Forge operators boost productivity and energy efficiency with new induction furnace technology

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A growing number of forge industry leaders have taken advantage of the improved energy efficiency, higher productivity, and eco-friendliness offered by the newest generation of innovative induction heating technologies. The advent of intelligent induction furnace zone control, known as iZone™ technology, marks a significant milestone in the ongoing pursuit of manufacturing excellence.

Germany produces about 2.3 million tons of forged parts each year, with an energy consumption of about 1,300 MWh/year to heat these parts to the proper forging temperature. With a typical energy price of 0.10 €/kWh, the annual energy bill adds up to €130 million (about $190 million), underscoring the potential benefits available to forge operators deploying new high-efficiency induction furnace technology. In response to rising energy costs and the desire for greater environmental stewardship, iZone™ induction heating technology sets new standards for efficiency, productivity, and resource conservation.

The key to unlocking higher induction heating efficiencies was the development of an entirely new generation of converters featuring L-LC (inductor-inductor/capacitor) resonance circuits with switching at the inverter output (**Fig. 1**). Comprised of an unregulated rectifier, intermediate circuit capacitor, IGBT inverter, and output choke, this converter has a real-world operating efficiency of 97 % and a power factor (cos φ) across its entire output power range.

The following paragraphs describe how the iZone™ induction furnace has been successfully integrated with a hot shear to achieve greater production flexibility and productivity in the forging of large workpieces.

Process requirements and equipment layout

A magazine delivers individual bars (bar dimensions: Ø 120 mm to 300 mm, or Ø 4¾" to 12", with a maximum length

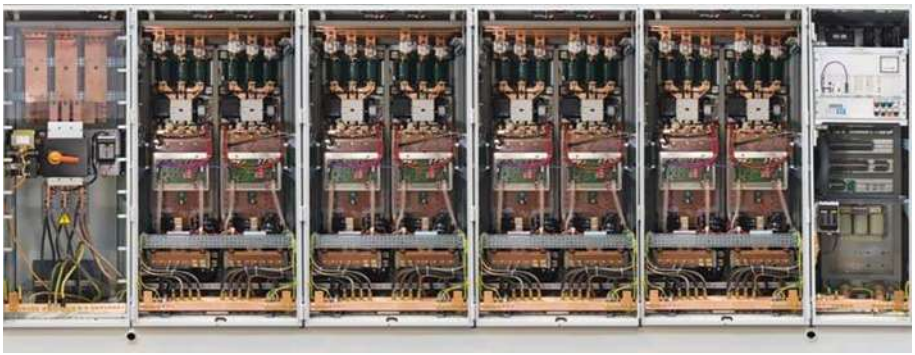

Fig. 1: The 97 % efficiency L-LC induction furnace converter with eight zones

Fig. 2: High performance induction furnace for large bar heating

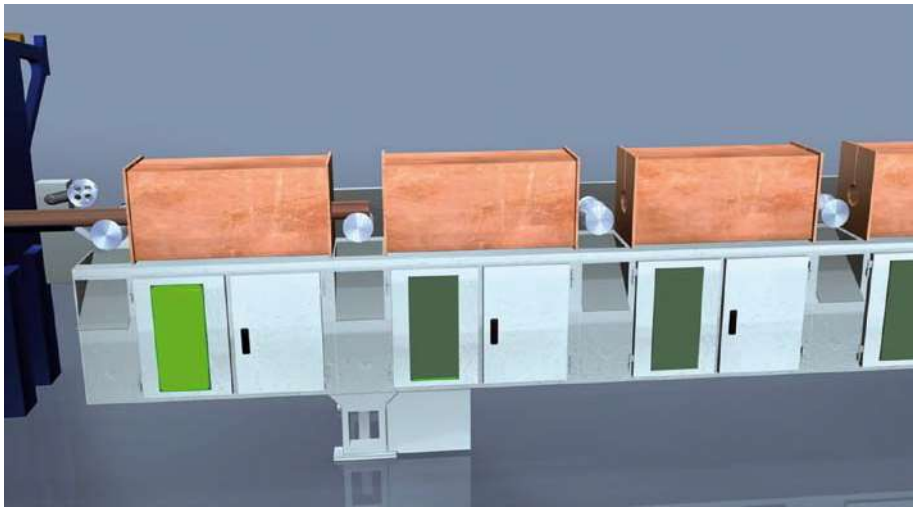

Fig. 3: Production Start Sequence: Cold bar entering the furnace from the left (green panel indicates energized furnace zone). Each zone is automatically turned on as the bar enters.

