THE HEAT TREAT DOCTOR

About the columnist . . .

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Dan's credentials include his appointment as a research associate professor at the Thermal Processing Technology Center, Illinois Institute of Technology, Chicago. He also serves on the ASM Heat Treating Society Board and is active on several HTS Committees.

Comparing Carbonitriding and Nitrocarburizing

Understanding the terminology of heat treating is often a challenge since we sometimes use one word when we really mean another. As engineers, we often know the names but don't fully comprehend what they mean, as was the case at a recent gear symposium when the question was asked, "I've heard everyone using the terms carbonitriding and nitrocarburizing as if they were two different case hardening processes. I always thought they were one in the same. What's the real difference between them?"

It was time to call "the Doctor" for help.

Part of the confusion lies in the fact that carbonitriding has been known by many names over the years, including "dry cyaniding," "gas cyaniding," "nicarbing," and . . . "nitrocarburizing"! It is this last designation that is often the source of confusion. Let's look at these two case hardening processes and examine their similarities and differences.

The carbonitriding process

Carbonitriding is a modified carburizing process, not a form of nitriding. This modification consists of introducing ammonia into the carburizing atmosphere in order to add nitrogen to the carburized case as it is being produced (Fig. 1).

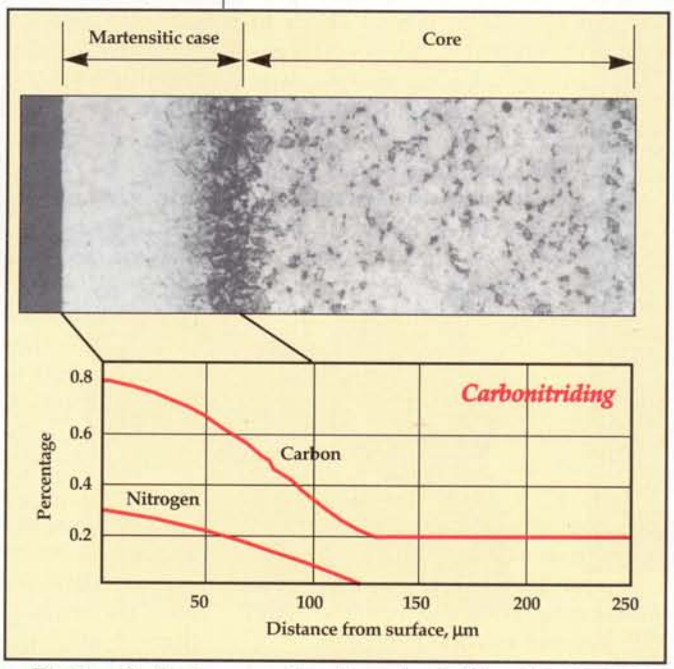


Fig. 1 — Surface layers produced by carbonitriding of steel at 850°C (1560°F), where carbon predominates in the formation of a martensitic layer. (Ref. 1)

Typically, carbonitriding is done at a lower temperature than carburizing — between 700 and 900°C (1300 and 1650°F) — and for a shorter time. Combine this with the fact that nitrogen inhibits the diffusion of carbon, and what generally results is a shallower case than is typical for carburized parts. A carbonitrided case is usually between 0.075 and 0.75 mm (0.003 and 0.030 in.) deep.

