Pack Carburizing

Process Control

In pack carburizing, as in other carburization processes, the carbon-concentration gradient obtained is a function of carbon potential, carburizing temperature and time, and the chemical composition of the steel. Pack carburizing normally is performed at temperatures ranging from 815 to 955 °C (1500 to 1750 °F). In recent years, the upper limits have been steadily raised, and carburizing temperatures as high as 1095 °C (2000 °F) have been used.

Because most pack-carburized parts are reheated and quenched from a lower temperature after being carburized and slow cooled, grain growth is not a concern when high carburizing temperatures are used. The larger concern would be the presence of surface carbides due to the higher surface carbon levels at saturation from the higher carburizing temperature.

Surface Carbon Content. Under equilibrium conditions, carbon content obtained at the surface of the work increases directly with an increase in the ratio of carbon monoxide to carbon dioxide. For given gas mixtures, the available carbon is higher at the lower temperatures (Fig. 3, 4). Although values from these two experimentally derived charts in Fig. 3 and 4 are not exactly the same, they show the basic trend of the equilibrium isotherms of CO and CO_2 mixtures with carbon concentration in iron. Thus, more carbon is made available at the work surface by the use of energizers and carburizing materials that promote formation of carbon monoxide.

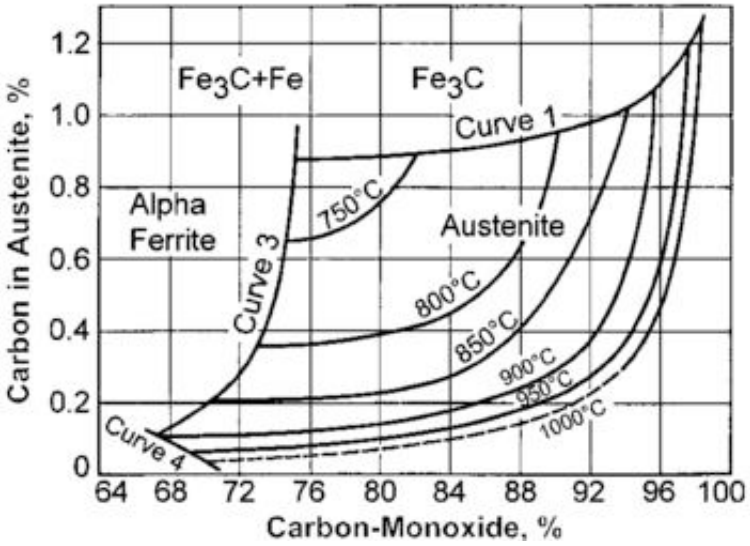

Fig. 3 Isotherms of carbon in austenite at high levels of carbon monoxide. Source: Ref 3

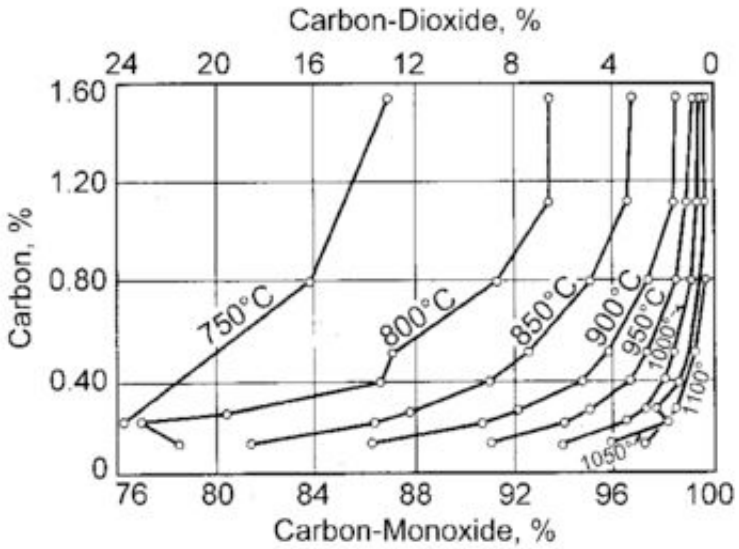

Fig. 4 Isotherms showing equilibria between various CO-CO_2 mixtures and iron with various carbon contents at a series of temperatures. Source: Ref 3

