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Enhancing Control of Distortion Through 'One Piece Flow – Heat Treatment'

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Enhancing Control of Distortion Through ‘One Piece Flow – Heat Treatment’

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Proper control of distortion has become even more important in new powertrain designs. To answer the demand for fuel-efficient vehicles, modern transmissions are built much lighter, therefore the components of the transmission exhibit less wall thickness which makes them more sensitive to distortion. Distorted gear components can create noise in the transmission, require post heat treat machining processes and may even create problems during transmission assembly.

By applying the technology of Low Pressure Carburizing (LPC) and High Pressure Gas Quenching (HPGQ), the distortion caused by heat treatment can be significantly reduced. This technology has been successfully established in serial production for many different gear applications.

With the introduction of ‘One Piece Flow – Heat Treatment’, the distortion control can be further improved. This ‘One piece Flow – heat treatment’ allows for a rapid case hardening where the components are low pressure carburized at high temperatures (1050°C) followed by gas quenching. The components are not treated in conventional big batches with multiple layers, but they are treated in small batches consisting of one layer only. The quench intensity is controlled more precisely to allow for processes which are customized individually for each gear-component. The single-layer treatment provides

- homogenous and rapid heating of the components,
- homogenous and rapid carburizing of the components,
- homogenous and precisely controlled gas quenching.

All the variations from layer to layer are eliminated, which leads to reductions in distortion-variation within the load.

In addition, this new technology allows strong costs-savings for logistics. The manufacturing-line can be completely automated since the parts are first taken one by one from the soft machining unit, then heat treated in time with the cycle-time of soft machining (“Synchronized heat treatment”) and then finally passed down one by one to the hard machining unit.

The paper presents applications for enhanced distortion control when using ‘One Piece Flow – Heat Treatment’.

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Introduction

Proper distortion control has become even more important than in previous days. Distorted gear components cause noise in the transmission and may even create problems during transmission assembly. Distortion has a strong cost-impact, because distorted components often need to be hard-machined after heat treatment.

Better control of distortion means:

- less cycle time per part in hard-machining,
- less hard-machining capacity needed and
- less tooling cost for hard-machining.

With an excellent control of distortion for some applications hard machining can be completely eliminated.

Distortion mechanisms and high pressure gas quenching, HPGQ

The relevant mechanisms that cause distortion of components during heat treatment have been described extensively in literature [1]. Three different types of stress in the material contribute to distortion: residual stresses, thermal stresses and transformation stresses.

These stresses are influenced by part-geometry, steel-grade, casting, forging, machining etc., and they depend on the heat treatment. If the total stress in the component exceeds the yield stress, then distortion of the component takes place. Figure 1 gives an overview over the potential factors influencing distortion. Walton [2] published the numerous potential factors that are influencing distortion in more detail.

