{Ms}</td>
<td>113 kWh/t_{Cu}</td>
</tr>
<tr>
<td>Power consumption of IBE</td>
<td>≈ 215 kWh_{el}/t_{Al}</td>
<td>≈ 152 kWh_{el}/t_{Ms}</td>
<td>≈ 202 kWh_{el}/t_{Cu}</td>
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<tr>
<td>Energy efficiency of IBE</td>
<td>60.5 %</td>
<td>65.1 %</td>
<td>55.9 %</td>
</tr>
</tbody>
</table>

**Table 1**: Power consumption of an induction heater with multi-layer coil and IGBT frequency converter

### Specific CO₂ emission

<table>
<thead>
<tr>
<th></th>
<th>Aluminium</th>
<th>Brass</th>
<th>Copper</th>
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</thead>
<tbody>
<tr>
<td>Germany</td>
<td>0.134 t_{CO₂}/t_{Al}</td>
<td>0.0945 t_{CO₂}/t_{Ms}</td>
<td>0.126 t_{CO₂}/t_{Cu}</td>
</tr>
<tr>
<td>France</td>
<td>0.002 t_{CO₂}/t_{Al}</td>
<td>0.001 t_{CO₂}/t_{Ms}</td>
<td>0.002 t_{CO₂}/t_{Cu}</td>
</tr>
<tr>
<td>Sweden</td>
<td>&lt; 0.001 t_{CO₂}/t_{Al}</td>
<td>&lt; 0.001 t_{CO₂}/t_{ Ms}</td>
<td>&lt; 0.001 t_{CO₂}/t_{Cu}</td>
</tr>
</tbody>
</table>

**Table 2**: Comparison of CO₂ emissions based on national electricity mix [Eurostat, 2007]

### Specific operating costs

<table>
<thead>
<tr>
<th></th>
<th>Aluminium</th>
<th>Brass</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>24.33 €/t_{Al}</td>
<td>17.20 €/t_{Ms}</td>
<td>22.86 €/t_{Cu}</td>
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<tr>
<td>France</td>
<td>15.09 €/t_{Al}</td>
<td>10.67 €/t_{Ms}</td>
<td>14.18 €/t_{Cu}</td>
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<tr>
<td>Sweden</td>
<td>14.34 €/t_{Al}</td>
<td>10.13 €/t_{Ms}</td>
<td>13.47 €/t_{Cu}</td>
</tr>
</tbody>
</table>

**Table 3**: Comparison of operating costs on the basis of average electricity prices [Eurostat, 2009]
Summary
The use of an OTTO JUNKER induction heater based on IGBT technology, whether as a standalone unit or operating in series with a fuel-fired preheater, provides significant advantages that may justify its use even in the face of higher specific operating costs. In the final analysis, these benefits can be summarized thus:

➔ high electrical efficiency due to FEM-designed inductors
➔ best reproducibility of billet temperatures with and without taper
➔ no damage to product during loading and unloading due to OTTO JUNKER trough conveyor system
➔ maximum flexibility in the case of quick temperature changes (lot size „1“)
➔ wear-free, freely configurable frequency converter produced in-house
➔ power supply infinitely variable from 0 to 100%
➔ no demands on cooling water conductivity (e.g., no need for demineralized water)
➔ rapid coil box replacement thanks to keyed quick-acting couplings
➔ defined thermocouple-to-billet contact due to temperature measurement from top
➔ short magnetic field extender
➔ longer thermocouple life due to „blind heating“
➔ scrap-free production in combination with welder and „narrow-cut“ cold saw
➔ product tracking and data management capability in line with quality assurance needs
➔ software development and commissioning by our own engineers

Operators can be sure to benefit from these advantages thanks to the extensive process and equipment expertise of OTTO JUNKER's specialized staff. The particularly efficient combination of a gas-fired preheater for basic heating with an induction heater for final heating, both from a single source, constitutes a unique OTTO JUNKER GmbH proposition. Several renowned extrusion plant operators have recently opted for the advantages of OTTO JUNKER's technology. Major reference applications to be mentioned here include CONSTELLIUM SINGEN (2 induction heaters with cold saw and vertical magazine), SAPA BOLZANO (2 induction heaters replacing the HTS heater), and SCAP CHONGQING (6 induction heaters with cold saw and vertical magazine).