CASE HARDENING

Introduction

Surface hardening is a process which includes a wide variety of techniques is used to improve the wear resistance of parts without affecting the softer, tough interior of the part. This combination of hard surface and resistance and breakage upon impact is useful in parts such as a cam or ring gear that must have a very hard surface to resist wear, along with a tough interior to resist the impact that occurs during operation. Further, the surface hardening of steels has an advantage over through hardening because less expensive low-carbon and medium-carbon steels can be surface hardened without the problems of distortion and cracking associated with the through hardening of thick sections.

Casehardening

Casehardening produces a hard wear resistant surface or case over a strong, tough core. Casehardening is ideal for parts which require a wear resistant surface and at the same time, must be tough enough internally to withstand the applied loads. The steels best suited to casehardening are the low carbon and low alloy steels. If high carbon steel is casehardened, the hardness penetrates the core and causes brittleness. In casehardening, the surface of the metal is changed chemically by introducing a high carbide or nitride content. The core is chemically unaffected.

When heat treated, the surface responds to hardening while the core toughens. The common forms of casehardening are carburizing, cyaniding and nitriding.

The surface hardening by diffusion involves the chemical modification of a surface. The basic process used is thermo-chemical because some heat is needed to enhance the diffusion of hardening species into the surface and subsurface regions of part. The depth of diffusion exhibits time-temperature dependence such that:

$$\text{Case depth} \approx K\sqrt{\text{Time}}$$

where the diffusivity constant, K, depends on temperature, the chemical composition of the steel, and the concentration gradient of a given hardening species. In terms of temperature, the diffusivity constant increases exponentially as a function of absolute temperature. Concentration gradients depend on the surface kinetics and reactions of a particular process.

Methods of hardening by diffusion include several variations of hardening species (such as carbon, nitrogen, or boron) and of the process method used to handle and transport the hardening species to the surface of the part. Process methods for exposure involve the handling of hardening species in forms such as gas, liquid, or ions. These process variations naturally produce differences in typical case depth and hardness (Table 1). Factors influencing the suitability of a particular diffusion method include the type of steel (Table 3). It is also important to distinguish between total case depth and effective case depth. The effective case depth is typically about two-thirds to three-fourths the total case depth. The required effective depth must be specified so that the heat treatment can process the parts for the correct time at the proper temperature.

Table 1: Typical characteristics of diffusion treatments

Process	Nature of case	Process temperature (°C)	Typical case depth	Case hardness (HRC)	Typical base metals
Carburizing Pack	Diffused carbon	815-1090	125µm-1.5mm	50-63*	Low-carbon steels, low-carbon alloy steels
Gas	Diffused carbon	815-980	75 µm-1.5mm	50-63*	Low-carbon steels, low-carbon alloy steels
Liquid	Diffused carbon and possibly nitrogen	815-980	50 µm-1.5mm	50-65*	Low-carbon steels, low-carbon alloy steels
Vacuum	Diffused carbon	815-1090	75 µm-1.5mm	50-63*	Low-carbon steels, low-carbon alloy steels
Nitriding Gas	Diffused nitrogen, nitrogen compounds	480-590	12µm-0.75mm	50-70	Alloy steels, nitriding steels, stainless steels
Salt	Diffused nitrogen, nitrogen compounds	510-565	2.5µm-0.75mm	50-70	Most ferrous metals. Including cast irons
Ion	Diffused nitrogen. nitrogen compounds	340-565	75µm-0.75mm	50-70	Alloy steels, nitriding steels, stainless steels
Carbonitriding Gas	Diffused carbon and nitrogen	760-870	75µm-0.75mm	50-65*	Low-carbon steels, low-carbon alloy steels, stainless steels
Liquid (cyaniding)	Diffused carbon and nitrogen	760-870	2.5-125µm	50-65*	Low-carbon steels
Ferritic nitrocarburizing	Diffused carbon and nitrogen	565-675	2.5-25µm	40-60*	Low-carbon steels
Other Aluminizing (pack)	Diffused aluminum	870-980	25µm-1mm	< 20	Low-carbon steels
Siliconizing by chemical vapor deposition	Diffused silicon	925-1040	25µm-1mm	30-50	Low-carbon steels
Chromizing by chemical vapor deposition	Diffused chromium	980-1090	25-50µm	LCS < 30; High-carbon 50-60	High- and low carbon steels
Titanium Carbide	Diffused carbon and titanium, TiC compound	900-1010	2,5-12.5µm	> 70*	Alloy steels, tool steels
Boriding	Diffused boron. boron compounds	400-1150	12,5-50µm	40- > 70	Alloy steels, tool steels, Cobalt and nickel alloys

Table 2. Types of steels used for various diffusion processes

Diffusion substrates			
Low-carbon steels	Alloy steels	Tool steels	Stainless steels
Carburizing Cyaniding Ferritic nitrocarburizing Carbonitriding	Nitriding Ion nitriding	Titanium carbide Boriding Salt nitriding Ion nitriding Gas nitriding	Gas nitriding Titanium carbide Ion nitriding Ferritic nitrocarburizing

Carburizing

Carburizing is a casehardening process in which carbon is added to the surface of low carbon steel. Thus, carburized steel has a high carbon surface and a low carbon interior. When the carburized steel is heat treated, the case is hardened while the core remains soft and tough.

