Print from "HEAT PROCESSING" · Issue 2, May 2009 · pages 131-135

Low pressure carburizing services for precision parts

Dr. Volker Heuer, Dr. Klaus Löser, ALD Vacuum Technologies GmbH, Hanau (Germany)

VULKAN-VERLAG · HUYSSENALLEE 52-56 · 45128 ESSEN · GERMANY

Low pressure carburizing services for precision parts

Volker Heuer, Klaus Löser

For decades manufacturers of precision parts used atmosphere batch furnaces with integral oil quenches for the case hardening process. In recent years Low Pressure Carburizing (LPC) and High Pressure Gas Quenching (HPGQ) have become a preferred technology for fuel injection components and for the latest generation of transmissions, such as double clutch transmissions or 6/8 speed automatic transmissions. The manufacturers have the option to either heat treat in-house or to outsource the heat treatment. ALD Vacuum Technologies is offering both furnace equipment for in-house treatment as well as service-centers for the outsourcing of heat treatment. This paper discusses the pros and cons of outsourcing the LPC heat treatment. It presents insights into the technology of the equipment and into the LPC/HPGQ -process. Finally ways and means how to assure quality of the treated parts are briefly described.

LPC is a case hardening process which is performed in a pressure of only a few millibar in a protective atmosphere. In most applications acetylene is used as carbon source. The advantages of LPC compared to conventional gas carburizing are:

- No intergranular oxidation and no surface decarburization,
- Faster carburizing and
- Higher carburizing temperatures leading to significantly shorter cycle times.

LPC is usually combined with High Pressure Gas Quenching (HPGQ). During HPGQ the load is quenched using an inert gas-stream instead of a liquid quenching media. Usually nitrogen or helium are used as quench gas.

The benefits of the HPGQ compared with liquid quench are numerous:

- Reduced distortion in most applications
- Clean surfaces after heat treatment (even in blind holes)
- Environmentally friendly with no post washing of parts required
- Heat treatment can be integrated into the production line.

Fig. 1 depicts a schematic overview of the LPC and HPGQ process.

Furnace technology

In 2001, ALD introduced the ModulTherm® system (**Fig. 2**). This concept in equipment is a system that connects up to 10 independent vacuum treatment chambers with a transfer and external quench chamber which moves on a rail system. The system is extremely flexible allowing different processes to be active at the same time, all utilizing a common quench system.

Since the system is modular, the manufacturer can start with as few as two vacuum treatment chambers and expand (up to 10 per system) as his volume dictates. When volume drops, the equipment can be idled without affecting other units. Units taken off line can be kept under vacuum so they are ready to go when needed. Likewise, should maintenance be required, only the affected cells are taken off line and the production process continues [1].

More than 30 ModulTherm® systems comprising 150 treatment chambers have been commissioned worldwide.

Heat treatment services for precision parts

Since about 10 years ALD Vacuum Technologies is offering besides furnace equipment for inhouse treatment as well global resource centers for the outsourcing of heat treatment. This business concept introduced as "Own &

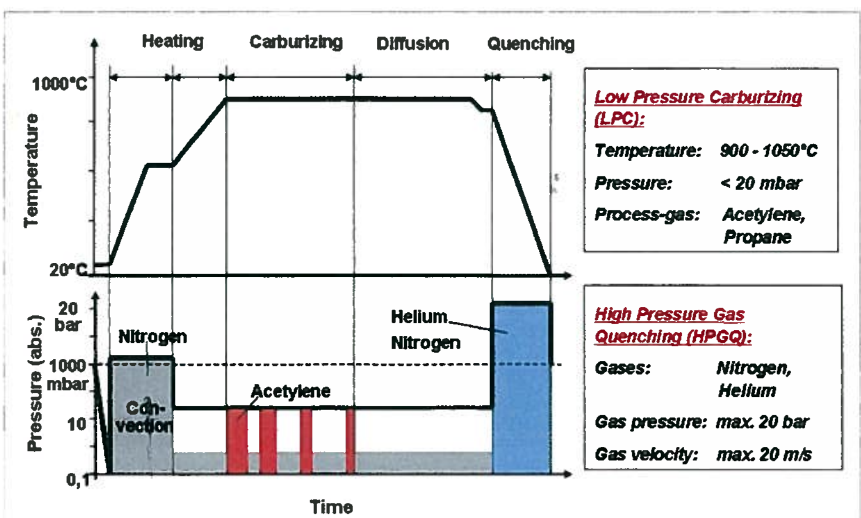

Fig. 1: LPC and HPGQ process (schematic process-cycle)

