



AGMA Technical Paper

Press Quenching and the Effects of Prior Thermal History on Distortion during Heat Treatment

By A.C. Reardon, The Gleason
Works

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Arthur C. Reardon, The Gleason Works

[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

Precision components such as industrial bearing races and automotive gears often distort unpredictably during heat treatment due to the deleterious effects of free or unconstrained oil quenching. Press quenching is a method that can be utilized to minimize the distortion of these complex components during heat treatment. This is accomplished in a quenching machine by utilizing specialized tooling for generating concentrated forces to constrain the movement of the component during oil quenching. When performed correctly, this method of quenching can often achieve the relatively stringent geometrical requirements stipulated by industrial manufacturing specifications. It can be performed on a wide variety of steel alloys. These include high carbon through-hardening grades such as AISI 52100 and A2 tool steel, as well as low carbon carburizing grades such as AISI 3310, 8620, and 9310. The relevant aspects of this specialized quenching technique will be presented together with a case study of the effects of prior thermal history on the distortion that is generated during press quenching.

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American Gear Manufacturers Association
1001 N. Fairfax Street, Suite 500
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Introduction

Press quenching is a specialized quenching technique that may be utilized to minimize the distortion of complex geometrical components during heat treatment¹. Distortion is routinely encountered in industrial heat treating operations, and is an especially important consideration where high accuracy, precision components are concerned. It can result from a wide variety of independent contributing factors. In press quenching these can include, among others,

1. The quality and prior processing history of the material from which the part in question has been manufactured;
2. The prior thermal history and residual stress distribution contained within the part;
3. The generation of unbalanced thermal and transformation stresses induced by the quenching operation;
4. The grade of material and austenitizing temperature that is used;
5. Transfer time between the austenitizing furnace and the quenching machine;
6. The type, condition, quantity, and temperature of quenchant used;
7. Direction and selective metering of quenchant flow over the component;
8. Duration of the quench at various flow rates;
9. Locations of contact points on the component for applying external loads;
10. Magnitude of the forces applied for maintaining the required part geometry;
11. Proper quench die tooling design, set-up, and maintenance;
12. Pulsing methodology.

Distortion issues during quenching

High precision components such as automotive spiral bevel gears and aerospace quality bearing races can often distort appreciably during open tank oil quenching. Press quenching can help to minimize the distortion of such components by utilizing specialized tooling for generating concentrated forces at key locations to constrain the movement of the component in a carefully controlled manner. It can be performed on a wide variety of components manufactured from both ferrous and non-ferrous based alloys. For example, a number of aluminum alloys are routinely press quenched. Common steel alloys that are press quenched include high carbon through-hardening grades such as AISI 52100 and A2 tool steel. Press quenching is particularly well suited for the processing of carburizing steel grades such as AISI 9310, 8620, and 3310.

Ideally, the transformation temperature should be the same throughout the entire cross-section of the component during quenching so that the material is capable of transforming in a uniform manner. However, in case carburized parts the martensite start transformation temperature (M_s) is not uniform throughout the entire cross-section of the part. During carburizing a composition gradient is produced as carbon is diffused into the part surface. This results in a corresponding gradient in the transformation temperature near the surface that can promote or aggravate distortion issues in such components during quenching. Non-uniformities in the base material microstructure due to segregation or improperly normalized material can also contribute to this type of distortion. Thin walled components such as large diameter bearing races are generally more susceptible to these distortion related issues than are relatively massive, compact geometries. Although press quenching cannot eliminate these effects, its use can help to minimize their contribution to the overall distortion that is produced during heat treatment.

The amount of distortion encountered depends strongly on the nature of the heat treating process that is used. In order to minimize distortion related issues during quenching, heat should be extracted from the