Heat treatment plants for structural components in the automotive industry

by Hermann Meyer

Due to the increasing complexity and daily-extended range of structural components for the automotive industry, their heat treatment is subject to continuous change. The application of new technologies for chassis and drives enhances the new development of components. They are nowadays preferably made of aluminium because of the quite favourable processing capabilities of this material and the very low weight of even complex aluminium parts. With regard to environmental protection aluminium is an important factor due to its recycling capability without quality loss. Moreover, the recycling of aluminium requires less than 5 % of the energy needed for energy generation from alumina. Furthermore, the moderate heat treatment temperatures entail lower energy consumption in comparison with other equivalent materials.

Increased heat treatment capacity is actually needed in line with the rising demand for highly stressed aluminium components. As the process can mostly only be developed on the production plants, the development of process and plant requires a lot of time. Considering the more sophisticated requirements for structural components, a continuous enhancement and improvement of the process technology applied to known structural parts is indispensable. It is therefore helpful to use flexibly configurable plants for the heat treatment, which can be adjusted to the new or modified processes. The tests for process development and optimization can be run on both, small scale production plants and flexibly adjustable production lines.

The process adjustment concerns the treatment temperature and time as well as the quenching process. The required plant modification refers to the new process specification and throughput.

The design of production plants allows comprehensive possibilities to adjust the heat treatment processes and quenching modalities.

Promoting the development of processes and plants, Tenova LOI Thermprocess runs a pilot plant. Designed as small scale production plant, it is suitable for a production-related process control. Right from the start, it is possible to develop the processes with real-size components and to flexibly adjust the parameters, sequences and process steps to optimize the future production plant.

CONTINUOUS HEAT TREATMENT PLANT WITH QUENCHING FACILITY

Aiming at offering a flexible production and all required quenching processes, the continuous heat treatment plant (Fig. 1) is equipped with a roller conveyor system and quenching facility.

In consequence of the double-storey arrangement of the furnaces, the required floor space is reduced. The heat treatment plant with quenching centre
Heat Treatment

The treatment plant comprises the solution annealing furnace (acc. to Fig.1 arranged in the lower part), the quenching facility and the age-hardening furnace (acc. to Fig. 1 arranged in the upper part). The structural components are charged and discharged at a central location at one of the two furnace ends. The installed charge rack control ensures that the charge racks are not mixed up.

Every charge rack is recorded and identifiable by an engraved code and can be tracked during the heat treatment process. It is thus possible to issue charge protocols and mark components, if individual sensor data are outside the tolerance level during the heat treatment.

As function of structural component and alloy, different quenching methods are required for freezing the solution annealing state. Baths with water and polymer are classical quenching procedures. Air quenching methods with adjustable quenching parameters are applied to thin structural parts.

The quenching facility consists of an air quenching device, a polymer bath and a water quenching- respectively purging bath (Fig. 2). The air quenching device is located directly at the furnace exit, while the water and polymer quenching facility is installed downstream the air quenching device. The charge racks are transported to the respective aggregate stored in the recipe.

The entire process is automatically executed in accordance with the recipe; the operator and the quality assurance department are able to control the process with the help of the protocols.

Thanks to the high flexibility of the plant it is possible to heat-treat castings such as engine blocks and pressure die castings such as structural components. Moreover, first tests for new structural parts can be run for which totally different parameters will be used compared with those of actual production.

Different treatment times of individual charge racks can be implemented due to the roller conveyor system. The individual transport in the furnace sections allows the independent transport of individual charge racks. It is even possible to run individual test charges at the same heat treatment temperatures with deviating treatment times, while the normal production is going on.

**CHARGE RACKS**

A furnace plant is designed for the use of a particular basic rack. The basic body of the charge rack is identical for all structural components, while the fittings for accommodating and supporting the structural parts are adapted to the respective heating good.

The charge racks play an important role in the heat treatment of structural components: On the one hand, they ensure that the structural parts properly and smoothly pass through the furnace; on the other hand, they are also responsible for the dimensional accuracy of the structural parts during the heat treatment process.

The solution annealing temperature, the quenching process and the charge racks influence the deformation of the structural components. The solution annealing temperature is limited to a value as low as possible as a higher temperature of the heating good reduces the rigidity of the structural part during the solution annealing process and promotes deformations. Supporting the sensitive points of the structural component, the charge rack limits the deformation during the solution annealing and quenching process.
**SMALL SCALE PRODUCTION PLANT**

The small scale production plant (Fig. 3) is designed particularly for determining the process data under production-related conditions. This production plant, too, comprises the solution annealing furnace, quenching facility and age-hardening furnace.

