OTTO JUNKER

Publication

Operating experience with the mathematical modelling of the new Otto Junker strip coil annealing furnaces at Alunorf

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Following the placing of an order in November 2010, in mid-2011 Otto Junker GmbH delivered five coil annealing furnaces with a charging machine and a complete automation system to Aluminium Norf. In November 2011, with only a year between the placing of the order and the hand-over of the plant, the company declared its full acceptance. Test annealing operations show that, not least thanks to the mathematical modelling of the heat treatment process, substantial energy savings can be achieved.

As has already been reported in this journal, the new 'Strip annealer 3' is a closely monitored innovation project that has been supported by the German Federal Ministry of the Environment. The motive for that support was that the coil annealing furnaces to be supplied by Otto Junker perform better that the prior art, among other things thanks to a newly developed, integrated mathematical model by virtue of which significant CO_2 emission savings amounting to some 8,300 tpy are achieved.

After carrying out a total of 50 test annealing processes, which covered a large proportion of the product range, it was demonstrated that the innovative technology achieved remarkable savings of approx. 50% of electrical energy, 30% of natural gas and 70% of the protective gas required. The environmental label AL4++++ generated by Alunorf for its furnaces is therefore fully justified.

Besides this pleasing aspect for the environment, such savings of course bring a considerable reduction of operating costs. This shortens the amortisation period and contributes toward ensuring the competitiveness of Alunorf.

Structure of the new coil annealing facility

In all, Otto Junker installed five new coil annealing furnaces next to one another (Fig. 1). These are designed for strip thicknesses from 0.2 to 5 mm and strip widths from 750 to 1,720 mm. The coils heat treated are of the alloys AA1000 to AA8000, with a maximum furnace space temperature of 600 ℃. One furnace is additionally equipped for special annealing operations with a cooling cycle under a protective gas atmosphere.

The charging machine supplied for loading and unloading the furnaces is fitted with contact thermocouples, so that before the beginning of an annealing operation the entry temperature of the coils weighing up to 12 tonnes each can be measured, for the later calculation of process prescriptions. The furnaces are loaded and unloaded automatically, and the additional challenge of also serving the old furnaces positioned opposite has been overcome by virtue of a special design.

Photo: Susanne Dobler

Fig. 1: The new coil annealing furnaces of 'Otto Junker' design at Alunorf

The new furnaces are each divided into four mutually independent control zones, with the following characteristics:

- specially developed, high-efficiency circulation fan with continuously variable speed
- a nozzle system optimised for the particular application
- natural gas burners with integrated recuperators, incorporated in the radiation tube
- housing structure that saves protective gas and energy, particularly at the separation points and furnace entrances.

The idea of providing an individual control zone for each coil is necessary when the same annealing operation (material temperature, time) has to be ensured for different starting parameters (initial material temperature, geometry) by means of different process specifications (furnace temperature, time, fan speed). Only by virtue of the energy optimisation of the ‘hardware’ in the furnace design can the prerequisites be provided for the ‘software’ – in this case the mathematical model – to achieve its maximum additional utility.

The concept of the integrated mathematical model

It goes without saying that the furnaces supplied by Otto Junker allow fully automatic operation. This is ensured by a combination of several SPS controls, each with a superordinated visualisation system. Their structure is provided with redundancy so that, for example if one visualisation computer fails, the operation is not interrupted because its function is mirrored on each of the others. Besides displaying the most important process data, monitoring the situation and archiving, an order management system requiring no operator intervention is integrated: all the charge data (coil ID, coil geometry, alloy, etc.) and annealing operations are loaded by the Alunorf production planning system (Level 3) and require only to be approved by the operator before the heat treatment begins.

The heat treatment process takes place with the ‘online’ module of the mathematical model re-calculating the annealing process (specified temperature-time variation of the material) for each strip coil on the basis of the prescription (temperature-time-speed variation in the control zone) already in place, starting from the actual initial temperature and the actual mass, and controls the actors (burners, fan) accordingly. During this the material temperatures can be archived and visualised at any time during the furnace campaign, at up to six freely chosen positions for each strip coil.

