

Materials for Automobiles

Carburization

Lec 6

22 August 2011

Assignment

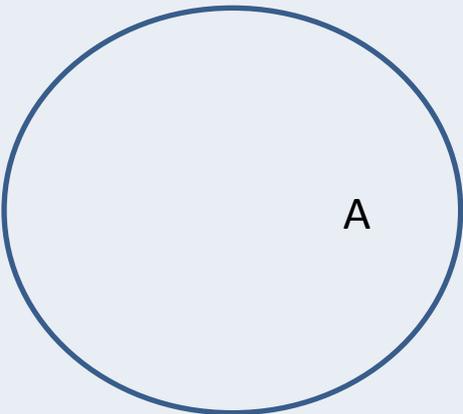
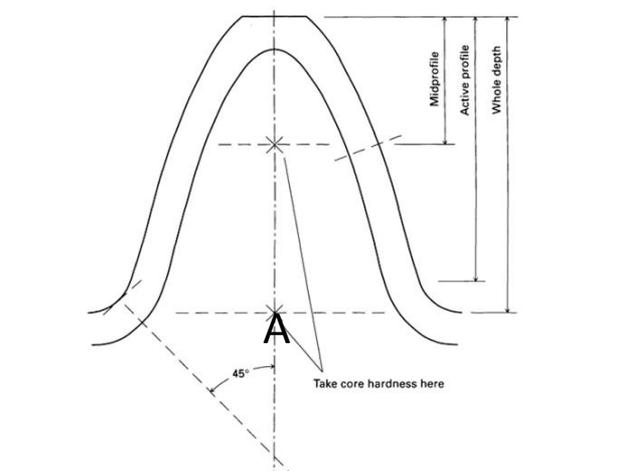
1	<p>Suggest suitable steel for:</p> <ul style="list-style-type: none">• Sewing Needle• Tipper load body• Hammer head	<p>State the properties expected and how the recommended steel meet this.</p>
2	<p>Select the steel and the heat treatment to meet a design requirement 1000 Mpa at the location marked A for the following parts :</p> <p>a. A cylinder of diameter 50mm and length 100mm</p> <p>b. A carburizing steel for a gear at root</p> 	

Fig. 3 Recommended locations for hardness traverses (dashed lines normal to tooth surface at midprofile, the pitch line, and root radius) and core hardness measurements of a gear tooth. Source: Ref 13

Plan

1	Review
2	Case carburizing

Case carburization of steel

Purpose	Ensure : Hard wear and fatigue resistant case Tough core
Components	<ul style="list-style-type: none">• Gears and gear box shafts• Propeller shaft UJ spider cross• Ball and roller bearings (Timken)
Common steels	Low carbon (< 0.2%) Carbon steel Alloy additions depend on the properties required
Process	Increase carbon on the surface layer by diffusion at high temperatures in a carburizing atmosphere to about 0.8 %. Then harden and temper the part.
Properties achieved	Case Hardness 58-62 HRC Case Depth : 0.8-1.0 mm (typical) Core hardness : 300 - 360 HV10

Carburization Process

	Temperature °C	Time Hrs	Details
Preparation	30	0.5	Cleaning
Heating stage	925	4	C potential :0.2%
Carburization stage	925	4	C Potential:0.9 %
Diffusion Stage	925	2	C Potential:0.2 %
Equalizing stage	800	2	C Potential:0.2 %
Quenching	60	0.5	Agitated or press Q
Tempering	200	2	

Fine Grain Steel for Direct Quench

In direct hardening, it is necessary to use steels whose austenite grainsizes do not grow much during carburizing. Suitable fine-grained steels are alloyed with aluminum and nitrogen and subjected to a thermomechanical treatment in which a fine grain develops that is stabilized by aluminum nitride precipitation on grain boundaries [81–84]. The ratio of aluminum to nitrogen ought to be about 3 to 5.

