New perspectives in heat treatment in the age of digitalization

Presenter:

Dr. Klaus Löser
ALD Vacuum Technologies GmbH, Hanau, Germany

Additional Authors:

Karl Ritter
ALD Vacuum Technologies GmbH, Hanau, Germany

1. Introduction

„One-Piece-Flow (OPF)“ for case hardening processes, a feature of the first generation SyncroTherm® plants (Fig.1), was presented to the gear industry at the 3^{rd} GETPRO congress in 2011 [1]. The advantages of this technology which is based on low pressure carburizing and high pressure gas quench set the path for the direct integration into the production line, thus closing the gap between soft machining and hard machining in the gear production chain. These advantages include high quality parts, short process times, less part distortion as well as high environmental compatibility.

2. SyncroTherm® for OPF technology

Figure 1. SyncroTherm®-system

In the new plant technology, the components are charged in a single layer on a workpiece carrier instead of in the usual large batch and case-hardened in so-called "2-D batches". These 2-D batches offer a variety of advantages. They can be heated much faster than the large, multi-layer 3D batches. Each individual component is directly radiated by panel radiators (Fig.2). This ensures fast and uniform heating. Single-layer charging offers the best conditions for uniform and reproducible results, also for the further process steps, carburizing and high pressure gas quenching (HPGA). In addition, single-layer charging allows individually controlled and component-adapted HDGA to be carried out for different component geometries and thus offers the potential to significantly reduce heat treatment distortion.

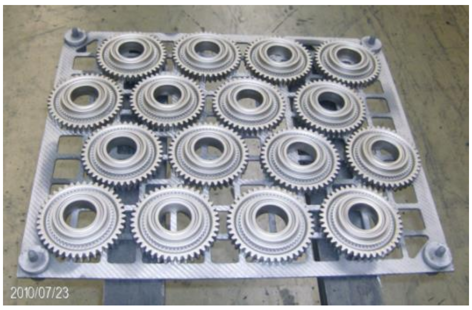

Figure 2. Single layer loading of 2D-batches

This first generation of SyncroTherm plants had the main focus on case-hardening processes of drive-train components and was designed to be strictly synchronized with the preceding soft machining steps like turning and milling and the successive hard machining processes like hard-turning and grinding. For that purpose the heat treatment process time was minimized by performing high-temperature carburizing to an extend that the case hardening steels were suitable without forming non permissible grain-coarsening.

3. SyncroTherm® for Small Batch Production

In the meantime, further fields of application for the SyncroTherm®-technology were explored, offering great advantages to the users which include, for example, the expansion to other processes such as tool hardening, annealing, brazing and sintering. In addition to the OPF application, i.e. sequential casehardening of gear parts in the mechanical machining cycle, another possible use has become established regarding flexible heat treatment of small batches or lots, i.e. the so-called “Small Batch Production (SBP)”.

While OPF systems and processes are in many cases designed for the highest possible part throughput with identical processes, SBP's aim is to heat treat small series or small batches of different gear components in one heat treatment system and in such a way that the logistics of the production chain are not interrupted. The focus is therefore not on the shortest possible process and cycle times, but on the optimized processing of various heat treatment orders with different components and processes with the aim of achieving the highest possible efficiency and profitability. This requires a correspondingly flexible control of the sequences and processes within the heat treatment plant as well as in the periphery.

Meanwhile, the industry has gained substantial production experience for both applications of SyncroTherm®-technology. More than 30 systems are operational, from a manually operated single plant to a complex, highly automated plant system, including automated charging of the parts on a workpiece-carrier.

4. SyncroTherm® 2.0

Many activities which are today related to “Industry 4.0“, should be better referred to as “Digitalization“. Fig. 3 shows several topics and activities in the field of digitalization of heat treatment.