Carburizing is the addition of carbon to the surface of low-carbon steels at temperatures generally between 850 and 950°C (1560 and 1740°F), at which austenite, with its high solubility for carbon, is the stable crystal structure. Hardening is accomplished when the high-carbon surface layer is quenched to form martensite so that a high-carbon martensitic case with good wear and fatigue resistance is superimposed on a tough, low-carbon steel core.

Case hardness of carburized steels is primarily a function of carbon content. When the carbon content of the steel exceeds about 0.50% additional carbon has no effect on hardness but does enhance hardenability. Carbon in excess of 0.50% may not be dissolved, which would thus require temperatures high enough to ensure carbon-austenite solid solution.

Case depth of carburized steel is a function of carburizing time and the available carbon potential at the surface. The variation of case depth with carburizing time is shown in Figure-2.28. When prolonged carburizing times are used for deep case depths, a high carbon potential produces a high surface-carbon content, which may thus result in excessive retained austenite or free carbides. These two micro structural elements both have adverse effects on the distribution of residual stress in the case-hardened part. Consequently, a high carbon potential may be suitable for short carburizing times but not for prolonged carburizing.

Carburizing steels for case hardening usually have base-carbon contents of about 0.2%, with the carbon content of the carburized layer generally being controlled at between 0.8 and 1% C. However, surface carbon is often limited to 0.9% because too high a carbon content can result in retained austenite and brittle martensite.

Most steels that are carburized are killed steels (deoxidized by the addition of aluminum), which maintain fine grain sizes to temperatures of about 1040°C. Steels made to coarse grain practices can be carburized if a double quench provides grain refinement. Double quenching usually consists of a direct quench and then a re-quench from a lower temperature.

In another method of carburizing, called "gas carburizing," some material rich in carbon is introduced into the furnace atmosphere. The carburizing atmosphere is produced by the use of various gases or by the burning of oil, wood, or other materials. When the steel parts are heated in this atmosphere, carbon monoxide combines with the gamma iron to produce practically the same results as those described under the pack carburizing process.

A third method of carburizing is that of "liquid carburizing." In this method the steel is placed in a molten salt bath that contains the chemicals required to produce a case comparable with one resulting from pack or gas carburizing.

Alloy steels with low carbon content as well as low carbon steels may be carburized by either of the three processes. However, some alloys, such as nickel, tend to retard the absorption of carbon. As a result, the time required to produce a given thickness of case varies with the composition of the metal.

Quenching:

All of the carburizing processes (pack, gas, liquid) require quenching from the carburizing temperature or a lower temperature or reheating and quenching. Parts are then tempered to the desired hardness.

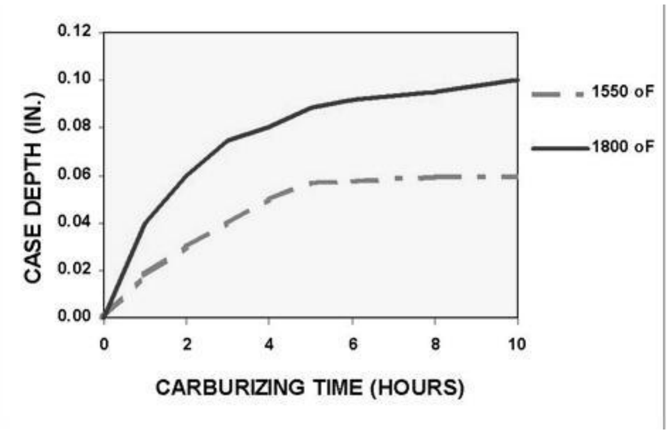


Figure 2.28 Case depth vs. Carburizing time

Pack Carburizing

In this process, the part that is to be carburized is packed in a steel container so that it is completely surrounded by granules of charcoal. The charcoal is treated with an activating chemical such as Barium Carbonate ($BaBO_3$) that promotes the formation of Carbon Dioxide (CO_2). This gas in turn reacts with the excess carbon in the charcoal to produce carbon monoxide; CO. Carbon Monoxide reacts with the low-carbon steel surface to form atomic carbon which diffuses into the steel. Carbon Monoxide supplies the carbon gradient that is necessary for diffusion. The carburizing process does not harden the steel. It only increases the carbon content to some predetermined depth below the surface to a sufficient level to allow subsequent quench hardening.