Hardenability of Carburizing steels

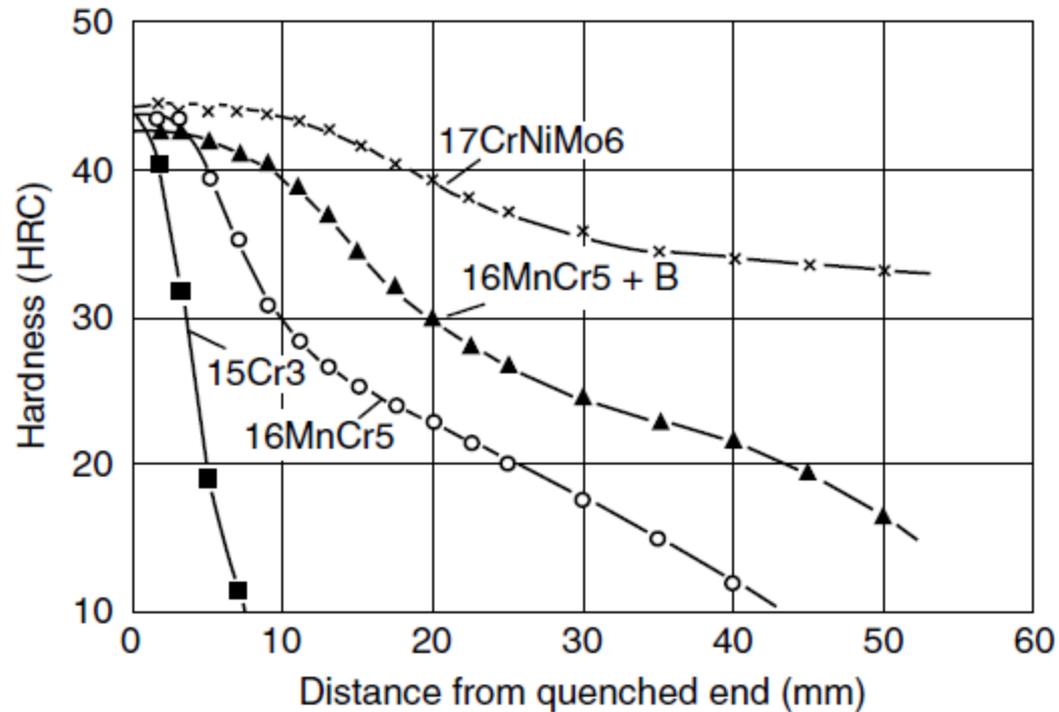
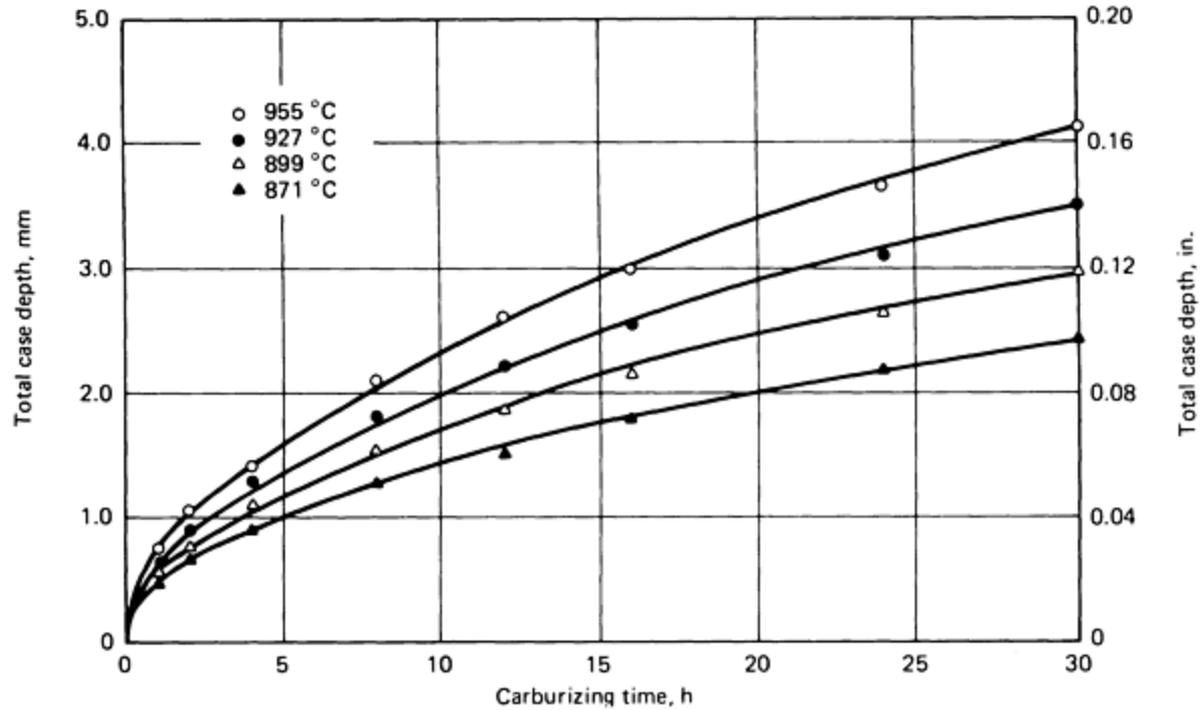


FIGURE 7.15 Jominy test results for some carburizing steels. (From H. Dietrich, W. Schmidt, *Thyssen Techn. Berichte* 10:105, 1984.)

