Improving Wear with a Novel Heat-Treatment Method

January 11, 2019

Service Heat Treating, a commercial heat-treating company located in Milwaukee, Wis., has developed an alternative heat-treatment process known as **WearAll**™ that has shown to provide better wear resistance than carbonitriding for a number of critical-service components. The company's goals are to help customers optimize part performance and to service customers in the Midwest by having the latest technology in batch integral atmosphere quench, vacuum and gas nitriding/nitrocarburizing furnaces.

This article will focus on an example of plain-carbon steel component parts that require added strength and wear resistance while being prone to distortion during carbonitriding. The WearAll™ process substantially reduced distortion and provided wear properties not otherwise achievable.

The Problem

Plain-carbon steel stampings such as brake levers (Fig. 1) require added strength and wear resistance but are prone to distortion during the relatively high-temperature process of carbonitriding. The manufacturer of this part initially specified the carbonitriding process, but the part distorted to an unacceptable level. Alternatively, ferritic nitrocarburizing (FNC) was used to minimize distortion, but the wear resistance was insufficient to prevent loss of material on the critical slot edge.

Fig. 1. Brake lever processed using **WearAll**™

The Challenge

Transforming the case of low-carbon steel to a fully martensitic and wear-resistant structure is commercially performed with the carbonitride and oil-quench process. This process, however, does not always optimize wear characteristics and is highly dependent on the grain size, the specific percentage of elements making up a particular heat of steel and the severity of the quench. In addition, holding close dimensional tolerances using carbonitriding is not always possible.

To meet the challenge of providing maximum wear protection while minimizing distortion, a specialized austenitic nitrocarburizing (ANC) process was developed. FNC is often thought to be a solution to this type of problem since its benefits include less distortion, added wear resistance and strength. However, it is not always robust enough for parts requiring maximum wear protection.

The Solution

The lever was processed using **WearAll**™, which provided the needed wear resistance and dimensional stability. Additionally, **WearAll**™ provided enough corrosion protection to eliminate the need for a zinc-phosphate coating. This is one of many parts being processed at Service Heat Treating with **WearAll**™. A new furnace (Fig. 2) is being installed to add capacity.

Fig. 2. Integral-quench furnace running the **WearAll**™ process

Confirmation

Two separate sets of SAE 1018 parts and test coupons were prepared to compare the hardness (Fig. 3) and wear resistance (Fig. 4) of the **WearAll**™, carbonitriding with a total case depth of approximately 0.30 mm (0.012 inch) and ferritic nitrocarburizing processes with a compound layer thickness of 0.013 mm (0.0005 inch). Wear was measured by volume of material lost during a dry-sand rubber-wheel abrasion test per ASTM G65 (Procedure E).

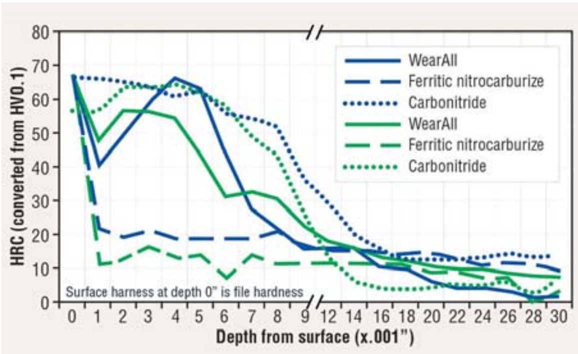

Fig. 3. Hardness test data

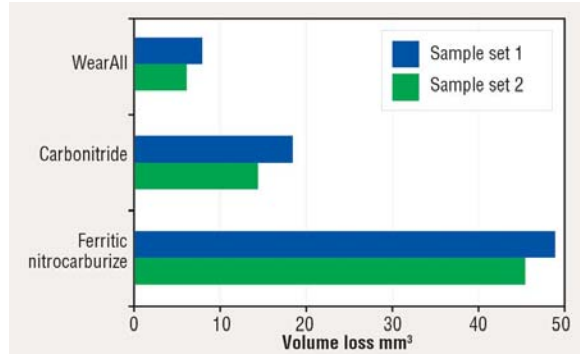

Fig. 4. Wear test data per ASTM G65

What is ANC, and how does it differ from similar case-hardening processes?

Austenitic Nitrocarburizing (ANC)

The low-temperature austenitic process associated with nitrocarburizing is performed in the 675-775°C (1250-1425°F) temperature range. The ferrite-to-austenite transformation temperature for the iron-carbon system is 723°C (1333°F). ANC can be controlled to produce a compound layer of iron, nitrogen and carbon. Upon quenching, a beneficial subsurface layer of austenite is retained, which can be subsequently transformed to martensite by freezing and/or tempering to provide a good support structure for the hard surface. It should be noted that there was almost no difference in the wear test result of a sample that was transformed with freezing and tempering and a sample that was tested as-quenched.