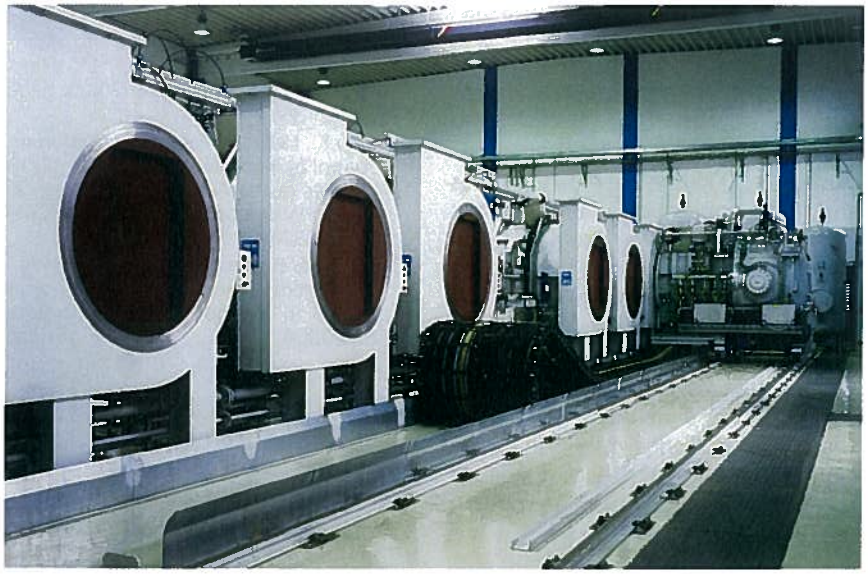

Fig. 2: ModulTherm® plant for LPC and HPGQ process

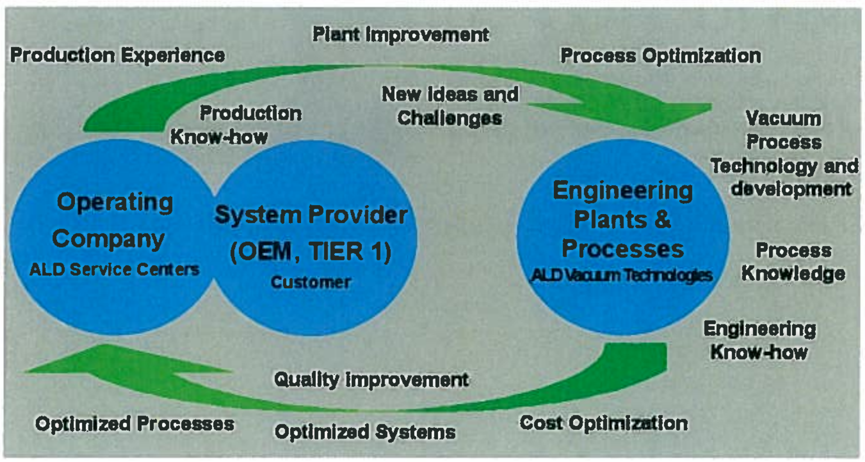

Fig. 3: Know-how exchange between plant manufacturer and service company

Operate" focuses on the transmission- and injection-industry, where ALD performs heat treatment for the customer as a service provider. Thus the customer profits from the furnace manufacturer's long-time heat treatment know-how and profits from the previously described advantages of LPC and HPGQ without taking financial and technical risks.

At the same time the furnace manufacturer profits from the service companies, as process experiences are reported back to him. Moreover, the continuous transfer of know-how from the furnace manufacturer to the O&O service companies leads to a steady improvement in productivity and quality as well as to reduced costs, see **Fig. 3**.

Once a gear manufacturer has decided to apply LPC and HPGQ, he must decide whether to perform in-house heat treatment or to outsource the heat treatment to a service provider.