Carburizing times



Surface carbon effects

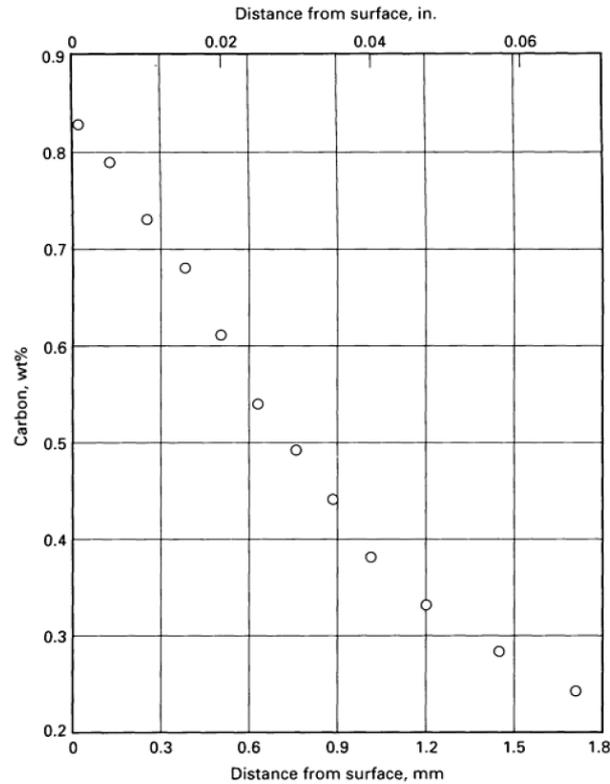


Fig. 1 Carbon gradient in a 25 mm (1 in.) diam test bar of 8620 steel after gas carburization °F). Source: Ref 12

