Inductive longitudinal seam-welding systems in tube and profile lines

Robert Jürgens, Dirk Wohlfahrt

Inductive welding is certainly the most important joining method for longitudinal-seam welded tubes and tube profiles. The process parameters required for the welding task in question differ according to the material, tube wall thickness and tube diameter. With the new components available in the electronic and electrical industries, it has been possible to develop new system components. Correct selection from the offered variety of frequency generators and HF resonant circuits is decisive for the performance, quality and economic efficiency of the welding process.

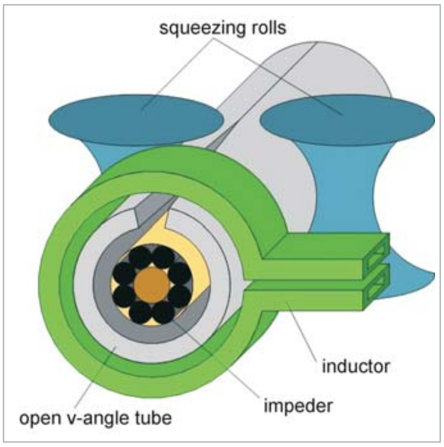

Fig. 2: FSchematic diagram of inductive longitudinal-seam welding

Longitudinal-seam welded tubes and tube profiles have become a matter of course in everyday life today. The variety of forms, however, also demonstrates that longitudinal-seam welded parts have become a significant economic factor and are thus a topic of continuous further development by industry (**Fig. 1**). It is the same physical procedure which is used to manufacture both aluminium window profiles, which are welded in the tube line at up to 200 m/min, and ferritic steel tubes with a diameter of 610 mm and a wall thickness of 24 mm, which are welded at a speed of 8 m/min.

Inductive longitudinal-seam welding has undergone a long development. For a long time, high-frequency tube generators were used as the power supply for the welding process. The tube generators have been replaced by static frequency converters since the beginning of the 1990s. The use of frequency converters, in turn, required capacitor units to provide the necessary capacitive reactive power at low voltages. The current generator concepts and the corresponding capacitor units will be introduced below.

But first a brief description of the inductive longitudinal-seam welding process.

The welding process

Selection of the correct welding parameters depends mainly on the strip speed, the strip thickness, the material, and the tube diameter. With inductive longitudinal-seam welding, the welding current is induced in a nearly closed tube using an induction coil. The induction current flows over a short distance along the strip edges and ends at the contact point (upsetting point) in the area of the upsetting rollers of the now closed tube (**Fig. 2**).

The induced current heats the strip edge up to melting temperature. At the upsetting point, the objective is a slight overheating into the molten range. If the overheating is too great, an uneven structure formation in the seam area will impair the welding quality. If the strip edge temperature remains too low, however, no structure is formed. The upsetting pressure must be configured such that a portion of the molten or paste-like material escapes from the seam area to the top and to the bottom.

The material pressed out is scraped off from the tube directly behind the upsetting rollers using external and internal scrapers.

How can the strip edge and welding point temperatures now be controlled such that a constantly good welding quality is achieved for each different strip thickness and tube speed?

How much of the strip edge area must be heated to melting temperature to achieve a low-flaw welding process?

