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A PROBLEM WITH NORMALIZING STEEL:

METALLURGICAL ANALYSIS OF AIRCRAFT SEAT HANDLE (flight Hardware)

GLOSSARY: "NORMALIZING" IS A HEAT TREATMENT USED TO RE CRYSTALLIZE STEELS FOLLOWING FORGING.

THE NORMALIZE PROCESS: THE STEEL IS HEATED TO ~1700°F, FOLLOWED BY COOLING IN STILL AIR.

RESULTING MICROSTRUCTURE: PEARLITE + FERRTIE

Background

An aircraft seat handle was forged from 4130 bar stock in a normal manner, employing open air furnaces for the purpose of heating the metal to the proper forging temperature. In the process of heating and forging at high temperature, all metal surfaces are expected to loose alloying elements; called "dealloying". Most folks in the industry often call this process as simply "decarburization", because carbon is the most significant element involved. Depending on the furnace conditions, time and temperature, decarburization / dealloying can be as much as 0.040" depth.

It is important to understand the good intentions of all parties involved with the making of this part. Although there were no specific requirements; the objective was to produce a part acceptable to all. With this in mind, the forge company sent the parts for a normalizing heat treatment. Upon receipt of the parts, the heat treat vendor opted to perform "endothermic normalizing", quench and temper, rather than cooling the metal slowly. The resulting microstructure was ***tempered martensite***.

The rationale used by the heat treat vendor to justify endothermic normalizing, oil quench and tempered to a soft condition, was to prevent additional loss of carbon during the normalizing process and to restore the decarburization caused by open air forging. The heat treat vendor did not understand the meaning of normalizing because Steel Mills today, understand the word "normalizing" in a procurement specification to mean, "metal must be heated to 1700°F"; how the metal is cooled is up to their discretion. The mill saves money by doing a quench and temper as opposed to slow cooling. Also, there is less decarburization / dealloying by quenching and tempering to a hardness range expected form a pearlite + ferrite microstructure. The problem with all of this wrong thinking is this: "tempered martenisitc microstructures crack when heated above the lower critical temperature of 1333°F, when being welded or hardened; pearlite + ferrite microstructure do not crack under the same conditions.

Following endothermic normalizing, the tempered martensite microstructure of the carbon restored surface area appears different than that of the base metal. In essence, the carbon restored surface becomes similar in appearance to a fine grain size AISI 1030 plain carbon steel, while the core metal remains a coarser grain size AISI 4130 alloy steel. This gives the incorrect impression that the part may have been subjected to carburization heat treatment rather then normalizing.

Rejection by Customer: Parts analyzed and rejected by the metallurgy department of the aircraft company as being "***carburized".***

The proof of correct processing of open air forged parts, which have been subjected to endothermic normalizing, regardless of microstructure, is to perform a microhardness traverse to determine the surface v. core hardness. "***A carbon restored surface is expected to be***

identical to core hardness." If the metal had been carburized, the carbon content would be at or above .8%, causing the tempered to be significantly harder than the .3% AISI 4130 steel base metal, following quench and tempering. ***Tempering*** produces the same hardness if the carbon content is the same on the surface and in the base metal core.

TBC Metallurgical Testing Proof:

Optical Microscopy:

Metallographic cross sections of two forged seat handles were prepared for optical microstructure examination using standard ASTM procedures. The microstructure of the carbon restored surface area and the core metal, along with Tukon-Knoop microhardness and scratch testing, are shown in Figures 1, 2 and 3.

Scratch Testing;

Although this test is somewhat unorthodox because of possible damage to the indenter, it is a very effective test to determine boundaries; hard and soft areas of microstructure etc. I usually perform this test before doing the microhardness traverse just to be sure the microhardness testing is conducted in the correct area. The scratch width is optically examined and measured in numerous areas, from surface to core, for width changes. When none are observed; the metal is assumed to be the same hardness.

Microhardness Testing:

The etched cross-section of one part was subjected to a microhardness test traverse to determine any changes in surface hardness from that of the core metal; see Figures 1,2 and 3. . The measured hardness is from 21.5 - 24.0 HRC; the average core hardness is 22.2 HRC. The part hardness is below 25 HRC / 125 ksi.