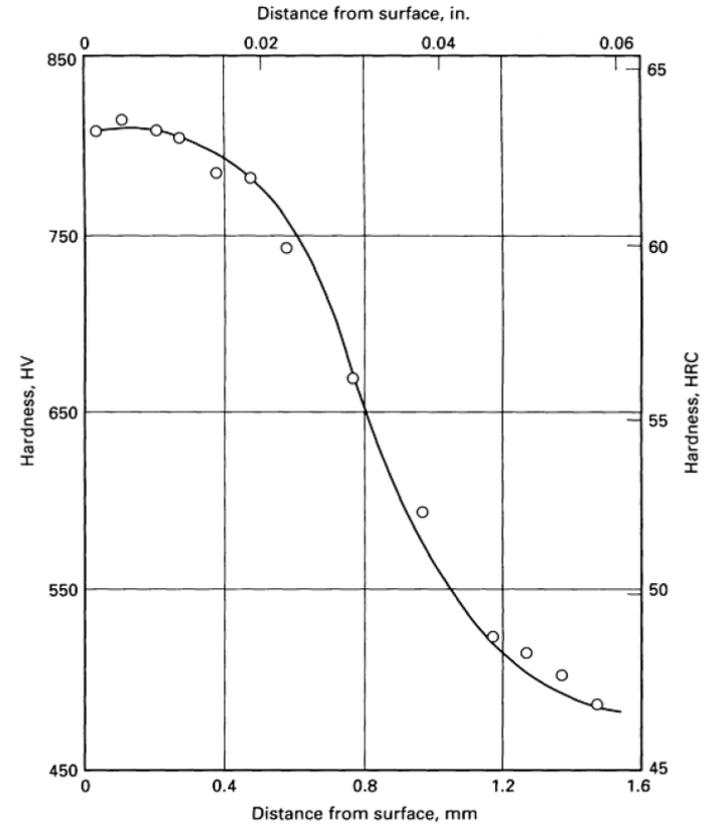
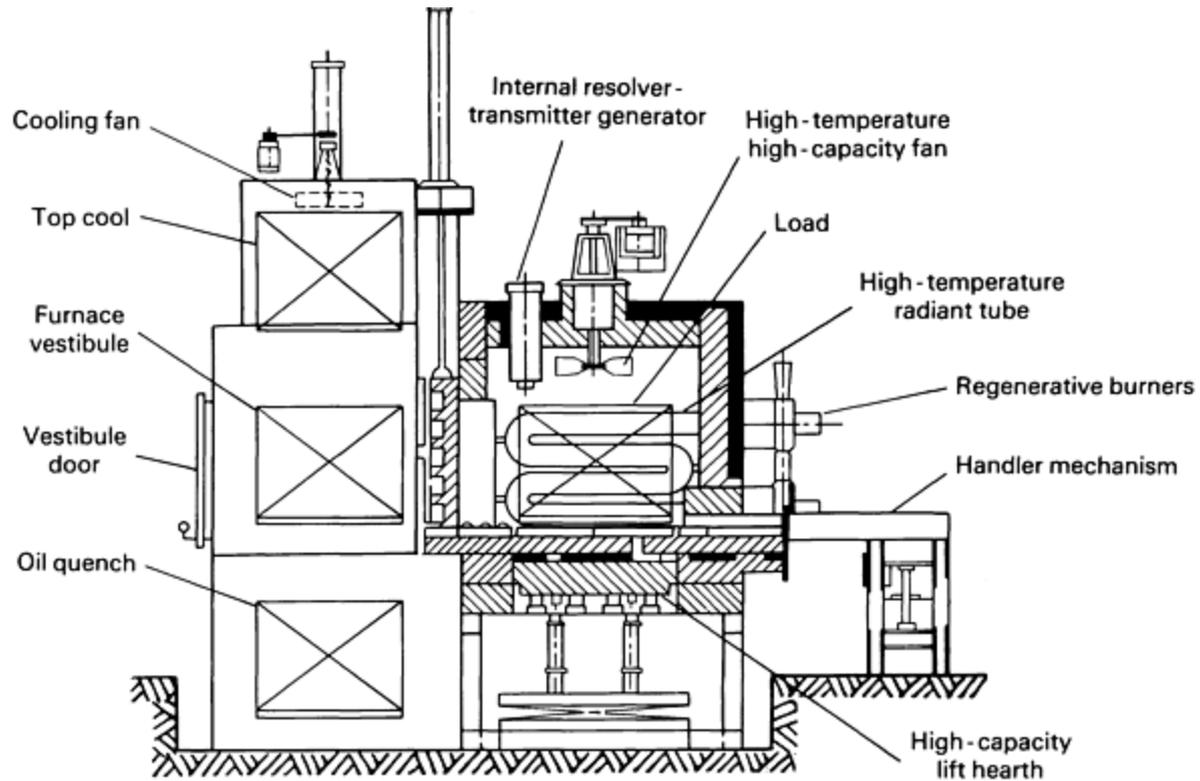
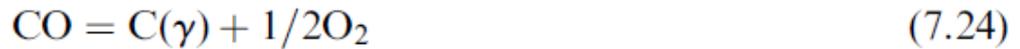
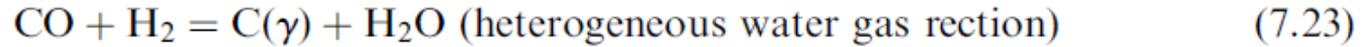
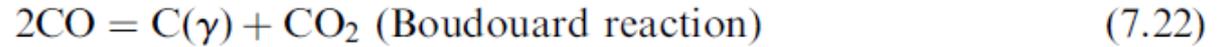