The advantages of outsourcing of heat treatment are:

- No investment in heat treatment equipment and the required infrastructure
- No additional staff to conduct heat treatment operations, laboratory or maintenance
- Access to the latest state-of-the-art heat treatment technologies without expenditures for development
- A certified quality control program tailored to meet customer requirements

Table 1: ALD Own & Operate Companies

	Founded	Customer	Number of employees (in 2008)	Number of installed treatment chambers	Number of treated parts per year
Vacuheat Limbach-Oberfrohna, Germany	1999	Continental, Bosch, MAN, Behr	60	33	20 Mio (mainly fuel injection components)
ALD-TT South Carolina; Columbia, SC, USA	2001	Continental, RBC, Bosch, Garlock	30	11	2,5 Mio (mainly fuel injection components)
ALD-TT Port Huron; Port Huron, MI, USA	2006	GM, PMG, Stackpole, Camcraft	75	24	7,5 Mio (mainly gear components)
ALD-TT Ramos; Ramos Arizpe, Mexiko	2008	GM, Delphi	58	18	4,5 Mio (mainly gear components)

- Heat treatment costs are predictable and generally at a fixed price.

However there are some disadvantages too, such as:

- Loss of heat treatment as a core production competence
- Heat treatment can not be integrated into the production line
- Possibly transportation costs and increased inventory management requirements
- External interface to heat treatment, therefore higher costs resulting from communication and documentation.

Therefore each option must be systematically analyzed to decide if the outsourcing of heat treatment is an advantage for all parties involved.

Currently ALD operates four "Own & Operate"-facilities in USA, Mexico and Germany. **Table 1** shows the operating facilities.

Application of the technologies

The analysis of two (2) practical applications in a high volume environment are good case studies for the value of the contract services available.

1. Internal ring gear of a six (6) speed transmission
2. Nozzle for a diesel fuel injection system

Internal ring gear

The ring gear is manufactured from material 5130. It has an external diameter of 167 mm, a height of 28 mm and 89 internal teeth. The heat treat specification is given in **Table 2**.

The specific challenge in the heat treat process was to reduce distortion in such a way that subsequent machining operations could be entirely eliminated. As a result of extensive development in the quenching process and the use of specialized CFC-fixtures it was possible to meet the design intent.

Fig. 4 depicts a light weight fixture design which demonstrated significant stability at high temperatures. When compared to traditional alloy fixtures the CFC demonstrated no deflection or distortion after many subsequent years of use. By using CFC-fixturing it is guaranteed that all ring gears are always lying horizontally which helps to reduce heat treatment distortion.

Table 2: Heat treat specification of the internal ring gear

Case hardening depth	0,3 ... 0,6 mm
Surface hardness	79 ... 83 HRA
Core hardness	no requirements
Microstructure	- free of carbides - max. 30 % residual austenite on tip of the tooth - free of bainite until 0,2 mm from the surface
Distortion (geometry after heat treatment)	max roundness: 130 microns after heat treat max. lead variation: 70 microns after heat treat

Fig. 4: CFC-fixturing for internal ring gears

Furthermore, distortion values were significantly reduced through the use of "Dynamic quenching", where the quench intensity is varied to minimize distortion [2].

Fig. 5 shows the roundness values. The roundness of the ring gears in the green state already shows an average of 30 micrometers. The roundness values after heat treatment on an alloy fixture using standard gas quenching were far beyond the specified requirement of 130 micrometers. The values improved considerably when the CFC-fixture (graphite fixture) was used. However