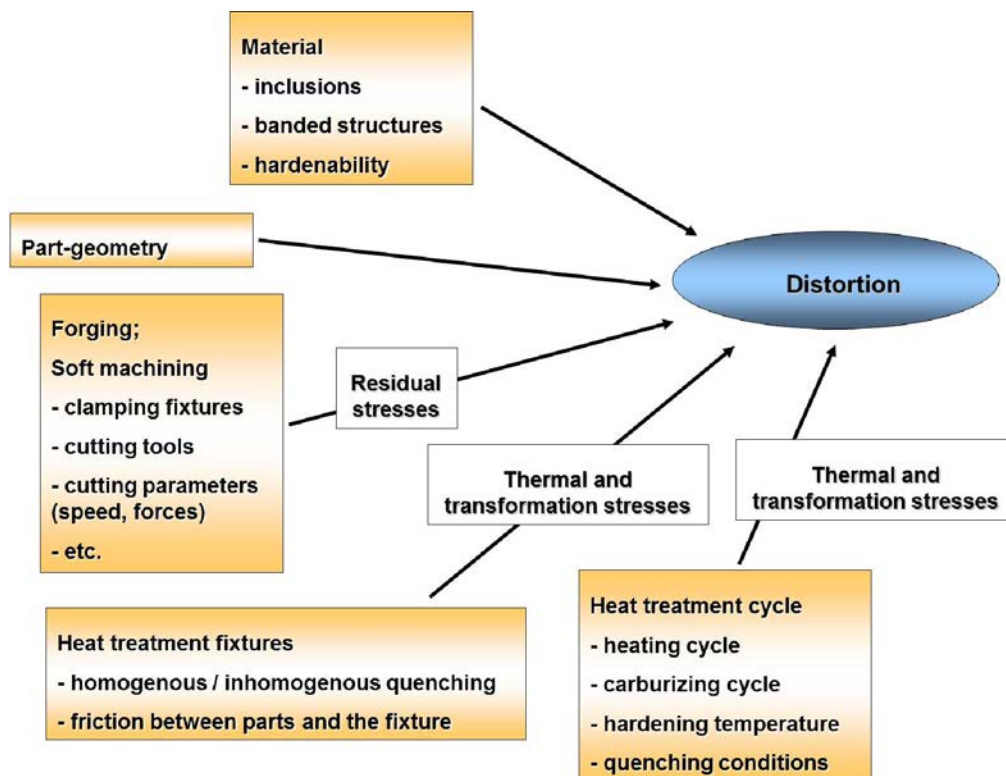


Figure 1. Potential factors influencing distortion

By applying the technology of low pressure carburizing, LPC, and high pressure gas quenching, HPGQ, heat treat distortion can be significantly reduced. LPC is a case hardening process which is performed in a pressure of only a few millibar using acetylene as the carbon source in most cases. 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 [3] [4].

HPGQ offers a tremendous potential to reduce heat treat distortion. Conventional quenching-technologies such as oil- or polymer-quenching exhibit inhomogeneous cooling conditions. Three different mechanisms occur during conventional liquid quenching: film-boiling, bubble-boiling and convection. Resulting from these three mechanisms the distribution of the local heat transfer coefficients on the surface of the component are very inhomogeneous, see Figure 2. These inhomogeneous cooling conditions cause tremendous thermal and transformation stresses in the component and subsequently distortion. During HPGQ only convection takes place which results in much more homogenous cooling-conditions [5].

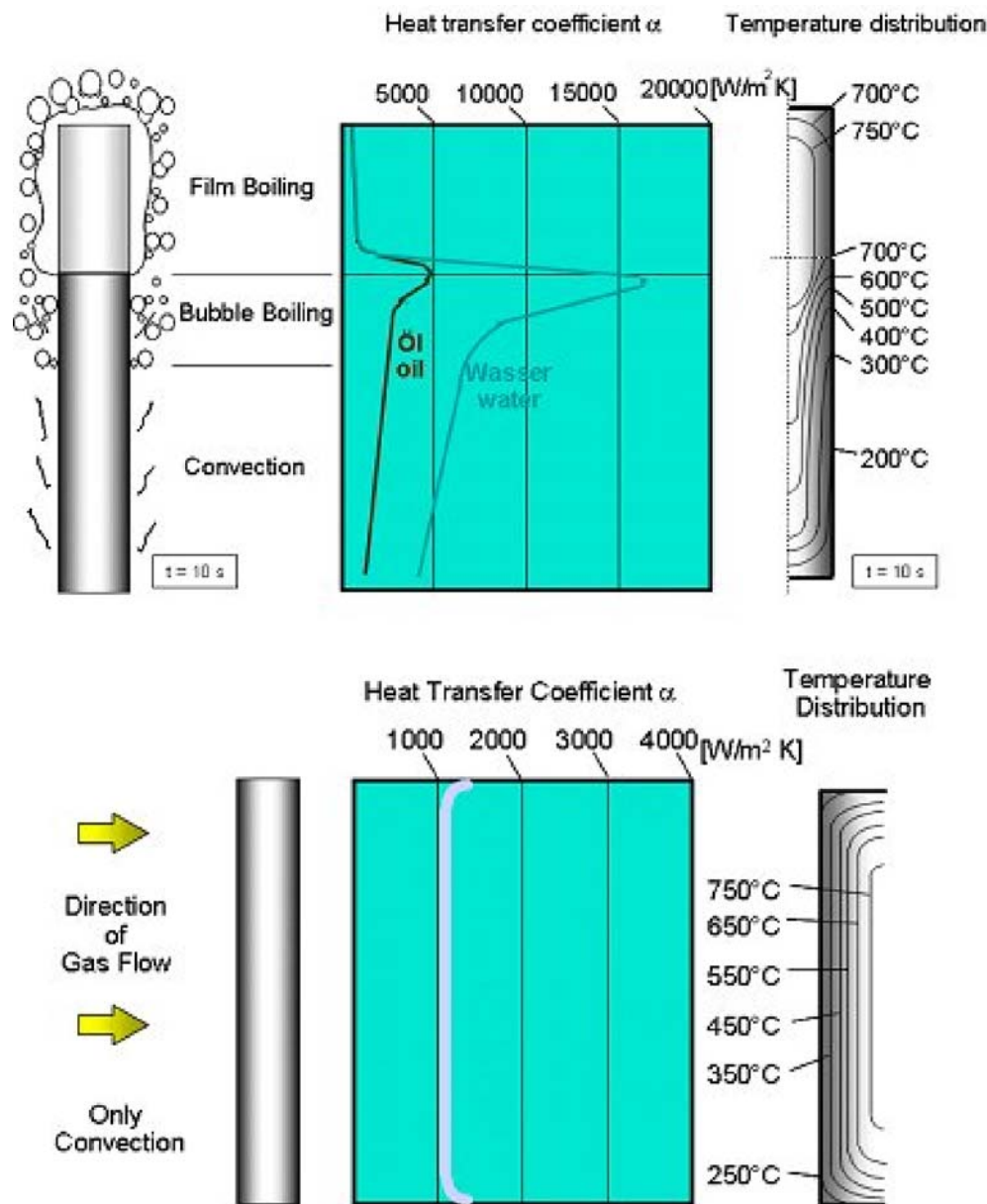


Figure 2. Heat transfer coefficient and temperature-distribution in liquid- and gas-quenching [5]