Fig. 2 Microhardness profile of 16 mm (0.63 in.) test bar of 8620 steel after gas carburization at 925 °C (1700 °F). Source: Ref 12

Gas Carburizing Furnace



Carburizing Reactions



and the homogeneous water gas equilibrium



Carburizing Atmosphere

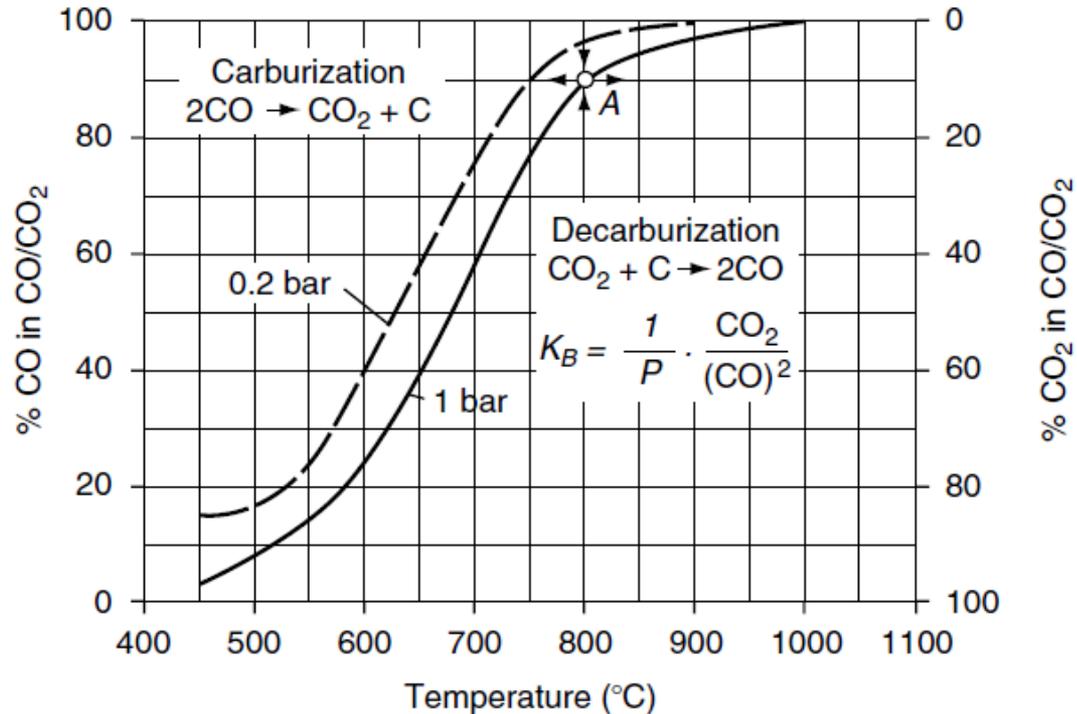


FIGURE 7.3 Boudouard reaction in equilibrium with pure carbon. (From F.E. Harris, *Met. Prog.* 84 (1945); Th. Schmidt, *Härtereitechn. Mitt. Sonderheft Gasaufkohlung* 11, 1952.)

Case depth

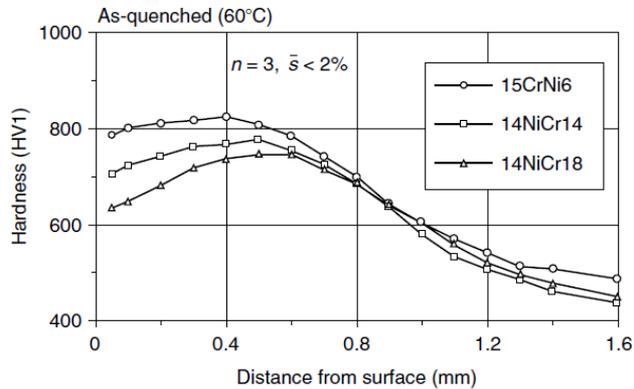


FIGURE 7.11 Hardness gradients of carburized microstructures with carbon gradients according to Figure 7.10. (From O. Schwarz, J. Grosch, C. Genzel, W. Reimers, *Härtereitechn. Mitt.* 49:134, 1994.)

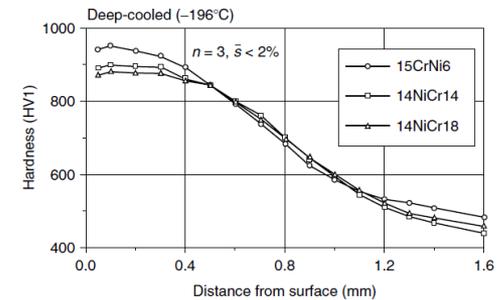


FIGURE 7.14 Hardness gradients, deep-cooled conditions. (From O. Schwarz, J. Grosch, C. Genzel, W. Reimers, *Härtereitechn. Mitt.* 49:134, 1994.)

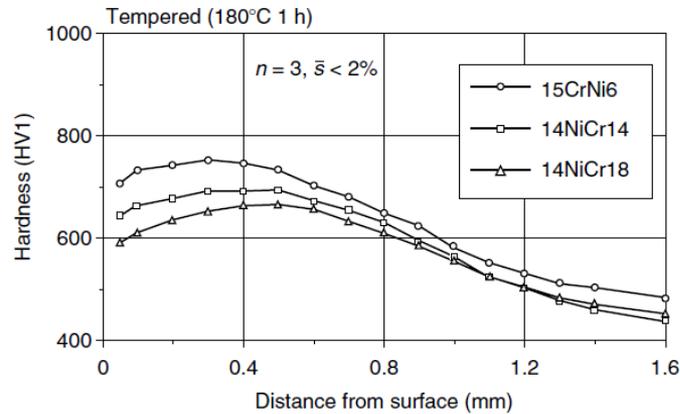


FIGURE 7.24 Effect of tempering on hardness gradients. (From O. Schwarz, J. Grosch, C. Genzel, W. Reimers, *Härtereitechn. Mitt.* 49:134, 1994.)

Retained Austenite

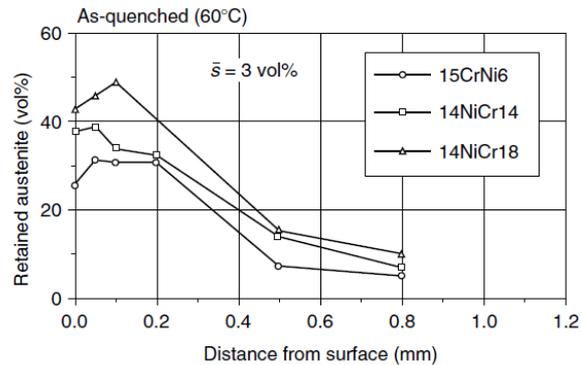


FIGURE 7.12 Amount of retained austenite, as-quenched conditions. (From O. Schwarz, J. Grosch, C. Genzel, W. Reimers, *Härtereit. Mitt.* 49:134, 1994.)