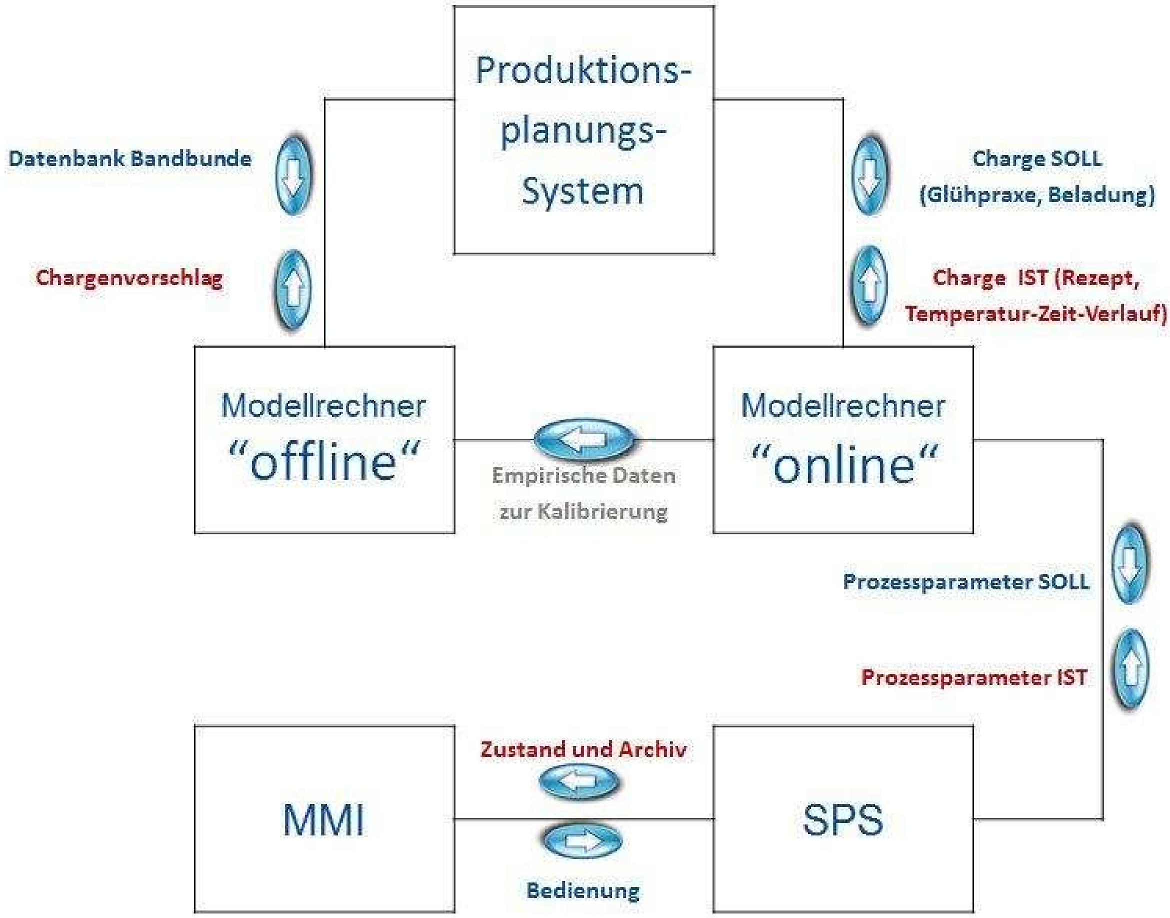

Fig. 2: Architecture of the automation concept

Up to the beginning of the heat treatment process, the 'offline' module of the mathematical model has already carried out decisive preliminary work in the production planning system: all the strip coils to be heat treated within a defined time window are entered in a databank at the level of the production planning system. From that databank the 'offline' module looks for strip coils that match one another optimally according to the criteria of annealing operation and geometry. From this a charge proposal is prepared. After approval by the production planner, the now adopted charge proposal is sent to Alunorf's production planning system and, from there, transmitted to 'Coil annealer 3' as an order. Changes of prescription owing to a different initial temperature or a different mass are automatically taken into account by the 'online' module. Both these parameters are measured during the loading of the charging machine. Manual changes of the charge composition can be carried out until the command "Close furnace door" is received.

