Level 2 optimization: new approaches in heat treatment

Heat treatment processes are becoming increasingly complex; the variety of products and formulas is constantly growing. Yet linear operation, which has been the norm up to the present, reaches its limits when a line has several furnaces and quenching tanks. In such cases, level 2 optimization has the potential to significantly increase the efficiency of the entire line, through quality, delivery reliability and energy efficiency. This article explores where the journey must lead in the coming years to ensure that forges can continue to compete on an international scale.

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Fig 1 Level 2 optimization allows forged parts to overtake each other

THE WAY THINGS STAND TODAY AND THE CHALLENGE OF EXPONENTIAL GROWTH

With the increasing complexity of heat treatment, new ideas are needed to make the entire process more efficient. In many plants, linear production planning has been perfectly adequate up to now, where a ring, for example, is first rolled and then heat-treated. The formulas for heating, quenching and tempering are processed step-by-step, and the workpieces are handled by rail-bound or free-moving handling machines. However, the steadily increasing number of materials and products used is accompanied by a trend towards more complex process chains. The number of different formulas with different dwell times in furnaces is growing, while batch sizes are becoming smaller. The specified furnace, transfer and quenching times must be precisely observed, especially when it comes to products that are subject to stringent requirements. Only in this way can they obtain the desired properties and be produced efficiently at the same time.

In making the process more efficient, the transfer of forgings between individual stations plays a decisive role. Because of the abundance of larger and smaller parts with their varying dwell times, a number of decisions must be made. Is a forging taken directly to the furnace or first to a storage area? Does it go from the furnace to the quenching tank or to the air quenching unit? Will it be transported from the quenching tank to the storage area, where it will be allowed to cool fully, or will it be placed in the furnace again? Finding the best route through the heat treatment process for each part is not easy. The number of ways to optimize these complex processes increases exponentially with the number of elements in the process chain, for example, furnaces, quenching tanks or manipulators. On top of that, heat treatment is a bottleneck in many forges because of long furnace travel times. According to the theory of constraints (*see information box, page xx*), production lines only achieve maximum productivity if every constraint always works at 100% capacity.

THE SOLUTION – PROCESS OPTIMIZATION AT LEVEL 2

As soon as more than two or three products, or formulas are involved in heat treatment, it is essential to move away from a linear process chain. This is the only way to determine the appropriate route for each individual workpiece, taking into account all current boundary conditions and constraints and making the best possible use of all equipment. Optimization at level 2 of the automation pyramid offers great potential for improving the performance of the entire forge. At this superordinate level, the individual machine controllers are connected in a network and their functions can be coordinated. This makes it possible to efficiently design the routes and sequence of individual parts as they move through the process, in part by allowing forged parts to overtake each other (*Figure 1*). For example, if a furnace becomes vacant, a product with a short furnace time may be able to be treated before one with a long dwell time, clearing a constraint elsewhere.

Similarly, forgings can be distributed flexibly among the furnaces available at any given time. This increases the capacity utilization of the furnaces, avoids idle times, uses energy efficiently, and increases the output of the entire line.

The starting point for optimization is production planning for the next few days at the plant level, level 3. The Manufacturing Execution System (MES) transmits the broad specification, including order data and deadlines, to the level 2. Detailed planning then takes place there within these degrees of freedom. In contrast to planning at level 3, detailed planning is carried out with full knowledge of all the formulas, dwell times and other parameters. This way, it can specifically control the occupancy of the furnaces and all other components of the process chain. In doing so, it departs from the rigid 'first-in, first-out' (FIFO) approach and optimizes material flow in such a way that both the desired product properties are achieved precisely, with all parts ready at the planned time, and all equipment utilized as fully as possible (*Figure 2*). In addition, on-site planning close to production makes it possible to take short-term changes into account in a flexible way.