In pack carburizing, the rate of evolution of carbonaceous gas is fixed and is almost always in excess of the rate required to supply the necessary carbon for a saturated surface layer. The surface carbon content is approximately that of the saturation limit for carbon in austenite (Fig. 3). At operating temperature, the desired average carbon level throughout the case is directly dependent on the carburizing temperature. When eutectoid (0.8 wt% C) cases are desired, the carburizing temperature is normally approximately 815 °C (1500 °F). As more carbon is required in the case, the temperature is increased. Although the carbon potential of the compound can be varied to limit the surface content, control of temperature serves the same purpose and is easier to achieve. Carbon potential (for a given gas mixture) is higher at low temperatures, but cementite (rather than saturated carbon in austenite) forms at the surface with higher CO levels and low temperatures (Fig. 3).

Carburizing Rates and Case Depth. Carbon potential refers only to available carbon at the surface and not the rate of carburization and the depth of carbon diffusion into the case. The rate at which the carburized case is formed increases rapidly with temperature. If a factor of 1.0 is representative of 815 °C (1500 °F), the factor increases to 1.5 at 870 °C (1600 °F) and to more than 2.0 at 925 °C (1700 °F). Improved containers, fine-grained steels, and other improvements now permit the use of a wide variety of temperatures.

The rate of change in case depth at a particular carburizing temperature is proportional to the square root of time. The rate of carburization is thus highest at the beginning of the cycle and gradually diminishes as the cycle is extended (Fig. 5). Higher temperatures also promote carbon diffusion and increase the case depth (Fig. 6).

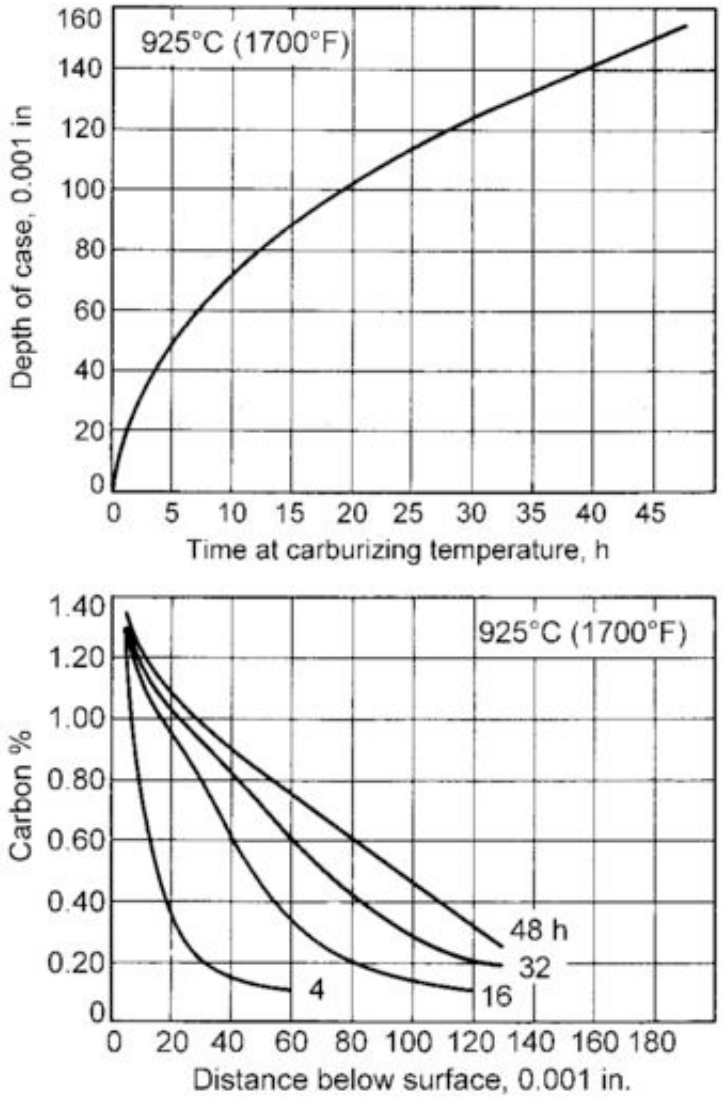

Fig. 5 Effect of duration of pack carburizing on case depth and carbon gradient in 3115 steel carburized in a compound containing hardwood charcoal, coke, and sodium carbonate