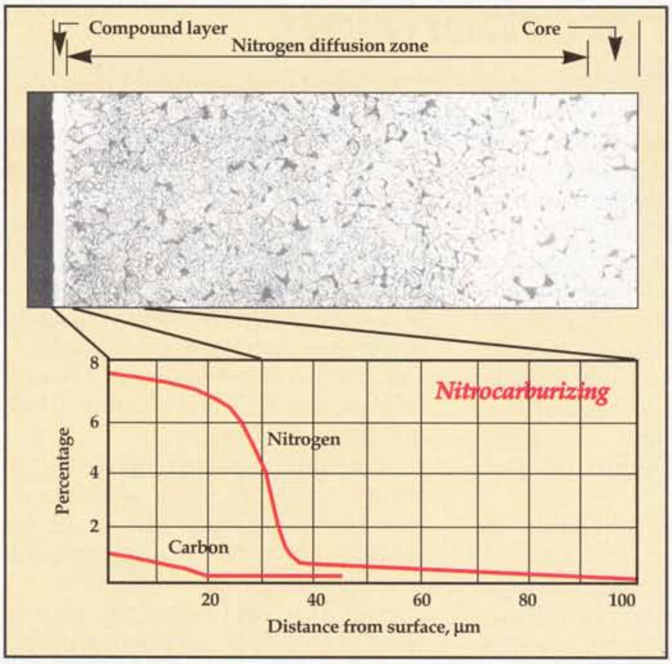
It is important to note that a common contributor to nonuniform case depths is to begin the ammonia addition before the load is stabilized at temperature. This mistake often occurs in furnaces that start gas additions as soon as the set point recovers. It's better to introduce a time delay for the entire load to reach temperature. Remember, too, that when the ammonia addition ends, desorption of nitrogen begins.

The temperature range for carbonitriding is not arbitrary. At higher austenitizing temperatures, the thermal decomposition of ammonia is too rapid, limiting nitrogen availability. At lower temperatures, a brittle structure is formed. Also, operating furnaces below 760°C (1400°F) can pose a safety concern.

Nitrogen content: The nitrogen in carbonitrided steel enhances hardenability and makes it possible to form martensite in plain carbon and low-alloy steels that initially have low hardenability. Examples include AISI 1018, 12L14, and 1117. The nitrides formed contribute to a high surface hardness.

Nitrogen, like carbon, manganese, and nickel, is an austenite stabilizer, so retained austenite is a concern after quenching. Lowering the ammonia percentage will reduce the amount of retained austenite and should be done if decreases in hardness or wear resistance cannot be tolerated. Another consequence of too-high nitrogen is the formation of voids or porosity. In general, the nitrogen content at the surface should be no greater than 0.40%.

A common carbonitriding variation is to introduce ammonia near the end of the carburizing cycle, typically 15 to 30 minutes before the load is quenched. Any loss of hardenability



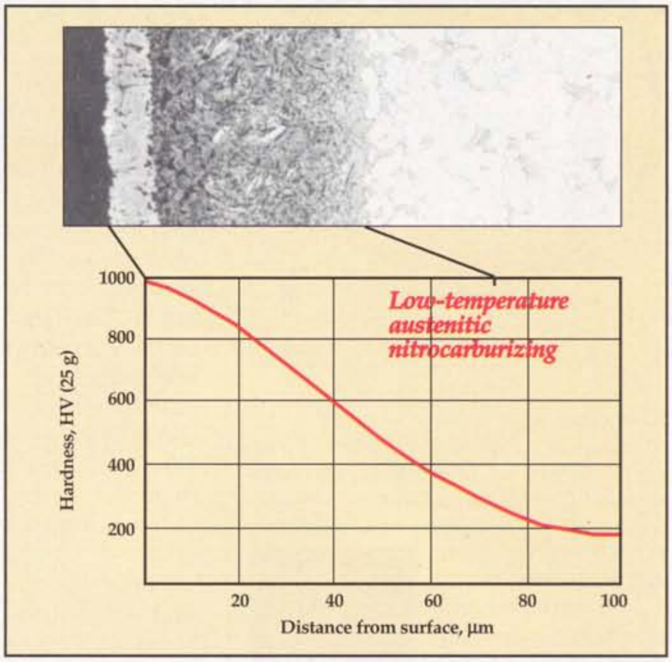


Fig. 2 — Surface layer produced by (ferritic) nitrocarburizing at 570°C (1060°F), where nitrogen is the predominant element in the epsilon (ε) carbonitride layer. (Ref. 1)

Fig. 3 — Surface layers produced by low-temperature austenitic nitrocarburizing at 700°C (1290°F). Beneath the ε-carbonitride layer is a layer of martensite and/or bainite. (Ref. 1)

that might occur due to internal (or intergranular) oxidation is partially offset by the nitrogen absorption.

