Print from "HEAT PROCESSING" · Issue 3, October 2005 · pages 149-151

Successful launch of the flexible heat treatment system ModulTherm®

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For the past 40 years gas carburizing pusher furnaces and oil quench baths were generally used to carburize and harden gear parts in the automotive industry. Since the mid-1990s vacuum carburizing processes with high pressure gas quenching were developed to meet higher demands on the parts' quality as well as environmental compatibility. At that time, however, the available plants were not capable of reaching the same core hardness in the generally used low alloyed materials as with oil quenching. As a result many users rejected this technology. Changing over to higher alloyed materials was considered impossible. The specified hardness was obtained only after the development of the cold chamber quenching technique, the use of helium as quenching gas and the limitation of the hardenability scatter band of the used materials. The additional advantages of the "New Technology", as vacuum carburizing with high pressure gas quenching is also called, launched the industrial breakthrough.

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The sequential vacuum hardening plant

In the semi-continuous vacuum furnace (**Fig. 1**) the heat treatment operation is divided into individual steps which are processed in different function modules. These modules are arranged successively and are especially equipped for the required process step. For example, in the loading chamber the atmospheric oxygen is removed and the charge is heated to the required process temperature in the heating zone, which may consist of several chambers.

The transport system is the essential part of a continuous furnace. ALD Vacuum Technologies GmbH has selected a special walking beam system as charge feeder for an extremely careful charge transport, i.e. no additional forces affect the base grid as in pusher plants, therefore the base grids may be of filigree construction.

Adjacent to the heating zone the carburizing chamber is installed. It is closed by two insulated, pressure-tight doors. The gas distribution for carburizing gas as well as the pump set which is especially designed for vacuum carburizing are also mounted on this chamber. This module is followed by the diffusion zone, comprising two thermally separated chambers.

The gas quench chamber is the last chamber of the semi-continuous system. It is designed for a quenching pressure of up to 20 bar and can be operated with different quenching gases. Two high-powered gas circulators and a ribbed tube heat exchanger made of copper releasing the heat of the charge to the cooling water are installed.

Fig. 1: Sequential vacuum hardening plant, throughput 800 kg/h

The advantage of the sequential vacuum heat treatment plant is that all charges take the same way through the plant. Therefore, highest reproducibility is possible. Similar to the gas carburizing pusher plants a malfunction of this construction type may effect several loads in the furnace. Furthermore, the amount of maintenance of the carburizing zone is relatively high, since this chamber is continuously supplied with carburizing gas. Contrary to conventional plants, however, maintenance can be carried out much faster since no time for inertization and conditioning is required. ALD has delivered 13 continuous plants, all of them operating in serial production.

Development of the ModulTherm® plant

The reduced flexibility of semi-continuous plants in view of expandability led ALD to develop a new plant generation in the year 2000. This development was based on experiences gained with sequential plants. These furnaces represent a rather rigid system which provides maximum throughput at a certain carburizing depth. Therefore, the user is compelled to develop a plant for maximum throughput from the very beginning, which in turn results in high investment costs at the beginning of a project. An increase in the number of parts as it is usually planned and adjusted investment costs are not possible with the furnace technology described.

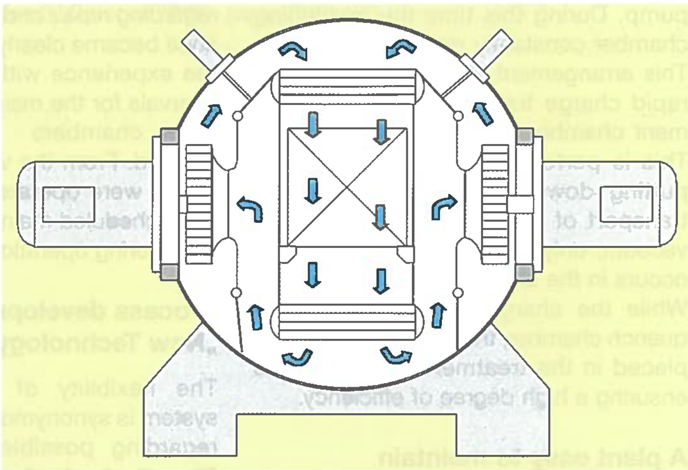
Therefore, a new system had to be developed for simple expandability. During the development phase, several possibilities were reviewed and finally, the principal of a linked single furnace plant, in short ModulTherm®, was considered the ideal solution. The design permits easy retrofitting of additional treatment chambers without interrupting operation of the basic plant.

The ModulTherm® concept represents a great advantage compared to systems with interconnecting tunnel between each chamber. For maintenance purposes the tunnel system is completely shut down and an expansion is only possible if the total system is shut down for several weeks.