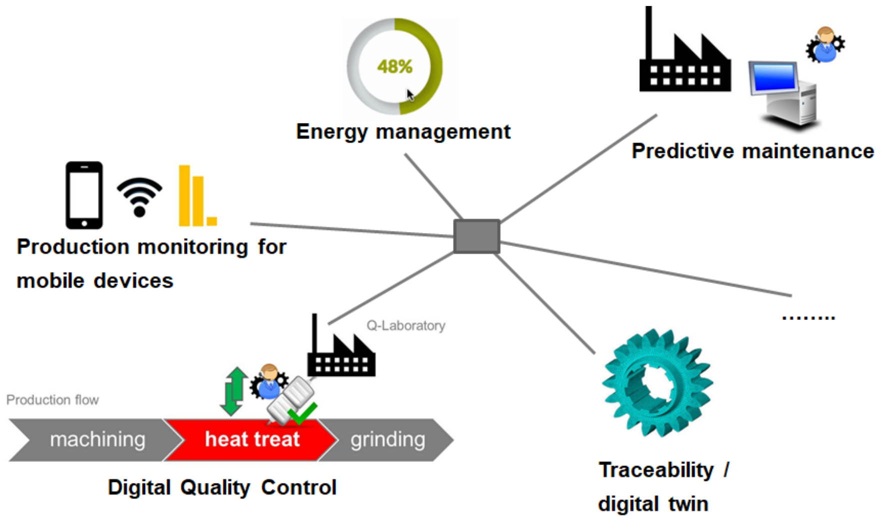

Figure 3: Digitalization of Heat Treatment [2]

“Production monitoring for mobile devices” will enable the management to get a quick overview about current performance in production. “Energy management” means a smart coordination of all production equipment aiming to reduce the electrical peak demand. With “predictive maintenance” the heat treatment furnace itself will indicate if certain maintenance-activities are needed, moving away from a timing-based maintenance towards a condition-based maintenance. “Traceability” has the goal to track the movement of individual parts through production and through assembly rather than tracking large charge-lots. “Digital twin” is the numerical simulation of all process steps simultaneously to the real time process step in production [2].

5. Process routings

The new SyncroTherm®*2.0*-plant offers even higher process flexibility through optional process routings within and outside of the system (Fig.4).

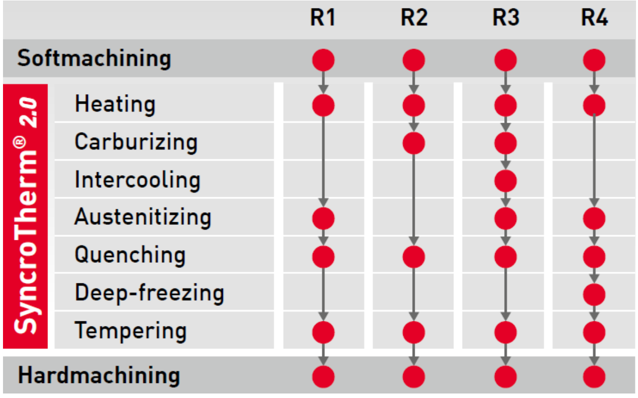

Figure 4. Optional process routings

For example process routing R3 allows to perform high-temperature carburizing of gear components (>1000°C). Generally this process requires micro-alloyed steel qualities to avoid grain coarsening during the high-temperature process phase. In order to enable such a process with standard steel grades, routing R3 represents a process where the gear parts are heated and high temperature carburized e.g. at 1050°C. During that process phase grain-coarsening will occur. The next step is a so-called intermediate cooling step. Therefore, the workpiece-carriers are transported in a separate cooling zone within the SyncroTherm. In this zone the parts are cooled by radiation to a temperature in the range of 600°C. In the next step the workpiece-carrier is transported in a hot zone where the gear parts are reheated to austenitizing temperature (850°C). The goal of this process is to achieve a grain refining process within the gear material. Following the austenitizing process the parts are moved to the quenching zone where the parts are high-pressure gas quenched. In the final process step, the gear parts are tempered in an external tempering furnace. Intermediate cooling processes allow to significantly reduce process time by high-temperature carburizing using standard steel grades.

