技術資料

Technical Data

“Own & Operate”-LPC/HPGQ-Heat Treat Services for Automotive Components

Dr. Volker Heuer*, Dr. Klaus Löser*

概　要

精密部品の焼入処理は何十年にわたって雰囲気バッチ炉にて油冷却されていたが近年，真空浸炭処理及び真空高圧ガス焼入（LPC／HPGQ - Process）が燃料噴射用部品あるいは最新のトランスミッションの構成部品の熱処理に最適な処理技術となっている。ALD vacuum technologies社では顧客向けの設備納入のみならず，14年前から顧客の外部委託のニーズに応える為，熱処理の受託事業（Own & Operate）を展開している。精密部品メーカは自社内に熱処理設備を保有して社内処理するか，外部委託する方法のいずれかを選択できる。顧客にとって熱処理の外部委託はユーティリティ設備を含めた熱処理設備の投資が不要であるばかりか，設備の操業，保守点検，試作から解放され開発費用も掛けずに要求を満たす品質を手にすることができる。真空浸炭技術は粒界酸化や表面脱炭の心配が不要，浸炭処理速度が速い，処理歪が少ない，処理後の表面状態がクリーン，環境負荷が低い，生産ラインへの組込みが容易など数多くの特長を有するのみならず，燃料噴射ノズルのような複雑な形状の部品にも均一な浸炭を可能にしている。本稿では，真空浸炭処理を外部委託する場合のメリット，デメリットを含め，当社の受託事業における処理品の品質確保の事例を紹介し，熱処理事業への取組みを紹介する。

1. Introduction

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 transmissions for next generation such as double clutch transmissions or 6/8 speed automatic transmissions.

The manufacturers have the options to either heat treat inhouse or to outsource the heat treatment. ALD vacuum technologies is offering both furnace equipment for inhouse 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 insight into the technology of the equipment and the LPC/HPGQ-process. Finally, ways and means how to assure quality of the treated parts are briefly described.

2. LPC/HPGQ-heat treatment technology

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 a carbon source. The advantages of LPC compared to conventional gas carburizing are:

2013 年 11 月 1 日受付

*R&D Vaccum Heat Treatment, ALD-Vacuum Technologies GmbH, Hanau, Germany

① No intergranular oxidation and no surface decarburization
② Faster carburizing and
③ Higher carburizing temperatures leading to significantly shorter cycle times.

LPC is usually combined with 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 a quench gas.

The benefits of HPGQ compared with liquid quench are numerous:

① Reduced distortion in most applications
② Clean surfaces after heat treatment (even in blind holes)
③ Environmentally friendly with no post washing of parts required
④ Heat treatment can be integrated into the production line.

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

3. Furnace technology

In 2001, ALD introduced the ModulTherm® system. This concept in equipment is a system that connects up to 12 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 12 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. (Fig. 2 shows ModulTherm®.)

