Recent developments and future trends in Electrotechnologies

Egbert Baake
Institute of Electrotechnology
Leibniz University Hannover
Hannover, Germany
baake@etp.uni-hannover.de

Bernard Nacke
Institute of Electrotechnology
Leibniz University Hannover
Hannover, Germany
nacke@etp.uni-hannover.de

***Abstract*—A wide range of industrial thermal processes are carried out using electrotechnologies. The application of electrothermal processes offers many advantages from technological, ecological and economical point of view. Although the technology level of the electro heating and melting installations and processes used in the industry today is very high, there are still potentials for improvement and optimization due to the increasing complexity of the applications and the strong requirements regarding the performance and quality of the products but also regarding the efficiency, flexibility and reliability of the processes and technologies. In this paper recent developments and future trends like hybrid technologies, additive manufacturing and digitalization in electrotechnologies are described and discussed along selected examples.**

***Keywords*—electrotechnologies, hybrid technologies, additive manufacturing, digitalization**

I. INTRODUCTION

Thermal processing technologies are an indispensable part of many industrial processes in particular in the production and further treatment of products in metallurgical industry. In many cases the processing and in particular the heating of materials can, in principle, be realized by both using electrical energy or fossil energy sources, like gas or oil. However, due to the continually growing demands on the effectiveness of the whole process chain, on the level of flexibility and automation, on the environmental sustainability of industrial processes, on the reliable quality and not at least on the improvement of the total energy and CO2-emission balance of a process or a product, electrical energy and particularly electrotechnologies in many cases offer excellent future oriented application possibilities in multifarious industrial processes [1]. For high-power applications the main areas of research and development today are the optimal control and the energy-efficient design and operation of processes and installations. In process-oriented applications the energy aspect plays a secondary role while the optimization of the production process itself is the primary task [2].

II. HYBRID TECHNOLOGIES

The substitution of conventional production processes by new innovative processes is a general important approach for improvement and optimization of the productivity and overall efficiency in many industrial processes. This includes also the substitution of the final energy sources. Instead of the complete substitution of the used thermal technology sometimes the combination of different technologies leads to an overall improvement of the process. A typical example is the combination of different heating methods and processes in hybrid installations, like induction heating in combination with a gas fired furnace, microwave heating integrated in a convective heated furnace, induction heating in combination with laser or an induction stirrer used in gas fired aluminium melting furnaces. Practical examples can be found e.g. in applications for strip heating, where the fast heating up of the strip can be realized efficiently by induction heating and the time dependent metallurgical process, like annealing for re-crystallisation of the material, can be done using a long gas-fired soaking furnace [3].

Currently a lot of investigations are carried out for the optimal heating process for hot forming and press-hardening of metal blanks in automotive industry. Fig. 1 illustrates four possible concepts to heat a pre-shaped sheet or endless strip.

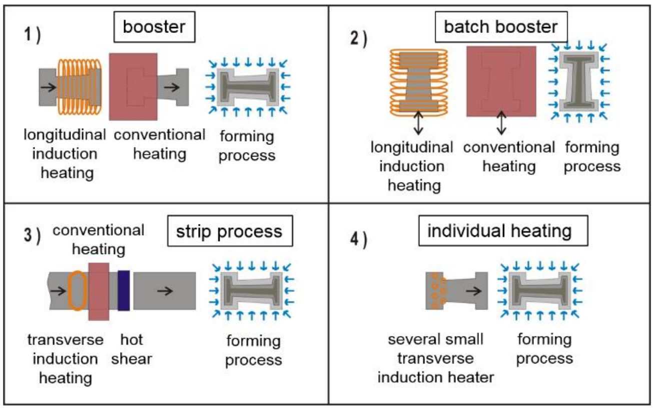

Fig. 1. Heating concepts for hot forming of high strength steel: 1) combined longitudinal flux heating and conventional furnace for continuous mode; 2) batch mode of the combined process; 3) transverse flux heating of endless strip with hot shear; 4) heating by a combination of several small transverse induction heaters [4]

