



TOOTH TIPS

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Despite excellent design and manufacture, if a gear's hardness doesn't meet the requirements of the application then all your work is for nothing.

CRITICAL TO A GEAR'S PERFORMANCE are the flank hardness its depth and the tooth's core hardness. The tooth flank hardness can be defined as its resistance to permanent deformation. It is a measure of the tooth's load carrying capacity, its absorption of the allowable rolling pressures and, finally, the root's fatigue strength.

The heat treater will have included a machined piece of the same material of the general tooth size and shape. The diameter and length should be at least three times the whole depth of the tooth with the slot's radius approximately equal to the minimum gear tooth's fillet radius. A comparison of materials can be made with the blank hardness and face-quenching tests. The blank hardness value tests the core strength of a disc with a specified thickness measurement after the quenching process. These tests are rarely used today and have been replaced by the Jominy test. Hardenability can be determined by the Jominy end-quench test, developed by Jominy and Boegehold to provide the maximum information with the least effort and time. A test specimen is used that is usually one inch diameter by four inches long. The specimen is heated to a standard austenizing temperature and then quenched by a gentle water jet strike on one end face only. After cooling both ends are ground and Rockwell C readings are taken 0.062" from the quenched end and at greater intervals beyond that point. The data is then plotted and a hardenability curve generated. The anticipated tolerance should be within ± 1.5 HRC.

Surface hardness is generally measured by one of three principal methods; Rockwell, Knoop/Vickers, and Brinell. Brinell is normally used for gears that are not case hardened and it is a destructive test leaving a large impression. The Vickers test is time consuming and requires a high quality surface preparation. The popularity of the Rockwell test is that it leaves a very small impression and takes only a few seconds. There are eight cycles split between the applying and removal of the test forces and the dwell time. Results will differ if the cycles fluctuate. Also Rockwell has numerous scales depending on the indenter used. The HRC scale uses a spherical conical diamond. Test methods are covered by ASTM E 110-82 for metallic materials, or ISO 6508-1

ABOUT THE AUTHOR:

William P. Croser 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*.

test scales AQ through T. The NIST booklet 960-5 by Samuel R. Low is also recommended.

When a shallow case is present, a few thousandths of error can make a more significant difference than when a deep case is present. A shallow case reduces bending and contact load capacities. In alloys with a high hardenability it is not always easy to determine where the core begins. The specimen must be more carefully prepared.

AGMA provides case depth calculations based on the maximum shear from contact loading. The equations are based on mathematically accurate transformations that can be used for all spur and helical gears with an involute tooth form. If the inspector does not have the necessary magnification, a laboratory microscopic examination would be needed. Digital systems are now available with image analyzers that measure hardness impressions and depths. They are functional, accurate, and do not need a laboratory environment.

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The most accurate case depth measurement is the Knoop indenter used with a micro-hardness test. One of the latest developments used for automotive transmission gears is known as multi-frequency eddy current testing. Four locations along a shaft with five integral gears are checked. The test is automatically triggered and the hardness, case depth, and core hardness determined for each test position, and the data printed. Pulsed eddy currents have overcome previous problems with the formerly used continuous wave eddy currents. Checks on the surface hardness of carburized gearing can be made prior to the final process. An Emco test Rockwell C can be made at 120° spacing on the pitch circle. To assure uniformity of the hardness further checks are made at three locations on the tooth flank. 