HIGHLY EFFICIENT INDUCTION HEATING UNITS FOR METALLURGY AND MACHINE CONSTRUCTION


Induction heating units are being used increasingly widely in metallurgy and machine construction in all industrially developed nations: in metallurgy — to refine ferrous, nonferrous, and noble metals, including in vacuums; in machine construction — for quenching, soldering, annealing, stamping, hard-facing, and other operations. The reason is the possibility of moving products at high speeds in such furnaces within a precisely prescribed heating zone thanks to the formation of eddy currents induced in the material to a certain depth by the variable electromagnetic field of the induction coil.

Experience gained in the design and use of induction heating units at the plants of the Russian Electrotechnical Company (RÉLTEK) confirm the high efficiency of these pieces of equipment and the advantages they offer over other heating facilities. The most distinctive features of induction heating units are the low electric power consumption (Table 1) and high productivity, which is due in particular to the level of automation and mechanization that can be achieved.

It can be seen from Table 1 that the unit consumption of electric power is minimal in channel-type induction furnaces. However, this advantage is lost due to the need to maintain a bath of liquid metal 24 h a day. This requirement is particularly a problem when the production schedule is irregular. Also, the charge must be of a certain quality in these furnaces in order to avoid contamination of the channels by slags. These deficiencies significantly restrict the range of application of channel-type furnaces.

For the periodic refining of metals, it is best to use crucible-type induction furnaces. In addition to having a unit electric power consumption comparable to arc furnaces, these furnaces have clear advantages over the latter. Crucible induction furnaces make it possible to make high-alloy and low-carbon steels and steels with a high content of aluminum. They also allow the use of chips (up to 95%) in the charge and accurate control of the temperature of the liquid metal. Bath temperature can be adjusted to any specified value (with allowance for the heat resistance of the lining). Active motion of the liquid phase of the metal by the powerful electromagnetic field is another advantage of induction furnaces. The benefits of induction furnaces are especially evident in units designed for such operations as soldering, surface quenching, and heating prior to upsetting, when local heating of the product is required.

A great deal of experience in the development and introduction of such equipment has been accumulated by the specialists at the "ÉLTERM" Scientific-Industrial Association, which is a subsidiary of the company "RÉLTEK." In particular, the advantages of induction soldering compared to other types of soldering have been demonstrated by the introduction of several units made by the association for soldering different drill bits at plants in Novokuznetsk, Kyshtym, Ekaterinburg, and other cities. By choosing the proper amount of energy to be delivered to the soldering zone and the proper current frequency and thus establishing the correct heating rate and depth, users of the units have been able to significantly reduce warping and oxidation of the parts being soldered and double productivity. Also, thanks to the development of a special induction coil, the bits are heat-treated while they are being soldered: the top part is heated for the soldering operation as the shank is heat-treated. Thus, a complete treatment is administered to the part in one operating cycle.

The coil is powered from a single thyristor frequency converter with a power of up to 100 kW and a frequency of 2.4-10.0 kHz, the exact values depending on the dimensions of the bit. If necessary, one converter can be loaded by several soldering machines. As a rule, the soldering operation is mechanized. The operator has only to place the next bit, with the hard-alloy element and the flux, on the soldering machine. Then the bit is automatically moved in succession from the...
TABLE 1. Unit Consumption of Electric Power in the Refining of Copper, Aluminum, and Steel in Furnaces of Different Types and Capacities

<table>
<thead>
<tr>
<th>Type of furnace</th>
<th>Unit consumption of electric power, kWh/ton, during refining</th>
<th>Copper</th>
<th>Aluminum</th>
<th>Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel-type</td>
<td>200/200 **</td>
<td>350/400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>induction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crucible-type</td>
<td>310/295</td>
<td>590/570</td>
<td></td>
<td>540/500</td>
</tr>
<tr>
<td>induction*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arc</td>
<td>320/300</td>
<td></td>
<td>560/530</td>
<td></td>
</tr>
<tr>
<td>Resistance</td>
<td>--</td>
<td>600/650</td>
<td></td>
<td>--</td>
</tr>
</tbody>
</table>

*Thyristor frequency converters were used as the power sources.
**The numerator and denominator show data for furnaces of 0.5 tons and 2.5 tons capacity, respectively.

preparation zone to the heating and precooling zones. It is then sent into a quenching bath and discharged. Stabilization of the high-frequency energy transmitted from the thyristor converter and precise control of the duration of all steps in the soldering operation make it possible to consistently realize quality soldering and quenching of drill bits.

Rapid and local heating to a prescribed depth is also important in surface quenching. Continuous-sequential quenching is generally used for long products. While preserving the viscosity of the core, this regime also produces high hardness in the surface layer to the required depth (usually no more than 2.5 mm). The problem of surface quenching has been successfully resolved by the development of an induction unit designed for quenching long drill rods. The unit was developed and made by specialists at "ELTERM." The main problem encountered, related to warpage of the rods, was solved by creating tensile forces (greater than 10 kN, or 1.0 ton-f) in them and maintaining these forces during the entire quenching stage.

Through proper selection of such parameters as the speed of the induction coil along the rod, the amplitude and frequency of the induced current, the speed of rotation of the rod about its own axis, quenching temperature, and cooling rate, it became possible to achieve the required quenching results:

- depth of quenching — 2.0-2.5 mm; surface hardness — at least 54 HRC; hardness of the core — no more than 32 HRC.

One such unit is now being successfully used at the "RELTEK" factory to quench drill rods ordered by plants in the mining industry.

The advantages of local quenching have also become evident in the use of a unit to heat drill rods prior to upsetting to form the collar. The shank is then also quenched. The unit was introduced at facilities of the firm "Sevuralboksitruda" (in Severoural'sk) and took the place of a contact (direct) heating unit. The change in equipment made the following possible:

- complete elimination of the phenomenon of "burn-through" of the rod and frequent repairs to the copper contacts;
- doubling of heating rate for upsetting and an increase of more than threefold in the heating rate for quenching of the shank;
- a substantial increase in the quality of the upset collar and an improvement in working conditions for the operator.

No less effective is the use of through induction heating for the heat treatment of parts: annealing, tempering, normalizing, recrystallization, etc. Use of one of the three known methods of through induction heating (normal, accelerated, stepped) makes it possible to realize the necessary heat-treatment regime. Compared to furnace heating, through induction heating significantly reduces oxidation of the surface and loss of carbon from the products being treated. It also expands the capabilities of the operator to produce parts with prescribed properties.

The above principles were the foundation for the development of units for the heat treatment of welds and products for forging at "RELTEK" plants. Similar units are now being developed at many facilities in the power and machine-building sectors in the nations of the CIS (Commonwealth of Independent States).