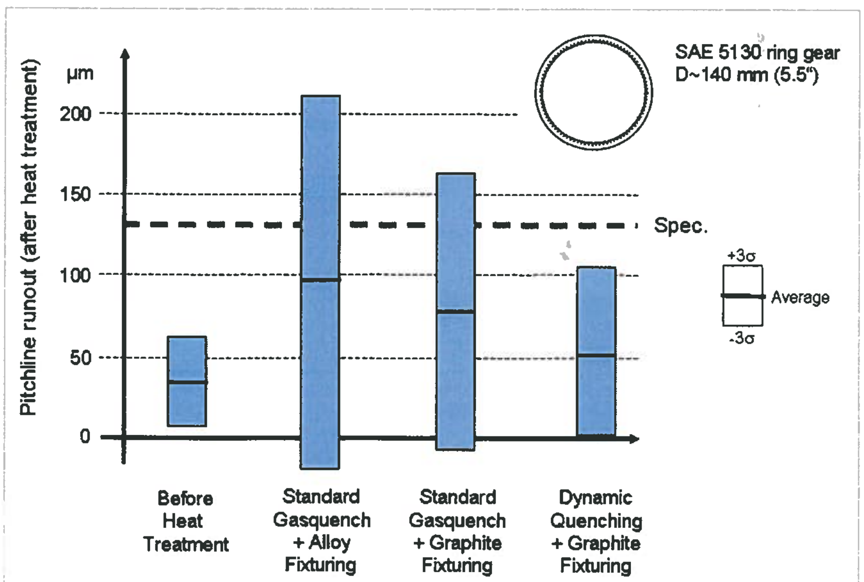

Fig. 5: Roundness values of internal ring gears before and after heat treatment

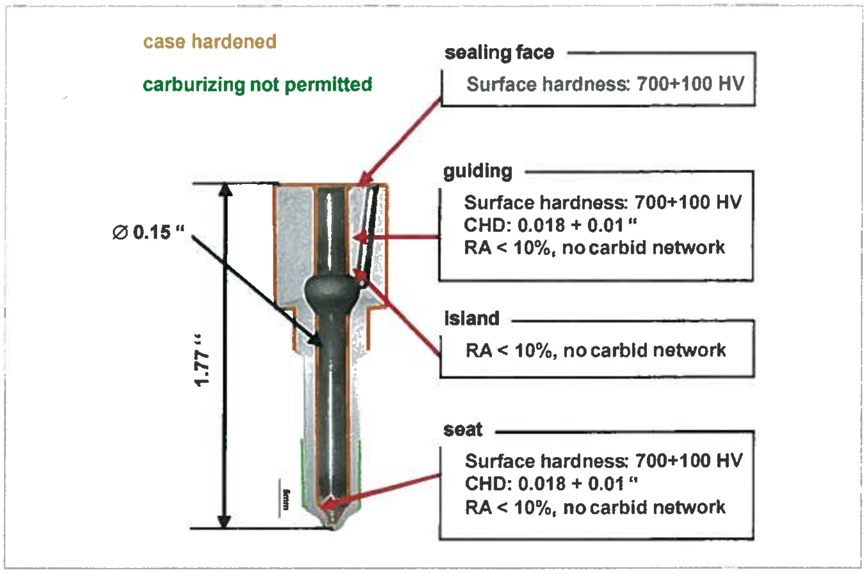

Fig. 6: Specification of a nozzle for a diesel injection system with piezo technology

only through the application of "Dynamic quenching" and the use of the CFC-fixture the specified roundness-values could be met [3].

The internal ring gears have been in continuous production since 2006. After the incoming goods inspection, the ring gears are cleaned in a spray washing machine, followed by LPC using acetylene and HPGQ using helium and "Dynamic quenching". After tempering, the metallurgical and geometrical quality is examined in the laboratory. This is followed by deburring by means of shot blasting and then by conservation with an antirust agent.

The customer was able to achieve the design intent by eliminating all machining operations of the rings gears after LPC/HPGQ utilizing the special fixtures and quench methodology. Subsequent testing and monitoring over a two year period progressively demonstrated that conformance and quality inspection was reduced accordingly.

Nozzle for diesel injection system with piezo technology

The nozzle is made of 18CrNi8 material. **Fig. 6** shows the specification of the nozzle after heat treatment. The special challenge during the case hardening of this nozzle is to guarantee homogeneous carburizing despite of the complex shape. The component requires tight control with carburizing evident in the blind hole while at the same time partial over-carburizing must be prevented as for example in the area of the so-called "island".

The nozzles are treated with LPC utilizing acetylene and gas quenched with nitrogen. Areas which do not require carburizing are covered. The components are austenitized twice and quenched twice to increase fatigue strength. This is followed by a deep freezing step at -100°C to transform any retained austenite into martensite and then followed by tempering. **Fig. 7** shows the measured hardening profile at various measuring points [4].