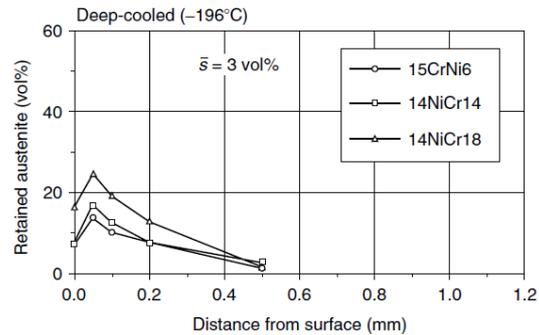


FIGURE 7.13 Amount of retained austenite, deep-cooled conditions. (From O. Schwarz, J. Grosch, C. Genzel, W. Reimers, *Härtereit. Mitt.* 49:134, 1994.)

Case microstructure

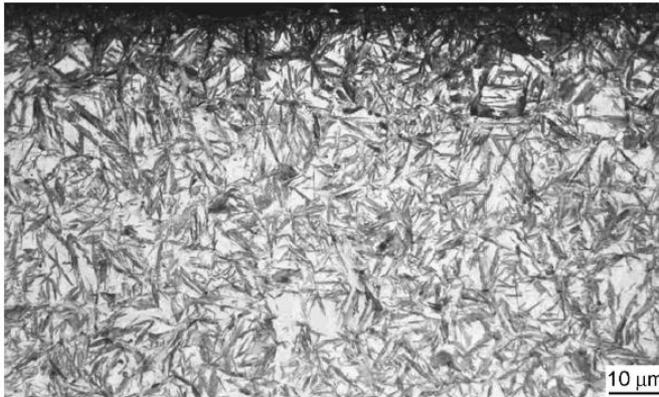


FIGURE 7.16 Plate martensite and retained austenite in the case (14NiCr18, 0.7% C, 20% retained austenite). (From O. Schwarz, J. Grosch, C. Genzel, W. Reimers, *Härtereitechn. Mitt.* 49:134, 1994.)

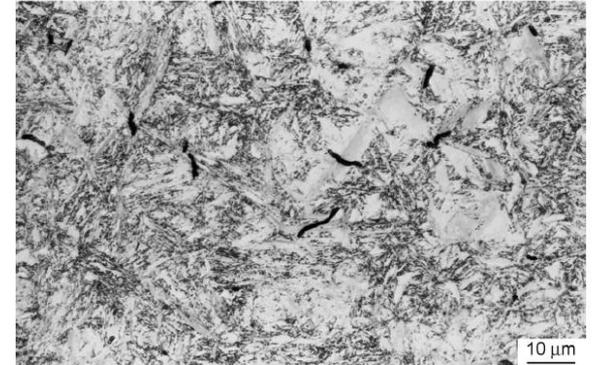


FIGURE 7.22 Microcracks in the plate martensite (16MnCr5).

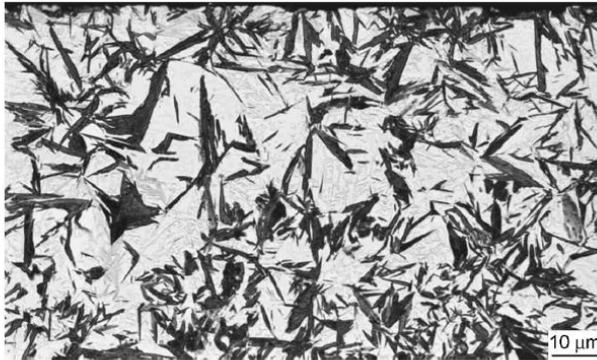


FIGURE 7.17 Plate martensite and retained austenite in the case (14NiCr18, 1.0% C, 60% retained austenite). (From O. Schwarz, J. Grosch, C. Genzel, W. Reimers, *Härtereitechn. Mitt.* 49:134, 1994.)

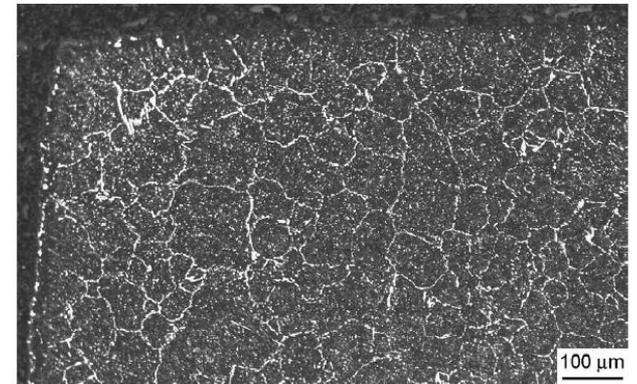


FIGURE 7.28 Carbides on grain boundaries in the carburized case (15CrNi6).

