W. D. Kehr
H. E. Seese

Surface Attack in Chromium-Iron Alloys

Welchner and Roush[1] used the term "surface attack" to describe supposed grain-boundary oxide deposits which they observed at and immediately beneath the surface of case-carburized steel parts. Hultgren and Hägglund[2] proposed that grain-boundary oxides could form during carburizing, provided certain alloying elements (such as chromium) having a greater affinity than iron for oxygen were present. The formation of iron or alloy nitrides[3] and the formation of certain hydrogen compounds[4] have been held responsible for the appearance of surface attack during gas carbonitriding.

It is well known that the presence of undesirable microconstituents can impair the mechanical properties of case-hardened parts. Reductions (on the order of 25%) in fatigue strength[5] and reductions in impact-fatigue endurance[6] due to surface attack have been reported. Thus, in the course of an investigation to determine whether oxygen, nitrogen, or hydrogen (or some combination of them) is the principal heat-treating atmosphere contributor to surface attack, it was of interest to study the effects of chromium additions on the extent of this phenomenon in gas-carbonitrided commercially pure (ingot) iron.

Annealed investment-cast ingot-iron specimens containing 0.20, 0.45, 0.91, 1.85 and 4.74% chromium were gas carbonitrided for 6, 12, 24, 48 and 96 minutes at 1550°F and oil quenched. The furnace atmosphere consisted of 250 CFH endothermic gas (AGA Class 301), 10 CFH natural (methane) gas, and 40 CFH ammonia gas, with a measured dew point 31° to 37°F.

The maximum depth of surface attack was metallographically measured on unetched cross sections cut from the various carbonitrided specimens. A portion of a typical cross section is shown in Fig. 1. The most severely attacked specimens were those containing 0.45% chromium, as shown in Fig. 2. No carbide or carbonitride networks were detected in the specimens after etching, but retained austenite to depths exceeding that of the attack was observed.

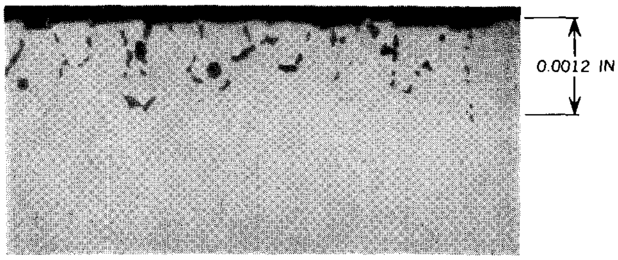

Figure 1 Surface attack in 0.45% Cr specimens carbonitrided for 24 min. × 500, unetched.

If surface attack is internal oxidation, i.e., if nascent (atomic) oxygen absorbed from the decomposition of carbon monoxide (the endothermic gas used contains a nominal 20% CO by volume) migrated to the grain boundaries and formed some chromium-oxygen compound or compounds, the observed maximums at 0.45% chromium might be explained by the following hypothesis. As can be seen in Fig. 2, the depth of attack increased as the chromium content increased up to 0.45%, since additional chromium was available for oxide formation. At higher concentrations it is reasonable to assume that the probability of an oxygen atom penetrating the surface and diffusing to a grain boundary would decrease with increasing chromium content such that oxidation would have more likely occurred on the surface than internally. No unusual surface oxidation was observed, however, since the furnace atmosphere was essentially carburizing,

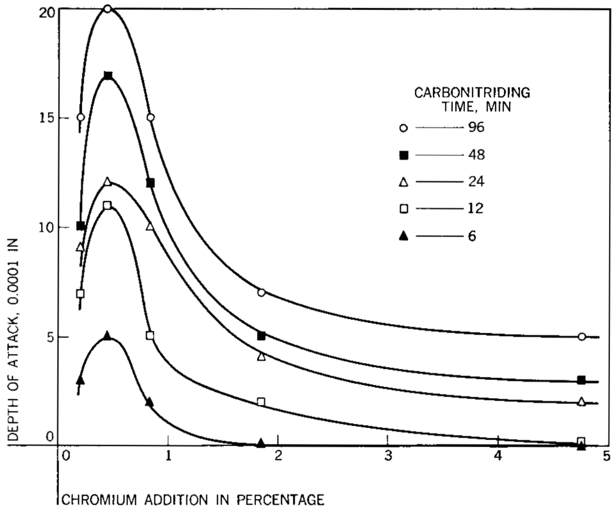

Figure 2 Variation of depth of surface attack with Cr additions.

i.e., reducing. Similar reasoning might be appropriate if the attack was caused by chromium-nitride formations, or some compound containing hydrogen and chromium, such as chromous hydroxide ($Cr(OH)_2$).

As a practical matter, it can be predicted that a carburizing grade of steel nominally containing about 0.50% chromium, e.g., AISI 8620, should be more susceptible to surface attack than either a plain carbon steel or a steel containing a greater percentage of chromium, such as AISI 5120 (0.70%–0.90% chromium).

References

1. J. Welchner and R. W. Roush, "Supposed Graphite in Carburized NE and S.A.E. Steels," *Metal Progress* **43,** 889–896 (1943).
2. A. Hultgren and E. Hägglund, "Carbide and Oxide in Surface Zones of Carburized Alloy Steels," *Am. Soc. Metals, Trans. Quart.* **39,** 820–837 (1947).
3. W. Scheuble and P. Wiest, "Bemerkungen zur Entstehung der Randoxydation bei der Aufkohlung und ähnlicker Erscheinungen beim Karbonitrieren," *Das Industrieblatt* **59,** 531–535 (1959).
4. G. Koves, "The Case-Hardening Response of Free-Machining Steel," *Am. Soc. Metals, Trans. Quart.* **56,** 351–360 (1963).
5. J. B. Bidwell et al., *Fatigue Durability of Carburized Steel,* ASM, Metals Park, Ohio, 1957, p. 40.
6. K. B. Valentine, "Structure and Properties of Some Carbo-Nitrided Cases," *Metal Progress* **63,** 97–103 (1953).

Received June 24, 1966