Significant reductions of distortion by substituting Oil-quench with HPGQ have been published [6]. Another advantage of HPGQ is the possibility to adjust the quench-intensity exactly to the needed severity by choosing quench-pressure and quench-velocity. Typical quench pressures range from 2 bar to 20 bar. The gas-velocity is controlled by a frequency converter. Typical gas-velocities range from 2 m/s to 15 m/s depending on the part-geometry and the steel-grade of the component. Figure 3 shows a typical industrial system for the HPGQ-process. The batches for such systems consist of several layers of production parts, so called "multiple layers".

One piece flow - heat treatment

Today's production philosophy for gear components usually relies on the traditional separation between soft machining, heat treatment and hard machining. Heat treatment is performed in a central hardening shop. There is no continuous flow of production-parts between the different operations such as soft machining, heat treatment, shot-peening and hard machining. Instead the parts are collected into batches and then moved from operation to operation. So large numbers of production-parts are stored in buffers or are in transit between the different operations.

In order to establish a more effective and economic production of gear components, the goal is to move away from batch type logistics and move towards a "One Piece Flow" of production, see Figure 4.

The goal is to move single parts from operation to operation instead of moving batches of parts. This one piece flow, OPF, production system would realize a continuous flow of production parts and would avoid huge efforts for storage and transportation of parts between operations [7], [8]. If such a total integration of all operations can be established, then this will offer new possibilities for automation, which again leads to a reduction of costs. Additionally a higher level of automation will result in a reduction of defects in quality.

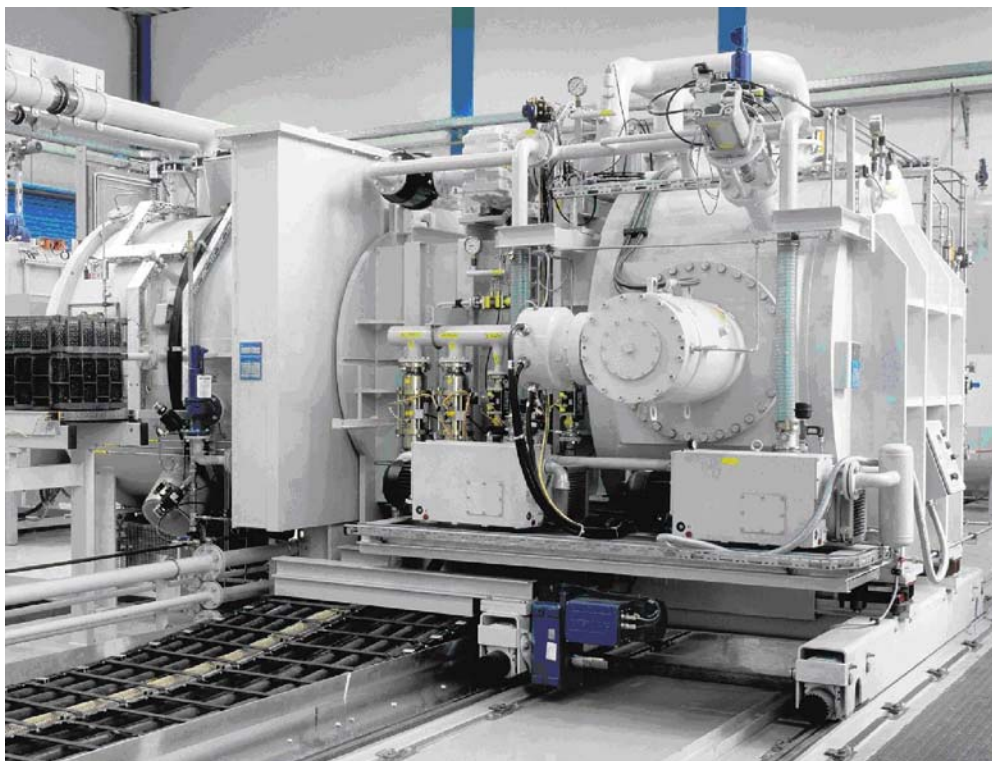


Figure 3. ModulTherm heat treat system with gas quenching chamber (multiple layer treatment)