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Q&A INDUCTION HEATING

This month's column features the answer to a reader's question about what is the main reason for selecting a vertical induction system over horizontal coil arrangements when heating large billets.

Question: In the Professor Induction article "How do I select inductors for billet heating?" (*Heat Treating Progress*, May/June 2008, p 19-21), you stated "… When heating large-diameter steel or titanium billets (8 to 12 in., or 200 to 300 mm, and larger), it is often advantageous to use static heating with a vertical coil arrangement"… What is the main reason you say that static vertical heating is good for billets over 200 mm in diameter and why do you set the limit over 200 mm? Is this related to the running cost, initial system cost, or other reasons[1]?

Answer: There are several reasons why in recent years there is a tendency to use vertical inductors instead of horizontal coil arrangements for heating large diameter billets. Some of these are stated below.

1). Large diameter billets (for example, 200 mm and greater) are typically relatively long (usually 500 to 1,200 mm, or 20 to 47 in.), meaning that such billets are quite heavy. Therefore, it is necessary to provide sufficient mechanical support for such billets. In the case of using a horizontal coil arrangement, heavy billets cannot be simply placed on thermal refractory because they will crush it. In addition, if horizontal coils are used to heat large diameter billets, then there is often a challenge to install some kind of support liners inside the inductor; for example, stainless steel liners (water cooled or not water cooled) can be positioned between the coil refractory and billets over the length where support is required. In this case, there is a challenge to provide reliable, sufficiently strong, wear-resistant, and long-lasting liners that can provide the required mechanical support for heavy billets located inside of horizontal induction coils.

2). To provide sufficient surface-to-core temperature uniformity, large diameter billets require longer heating times compared to induction systems used to heat small and medium size billets, even when low

Professor Induction welcomes comments, questions, and suggestions for future columns. Since 1993, Dr. Rudnev has been on the staff of Inductoheat Group, where he currently serves as group director – science and technology. He has 28 years of experience in induction heating. His expertise is in materials science, metallurgy, electromagnetics, heat treating, computer modeling, and process development. Credits include 18 patents and 146 publications.
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The Systematic Analysis of Induction Coil Failures series will continue in the next issue of *Heat Treating Progress*. Part 14 of the series will discuss failure analysis and prevention of split-return induction coils.

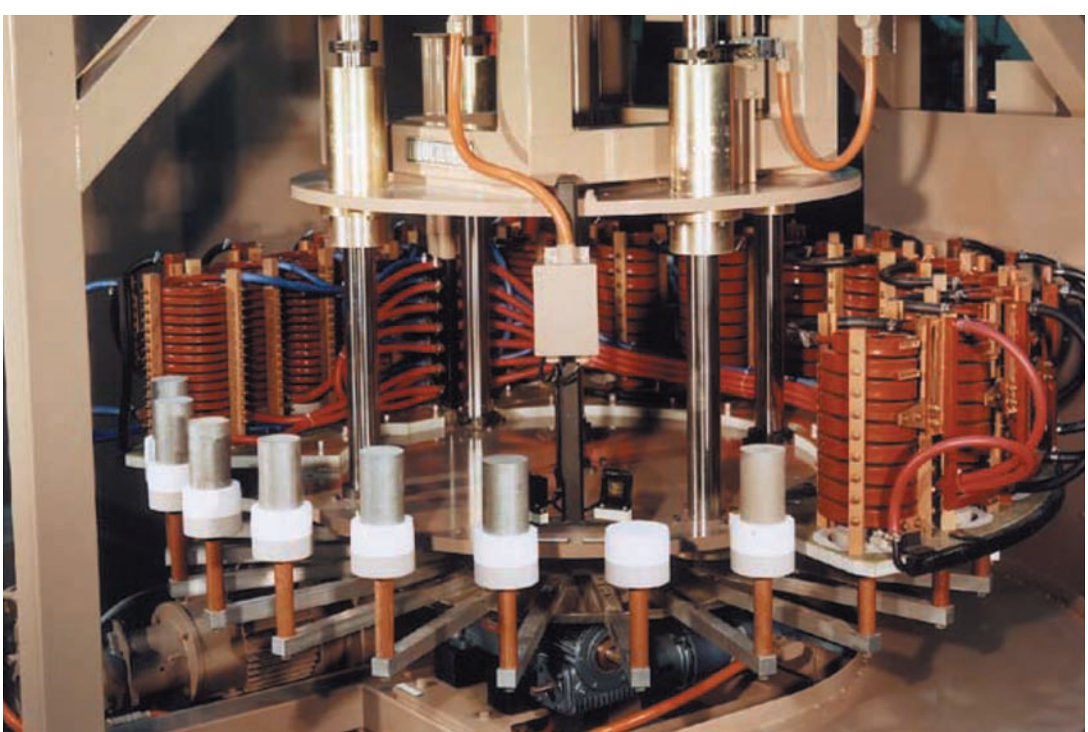

Fig. 1 — Aluminum slugs rest on ceramic pedestals in vertically arranged induction coils. Courtesy of Inductoheat Inc.

frequency is applied. Longer heating time is required for thermal conduction to heat the core. If water-cooled liners are used to provide support to heat large billets in horizontal induction systems, there is a danger of localized cold spots appearing in areas where the hot billet contacts water-cooled liners. This could negatively affect the billet's temperature uniformity around its perimeter.