Experience has shown that too small a welding zone results in a narrow process

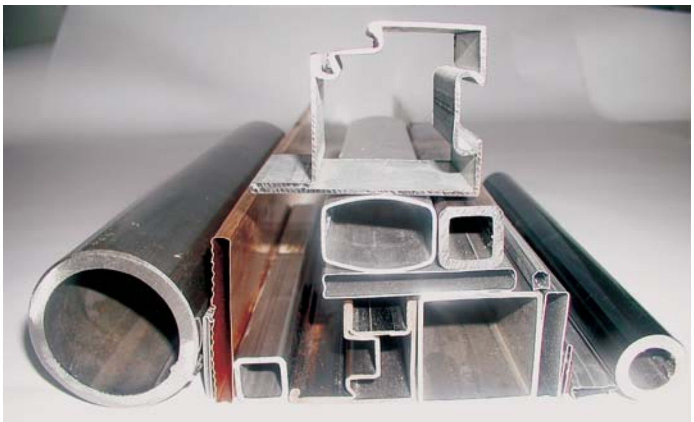

Fig. 1: Different forms of longitudinal-seam welded profiles

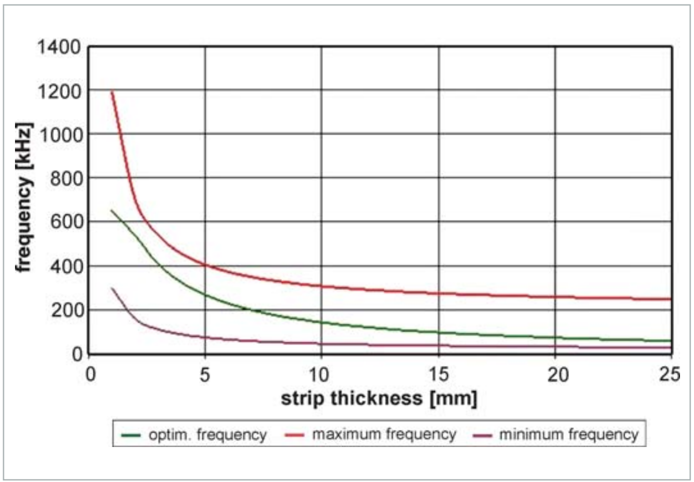

Fig. 3: Frequency of the welding current as dependent on the strip thickness

window in tube production. The width of the zone can be controlled by way of the welding current frequency and the time. If the frequency is too high, this results of an overheating at the strip edge and in a melting-off of the material. **Fig. 3** shows the upper frequency limit above which the edge is overheated. At the lower frequency limit, the heated area becomes so large that the strip edge becomes unstable and can no longer be guided reliably at the upsetting point. An optimised frequency characteristic determined by simulation calculations can be used as a target parameter for the welding process. Two areas can be identified in accordance with the wall thickness. Below a wall thickness of 4 mm, the required welding frequency increases rapidly. This dimension range corresponds to a frequency range of approx. 200 kHz ... 800 kHz. A wall thickness area > 4 mm corresponds to a frequency range between 50 kHz and 200 kHz.

State-of-the-art converter technology

The two frequency ranges are currently covered by two types of frequency converters. IGBT converters operate efficiently up to a frequency of 200 kHz. MOSFET converters operate efficiently in a range between 150 kHz and approx. 700 kHz. SMS ELOTHERM uses MOSFET converters as parallel-resonant-circuit converters. The most important subassemblies – controlled rectifier, DC link reactor and MOSFET inverter – are shown in the block diagram (**Fig. 4**).

Available output powers of this converter type range from 110 kW to 700 kW. The frequency range is configurable between 50 kHz and 600 kHz. For higher outputs, workpiece arrangement) is generated by having many capacitors connected in parallel. The capacitor unit can be connected either in parallel to or in series with the inductivity (inductor). Parallel or serial connection results in either parallel or series resonance if the capacitive and the inductive powers are of the same value. This is the case if the resonance conditions SMS ELOTHERM GmbH has developed IGBT converters. These have been conceived as series-resonant-circuit converters (**Fig. 5**). The most important subassemblies are the controlled rectifier, the capacitive DC link and the IGBT converter. The output powers of this HF frequency converter type range between 600 kW and 2,400 kW. This converter type can be operated at frequencies up to 200 kHz. The market of all profile forms which are welded with longitudinal seams can be served by these two converter types.

Compact HF resonant circuits

Frequency converters supply the resonant circuits in the welding lines with reactive power only. The reactive power for the inductive load (with longitudinal-seam welding, the inductor

$$j\omega L I^2 = \frac{1}{j\omega C} I^2 \quad (1)$$

or

$$j\omega C U^2 = \frac{1}{j\omega L} U^2 \quad (2)$$

are met.

In the parallel-resonant circuit, the voltage on the capacitor unit and on the inductivity is the same. In the case of resonance, the current is increased excessively. The term 'current resonance'

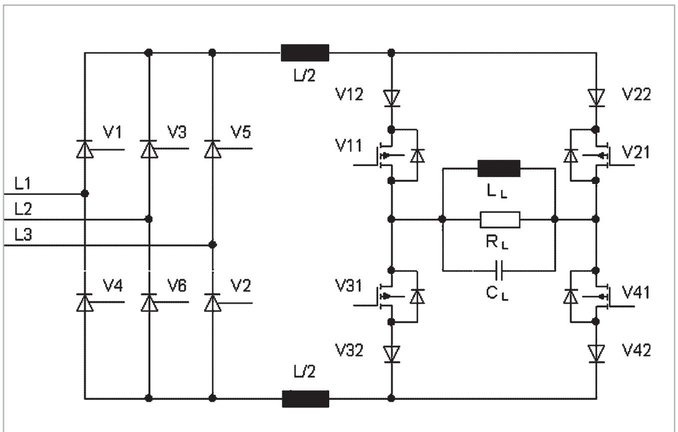

Fig. 4: Block diagram of a parallel-resonant-circuit converter with MOSFET inverter