Carbon Monoxide reaction: $CO_2 + C \text{ ---> } 2\,CO$

Reaction of Cementite to Carbon Monoxide: $2\,CO + 3\,Fe \text{ ---> } Fe_3C + CO_2$

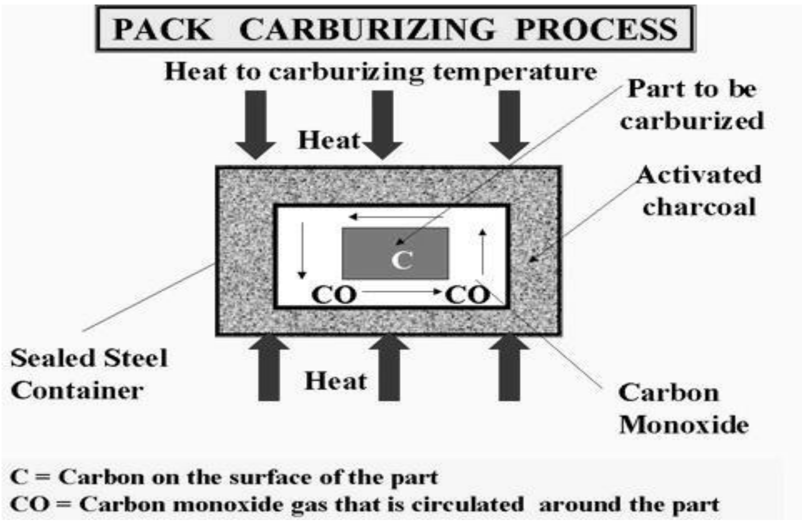


Figure 2.29 Pack carburizing process

Quenching Process:

It is difficult to quench the part immediately, as the sealed pack has to be opened and the part must be removed from the pack. One technique that is used often is to slow cool the entire pack and subsequently harden and temper the part after it is removed from the sealed pack.

Depth of Hardening:

There is no technical limit to the depth of hardening with carburizing techniques, but it is not common to carburize to depths in excess of 0.050 in.

Carburizing Time: 4 to 10 hour

Gas Carburizing

Can be done with any carbonaceous gas, such as methane, ethane, propane, or natural gas. Most carburizing gases are flammable and controls are needed to keep carburizing gas at 1700 ^{o}F from contacting air (oxygen). The advantage of this process over pack carburizing is an improved ability to quench from the carburizing temperature. Conveyor hearth furnaces make quenching in a controlled atmosphere possible.

In gas carburizing, the parts are surrounded by a carbon-bearing atmosphere that can be continuously replenished so that a high carbon potential can be maintained. While the rate of carburizing is substantially increased in the gaseous atmosphere, the method requires the use of a multicomponent atmosphere whose composition must be very closely controlled to avoid deleterious side effects, for example, surface and grain-boundary oxides. In addition, a separate piece of equipment is required to generate the atmosphere and control its composition. Despite this increased complexity, gas carburizing has become the most effective and widely used method for carburizing steel parts in large quantities.

In efforts required to simplify the atmosphere, carburizing in an oxygen-free environment at very low pressure (vacuum carburizing) has been explored and developed into a viable and important alternative. Although the furnace enclosure in some respects becomes more complex, the atmosphere is greatly simplified. A single-component atmosphere consisting solely of a simple gaseous hydrocarbon, for example methane, may be used. Furthermore, because the parts are heated in an oxygen-free environment, the carburizing temperature may be increased substantially without the risk of surface or grain-boundary oxidation. The higher temperature permitted increases not only the solid solubility of carbon in the austenite but also its rate of diffusion, so that the time required to achieve the case depth desired is reduced.

Although vacuum carburizing overcomes some of the complexities of gas carburizing, it introduces a serious new problem that must be addressed. Because vacuum carburizing is conducted at very low pressures, and the rate of flow of the carburizing gas into the furnace is very low, the carbon potential of the gas in deep recesses and blind holes is quickly depleted. Unless this gas is replenished, a great nonuniformity in case depth over the surface of the part is likely to occur. If, in an effort to overcome this problem, the gas pressure is increased significantly, another problem arises, that of free-carbon formation, or sooting.

Advantages of Gas Carburizing

- It takes less time when compared with pack Carburizing method
- Control is more accurate to achieve surface carbon content and case hardness
- When compare with pack Carburizing, complicated shape components are carburised by this method

Liquid Carburizing

Can be performed in internally or externally heated molten salt pots. Carburizing salt contains cyanide compounds such as sodium cyanide (NaCN). Cycle times for liquid cyaniding is much shorter (1 to 4 hours) than gas and pack carburizing processes. Disadvantage is the disposal of salt. (Environmental problems) and cost (safe disposal is very expensive).