Fig. 4: Production Stop Sequence with final bar exiting the furnace (green panels indicate energized furnace zones). Each zone is automatically turned off as the bar exits

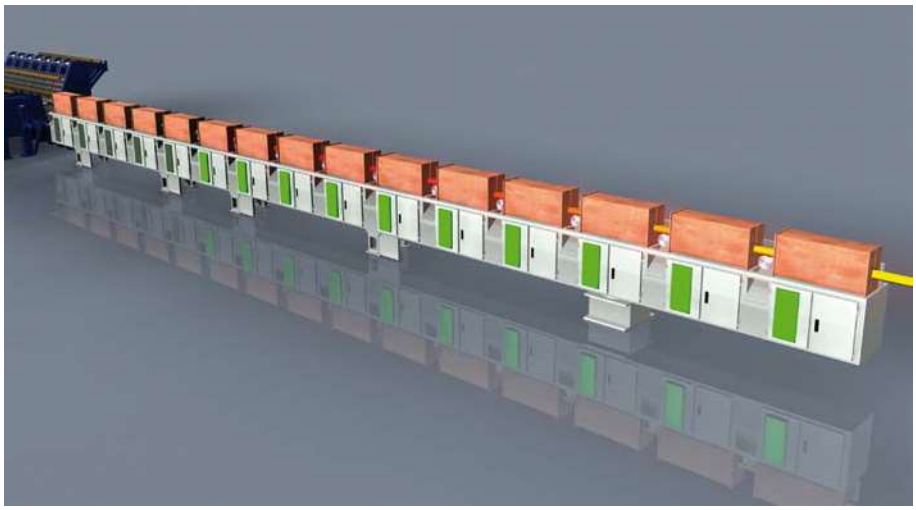

Fig. 5: Flexible Throughput Rates (green panels indicate energized furnace zones) 300 mm (12′) diameter bars are heated to forging temperature at a reduced throughput of 6 t/h. 20 % energy savings are realized through iZone™ recipe optimization vs. conventional furnace operations, and scale formation is minimized

of 12 m, or 40 feet) to a roll table, which transports the bars to and through an induction furnace consisting of nine 1,100 mm long (44″-long) heating coils, followed by one 1,800 mm long (71″ long) soaking coil at the furnace exit. The hot shear then cuts the precisely and uniformly heated bar into billets ranging from 150 mm to 1,000 mm (6″ to 40″) in length. The required throughput ranges from 1.5 to 9 metric t/h.

Two L-LC converters (**Fig. 2**) provide the 4,200 kW heating power required for the specified 9 t/h throughput. Each converter drives four independent furnace zones (eight zones in total). The first five coils comprising the furnace entry section are individually driven, making up the first five independent furnace zones. The sixth and seventh coils are grouped together in one zone, as are the eighth and ninth coils. The tenth coil (the soaking coil) makes up the eighth and final independently controlled furnace zone. All eight zones share the same control architecture, and all nine heating coils are identical and fully interchangeable for maximum flexibility and machine availability with minimal spares requirements. Only two spare coils are needed to support the entire furnace, saving both money and valuable floor space.

Energy-efficient start and stop sequences

Heating large bars from room temperature to 1,250 °C (2,280 °F) can require up to 50 min until the first billet can be hot sheared. The bar progresses from one heating coil to the next in about five minutes. The iZone™ controller tracks the bar location, activating each zone as the bar enters. Energy and money are thus saved by driving only the loaded furnace zones (**Fig. 3**). Analogous to the start sequence, the stop sequence turns off each furnace zone as the bar exits that zone (**Fig. 4**).

Optimal performance at any throughput rate

iZone™ equips modern forge operators to capitalize on the trend toward small lot sizes and flexible production schedules. The intelligent zone controller automatically optimizes the heating recipe for efficient performance at any production rate up to and including 100 % of the rated heating power. In

Fig. 6: iZone™Graphical User Interface (GUI)

this example, 300 mm (12") diameter bars are heated at a reduced throughput rate of 6 t/h with a net energy savings of about 20 % compared to conventional furnaces without iZone™ technology (**Fig. 5**).

User-friendly GUI for automatically accurate setups

iZone™ offers forge operators a variety of heating strategies, including options for reduced scale formation and "soft" heating (heating with reduced thermal gradients in the workpiece). The intelligent controller behind the operator-friendly GUI (graphical user interface) automatically optimizes the heating profile and furnace parameters in response to operator selections. With the press of a button, individual furnace zones are energized at the right moment with the right power, frequency, and load matching capacitance (**Fig. 6**).

"Soft" heating of crack-sensitive steels

Certain bearing steels, such as 100 Cr6, are prone to internal cracking induced by thermal stress during the heating process. Conventional induction furnaces required a set of custom "soft heating coils" to reduce the heating rate below the Curie temperature and avoid thermal cranking. Because the iZone™ controller can drive each furnace zone independently, it is able to create a soft heating profile with standard heating coils. No custom heating coils are required. iZone™ simply and immediately fine-tunes the furnace to match the requested throughput and heating profile, eliminating the cost and delay of maintaining and swapping multiple sets of custom heating coils (**Fig. 7**).

