

# The Calculation of Optimum Surface Carbon Content for Carburized Case Hardened Gears

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**American Gear Manufacturers Association**



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## 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

The International Gearing Standard ISO 6336, in part 5, addresses the metallurgical requirements to achieve the rated service performance.

For high quality carburise case hardened gears the heat treater is required to achieve, in conjunction with other properties, a surface carbon level of Eutectoid Carbon + 0.20% to - 0.10%.

This creates practical difficulties because, at present, there is no method to calculate eutectoid carbon from chemical analysis and the eutectoid carbon is not necessarily the best value to base the surface carbon requirement on.

The UK representatives on the international committee preparing the next issue of the standard agreed to attempt to solve this problem.

As a result this paper defines the conditions to calculate an optimum carbon level to minimise the possibilities of producing undesirable metallurgical phases including retained austenite, cementite and bainite.

A method is proposed to determine the optimum carbon level from regression equations which calculate CCT diagram bainite, ferrite, pearlite and cementite nose times plus martensite transformation temperatures from the alloy content and austenitising conditions.

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## Introduction

For high quality carburise case hardened gears achievement of close case carbon control is essential.

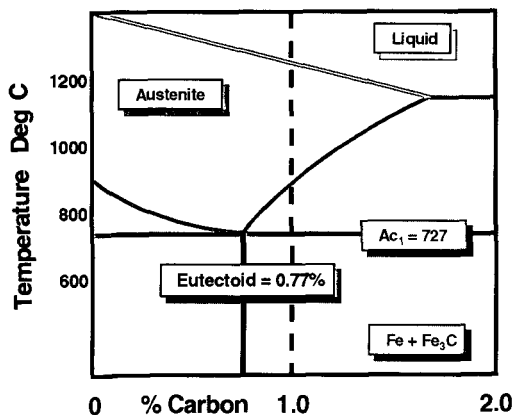
Whilst tight carbon control is possible, views on what optimum carbon level to target can be wider than the tolerance.

The ISO standard ISO 6336 in part 5 makes an attempt to specify a target and the tolerance for the highest quality grade as Eutectoid Carbon Percentage plus 0.20%, minus 0.10%.

This implies that either a method exists to calculate Eutectoid Carbon Content from alloy content or the values have been determined for a wide range of steels and are widely available. Unfortunately neither exist. Also implicit is that the Eutectoid Carbon is the optimum. But no rationale is given.

A simplistic interpretation is to use the Eutectoid Carbon Content from the Iron -Carbon Phase Diagram – see Fig 1. This value is 0.77% which seems reasonable at a first glance. However, experienced heat treaters realise that the higher alloy steels would develop excessive retained austenite if targeting 0.77% with the above tolerance.

Fig 1 Iron Carbon Phase Diagram



In practice the optimum carbon for a grade of steel is determined empirically by experience and is chosen to minimise the risk of forming undesirable

phases including retained austenite, carbides, bainite and pearlite.

The conclusion is that any calculation of optimum carbon content must reflect this requirement.

The objective of this paper is to define a readily available methodology to calculate optimum carbon content from alloy content and austenitising temperature at the hardening stage.

## Continuous Cooling Transformation ( CCT ) Diagrams

To avoid undesirable transformation products we turn to the effect that carbon content, alloy content and austenitising conditions have on the formation of phases during cooling.

CCT diagrams are one of the most effective ways of representing transformation behaviour.

Over 1000 diagrams representing the whole range of carburising alloys, carbon levels and austenitising conditions are available in the public domain.

Fig 2 is typical of an experimentally determined CCT diagram with hardnesses and microstructures. Temperature is the vertical linear axis and time is the logarithmic horizontal scale.

Fig 2 CCT Diagram, Hardnesses and Microstructures