In this process, the steel components are immersed in a liquefied carbon-rich bath of molten salts. The molten salt contains a mixture of sodium carbonate, sodium chloride and silicon carbide. The reaction in the bath is

$$2Na_2CO_3 + SiC \longrightarrow Na_2SiO_3 + Na_2O + 2CO + C$$

This saturates the metal with carbon. The bath is replenished from time to time. The components are immersed in the bath at a temperature of around 870 to 900^{o}C. So that the carbon is diffused into the surface of the steel. In this method the time required for carburising the metal surface of 0.2 to 0.3mm in 35 to 55min. Then the metal is then undergone rapid quenching to lock the carbon inside the structure. By this method uniform case hardening is obtained when compared with other methods.

Advantages of Liquid Carburizing

- Uniform case hardening depth is obtained
- Components are free from oxidation
- Soot is not formed on the surface of the component

CASE HARDENING

Lecture 2 (continue)

Nitriding

Nitriding is unlike other casehardening processes in that, before nitriding, the part is heat treated to produce definite physical properties. Thus, parts are hardened and tempered before being nitrided. Most steels can be nitrided, but special alloys are required for best results. These special alloys contain aluminum as one of the alloying elements and are called "nitralloys."

Principal reasons for nitriding are:

To obtain high surface hardness

To increase wear resistance and antigalling properties

To improve fatigue life

To improve corrosion resistance

To obtain a surface that is resistant to the softening effect of heat at temperatures up to the nitriding temperature.

In nitriding, the part is placed in a special nitriding furnace and heated to a temperature of approximately 1,000°F. With the part at this temperature, ammonia gas is circulated within the specially constructed furnace chamber. The high temperature cracks the ammonia gas into nitrogen and hydrogen. The ammonia which does not break down is caught in a water trap below the regions of the other two gases. The nitrogen reacts with the iron to form nitride. The iron nitride is dispersed in minute particles at the surface and works inward. The depth of penetration depends on the length of the treatment. In nitriding, soaking periods as long as 72 hours are frequently required to produce the desired thickness of case. Nitriding can be accomplished with a minimum of distortion, because of the low temperature at which parts are casehardened and because no quenching is required after exposure to the ammonia gas.

In this process, nitrogen is diffused into the surface of the steel being treated. The reaction of nitrogen with the steel causes the formation of very hard iron and alloy nitrogen compounds. The resulting nitride case is harder than tool steels or carburized steels. The advantage of this process is that hardness is achieved without the oil, water or air quench. As an added advantage, hardening is accomplished in a nitrogen atmosphere that prevents scaling and discoloration. Nitriding temperature is below the lower critical temperature of the steel and it is set between 925 ^{o}F and 1050 ^{o}F. The nitrogen source is usually Ammonia (NH_3). At the nitriding temperature the ammonia dissociates into Nitrogen and Hydrogen.

$$2NH3 \text{ ---> } 2N + 3H$$

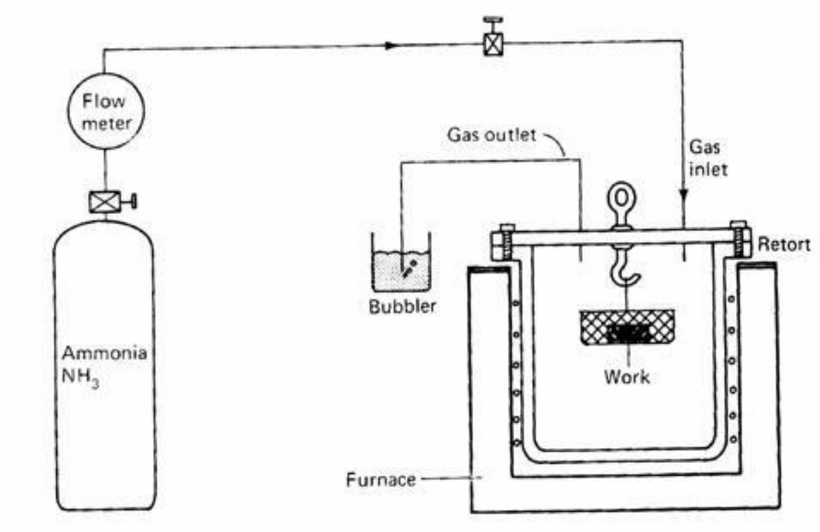


Figure 2.30 Nitriding process

The nitrogen diffuses into the steel and hydrogen is exhausted. A typical nitriding setup is illustrated in Figure 2.30.