Stop and go operation with holding mode

In the past, disruptions in forge process pacing (faults, pauses, and outages) usually required that the induction furnace

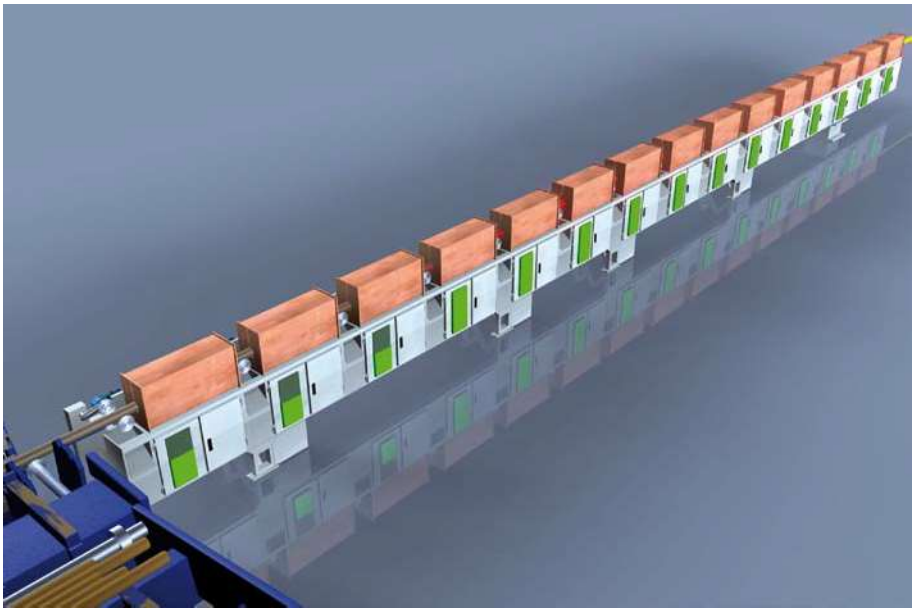

Fig. 7: Soft Heating of Crack-Prone Steels (green panel indicates energized furnace zone.) Zones one through three provide soft heating below the curie temperature to prevent thermal cracking, without using special soft heating coils

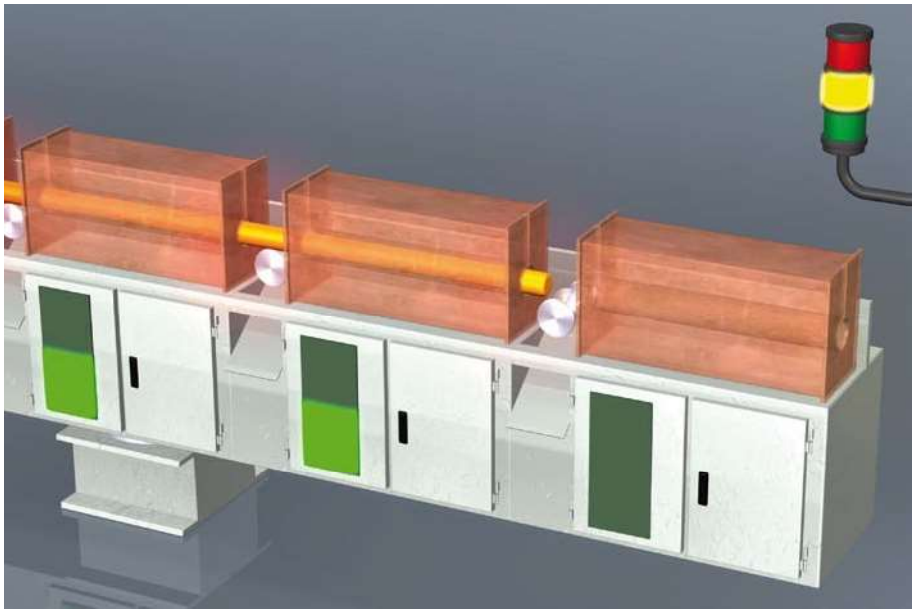

Fig. 8: Warm charging & soaking for immediate recovery after a production stoppage (green panel indicates furnace zone operating in "holding" mode)

be purged of all in-process material, resulting in wasted energy, time, and money. By contrast, iZone™ can maintain partially heated bars at the appropriate intermediate temperature until production resumes with no down time and no loss of product. This Stop and Go operation allows warm charging, holding, and soaking of partially heating bars based on the workpiece heat content (enthalpy) in each of the furnace zones. Oscillation (continuous forwards/backwards cycling motion of the bar) essentially eliminates residual thermal gradients (zebra-striping) along the bar length. Strategically located pyrometers verify the bar temperature and provide input to the iZone™ adaptive controller (**Fig. 8**).

Conclusion

Modern forge operators have realized significant productivity improvements through the benefits of iZone™ induction furnace technology, including:

- Peak efficiency at any throughput rate in all operating modes, including
  - startup,
  - soaking,
  - shutdown and
  - continuous production
- Simple and fast (less than two minute) product/process changeovers
- Adaptable heating profiles for reduced scale formation, crack prevention, etc.
- Stop and Go operation for fast, efficient re-starts following production pauses
- Reduced heating coil inventories and spares requirements.

iZone™ has been particularly well received by European forge operations wanting to boost productivity while reducing costs and emissions, and by Asian forge operators working with limited power availability. Meanwhile, new technologies for even greater induction heating efficiency are under development, and will soon be incorporated into robust furnace systems for the forging and long products industries. ■

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