The accuracy of the FD process used for calculating the material temperatures demands special knowledge, such as:

- heat transfer as a function of temperature, speed and nozzle distance
- proportions of radiation/forced convection
- temperature-dependence of the material properties (heat capacity, thermal conductivity)
- influence of the winding factor
- ratio between radial and axial thermal conductivity
- influence of the surface (structure, flatness)
- influence of stored heat

Some of the necessary fundament al investigations were carried out at the Institute for Industrial Furnace Engineering of RWTH Aachen using a 1:1 cold model of a furnace zone. The results contributed equally to the design of the furnace itself and to the computational core of the mathematical model.

Operating experience

The evaluation of the production data shows that the deviation between actual and calculated material temperatures conforms to formulated expectations in a reproducible and stable manner.

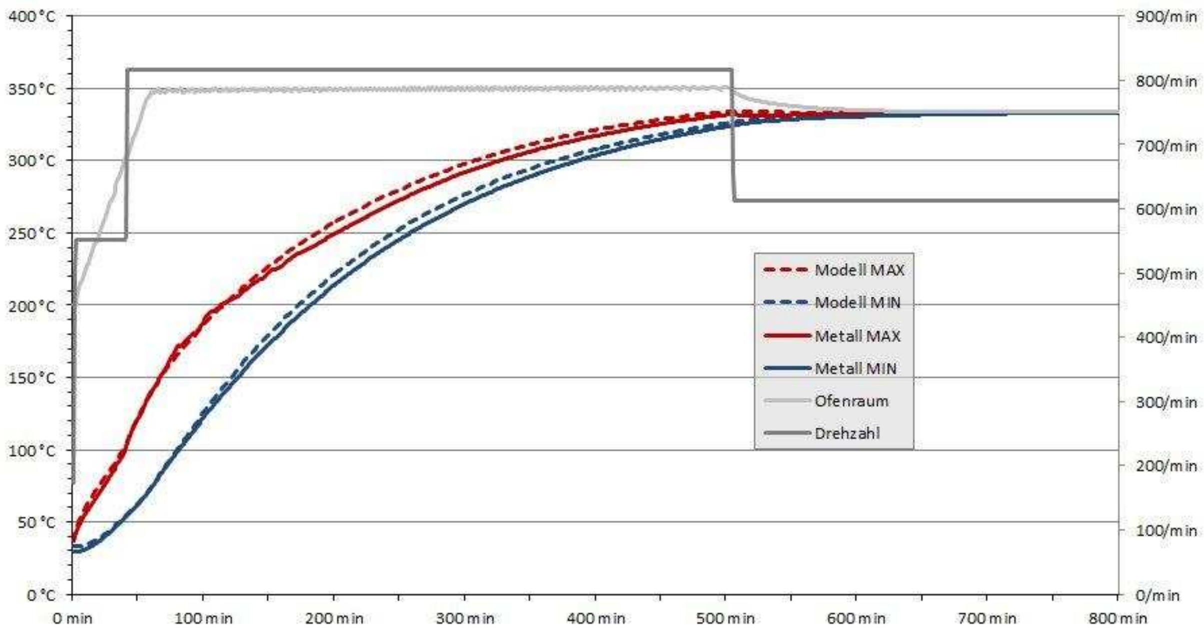

Fig. 3: Comparison of calculated and measured metal temperatures

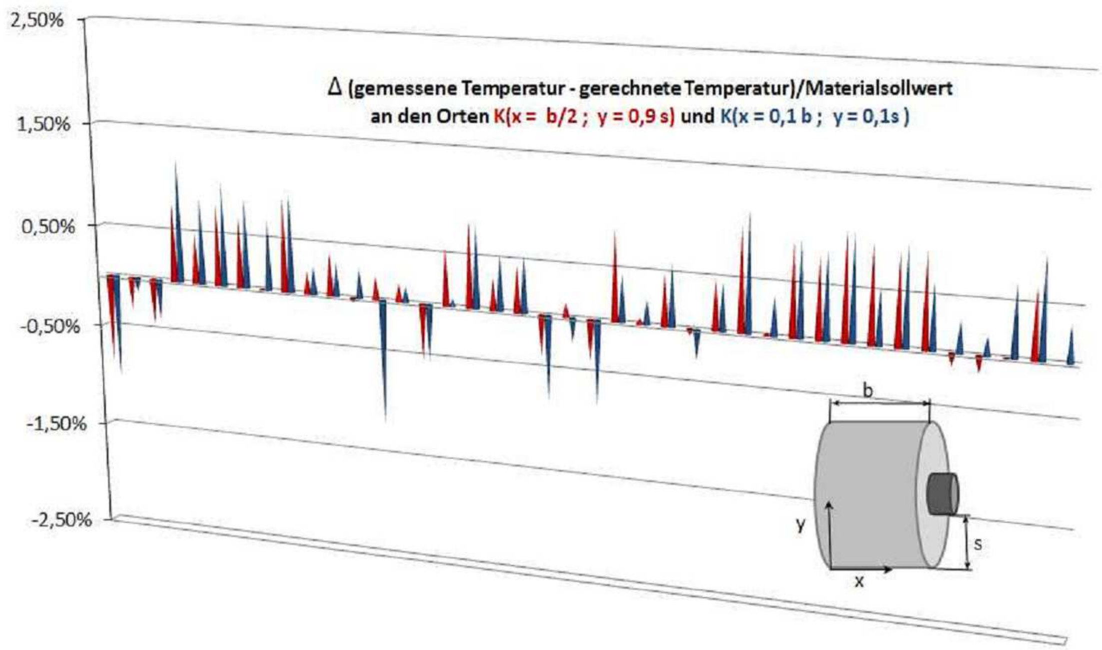

Fig. 4: Relative 'calculated/measured' deviation for 50 strip coils in various charges

This level of accuracy is sufficient for by far the majority of applications. However, individual special cases in which narrower tolerances must imperatively be maintained have to be heat treated in a furnace with integrated material temperature measurement.

One of the five furnaces has been provided with the requisite equipment, which therefore also constitutes an additional optimisation tool: by comparing the actual material temperature with the calculates values, the mathematical model can be calibrated.

In summary, according to present experience obtained with the integration of a mathematical model the following advantages can be expected:

1) Thanks to the possibility of allowing larger geometrical differences between the strip coils of the same charge, the furnace can more often be filled to 100%. This increases the utilisation level of the furnace and reduces the specific energy demand.
2) Likewise, larger differences between the initial temperatures of the strip coils can be coped with. Consequently, both cold coils and coils hot from rolling can be used in one and the same charge. This mainly reduces the energy demand, but also increases furnace utilisation level.
3) Deadline-critical strip coils can be heat treated individually in an energy-optimised manner. The specific natural gas demand increases only be the empty value of the furnace, while the electric power demand stays almost constant.
4) From a comparison of process data with the results of the heat balance included in the mathematical model, information relevant to maintenance can be extracted.
5) In contrast to physical material temperature measurements methods, the mathematical model requires no fitting time or maintenance.

It can be assumed that with their joint development, Otto Junker and Alunorf are setting a new standard for the heat treatment of aluminium strip coils. At this point the authors wish to thank all their colleagues and external partners who contributed to the realisation of the project and who are still assisting during the optimisation stages.