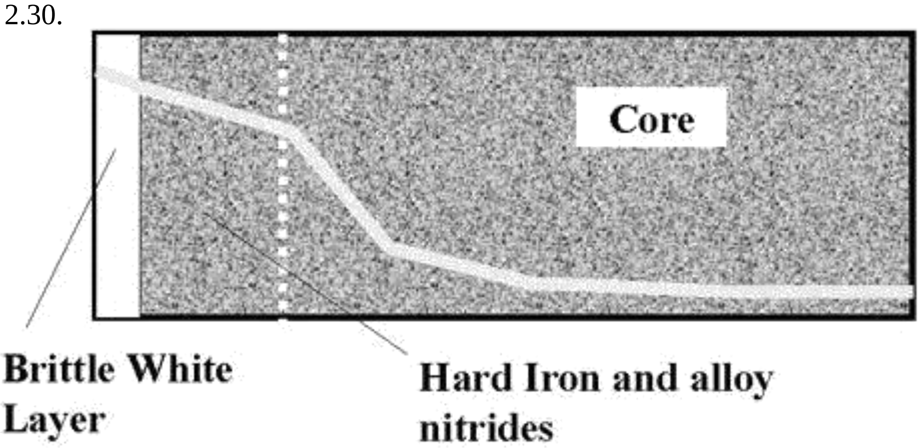


Figure 2.31

The white layer shown in Figure 4 has a detrimental effect on the fatigue life of nitrided parts, and it is normally removed from parts subjected to severe service. Two stage gas-nitriding processes can be used to prevent the formation of white layer. White layer thickness may vary between 0.0003 and 0.002 in. which depends on nitriding time. The most commonly nitrided steels are chromium-molybdenum alloy steels and Nitralloys. Surface hardness of 55 HRC to 70 HRC can be achieved with case depths varying from 0.005 in to 0.020 in. Nitrided steels are very hard and grinding operations should not be performed after nitriding. White layer is removed by lapping.

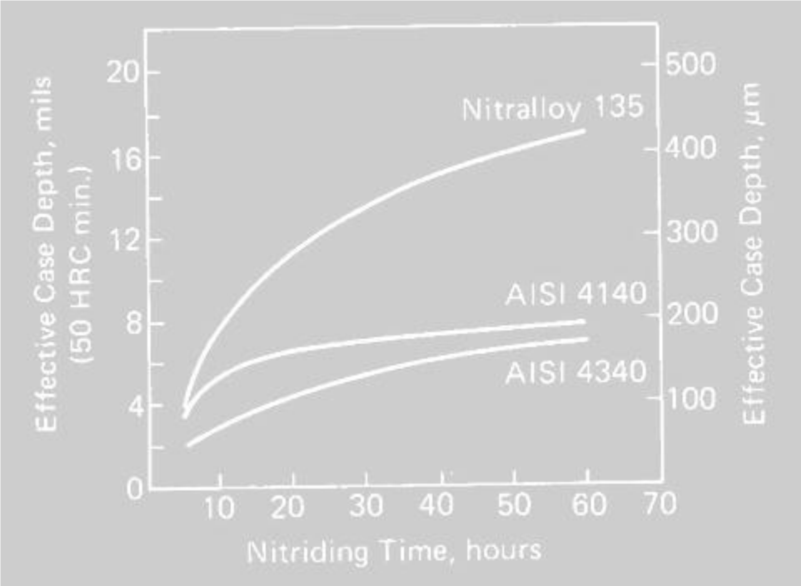


Figure 2.31 Nitriding time for various types of alloy steels

CARBURISING Vs. NITRIDING

Gas nitriding is emerging as the significant surface hardening process for today's and future industry, constituting a viable alternative to the well-established carburizing process. Most gears, shafts, hubs, pins and other parts are carburized in mass production to various case depths with accurate carbon potential control. Yet, carburizing is handicapped by several disadvantages. Below table compares certain important features of the two processes.

FEATURE COMPARED	CARBURISING	NITRIDING
Material compatibility	Limited selection of steel types	Wide variety of steel grades, including austenitic stainless, maraging and precipitation – hardening range
Typical treatment temperature	850 – 950°C	460-600°C
Accompanying heat treatment	Requires hardening and tempering (optionally: sub-zero treatment)	No additional treatment required
Finish Machining	Often requires costly grinding	In most cases, does NOT require finish grinding
Distortion	May be substantial	Due to lower heat treatment temperature and absence of transformation in bulk material, distortion minimum to nil
Surface cleanliness	In most cases requires washing to remove quenching oil	After nitriding, surface ready for shipping
Surface hardness	60 – 65 HRC	Depending on steel grade, may reach 70 HRC
Corrosion resistance	High carbon concentrations are conductive to stress corrosion cracking	Compound layer enhances corrosion resistance (with the exception of stainless steels)

Carbonitriding:

Carbonitriding is a modified form of gas carburizing, rather than a form of nitriding. The modification consists of introducing ammonia into the gas carburizing atmosphere to add nitrogen to the carburized case as it is being produced. Nascent nitrogen forms at the work surface by the dissociation of ammonia in the furnace atmosphere; the nitrogen diffuses into the steel simultaneously with carbon. Typically, carbonitriding is carried out at a lower temperature and for a shorter time than is gas carburizing, producing a shallower case than is usual in production carburizing.

