Importance of EPM Technologies

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Technologies for Electromagnetic Processing of Materials (EPM) 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 CO_2-emission balance of a process or a product, electrical energy and particularly electromagnetic sources in many cases offer excellent future oriented application possibilities in multifarious industrial processes. Potentially electricity can replace up to 100% of other energy carriers currently used for process heat.

A lot of industrial processes are dependent on electricity to guarantee high product quality. Other production processes especially those for innovative high-tech materials can only be carried out by using electricity for heating purposes or for the electromagnetic processing of these materials. Typical examples can be found in the semiconductor and aerospace industry (Figure 1).

Figure 1: Melting of titanium in an induction furnace with cold crucible

Multifarious features and applications

Electro processing technologies are suitable for heating and melting any electrically conducting and non-conducting material. A great number of industrial processes including melting, hardening, tempering, annealing, brazing, galvannealing, drying, crystal growing, preheating before rolling, forging or coating are carried out using electrothermal processing technologies. But not only for heating and melting but also for electromagnetic controlling, steering, braking or confining of melt flows during casting processes, separating of inclusions

or controlling of solidification processes the electromagnetic processing technologies become more and more significant. The increasing use of electric energy for all these processes depends on the special features and the numerous advantages of electric energy, as described below.

The major advantages of using electrical energy for thermal and in particular electromagnetic processing technologies can be listed as follows:

- heat can be generated within the workpiece (direct heating)
- high energy density and consequently fast heating
- demanded temperature distributions within the workpiece
- very high temperature, if required
- lower specific energy consumption than other methods
- flexible operation and low thermal inertia
- selective, localized heating, if required
- excellent environmental conditions
- clean heating in any media including vacuum or a controlled atmosphere
- high reliability
- electromagnetic forces on liquid electrically conducting material for stirring, braking, homogenizing, confining, levitating or separating of inclusions
- electromagnetic processing of materials

Electrical heating methods, can be used much more effectively and in a much more targeted manner than competitive energy sources. Electrothermal technologies are characterized by high process efficiency and, in spite of having a higher energy price than fossil fuels, by better profitability than other energy sources as a result of lower operating or raw material costs. Electric heating processes are very flexible in operation and they provide excellent possibilities of a high level of automation.

The application of electrothermal and electromagnetic processing treatment allows a desired heating which is easily reproducible means that defined material properties can be set in order to improve the technical characteristics of the semi finished or final product. Using electric heating the fast heating-up rate, the exact temperature control as well as the predictable and reproducible spatial temperature distribution result in high thermal efficiency and noticeable saving of raw material, e.g. due to the low combustion losses. This becomes particularly clear in induction, conduction, dielectric and microwave processes where the heat is generated in the workpiece itself.

On the basis of the short heating-up period, which is reduced by up to 90% compared with fossil fuel heated installations, metallurgical modifications of the workpiece surface, such as oxidation and decarbonisation, are considerably restricted and this results in high quality of the products. Also, an flexible and immediate readiness for operation is given and the storing of heated or melted material is not necessary in many cases. Electric heating installations are very compact and require a relatively small floor space, so they can be easily integrated in existing production lines. This results in considerable improvement of the production course.

Evaluation criteria

Before the decision which technology allows as optimum a heat or melting operation as possible, taking into account economic and technology criteria (Figure 2), other criteria in addition to the profitability ratios for the evaluation of systems and methods have to be taken into consideration, criteria such as:

- product quality
- operational flexibility
- saving of energy and raw materials
- environmental impact
- working conditions
- ...

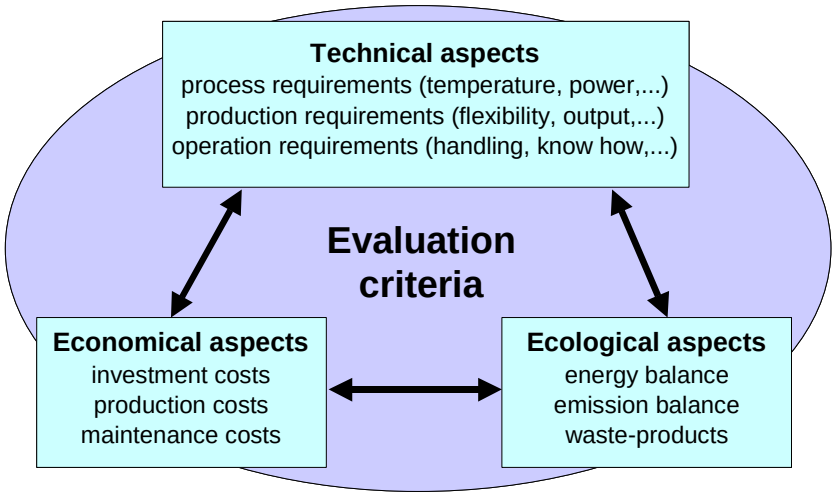

Figure 2: Evaluation criteria of thermal process technologies

These evaluation criteria, which are in part not directly monetary, have in the past years resulted in an increasing appreciation of the value of electrical energy in industrial processing technologies. This results in an increasing use of electric heat in a variety of manufacturing and treatment processes in industry.

Developments

Saving of process steps and the reduction of the production line is frequently the key of success for saving energy and costs by the optimization of the total efficiency and productivity of a complete production process. But therefore the development and realization of new innovative future oriented processes and technologies is indispensable. Near net shape production processes are a typical trend for saving of process steps as well as saving of raw material and energy consumption and so finally the increasing of the total efficiency and productivity. Examples, which are still in development or already in practical use are thixoforming processes, thin strip continuous casting processes or precision forging and forming processes. In those innovative processes an exact temperature distribution in the workpiece to be treated is absolutely necessary. This strong technological requirement can be carried out with electrical heating, like induction heating, where a precision automatic temperature control is possible.

The substitution of conventional production processes by new innovative processes is a general important approach for improvement and optimization of product quality, 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 efficiency. 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.

Future outlook

The application of electrothermal technologies in industrial production processes offers many technological, ecological and economical advantages. 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 requirement to the products and the desire for production processes which are both as efficient as possible and have minimum environmental impact. From ecological point of view in the future the use of electricity for all kinds of industrial and domestic applications including all kinds of thermal processes will lead to a considerable reduction of CO_2-emissions and therefore to a reduction of the carbon footprint, due to the significant increasing share of electricity generated by renewable energy sources.

Well established electromagnetic processing technologies will be continuously improved and optimised from technological, energetic, and last but not least economic point of view. Future oriented tasks of researchers, producers and users of electrothermal technologies are the development and realization of process oriented customized solutions, where the optimization is not concentrated on a single heating or melting installation but the whole production line including material transport, overall energy balance and productivity and in particular the total efficiency of the line must be taken into account.