

**Case depth can be seen as the foundation for tooth strength. In this installment the author discusses how it can be achieved, and then measured, helping avoid tooth-tip breakage.**

Specifications for carburized gearing of necessity pay attention to the required surface hardness. Not to be ignored, due to equal importance, is the case depth. This depth is defined in several ways that include effective case depth, etched case depth, total case depth, and the depth to 0.40 carbon. For the most part gear standards use effective case depth. The case depth of flame- or induction-hardened teeth is defined as the depth at which the hardness is 10 HRC points below the minimum specified surface hardness. The case depth of nitrided gears is even more closely defined. With such gears a micro hardness tester takes a measurement normal to the tooth surface at 0.5 tooth height and at mid face width. The depth is at the level where the hardness is 105 percent of the measured core hardness. Charts for typical effective case depths are supplied in ANSI/AGMA 2004-B89 with recommended inspection techniques.

In many gears the case depth at the tip is deeper than at the pitch line, and the thinnest depth is in the root. Specifications should indicate how the effective depth is to be determined. The case depths at the pitch line and in the dedendum are critical, as these are the areas most susceptible to pitting. Obtaining the correct case depth at all these points is only feasible above 20 pitch. Gas and vacuum carburizing are an efficient method of producing the deep case depths required when there is high bending and contact stresses.


The core of the gear is kept in the range of 30 to 40 HRC. Case depths can vary from 0.005 to 0.325 of an inch. While surface and core hardness are kept within narrow limitations the depth can have a wide range, even

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though the value has a direct influence on the strength profile in the carburized layer. If the core hardness is too low it cannot support the case under high loads, if the hardness is too high the gear teeth will have a tendency to chip at the case/core interface. Typically, approximately four hours is required for a depth of one mm, while nitriding would require 70 hours.

It can clearly be seen that the case depth is directly related to the cost. The heat treater has to ensure that the gear's mass, steel hardenability, and quench vigor—using the Jominy end-quench specimen—are suitable for the required depth. Failure modes of pitting and breakage at the root are directly attributable to case depth. Test results provide a clear indication that the bending strength is influenced by the ratio of case depth to the diametral pitch. A leading E.U. company specifies a minimum case depth after grinding of 0.15-0.20 times the module after finish grinding. The case depth penetration must be in accordance with the curve of maximum stress. The Hertzian pressure results in the maximum stress developing below the surface. There are some gear experts who believe that the case depth needs to be determined by the transmit-

ted load and not by any relationship to the diametral pitch. Even so they recommend that, to avoid tooth tips from breaking off, the depth at the tip should not exceed 0.40 divided by the normal diametral pitch. This can only be accomplished when the high core strength requires a smooth transition through the hardened layer. Reducing the sound pressures from spur gears has resulted in designs with thinner teeth for higher contact ratios. This design change has resulted in shallower case depths and high (0.90 percent) surface carbon levels.

The automotive industry has always led to technological changes, and it now has popularized vacuum carburizing. Sun gears from AISI 4820 have an effective case depth from 0.030 to 0.035 inches. Off-highway and heavy truck transmission gears from AISI 8620 have depths from 0.045 to 0.065 inches, and for AISI ring gears the depths are from 0.70-0.90 inches. Aerospace gears from AISI 9310 use effective case depths from 0.055 to 0.065 inches. To control any process, measurement at its output is essential. Case depth is normally measured either in the laboratory or production facility. The use in production is to expedite, and it is not as accurate. The laboratory is able to cut and mount the specimen that is ground and polished to a mirror finish. The part is then etched and examined under a microscope. A precise measurement can then be taken of the demarcation line between the core and case. Shallow cases obviously require more accuracy. Production use of handheld low-magnification Brinell microscopes can lead to inaccuracies. Fortunately, today we have digital systems with image analyzers that not only measure Brinell impressions, but can also be used to measure total depth. 

### ABOUT THE AUTHOR:

William P. Crosher is former director of the National Conference on Power Transmission, as well as former chairman of the AGMA's Marketing Council and Enclosed Drive Committee. He was resident engineer-North America for Thyssen Gear Works, and later at Flender Graffenstaden. He is author of the book *Design and Application of the Worm Gear*.