Carbonitriding is used primarily to impart a hard, wear-resistant case, generally from 0.075 to 0.75 mm (0.003 to 0.030 in.) deep. A carbonitrided case has better hardenability than a carburized case. Consequently, by carbonitriding and quenching, a hardened case can be produced at less expense within the case-depth range indicated, using either carbon or low-alloy steel. Full hardness with less distortion can be achieved with oil quenching, or, in some instances, even gas quenching, employing a protective atmosphere as the quenching medium.

Steels commonly carbonitrided include those in the AISI 1000, 1100, 1200, 1300, 1500, 4000, 4100, 4600, 5100, 6100, 8600, and 8700 series, with carbon contents up to about 0.25%. Also, many steels in these same series with a carbon range of 0.30 to 0.50% are carbonitrided to case depths up to about 0.3 mm (0.01 in.) when a combination of a reasonably tough, through-hardened core and a hard, longwearing surface is required (shafts and transmission gears are typical examples). Steels such as 4140, 5130, 5140, 8640, and 4340 for applications like heavy-duty gearing are treated by this method at 845°C (1550°F).

Often, carburizing and carbonitriding are used together to achieve much deeper case depths and better engineering performance for parts than could be obtained using only the carbonitriding process. This process is applicable particularly with steels with low case hardenability, that is, the 1000, 1100, and 1200 series steels. The process generally consists of carburizing at 900 to 955°C (1650 to 1750°F) to give the desired total case depth (up to 2.5 mm. or 0.100 in.), followed by carbonitriding for 2 to 6 h in the temperature range of 815 to 900°C (1500 to 1650°F) to add the desired carbonitrided case depth. The subject parts can then be oil quenched to obtain a deeper effective and thus harder case than would have resulted from the carburizing process alone. The addition of the carbonitrided surface increases the case residual compressive stress level and thus improves contact fatigue resistance as well as increasing the case strength gradient.

When the carburizing/carbonitriding processes are used together, the effective case depth (50 HRC) to total case depth ratio may vary from about 0.35 to 0.75 depending on the case hardenability, core hardenability, section size, and quenchant used.

The fundamental problem in controlling carbonitriding processes is that the rate of nitrogen pick-up depends on the free ammonia content of the furnace atmosphere and not the percentage of ammonia in the inlet gas. Unfortunately, no state-of-the-art sensor for monitoring the free ammonia content of the furnace atmosphere has yet been developed.

Case Composition. The composition of a carbonitrided case depends on the type of steel and on the process variables of temperature, time, and atmosphere composition. In terms of steel type, the case depth achieved during a given carbonitriding process will be lower in steels containing higher amounts of strong nitride formers such as aluminum or titanium.

In terms of process variables, the higher the carbonitriding temperature, the less effective is the ammonia addition to the atmosphere as a nitrogen source, because the rate of spontaneous decomposition of ammonia to molecular nitrogen and hydrogen increases as the temperature is raised.

At a given temperature, the fraction of the ammonia addition that spontaneously decomposes is dependent on the residence time of the atmosphere in the furnace: the higher the total flow of atmosphere gases, the lower the fraction of the ammonia addition that decomposes to nitrogen and hydrogen. The addition of ammonia to a carburizing atmosphere has the effect of dilution by the following reaction:

$$2NH_3 \rightarrow N_2 + 3H_2$$

Dilution with nitrogen and hydrogen affects measurements of oxygen potential in a similar manner; the carbon potential possible with given oxygen potential is higher in a carburizing atmosphere than in a carbonitriding atmosphere. Water vapor content, however, is much less affected by this dilution. Thus, the amount of dilution and its resulting effect on the atmosphere composition depends on the processing temperature, the amount of ammonia introduced, and the ratio of the total atmosphere gas flow rate to the volume of the furnace.