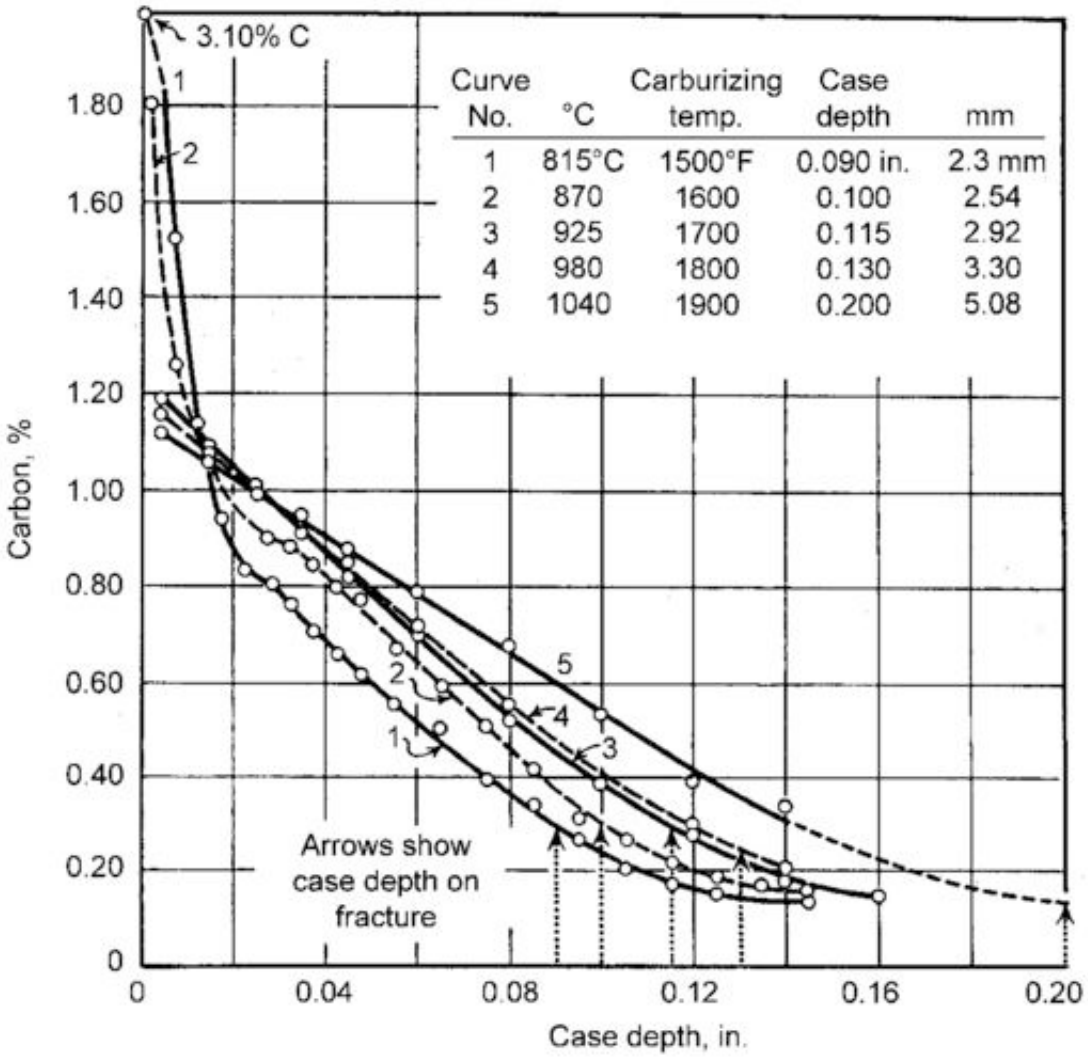

Fig. 6 Case depth-carbon content curve. Shows the effect of carburizing temperature on carbon concentration after pack carburizing at temperature given. Source: Ref 3

Example. A rock bit section made of 4815 steel was pack carburized with a compound of charcoal (16 to 30 mesh or finer) with approximately 8 to 15% potassium carbonate energizer. Carburizing at 925 °C (1700 °F) for approximately 9 h produced a case depth of about 1.65 mm (0.065 in.) with approximately 1.0% C at the surface.

Reference cited in this section

3. M.A. Grossman, A Review of Some Fundamentals of Carburizing, *Carburizing*, American Society for Metals, 1938