Residual stress

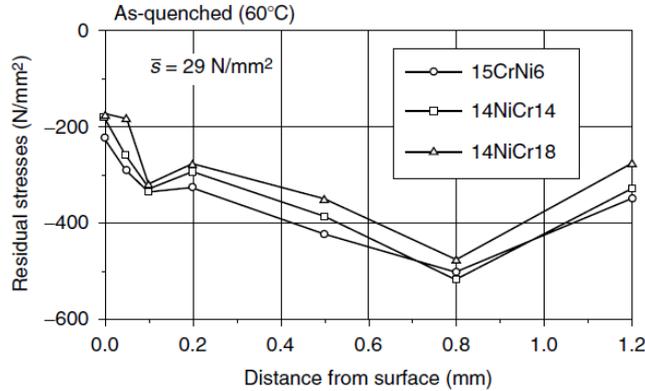


FIGURE 7.23 Residual stresses in the carburized case. (From O. Schwarz, J. Grosch, C. W. Reimers, *Härtereitechn. Mitt.* 49:134, 1994.)

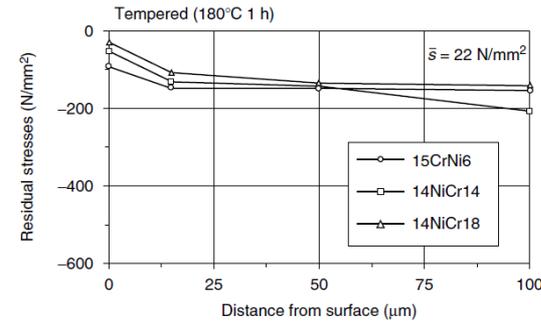


FIGURE 7.25 Effect of tempering on residual stresses. (From O. Schwarz, J. Grosch, C. Genzel, W. Reimers, *Härtereitechn. Mitt.* 49:134, 1994.)

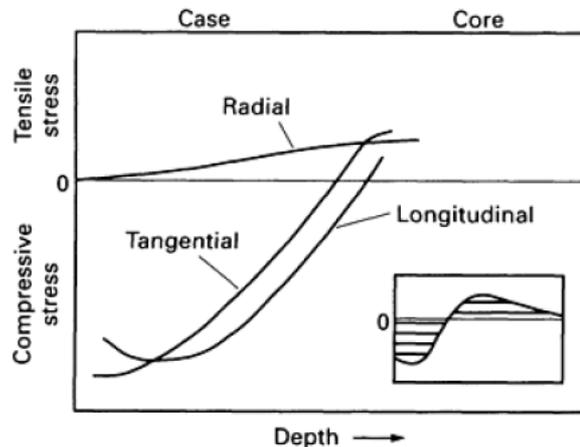


Fig. 21 Schematic diagram of residual stresses in carburized steels. Insert shows that surface compressive residual stresses are balanced by interior tensile stresses. Source: Ref 8

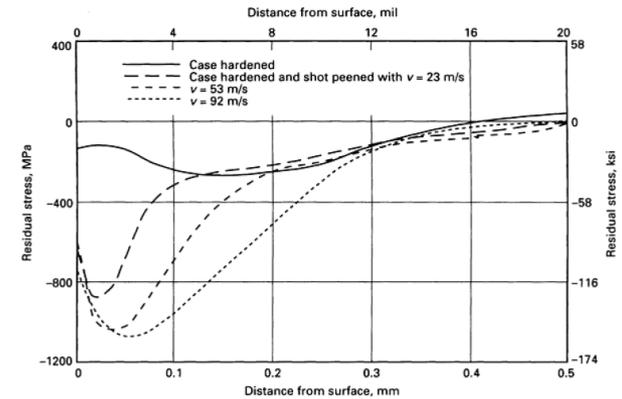


Fig. 22 Effect of shot peening at different velocities on compressive residual stresses in carburized 16MnCr5 steel (1.23% Mn, 1.08% Cr). Source: Ref 52

Carburization microstructures

Case: Martensite + minor amounts retained austenite(15% max) and isolated globular carbides not forming network.

Core : lath martensite or bainite and low quantities of ferrite

In all the oxygen-containing carburizing atmospheres, oxygen reacts with the elements of the case microstructure, with chromium, manganese, and silicon oxidizing under carburizing conditions, with the reduction of iron, molybdenum, and nickel [109]. As a consequence, surface oxidation occurs and is most prominent alongside the grain boundaries where diffusion is faster [109–111]. The silicon content of the carburizing steels seems to be a measure of the surface oxidation depth, whereas the manganese content controls the intensity of the intergranular oxidation [111]. The intergranular surface oxidation (Figure 7.26) is a characteristic of carburized microstructures [110,111] that can be avoided only by oxygen-free carburizing atmospheres as generally used in low-pressure carburizing or in plasma carburizing [26–29].