Temper resistance: Several other points are worth mentioning. The nitrogen in the carbonitrided case increases the steel's resistance to softening on tempering, just like some alloying elements do. The greater the nitrogen content, the greater the resistance to softening. This is why higher tempering temperatures — up to 225°C (440°F) — are often used on carbonitrided parts.

The resistance to tempering manifests itself in improved wear resistance. Carbonitrided gears, for example, often exhibit better wear properties than carburized gears. In addition, many shallow-case, thin-section parts made of unalloyed steel, such as die-cutting punches, can be used without tempering.

The nitrocarburizing process

Today, "ferritic nitrocarburizing" is commonly called simply "nitrocarburizing." (It's no wonder that people are confused: remember that "nitrocarburizing" is a former label for carbonitriding!)

(Ferritic) nitrocarburizing: Basically, nitrocarburizing is a modification of nitriding, not a form of carburizing. In the process, nitrogen and carbon are simultaneously introduced into the steel while it is in a ferritic condition; that is, at a temperature below that at which austenite begins to form during heating (Fig. 2).

Nitriding is typically done using ammonia, with or without dilution of the atmosphere by dissociated ammonia or a nitrogen/hydrogen mixture, in the 495 to 565°C (925 to 1050°F) temperature range. By comparison, nitrocarburizing is typically performed at 550 to 600°C (1025 to 1110°F) in an atmosphere of 50% endothermic gas + 50% ammonia, or 60% nitrogen + 35% ammonia + 5% carbon dioxide. Other atmospheres, such as 40% endothermic gas + 50% ammonia + 10% air, also are used. The presence of oxygen in the atmosphere activates nitrogen transfer kinetics .

Nitrocarburized case: A complex sequence is involved in the formation of a nitrocarburized case. Of importance here is that normally a very thin layer of single-phase epsilon (ε) carbonitride is formed between 450 and 590°C (840 and 1095°F). The thickness of this white or compound layer is a function of gas composition and gas volume (flow). Associated with the compound layer is an underlying diffusion zone containing iron (and alloy) nitrides and absorbed nitrogen.

The compound layer has excellent wear and antiscuffing properties and is produced with minimum distortion. The diffusion zone, provided it is substantial enough, improves fatigue properties such as endurance limit, especially in carbon and low-alloy steels. The diffusion zone also is responsible for some of the increased hardness of the nitrocarburized case, especially in the more highly alloyed steels that contain strong nitride formers.

Porosity: It is not uncommon to observe porosity in the compound layer due to a carburizing reaction at the steel surface. This reaction influences the nitriding kinetics and therefore the degree and type of porosity at the surface of the ε-carbonitride layer. Three types of layer can be produced: no porosity, sponge porosity, or columnar porosity. Some applications require deep, nonporous ε layers. Others applications where, for example, optimum corrosion resistance is needed benefit from the presence of sponge porosity. Still others benefit from columnar porosity where oil retention can enhance wear resistance.

Nitrocarburizing is often followed by an oxidizing treatment to enhance both corrosion resistance and surface appearance.

Austenitic nitrocarburizing: To add somewhat to the confusion, there's also the low-temperature austenitic nitrocarburizing process. It is performed in the 675 to 775°C (1250 to 1425°F) temperature range. (The ferrite-to-austenite transformation temperature is 723°C [1333°F].) The process can be controlled to produce a surface compound layer of ε carbonitride with, upon quenching, a subsurface layer of bainite and/or martensite that provides a good support structure for the hard surface.

The microstructure produced by low-temperature austenitic nitrocarburizing (Fig. 3) is particularly useful in intermediate-stress, point-contact-resistance applications such as helical gears.

Hopefully, you now have a better understanding of the differences between the carbonitriding and nitrocarburizing processes. **HTP**

Reference

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How useful did you find the information presented in this column?
Very useful, **Circle 273**
Of general interest, **Circle 274**
Not useful, **Circle 275**

Generic and practical information presented here is not intended to replace or supplement federal, state, and local codes, government standards, insurance requirements, company policies and procedures, or common sense. In addition, all equipment manufacturers' instructions and operating and maintenance manuals should always be thoroughly read and followed. Further, personnel training should be provided unequivocally to everyone who will be associated with operating such equipment.