ALD took special care in selecting a transport system which transports the charge from loading position into the treatment chamber (TC), resp. from the TC into the quenching chamber (**Fig. 2**). A fork lift system, readily available in the market, which is used for shelf systems for example, was chosen. Due to the relatively high load temperature an oversized transport fork considering the charge weight, was selected. Subsequently, a basic version for a charge weight of 500 kg and an option of up to 1000 kg was specified. A special advantage of this design is that neither the cooling water lines nor limit switches or other drives are installed in the treatment chambers. The drives and suitable drive shafts are positioned outside of the chambers. Only gear wheel/rack and pinion drive are positioned within the chamber.

The emphasis in the construction of the treatment chambers was placed on easy maintenance. For example, in order to allow maintenance of individual chambers during operation of the plant, a service door was installed in the rear side of the treatment chamber. The treatment chambers may be equipped with or without convective heating. This system is perfectly suited for tempering processes of up to 750 °C in one chamber, thus ensuring the flexible use for the annealing of tool steels or section steels.

Fig. 3: Modular quenching chamber for high pressure quenching (20 bar)



New generation of the gas quench chamber

In addition to vacuum carburizing which is carried out in the individual treatment chambers, high pressure gas quenching to harden the parts is another important process step. The new development of a suitable chamber (QC) is also based on the experience acquired with continuous furnaces. The pressure vessel was designed as a horizontal cylinder. The door construction comprises laterally movable doors with pneumatic sealings. High-powered gas circulators accelerate the velocity of the quenching gas in the chamber by means of flow guides for a very homogeneous flow through the charge (**Fig. 3**). The circulators are arranged left and right from this cylinder.

The modular quenching chamber can be equipped with a flow reverse system, if required. An internal valve system guides the gas flow over the charge either from top to bottom or vice versa, thus obtaining a minimized scattering of hardness within a charge, especially in solid parts of higher alloyed steels, which in turn directly affects distortion behavior.

The fan motors are suitable for vacuum startup, i.e. they accelerate to maximum speed prior to gas flooding ensuring maximum quenching performance at the beginning of the quenching process. This is especially important for hardening of thin-walled parts made of low-alloyed steels.

In order to meet the requirements of a modern production environment the quenching chambers are equipped with special flooding systems, which absorb the short but intensive gas flooding noise.

The quench chamber is suitable for standard gas quenching processes with steady gas pressure and gas velocity as well as for new quenching processes, such as ALD's Dynamic-Quenching, for example. In this process, the quenching parameters gas pressure and flow velocity are varied temperature- resp. time-dependently during the quenching process. It is perfectly suited to reduce part distortion, especially in thin-walled parts.

The quench chamber and the transport chamber which contains the transport system are mounted on a carriage. For quenching, the shuttle, as the combination transport chamber/quench chamber is called, docks on the appropriate treatment chamber by lifting the transport chamber and subsequently drawing out the atmospheric oxygen via vacuum

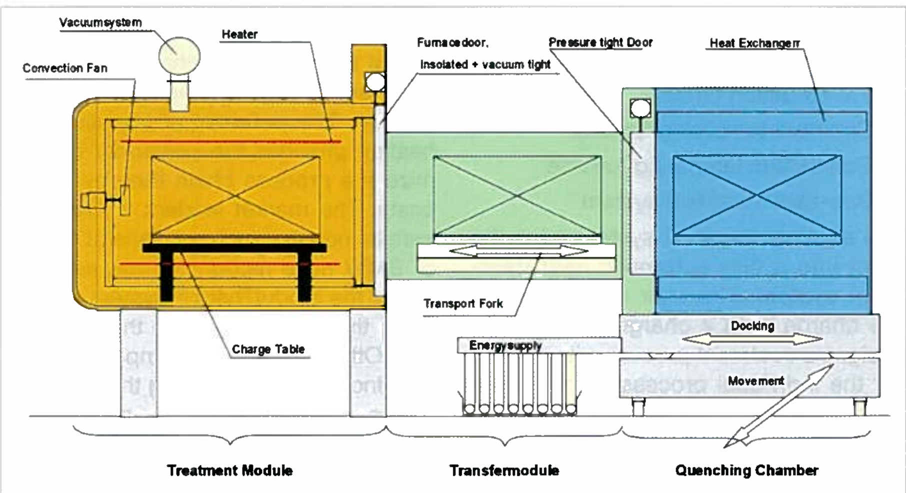


Fig. 2: Transport scheme of linked multi-chamber furnace system modultherm

pump. During this time the quenching chamber constantly remains in vacuum. This arrangement permits an extremely rapid charge transport from the treatment chamber to the quench chamber. This is performed all at once without putting down the charge. Since the transport of the charge takes place in vacuum, only a slight temperature drop occurs in the charge during the transfer. While the charge cools down in the quench chamber, the next charge can be placed in the treatment chamber thus ensuring a high degree of efficiency.