Level 2 optimization defines which part should be where and when. For example, if it is known that a product will not be needed for another week and it requires six hours of furnace time, it can be put into an appropriate gap that arises some time beforehand. This saves furnace time and energy, and also makes optimum use of the capacity of the entire heat treatment line. For optimization to succeed, all machines and systems involved in the process must communicate closely with each other. For example, the door of a furnace is not allowed to open until the manipulator has reached its position and it is guaranteed that the forging will arrive in the quenching tank within the precisely defined time. The technical basis for communication is a network with Device Level Ring (DLR) topology (*Figure 3*). The individual machines and systems on level 1 are referred to as 'devices'. These can be furnaces, quenching tanks or manipulators. They are each connected to the DLR via a switch. A central managed switch then collects, addresses and distributes the data.

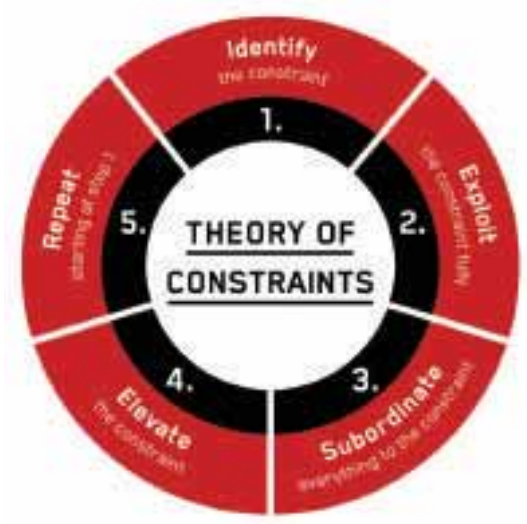
Yet communication is not just unidirectional from level 2 to level 1. The machines send data up to the control level so that, for example, preventive maintenance can be triggered. All Dango & Dienenthal machines can be equipped with extensive sensors and actuators and prepared for DLR. As soon as they are equipped with a switch, they are ready to exchange data; they then receive the driving jobs not from a human operator but from the level 2 controller. Once a job has been completed, they send back a completion message.

Many state-of-the-art manipulators and robots are equipped with extensive sensors and electronics and ▷

Fig 2 An automatic handling system for a quenching facility that is adapted to transfer

Fig 3 The Device Level Ring connects the individual machines within a network

Fig 4 Handling system for the automated heat treatment of rings with a load capacity of 25t



THE THEORY OF CONSTRAINTS

In his theory of constraints, Eliyahu M. Goldratt developed a five-step method for improving the throughput of systems. The idea is to identify constraints and ensure that the relevant parts of the system are fully utilized at all times and that there is always enough work and material. The five steps are shown in the figure and listed below

1 Identify the constraint
2 Exploit the constraint fully
3 Subordinate everything to the constraint
4 Elevate the constraint
5 Repeat starting at step 1

Since level 2 optimization has all the information about utilization of plant components, it is the appropriate tool for identifying and eliminating constraints.

Information box: The five steps of the theory of constraints

Fig 5 A fully automatic fork transfer system for the heat treatment of crankshafts with a load capacity of 75t

communicate with the control level (*Figures 4 & 5*). They work so quickly and precisely that they reliably meet the specified transport or cycle times, even under the challenging conditions in a forge. However, their intelligence is limited to their own function. Level 2 optimization brings together the seemingly 'dumb' individual components, stationary and mobile systems and machines, in an intelligent process across all levels of the automation pyramid.

Moving away from FIFO means that products can overtake each other. Therefore, additional storage space must be available or provided so that parts can be temporarily stored and later retrieved. The occupancy of these storage facilities is managed by level 2 optimization as part of material tracking.

THE BENEFITS – WHAT IT DELIVERS

Against a backdrop of increasing complexity and low selling prices and margins, level 2 optimization is a tool that can be implemented quickly, such that forges can streamline processes, significantly improve quality, delivery reliability and contribution margins and reduce costs. Optimization improves furnace utilization, eliminates constraints and increases the overall productivity of the forge. However, if production data is kept within tolerances, there is a 99% certainty that finished products will have the desired properties.

Since level 2 optimization records and stores all process data, it is also the ideal tool for seamless documentation of quality and integrated quality management, all the way up to the corporate management level at level 4 (ERP) in the company cloud. As a consequence, optimized use of existing resources can even eliminate the need to invest in additional furnaces with their high operating costs. This is an important aspect not only in terms of investment, but also in terms of CO_2 management for the entire company. **MS**

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