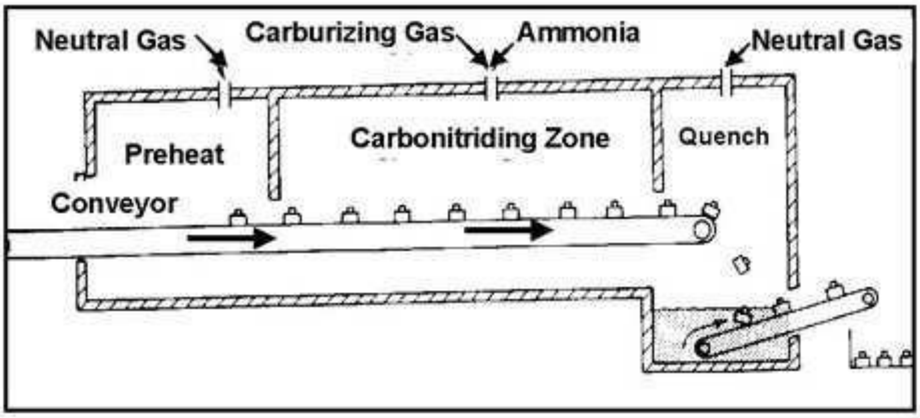
Depth of Case. Preferred case depth is governed by service application and by core hardness. Case depths of 0.025 to 0.075 mm (0.001 to 0.003 in.) are commonly applied to thin pans that require wear resistance under light loads. Case depths up to 0.75 mm (0.030 in.) may be applied to parts for resisting high compressive loads. Case depths of 0.63 to 0.75 mm (0.025 to 0.030 in.) may be applied to shafts and gears that are subjected to high tensile or compressive stresses caused by torsion, bending, or contact loads.

Medium-carbon steels with core hardness of 40 to 45 HRC normally require less case depth than steels with core hardness of 20 HRC or below. Low-alloy steels with medium-carbon content, such as those used in automotive transmission gears, are often assigned minimum case depths of 0.2 mm (0.008 in.).

Measurements of the case depths of carbonitrided parts may refer to effective case depth or total case depth, as with reporting case depths for carburized parts. For very thin cases, usually only the total case depth is specified. In general, it is easy to distinguish case and core microstructures in a carbonitrided piece, particularly when the case is thin and is produced at a low carbonitriding temperature; more difficulty is encountered in distinguishing case and core when high temperatures, deep cases, and medium-carbon or high-carbon steels are involved. Whether or not the core has a martensitic structure is also a contributing factor in case-depth measurements.

Hardenability of Case. One major advantage of carbonitnding is that the nitrogen absorbed during processing lowers the critical cooling rate of the steel. That is, the hardenability of the case is significantly greater when nitrogen is added by carbonitriding than when the same steel is only carburized. This permits the use of steels on which uniform case hardness ordinarily could not be obtained if they were only carburized and quenched. Where core properties are not important, carbonitriding permits the use of low-carbon steels, which cost less and may have better machinability or formability.

This process involves with the diffusion of both carbon and nitrogen into the steel surface. The process is performed in a gas atmosphere furnace using a carburizing gas such as propane or methane mixed with several percent (by volume) of ammonia. Methane or propane serve as the source of carbon, the ammonia serves as the source of nitrogen. Quenching is done in a gas which is not as severe as water quench. As a result of les severe quench, there is less distortion on the material to be treated. A typical carbonitriding system is shown in the following slide. Case hardnesses of HRC 60 to 65 are achieved at the surface.(Not as high as nitrided surfaces.) Case depths of 0.003 to 0.030 in can be accomplished by carbonitriding. One of the advantages of this process is that it can be applied to plain carbon steels which give significant case depths. Carbonitriding gives less distortion than carburizing. Carbonitriding is performed at temperatures above the transformation temperature of the steels (1400 ^{o}F -to 1600 ^{o}F)



Conveyor Hearth Carbonitriding

Figure 2.32

Applications. Although carbonitnding is a modified carburizing process, its applications are more restricted than those of carburizing. As has been stated previously, carbonitriding is largely limited to case depths of about 0.75 mm (0.03 in.) or less, while no such limitation applies to carburizing. Two reasons for this are: carbonitriding is generally done at temperatures of 870°C (1600°F) and below, whereas, because of the time factor involved, deeper cases are produced by processing at higher temperatures; and the nitrogen addition is less readily controlled than is the carbon addition, a condition that can lead to an excess of nitrogen, and, consequently, to high levels of retained austenite and case porosity when processing times are too long.

The resistance of a carbonitrided surface to softening during tempering is markedly superior to that of a carburized surface. Other notable differences exist in terms of residual-stress pattern, metallurgical structure, fatigue and impact strength at for many applications, carbonitriding the less expensive steels will provide properties equivalent to those obtained in gas carburized alloy steels.

CASE HARDENING

Induction Hardening:

In this process an electric current flow is induced in the work piece to produce a heating action. Every electrical conductor carrying a current has a magnetic field surrounding the conductor. Since the core wire is a dead-end circuit, the induced current cannot flow anyplace, so the net effect is heating of the wire. The induced current in the core conductor alternates at frequencies from 60 cycles per second (60 Hz) to millions of Hertz. The resistance to current flow causes very rapid heating of the core material. Heating occurs from the outside inward. Induction hardening process includes water quench after the heating process. The big advantage of this system is its speed and ability to confine heating on small parts. The major disadvantage is the cost.