6. Traceability in heat treatment

Improved part- and process documentation and continuous tracking of the parts during the entire production process by means of process integrated laser coding of the parts will become possible. Today's traceability of the production process is typically limited to the quantity of charge-lots. This means that the movement of charge-lots through production is tracked, but not the movement of individual parts through each process steps and through assembly. And in many cases the FIFO-principle ("First in First out") is not executed on the shop-floor. This means that in some cases traceability gets lost. In the unwanted event of a quality deviation (e.g. in soft machining or in heat treatment) large quantity of parts must be recalled. With an individual labeling of all produced parts a complete traceability can be established. Therefore the need for recalls would be reduced. Or in the unwanted event of a recall, the number of parts being recalled would be significantly reduced. In the past an individual labeling of parts was not possible, because the label was not readable after heat treatment. Recently a laser-engraving method was developed specifically for the LPC-process which is readable even after heat treatment, see Fig. 5.

The usage of a DMC-code as a label is recommended for the identification of individual parts. This DMC code should contain an identity-number for the individual part. In a digital database (e.g. in the ERP-system) the identity-number should be stored with all production details related to this part.

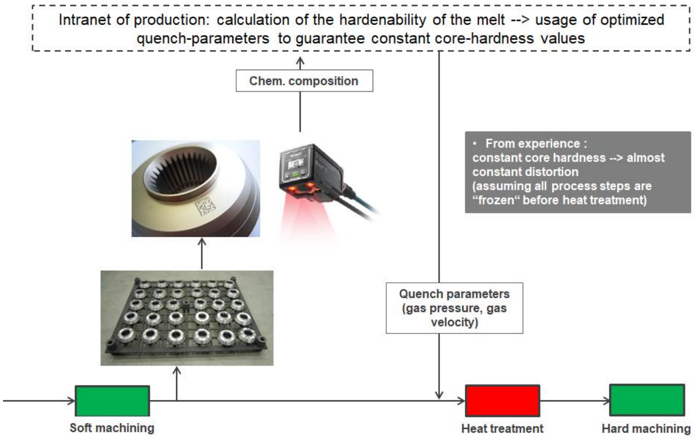

Figure 5: Traceability of individual parts in the manufacturing-line including heat treatment [2]

7. Other "Industry 4.0" features

Based on the proven first generation plant technology, the new SyncroTherm® *2.0* now offers additional control features in order to meet all the requirements of a modern Industry 4.0 setting. These include standardized interfaces for the simple integration of external plant components into the SyncroTherm® *2.0* furnace system and I4.0-compatible interfaces (XML) for data transmission to superior customer-ERP-systems. The web-based visualization will allow viewing plant and charge data on any mobile device, see Fig. 6

Figure 6. Plant and charge data on mobile devices

Easy handling through plain text alarms and notifications including the display of additional information will increase the ease of operation.

An efficient automation and digitalization based on TIA portal as well as compliance to important Quality standards in the automotive- and aerospace industry, e.g. CQI-9 and Nadcap complete the new system.

8. Summary

A tried-and-tested plant system was developed further with the SyncroTherm® *2.0*, meeting all the demands of Industry 4.0 or Digitalization. Target markets include, among others, the automotive industry and their suppliers, especially parts for electro-mobility in the OPF. The use of flexible "Small Batch Production (SBP) broadens the application range for captive heat treaters and commercial heat treaters.

9. Literature

[1] Heuer, V.; Löser, K.: Schmitt, G. and Ritter, K.: „SyncroTherm® – volle Integration der Wärmebehandlung in die Fertigungslinie" Tagungsband des 3. GETPRO Kongresses zur Getriebeproduktion, 29.-30. 03. 2011, Würzburg, Band I, S. 85-96
[2] Heuer, V. and Schmitt, G.: „Digital Quality Control of Thermochemical Processes – Industry 4.0". Paper presented at the 4th International Conference on HTSE in automotive applications, June 5-7, 2018, Spartanburg, USA

Dr. Klaus Löser
ALD Vacuum Technologies GmbH

With company/institution since: 1991

Position: **Senior vice president**
Department: **Vacuum Heat Treatment**
Higher Education: **Mechanical Engineering: TU Darmstadt**