For thin moving sheets longitudinal flux heating can be used as a booster till Curie temperature (Fig. 1-1). The final temperature above 760 °C is reached by conventional heating such as hot air or radiation heating. In batch mode (the work-piece is placed without movement in the heating stations) it is also possible to heat thin sheets by longitudinal flux heating (Fig. 1-2). The same temperature limitation has to be taken into account like in the first concept. Therefore, higher temperatures need an additional conventional heating. Transverse flux heating is beneficial for endless strip. Therefore, a concept could be the heating of endless strip from ambient to final temperature by transverse flux heating with very good efficiency (Fig. 1-3). It is followed by cutting the strip to the required sheets length in hot condition just before the hot forming. High flexibility can be reached using several small transverse flux heaters with separate power control (Fig. 1-4). Depending on the work-piece an optimal selection of heaters and individual power is chosen. After a small overheating, time for equalization is required to get a maximum possible homogeneity of the temperature distribution. This concept can be used in batch or continuous mode. It has very high requirements on the design.

Furthermore, hybrid systems used in energy intensive industrial thermal processes will become increasingly important in the future due to the expanding volatile renewable energy generation. The application of hybrid heating or melting technologies, e.g. furnaces which can be heated alternatively and flexible by electrical and/or fossil energy can react flexible from the technical and economical point of view on the current offered energy mix [5].

III. Additive Manufacturing

The use of additive manufacturing processes for the production of components in the field of electrotechnologies offer many technological and economic advantages. Examples of components used for induction hardening processes, which are produced using different additive manufacturing technologies are coils and inductors (see Fig. 2) and quenching showers.

Fig. 2. Example of an inductor produced by additive manufacturing (Courtesy: SMS Elotherm GmbH)

For the additive manufacturing of inductors, which are usually made of pure copper or copper alloys the selective laser melting or the electron beam melting processes are used today [6]. The manufacturing principle is to melt powder at defined locations and to create thin layers of solidified material in order to get finally a 3D structure. In this way very complex geometries can be produced with very high accuracy and excellent repeatability.

Magnetic flux concentrators, which are used e.g. for induction heating in particular induction hardening processes are made from transformer sheets, so called laminates, from ferrites or from soft magnetic composites, based on ferromagnetic particles embedded in non-electrical conductive and non-magnetic materials. A new type of magnetic flux concentrators based on ferromagnetic particles embedded in ceramic matrix material in order to provide a high temperature mechanical stability and a flexible, customized, complex geometry, ready to use by the customer due to the additive manufacturing process is currently in development [7].

IV. Industry 4.0 and Digitalization

The characteristics of “Industry 4.0” are the strong customization of products under the condition of highly flexible mass production using automation technology with self-optimization, self-configuration, self-diagnosis, cognition and intelligent support of workers in their increasingly complex work. But what are the requirements for digitalization in electrotechnologies?

Digitalization requires the recording and digitalization of all relevant process and equipment data, e.g. production data, electrical data, process data, like temperatures, pressures, etc. The data quality requires aspects, like consistent, resilient, accessible, current, accurate, trustworthy, unique and assignable, understandable and as standardized as possible, available (timely and complete). The data processing (big data analysis) is necessary for process identification and monitoring in real time and for the process control by means of machine learning, digital twins and process self-optimization using artificial intelligence (AI).

The digitalization in electrotechnologies is a great challenge und offers big potentials for improving process efficiency, flexibility, reliability and product quality. Electrotechnologies are predestinated for the digitalization and offer many approaches for improving and optimization in particular also of classical well established heating and melting processes [8].

V. Conclusons

The use of electroheat will be increased in the future because electro processing technologies in particular meets the continually rising standards with regard to the requirements to the products and the desire for production processes which are both as efficient as possible and have minimum environmental impact. Future oriented tasks of researchers, producers and users of electrotechnologies are the development and realization of process oriented customized solutions, where the optimization is taken into account the whole production process, the overall energy balance and productivity and in particular the total efficiency. In the frame of this context hybrid technologies, additive manufacturing processes and in particular digitalization (Industry 4.0) will play important roles in the future development of electrotechnologies and processes.

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