

Effect of Uncontrolled Heat Treat Distortion on the Pitting Life of Ground, Carburized and Hardened Gears

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American Gear Manufacturers Association



TECHNICAL PAPER

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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

Heat treatment causes distortion of gear tooth geometry. To improve tooth quality, particularly after carburizing and hardening, gears are generally ground. For low distortion, stock removal is small up to a maximum of 0.005 inch from each tooth flank. This allows minimum surface hardness reduction with no possible detrimental effect on gear pitting life. Uncontrolled distortion, on the other hand, results in an undue amount of stock removal with a significant loss of tooth surface hardness. Lower surface hardness accelerates contact-stress-induced tooth pitting that reduces gear life. For heavily distorted gears, the pitting life may be reduced as much as 30 percent after grinding. For a realistic evaluation of the pitting life of ground, carburized and hardened gears with uncontrolled distortion, derating factors are necessary and established for a number of gear materials.

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Introduction

All heat-treated gears experience distortion. Of the various hardening processes, carburizing and quenching causes the highest distortion of the pre-heat treat tooth geometry. The mechanics of this distortion phenomenon are quite complex. Its in-depth analysis is beyond the scope of this paper. But the fact is that all carburized and hardened gears distort. For most applications, these gears need to be finish-machined for improved tooth geometry. Presently, grinding is considered to be the most economical process to achieve this quality.

However, the higher the distortion, the more stock needs to be removed from the tooth surface. This not only reduces case thickness but also lowers the surface hardness, detrimentally affecting gear pitting life. For a gear to meet expected pitting life, it is thus necessary that stock removed by grinding be minimized.

To establish minimum grind stock, distortion data of a gear after heat treatment are essential for which a clear definition of distortion is necessary. In general, a change in any one or more of the following dimensions are considered to define gear distortion and its severity:

- Profile, lead and spacing of teeth
- Pitch diameter (PD) growth and runout
- Flatness of rim and hub

In a well controlled carburizing and hardening process, distortions could be held to within one American Gear Manufacturers Association (AGMA) class below the pre-heat treat quality for gears made of commonly used materials in industrial

application, such as 4320H, 8620H and 9310H. Such a process allows the establishment of a minimum grind stock on a tooth surface and the maintenance of the minimum surface hardness required after grinding. This satisfies the design requirement for minimum gear pitting life in most applications. Unfortunately, the state-of-the-art carburizing and quenching technology is unable to assure low gear distortion consistently in a production mode of operation. Sometimes, distortions within the same batch of gears are found to vary widely. Hence, it is very likely to find some gears after heat treatment with distortion far more than others. Grinding of gears with unpredictable distortion necessitates inspection of every gear in a batch for distortion severity. Certainly, this increases the cost of gears. Furthermore, tooth surface hardness and effective case depth may not be acceptable after grinding.

Besides grinding, surface hardness reduction of carburized and hardened teeth is also influenced by the slope of hardness vs case depth gradient of gear steel. Each carburizing grade steel has its own unique slope and is primarily controlled by its alloying elements. The steeper the slope, the greater the hardness reduction on tooth surface after grinding. However, some special carburizing process or cycles such as 'boost-diffuse' may produce a flatter slope of this gradient that allows larger stock removal without any appreciable loss of surface hardness. Unfortunately, at present these processes, which are complicated and expensive, have limited use in industry and are not considered in this investigation.

In addition to the slope of hardness gradient, grinding machine set-up plays an important role in the amount of equal stock removal from each flank of the gear teeth, and its associated hardness reduction.