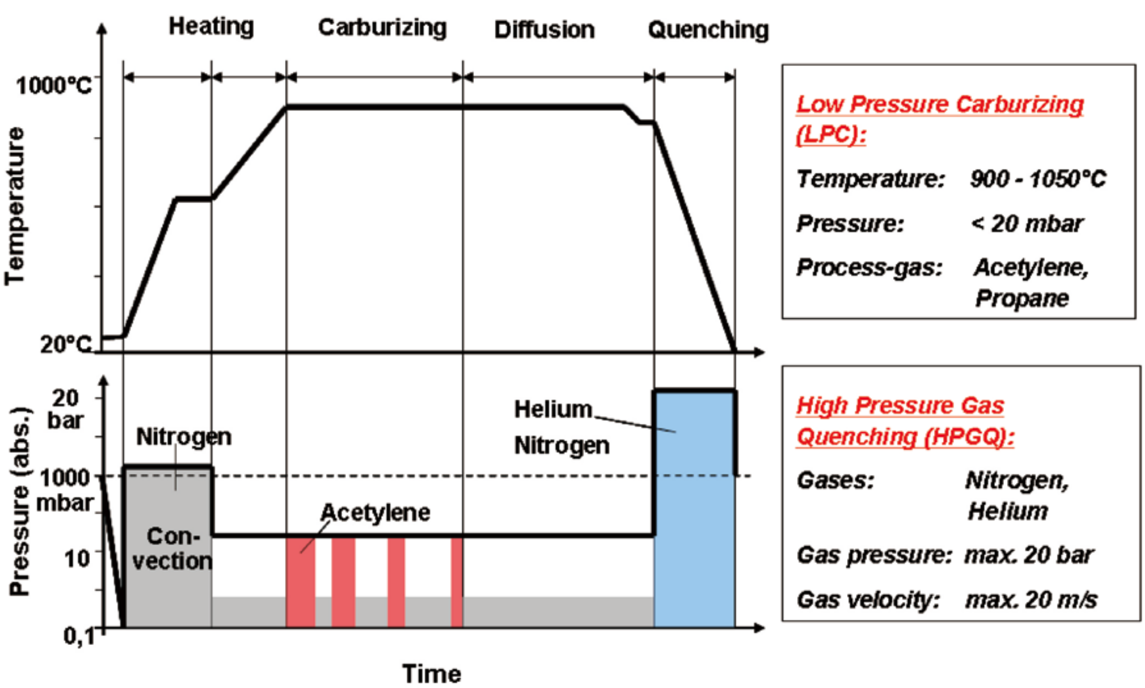

Fig.1. LPC and HPGQ process (schematic process cycle).

Fig. 2. ModuleTherm® plant for LPC and HPGQ process.

4. Heat treatment services for precision parts

Since ca. 14 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 & 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:

① No investment in heat treatment equipment and the required infrastructure

② No additional staff to conduct heat treatment operations, laboratory or maintenance

③ Access to the latest state-of-the-art heat treatment technologies without expenditures for development

④ A certified quality control program tailored to meet customer requirements

⑤ Heat treatment costs are predictable and generally at a fixed price.

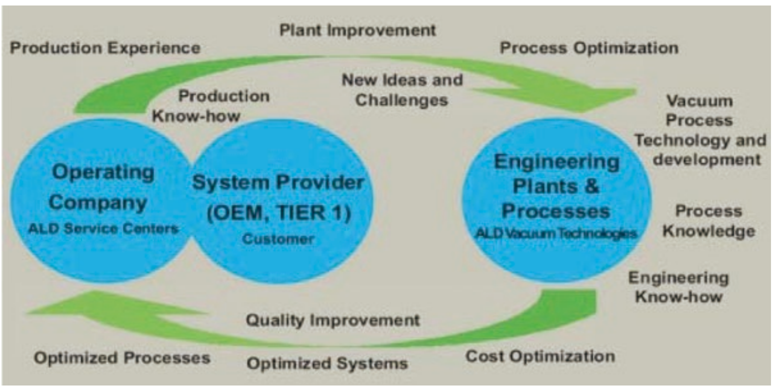

Fig. 3. Know-how exchange between plant manufacturer and service company.

However there are some disadvantages too, such as:

① loss of heat treatment as a core production competence
② heat treatment can not be integrated into the production line
③ possibly transportation costs and increased inventory management requirements
④ 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 three "Own & Operate" - facilities in USA, Mexico and Germany. Table 1 shows the operating facilities.

5.　Application of technologies

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

Application 1: Internal Ring Gear of a six speed transmission
Application 2: Nozzle for a diesel fuel injection system

5.　1　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.

Table 2. Heat treatment specification of internal ring gear.

Item	Spec.
Casehardening 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 tooth
	free of bainite until 0.2 mm from surface
Distortion (geometry after heat treatment)	max roundness: 130 microns after heat treatment
	max. lead variation: 70 microns after heat treatment

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.

Table 1. Own & Operate-companies.

	Founded	Customer	Number of employees 2012	Number of installed treatment chambers	Number of treated parts per year
Vacuheat GmbH Limbach-OberFrohna, Germany	1999	Continental, Bosch, Behr	45	33	20 million (mainly gear components)
ALD-TT Port Huron, MI, USA	2005	GM, Magna Systrand Continental	165	41	30 million (mainly gear components)
ALD-TT Ramos Arizpe, Mexico	2008	GM, Delphi, Magna, Linnamar	100	20	17 million (mainly gear components)

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.

Fig. 4. CFC-fixturing for internal ring gear.

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

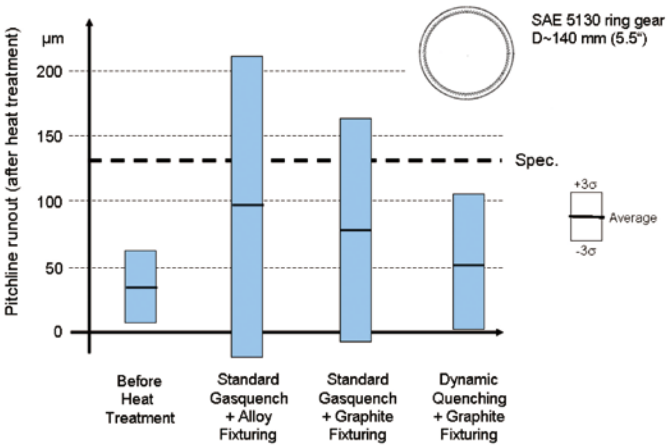

Fig. 5. Roundness values of internal ring gears before and after heat treatment.

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.

5. 2 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 casehardening 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 overcarburizing must be prevented as for example in the area of the so-called “island”.