FIGURE 7.26 Surface intergranular oxidation (15CrNi6).

Tempering

Carburized microstructures are almost always tempered to transform the unstable and brittle as-quenched martensite into the more stable tempered martensite. This leads to an increase in ductility and thus minimizes the occurrence of delayed fracture [86]. The transformation of retained austenite tends to decrease distortion. With common carburizing steels the tempering temperatures are limited to 180–200°C to ensure that the usually required surface hardness of more than 60HRC is still maintained, and for economic reasons the tempering time is almost always no more than 2 h.

Under the tempering conditions that are common practice in carburizing, only a small amount of retained austenite is transformed

Effective Case Depth for a Gear

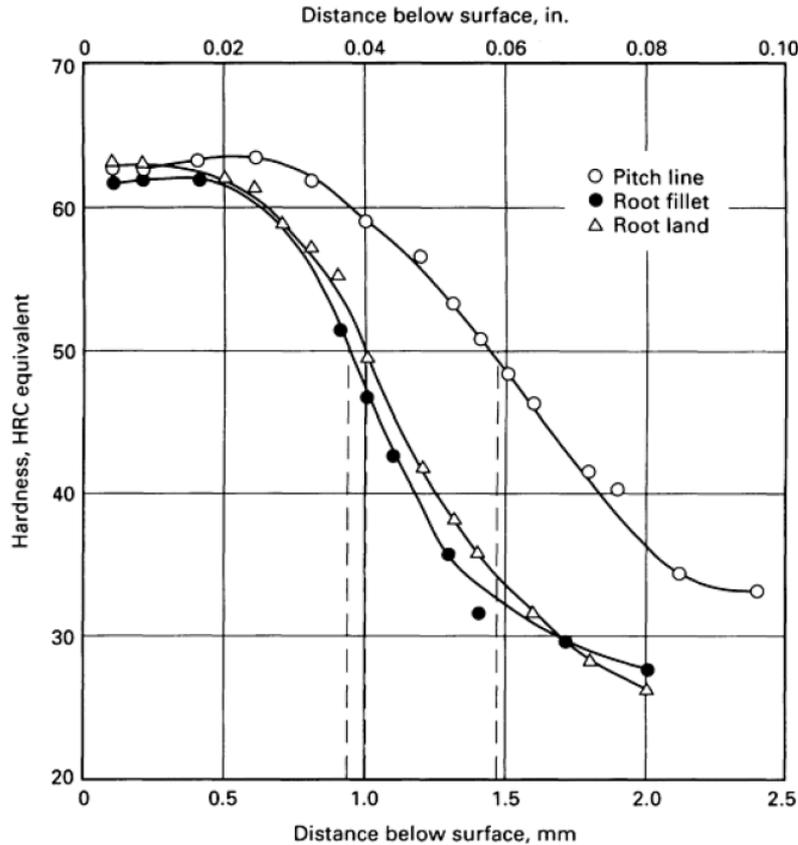


Fig. 4 Hardness profiles and effective case depths at 50 HRC for root and pitch line locations of a carburized and hardened 8620H steel gear. Source: Ref 4

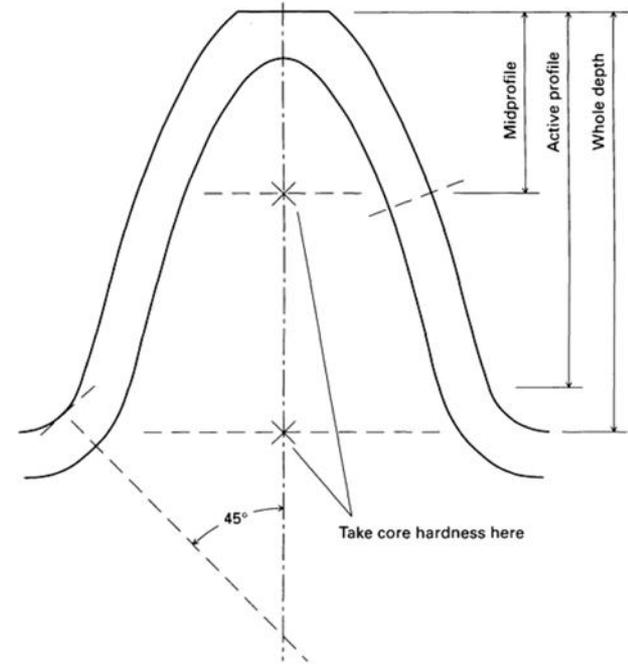


Fig. 3 Recommended locations for hardness traverses (dashed lines normal to tooth surface at midprofile, the pitch line, and root radius) and core hardness measurements of a gear tooth. Source: Ref 13