The plant is set for continuous, fully automatic operation; due to the recipe management, it can be run with various process parameters. The highly variable process including solution annealing (420 – 560 °C), quenching and age-hardening (150 – 250 °C) will be adjusted as required for the specific structural component.

As the quenching is a crucial issue, this small scale production plant was equipped with a quenching facility including air quench, polymer and water bath.

As charge racks with real dimensions for the production are used, the charge rack structure can be completely tested at the same time. The arrangement of the structural components is identical with that of a future production plant. Consequently, the behaviour of structural parts will be the same as in the future production process.

Due to the complete control system including adequate charge protocols, the small scale production plant is suitable for pilot production until it has advanced to the level of mass production. The process factors can be tested under real conditions; the process can be approved.

In this case, too, the roller conveyor system ensures the flexible plant use for different structural components and charge rack structures.

In principle, the process parameters are component and alloy-specific. Based on the wide range of experience and actual research results, they can be individually determined for each application and stipulated in recipes.

It is hence sufficient to install the production plant at the time of production start. It is no longer necessary to provide it a long time before in order to be able to meet the production requirements. As a result, the new production features a shortened start-up time and reduced costs.

**QUENCHING PROCESS AND FACILITY**

The selection of the quenching procedure depends on the quenching gradient determined by the material and the admissible component deformation, i.e. its geometry. A too abrupt quenching causes unacceptable deformations, which either require a supplementary alignment of the component or do not allow any alignment at all, or result in residual stress with subsequent crack formation. Moreover, the quenching process creates residual stress in the structural component, which depends from the selected quenching method (Fig. 4). Too high residual stress can reduce the lifetime and the max. admissible load of the structural part as the total of residual stress and service load must not exceed the admissible stress.

For achieving a good heat treatment result, it is essential to avoid the pre-cooling of the structural parts. Therefore, great importance is attached to quickly transporting the charge racks from the last station of the solution annealing furnace into the quenching facility. The faster the transport, the less the structural components are pre-cooled. The pre-cooling can shift the cooling curve into a critical temperature range (Fig. 5).

A very fast and reliable quenching of the structural components is important particularly in the range of the solution annealing temperature down to approx. 200 °C, which is revealed by the precipitation behaviour of aluminium alloys (Fig. 5).

The structural components can be quenched either in the charge rack or individually. The more complex the structural parts, the more a quenching of individual components (e.g. one-layer charge racks) is preferred in consideration of the more reliable reproducibility and uniformity of the quenching of all structural parts.

Structural components are usually quenched by air as the other quenching methods are still too abrupt and consequently tend to deformation. An optimal compromise between material strength, deformation and residual stress is aimed at.

In case of air quenching, the quenching speed is deter-
mined by the air impact. The air can be applied by nozzles arranged in line with the structural part geometry or by a plug-flow. In the latter case the air is not applied in a part-specific manner. Thanks to a sufficiently high flow speed, the desired quenching rate is achieved in both cases; in the event of plug-flow, a correspondingly higher volume flow is, however, required.

**CHARGE HEATING AND FURNACE HEATING SYSTEM**

The furnaces feature several control zones; each of them is equipped with air circulation. The charging good is heated by convection, i.e. hot gas is applied to the heating good. For this purpose, every furnace zone disposes of a recirculation fan, which sucks the furnace atmosphere from the treatment chamber and injects it into the flow channel; this method ensures a uniform gas application to the charging good in the treatment chamber. The furnaces are equipped with a gas heating system. A burner is allocated to every furnace zone which operates fully automatically as requested by the control system. Every burner disposes of an automatic gas mix control and ignition device. The circulation flow is heated by the combustion gas which is mixed in.

For consuming less energy, either recuperator burners will be installed or the waste gas heat from the solution annealing furnace with the higher temperature level is injected into the recirculation gas flow of the age-hardening furnace.

If needed, indirect gas heating systems can be installed for the heat treatment of sensitive alloys. Alternatively, the furnaces can be equipped with electrical resistance heating system or a combined gas/electrical heating system.

The high reproducibility requires close tolerances of the heat treatment temperatures, particularly if the age-hardening times are to be shortened. Due to the design of both furnaces, the real temperature deviates from the nominal temperature less than +/- 3K.

**SUMMARY**

Due to the reduced vehicle weights and the increasing complexity of individual structural components, a rising number of chassis parts are made of aluminium. The essential safety technology of the components set high standards for the properties of the structural parts.

Due to the component-specific heat treatment including solution annealing, controlled quenching and age-hardening the properties of the structural parts meet the high requirements and can moreover compete with high-tensile steels.

Tenova LOI Thermprocess develops adjusted and component-specific processes, which can be validated in pilot production, before the production, plant is eventually designed and installed. Due to the flexible design of the heat treatment plants, their extension, adjustment and process optimization can be implemented later in the future.

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