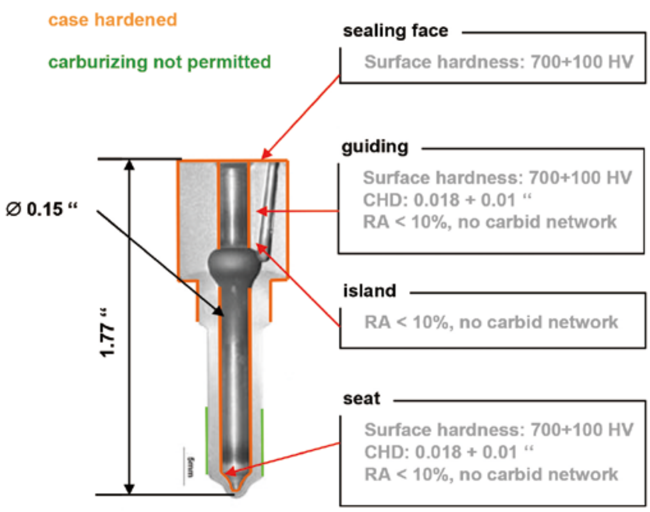

Fig. 6. Specification of nozzle for diesel injection system with piezo technology.

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 ℃ to transform any retained austenite into martensite and then followed by tempering. Fig. 7 shows the measured hardening profile at various measuring points.

6. 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.

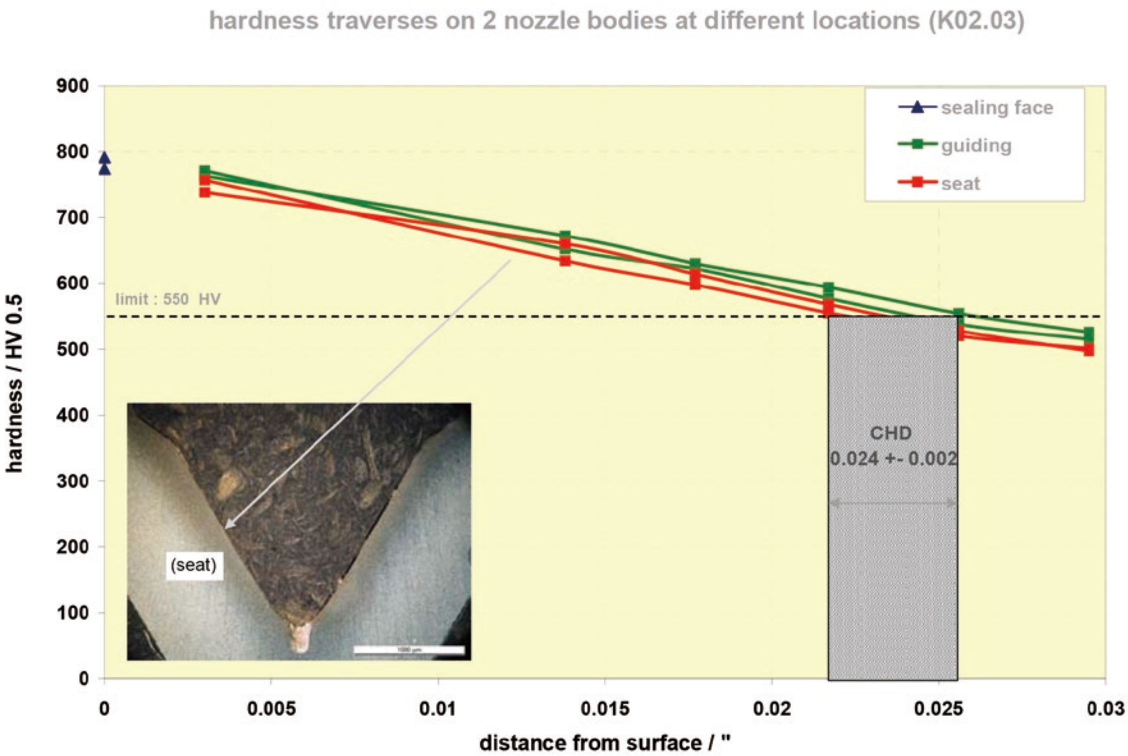

Fig. 7. Hardness profile for various measuring points on nozzle (x-axis in inches).

7. Summary

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 14 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 caseharden an Internal Ring Gear for a 6-speed-automatic transmission with minimum distortion, making subsequent machining-operations unnecessary. The second example showed the casehardening of a nozzle for a diesel injection system. The special challenge during the casehardening 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.

References

1) Löser, K., Ritter, K.: Betriebserfahrungen mit modularen Vakuum-Wärmebehandlungs-anlagen in der Antriebstechnik. In: elektrowärme international, Heft 3/2007, page159-164
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