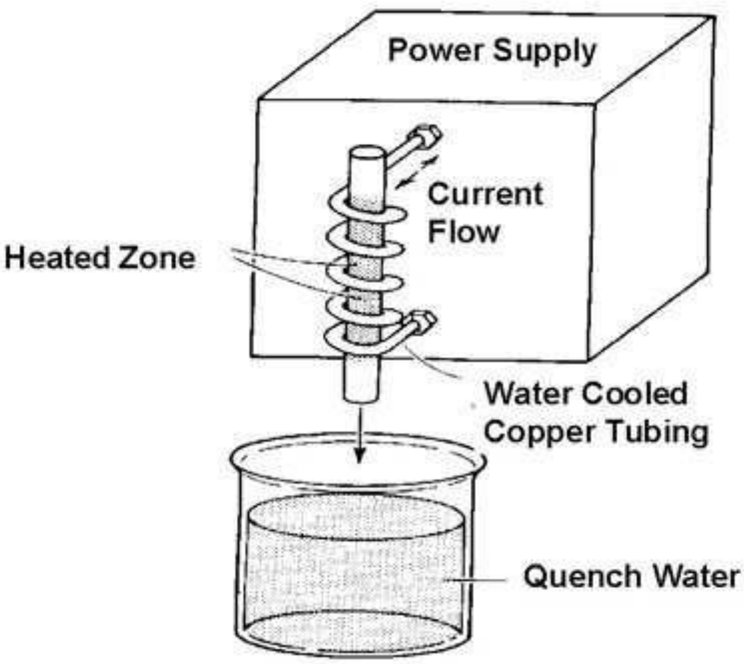


Figure 2.33. Induction hardening

Flame Hardening:

Flame hardening is the process of selective hardening with a combustible gas flame as the source of heat for austenitizing. (The material should have at least 0.40 % Carbon content to allow hardening.) Water quenching is applied as soon as the transformation temperature is reached. The heating media can be oxygen acetylene, propane, or any other combination of fuel gases that will allow reasonable heating rates. This procedure is applied to the gear teeth, shear blades, cams, ways on the lathes, etc.

Flame hardening temperatures are around 1500oF. Up to HRC 65 hardness can be achieved. For best results the hardness depth is 3/16 inch.

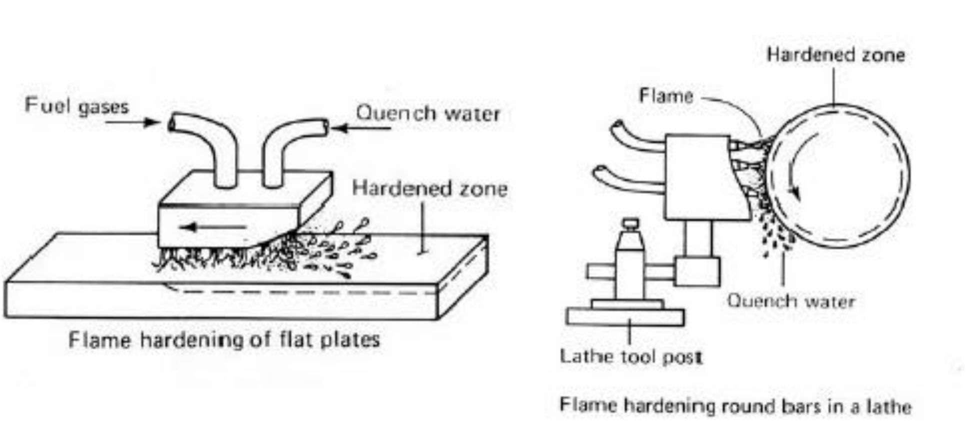


Figure 2.34 Flame hardening

There are three methods of flame hardening are

(1) SPOT Flame Hardening: Flame is directed to the spot that needs to be heated and hardened.

(2) SPIN Flame Hardening: The workpiece is rotated while in contact with the flame

(3) PROGRESSIVE Flame Hardening: The torch and the quenching medium move across the surface of the workpiece.

How to Select the Right Surface Hardening Method:?

(1) Carburizing is the best method for low carbon steels.

(2) Nitriding is a lower distortion process than carburizing but it can be used for certain type of steels such as chromium-molybdenum alloy steels or Nitralloy-type steels.

(3) Flame hardening is preferred for heavy cases or selective hardening of large machine components.

(4) Induction hardening works best on parts small enough and suitable in shape to be compatible with the induction coil.

(5) Electron beam and laser hardening are limited to the low alloy steels and plain carbon steels only.