The microstructure produced by the austenitic process

(Fig. 5) results in a matrix of tempered martensite with a relatively thick white layer, which is particularly useful in providing wear resistance and anti-galling in intermediate-stress applications.

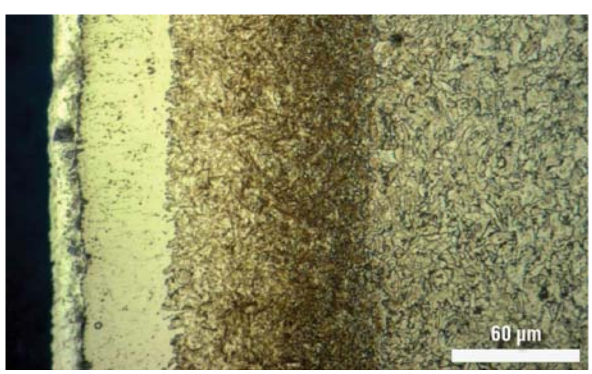

Fig. 5. Microstructure resulting from the **WearAll**™ process (400X, 3% Nital)

Carbonitriding (CN)

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. 6).

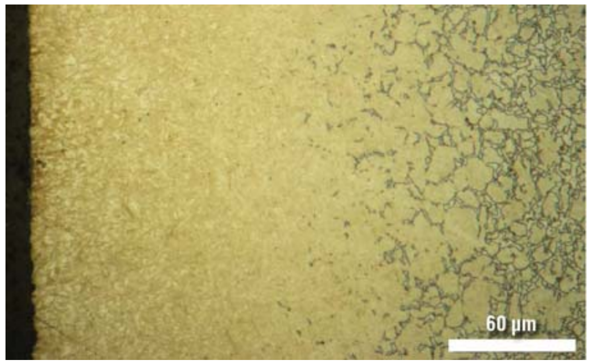

Fig. 6. Carbonitrided sample used for comparative analysis

Typically, carbonitriding is done at a lower temperature than carburizing in the range of 790-900°C (1450-1650°F) and for a shorter time. A CN case is usually between 0.075 and 0.75 mm (0.003 and 0.030 inch) deep. The CN temperature range is not arbitrary. At higher austenitizing temperatures the thermal decomposition of ammonia is too rapid, limiting nitrogen availability.

The nitrogen in CN steel enhances hardenability by making it more likely to form martensite in plain-carbon steels that initially have low hardenability. Examples include SAE 1018, 12L14, 1117 and 1026. The nitrides formed contribute to a high surface hardness.

The influence of prior austenite grain size on the microstructure of CN steels has been documented.[4] Intermediate transformation products are softer than martensite and form initially at grain boundaries if cooling is not sufficiently fast enough to produce complete martensitic transformation. As the grain size decreases, the grain-boundary area increases as do the sites for intermediate-transformation products. It is difficult to get complete transformation when carbonitriding low-carbon steels with small grains (ASTM 8-10) and minimal alloying elements, which can make the process very unpredictable.

Ferritic Nitrocarburizing (FNC)

A complex sequence is involved in the formation of a ferritic nitrocarburized case. Of importance here is that a very thin layer (typically less than 0.025 mm or 0.001 inch) of single-phase epsilon (e) carbonitride is normally formed between 450°C and 590°C (840-1095°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 anti-scuffing properties and is produced with minimum distortion. The diffusion zone – provided it is substantial enough – improves fatigue properties, especially in carbon and low-alloy steels. The diffusion zone is also responsible for some of the increased hardness of the FNC case, especially in the more highly alloyed steels that contain strong nitride formers. Nitrocarburizing is often followed by an oxidizing treatment to enhance both corrosion resistance and surface appearance.

Fundamental Differences Between the Various Case-Hardening Processes

The FNC process is a low-temperature process that results in a high concentration of nitrogen in the case. Carbonitriding, which is run at higher temperatures, results in a smaller percentage of nitrogen added to the subsurface layer. This nitrogen is in solution and primarily used to promote transformation of the case region to martensite. By contrast, ANC can be considered a hybrid of these two processes, used to produce both a case rich in nitrogen and a martensitic structure underneath.

Conclusion

The use of a modified austenitic nitrocarburizing process offers a new direction for companies hoping to avoid part distortion and improve wear characteristics on low-carbon steels. Stampings, drawn-over-mandrel components and many others are good candidates for this technology.

Service Heat Treating is currently processing production parts with the **WearAll**™ process. These parts have traditionally been processed by carbonitriding.

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