A "chimney" effect is also more pronounced when heating large billets. Its appearance in horizontal inductors makes the localized cold and hot spots more pronounced[2]. If non-water cooled support liners are used, then the appreciably longer heat times required in combination with billet's heavy weight results in a tendency of liners to sag due to a rise in the liner temperature resulting from thermal conduction from heated billet.

3). Some applications demand a specific surface condition of the heated billets. A heavy billet's surface condition could be altered when it is pushed through a horizontal induction coil during loading-unloading operations.

4). Most customers prefer having an induction coil that will be able to heat billets of different diameters. When heating different diameters, the majority of billets will be located non-symmetrically inside of horizontal inductor (the axis of symmetries of the billet and coil do not coincide). This causes the electromagnetic proximity effect to be more pronounced[2,3]. This could also result in a nonuniform temperature distribution along the billet perimeter and particularly at its end areas, negatively affecting the quality of heated billets.

Vertical induction systems

A vertical coil arrangement eliminates a majority of the above-mentioned drawbacks of horizontal induction systems, providing better equipment reliability, robustness, and improving quality when heating large billets. For example, with the vertical coil arrangement, it is not necessary to position the support liners between coil refractory and billet.

In vertical systems, billets are typically loaded (charged) using a mechanism that is located below the platform with a vertical induction coil. During the loading operation, billets are transferred (for example, by trolley conveyor or other means) into a horizontal cradle that is located under the induction coil. This cradle forms part of a rocking hanger, which pivots 90 degrees and sets the billet vertically over a charging jack[2]. The charging jack raises the billet vertically into the inductor. It moves through its full travel so that the lower end of the billet is always positioned at the same level inside the coil. The billet's upper end is positioned in the zone where the coil taps are located, adjusting the coil upper overhang and controlling end effect heating. Therefore, in the heating position, the billet simply rests on a specially designed, well-supported thermal pedestal. Sophisticated design and proper handling of electromagnetic end effect compensates some heat conduction toward a pedestal. Such an arrangement allows proper positioning of billets in both radial and axial directions inside of the induction coil. This results in better heating quality, achieving better temperature uniformity along billet's length and perimeter.

When heating is completed, a computer generates a signal checking whether the press is available to accept the billet. Otherwise, the inductor changes its heat mode over to a hold mode. Billet discharge occurs by the lowering of the jack followed by the 90 degree pivoting of the hanger, thus bringing the billet into a horizontal position, ready to be transported to extrusion press.

Vertical systems easily allow compensating a chimney effect by closing the top portion of inductor using thermal refractory materials. The vertical coil arrangement also significantly improves coil-to-billet electromagnetic coupling, because it is possible to have smaller coil-to-billet gaps resulting in higher electrical efficiency, lower coil copper losses and waste of energy (less coil water-cooling requirements), and lower coil current and magnetic forces experienced by coil turns. All of the above result in improved life of induction equipment. However, the reader should not be under the impression that it is advantageous using vertical coil arrangements only when heating large diameter billets. In some cases, application specifics make a vertical induction coil arrangement a preferable choice over horizontal systems even when heating small and medium size billets. For example, Figs. 1 and 2 show examples of using vertical coil arrangements when heating aluminum slugs for semi-solid processing and steel bar end heating, respectively.

Fig. 2 — Vertical induction bar-end heater. Courtesy of Radyne Corp.

The great majority of small and medium size billets are heated using horizontal induction heaters thanks to advantages discussed in Ref. 1-4. **HTP**

References

1. V. Rudnev, How do I select inductors for billet heating", *Heat Treating Progress*, May/June, 2008, p 19-21.
2. V. Rudnev, D. Loveless, R. Cook, and M. Black, *Handbook of Induction Heating*, Marcel Dekker Inc., N.Y., 2003.
3. V. Rudnev, Systematic analysis of induction coil failures. Part 13: Electromagnetic proximity effect, *Heat Treating Progress*, Oct., 2008, p 23-26.
4. V. Rudnev, Induction Heating Serves Today's Forging Industry, *Forge*, Nov., 2004, p 11-14.