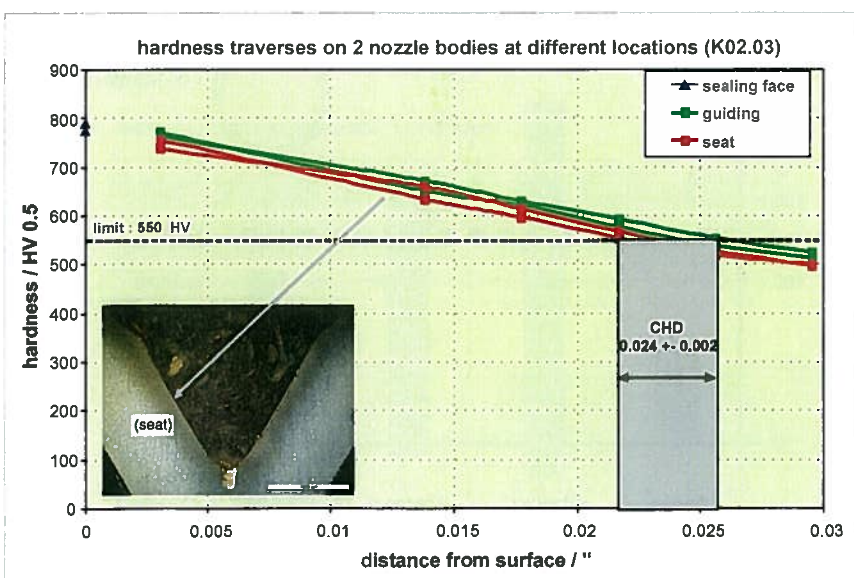

Fig. 7: Hardness profile for various measuring points on the nozzle (x-axis in inches)

Quality control

The quality control of the "Own & Operate"-facilities is based on an ERP-system (Enterprise Resource Planning) with an integrated CAQ-system (Computer Assisted Quality Assurance), which records all quality-data. For each load a "production traveler" is printed and this production traveler runs together with the load through all the operations. Barcodes for each operation are printed on the production traveler. The barcodes are scanned in each work-center and the information is stored in the ERP-system indicating the time and the work-center where the load was treated. Thus it is possible to retrace exactly when a load was washed, when and in which furnace it was heat treated and whether a load was shot-blasted. Consequently complete traceability of all process steps is assured.

On request it is possible to equip the ModulTherm® system with a digital camera. The camera is installed at the furnace entrance and takes photos of each load. These pictures are stored in a data base in order to visually document the load set up of each batch.

Furthermore the plants are also equipped with an integrated process control, called "Process Monitoring" which monitors all relevant process parameters such as temperature, process gas flows, cycle times etc.

After the heat treat process, specific parts from each load are examined in the metallurgical laboratory. Parts which are especially prone to distortion can be geometrically inspected after heat treatment by a CNC measuring machine. All measured values from the laboratory are entered into the CAQ system. Upon entering the values, the software verifies whether the entered values meet the parts specification. If a value is out of specification an error is recorded. Then the load is stopped and quarantined. Additionally an internal complaint is created in order to detect the root cause of the error and to initiate a counter-measure.

Conclusion

In addition to heat treatment plants for Low Pressure Carburizing (LPC) and High Pressure Gas Quenching (HPGQ) ALD Vacuum Technologies has been offering heat treatment services, called "Own & Operate", for the past 10 years. Once a manufacturer of precision components has decided to apply LPC and HPGQ he has the option to either invest in a heat treatment plant and to treat in-house or to outsource heat treatment to a service provider. The advantages and disadvantages of outsourcing were discussed.

Furthermore the heat treatment technologies used in "Own & Operate"-facilities were introduced by two examples. Since 2006, the use of CFC-fixtures and the application of "Dynamic Quenching" allow to case-harden an internal ring gear for a 6-speed-automatic transmission with minimum distortion, making subsequent machining-operations unnecessary. The second example showed the case hardening of a nozzle for a diesel injection system. The special challenge during the case-hardening of this nozzle is to guarantee homogeneous carburizing despite of the complex shape of the part.

The quality control system of the "Own & Operate"-service companies was briefly introduced.

Literature

[1] Löser, K., Ritter, K.: Betriebserfahrungen mit modularen Vakuum-Wärmebehandlungs-anlagen in der Antriebstechnik. In: elektrowärme international, Heft 3/2007, page 159-164

[2] Heuer, V., Löser, K.: Entwicklung des dynamischen Abschreckens in Hochdruck-Gasabschreckanlagen. In: Mat.-wiss. u. Werkstofftech. 34 (2003), page 56-63

[3] Löser,K., Heuer, V., Faron, D.R.: Distortion Control by Innovative Heat Treating Technologies in the Automotive Industry, Z. Werkst. Wärmebeh. Fertigung 61 (2006) 6, page 326- 329

[4] Reinhold, B.: Processing diesel injection components. Vacuum carburizing-symposium in Dearborn (Detroit) on Sep. 23rd 2008 ■

Dr. Volker Heuer

ALD Vacuum Technologies GmbH, Hanau (Germany)

Tel. +49 (0)6181-307 3372
dr.volker.heuer@ald-vt.de

Dr. Klaus Löser

ALD Vacuum Technologies GmbH, Hanau (Germany)

Tel. +49 (0)6181-307 3366
dr.klaus.loeser@ald-vt.de