A plant easy to maintain

The experience and know-how gained from sequential continuous vacuum furnaces as well as from other systems in the market were included in the design of the ModulTherm® plant (**Fig.4**). Compared to tunnel systems the ModulTherm® system possesses the following essential advantages:

- Vacuum-tight closure of all treatment chambers, therefore no interference in the process in the treatment chambers
- Process gases are exhausted directly from the treatment chamber, therefore no unwanted condensation of by-products in parts of the plant (i.e. tunnel)
- No cables, hoses, motors or limit switches within vacuum range or process atmosphere range.
- Easy expandability of the plant with additional treatment chambers while the remaining treatment chambers continue to operate
- Maintenance of individual treatment chambers without switching off the entire system
- Each treatment chamber is equipped with a rear door, therefore easy access.

A short time after the first ModulTherm® plant was installed the advantages regarding repair and preventive maintenance became clearly visible. Contrary to the experience with sequential plants, intervals for the maintenance of carburizing chambers were significantly delayed. From the very beginning these plants were operated around the clock and scheduled maintenance was performed during operation of the entire plant.

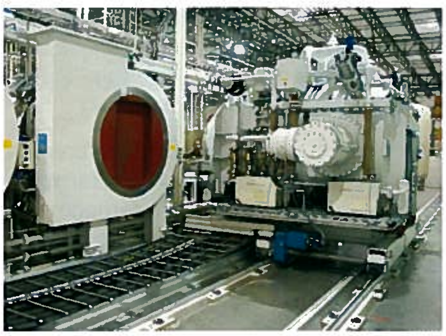


Fig. 4: Basic version of a modultherm-system

Process development in the field „New Technology"

The flexibility of the ModulTherm® system is synonymous with the flexibility regarding possible process options. Since the basic atmosphere in the treatment chambers is always vacuum, various processes can be alternated. Therefore the plant is perfectly suitable for the flexible use with alternating charges and processes. In most cases the ModulTherm® system is currently used for the serial production for casehardening of gear parts or in the diesel injection industry.

The ModulTherm® system is already used for the following processes:

- Hardening in a temperature range of up to 1250 °C
- Annealing (multiple tempering in the treatment chambers with intermediate cooling
- Carburizing of parts without hardening
- Casehardening in a temperature range of 800 °C to 1050 °C
- Carbonitriding of low alloyed case hardening steels
- De-oiling of parts made of sintering steels
- Brazing in a temperature range of p to 1200 °C

The ModulTherm® system can easily be expanded by integrating further plant components:

- Pre-washing machine
- Pre-oxidation furnace
- Chamber tempering furnace
- Continuous tempering furnace
- Sub-zero treatment system

The external transport system turns the plant into a fully automatic heat treatment system. The user merely places the charge onto a charging frame and assigns a treatment process with recipes for the individual process steps. Treatment of the charges is performed fully automatically. The plants are usually equipped with shelf-systems in order to produce several layers in the plant without operating personnel.

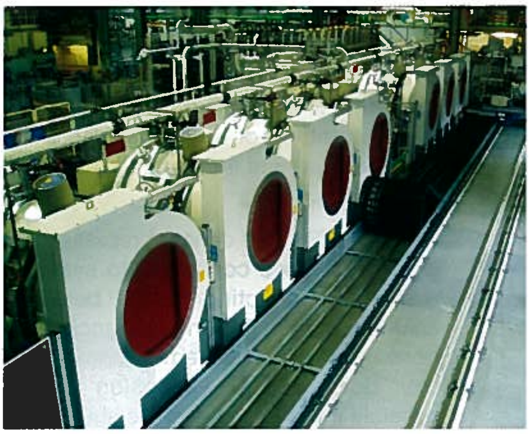


Fig. 5: Easy expanding of the modultherm-system up to 10 treatment chambers

Control of the plant

The total plant ModulTherm® with treatment chambers for hardening or casehardening and the suitable peripheral modules as described above, has a mutual control system. This control system maintains the individual processes and the corresponding recipes, which means individual treatment jobs are relayed from the control system to the controls of the individual components for further processing. Furthermore, the treatment data, charge data and exact time of treatment are recorded. This data can be displayed in a treatment record for each charge and can also be sent via existing network in order to save it on the server.

Conclusion

By developing the flexible heat treatment system ModulTherm® (**Fig. 5**), ALD has provided the market with an excellent tool for modern heat treatment. The high flexibility and charge throughput meet the requirements of serial production as well as of commercial heat treatment shops. The clean and dry processes of this furnace technology are perfectly suited for the integration into production. The potential of low-distortion heating provides the possibility to optimize the process chain thereby saving costs. The market leaders in the automobile industry such as General Motors or BMW have recognized the advantages of the ModulTherm® system and are using these advantages in their production. Other well-known companies in the gear industry are preparing the launch of the new technology based on the ModulTherm® system. It is expected that the new plant technology will continue to be successful in establishing itself in the market.