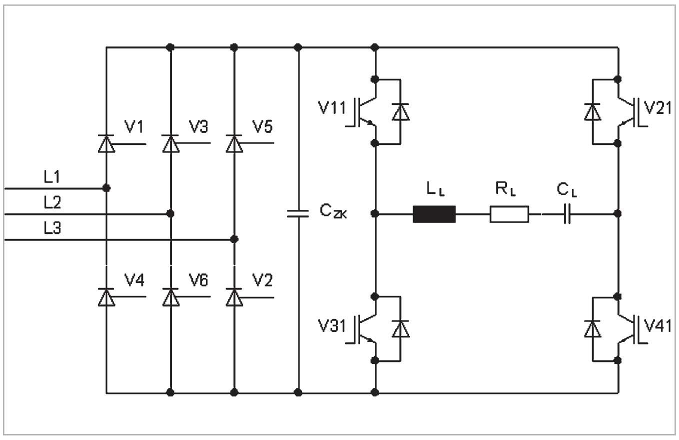

Fig. 5: Block diagram of a series-resonant-circuit converter with IGBT inverter

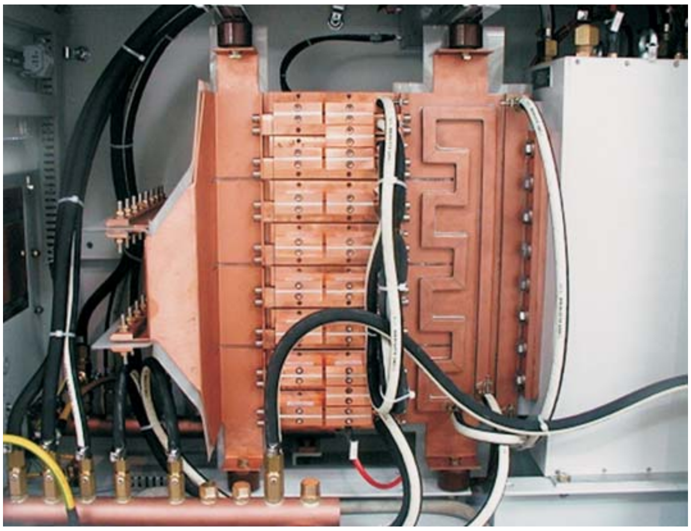

Fig. 6: Capacitor unit for high frequencies up to 600 kHz with output transformer, designed as a parallel-resonant circuit

Fig. 8: Welding seam of a longitudinal-seam welded tube with subsequent double annealing (ground section etched to show the ferrite line)

is used in this context. However, to ensure that a sufficiently high voltage is provided on the inductor to drive the current, a transformer is installed in the parallel-resonant circuit for power adaptation in most cases. Air-cooled transformers were formerly used as such transformers. Today, ferrite-core transformers are used. The design of a state-of-the-art capacitor unit with output transformer for a parallel-resonant circuit is shown in **Fig. 6**.

It is the current which is provided to the series-resonant-circuit. In the case of resonance, therefore, the voltage is increased excessively. For this reason, all components in the series-resonant-circuit are voltage-proof. The resonant-circuit power is controlled via the current flowing through the components. Often, a transformer is also used here for power adaptation to the converter. **Fig. 7** shows a state-of-the-art capacitor unit with input transformer for a series-resonant circuit during the manufacturing process.

Process control

Current plant control systems possess integrated algorithms which allow almost fully automatic operation of longitudinal-seam welding systems. Such algorithms include starting programs which control the welding power according to the speed and thus always supply the correspondingly correct power required by the welding process.

Warning and alarm messages are displayed on the operator panel of the control system to enable the operator to take the relevant steps for troubleshooting immediately. The process data are saved in an integrated process data management to reduce operator errors.

Conclusion

State-of-the-art inductive longitudinal-seam welding systems enable the plant operator to weld at a working frequency optimised for the welding process in question in accordance with the wall thickness. If the plant components are selected correctly, a welding process is achieved which is both high-quality and cost-effective. **Fig. 8** shows a ground section of a thick-wall longitudinal-seam welded tube in the seam area. The good welding quality can be seen from the scarcely discernible ferrite line. ■

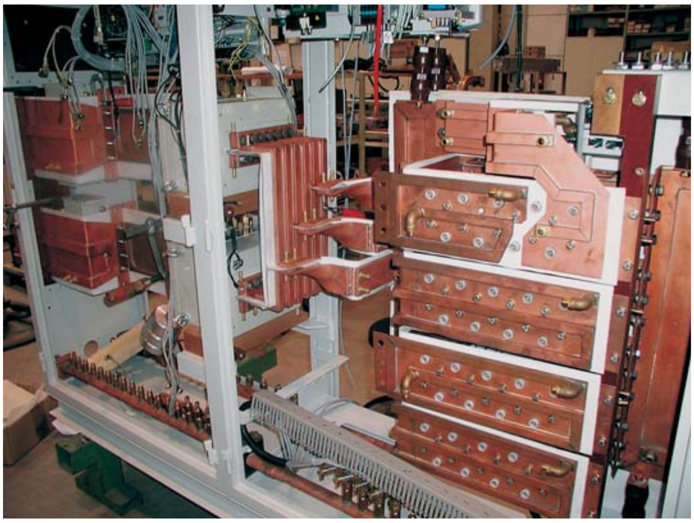

Fig. 7: Capacitor unit for high output powers up to 25,000 kvar with input switching transformer for power adaptation (during production)

Robert Jürgens

SMS Elotherm GmbH
(Germany)

Tel.: +49 (0) 2191 / 891-0
r.juergens@sms-elotherm.de

Dr.-Ing. Dirk Wolfahrt

SMS Elotherm GmbH
(Germany)

Tel.: +49 (0) 2191 / 891-527
d.wohlfahrt@
sms-elotherm.de