Discussion:

The microstructure of the carbon restored surface areas is tempered martensitic with a very fine dispersion of spheroidized carbide, as expected. The core microstructure is a coarser martensite. Because of dealloying, the carbon restored surface etches darker than that of the core metal.

The Tukon-Knoop microhardness testing conducted shows the carbon restored surface areas are the same hardness as the core AISI 4130 alloy steel. This finding should lay to rest any concerns about the surface metal being wrongly subjected to a carburizing process.

If quantitative verification of the surface carbon content becomes a requirement, a spectrographic analysis can be conducted (LECO Carbon Determination) to determine actual surface carbon content.

Conclusion:

These parts were wrongly processed and analyzed; an occurrence which happens much too often. The chief metallurgist of the aircraft company was terminated. The forge vendor and the heat treat vendor both received SCARs, "Supplier Corrective Action Request"; a written response form to justify what and why this variance occurred and to force the vendors to formulate procedures to prevent re-occurrence.

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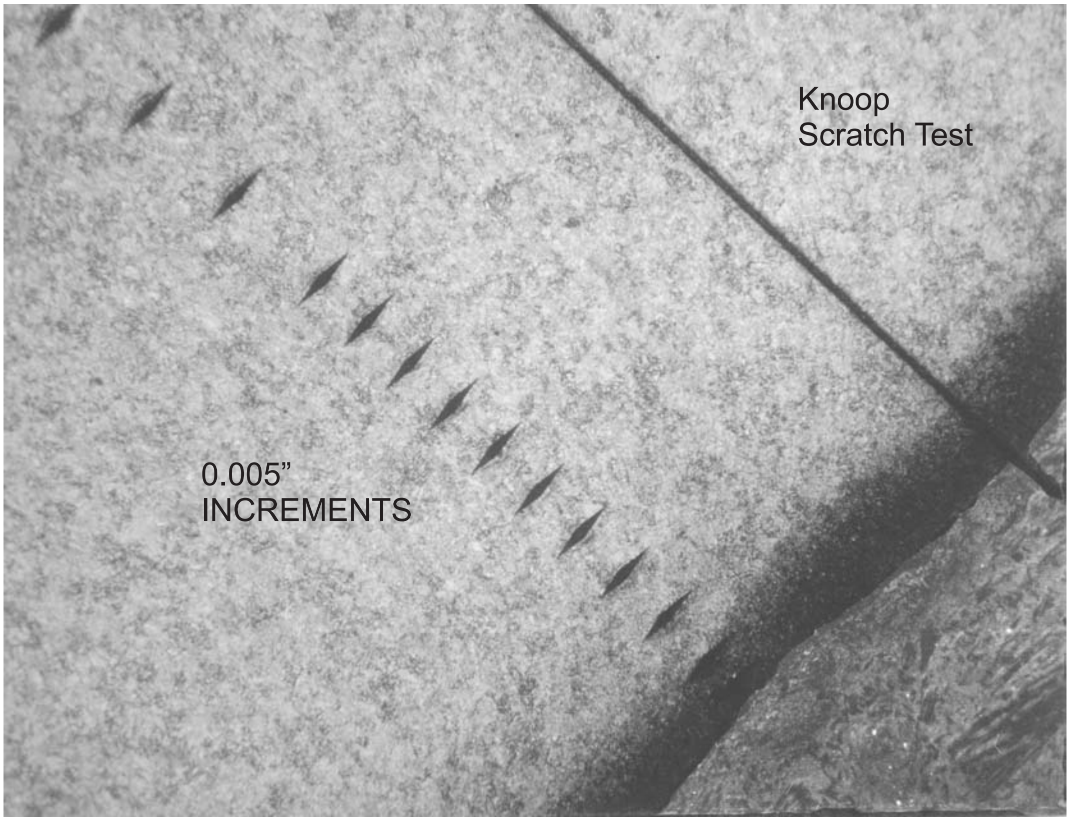
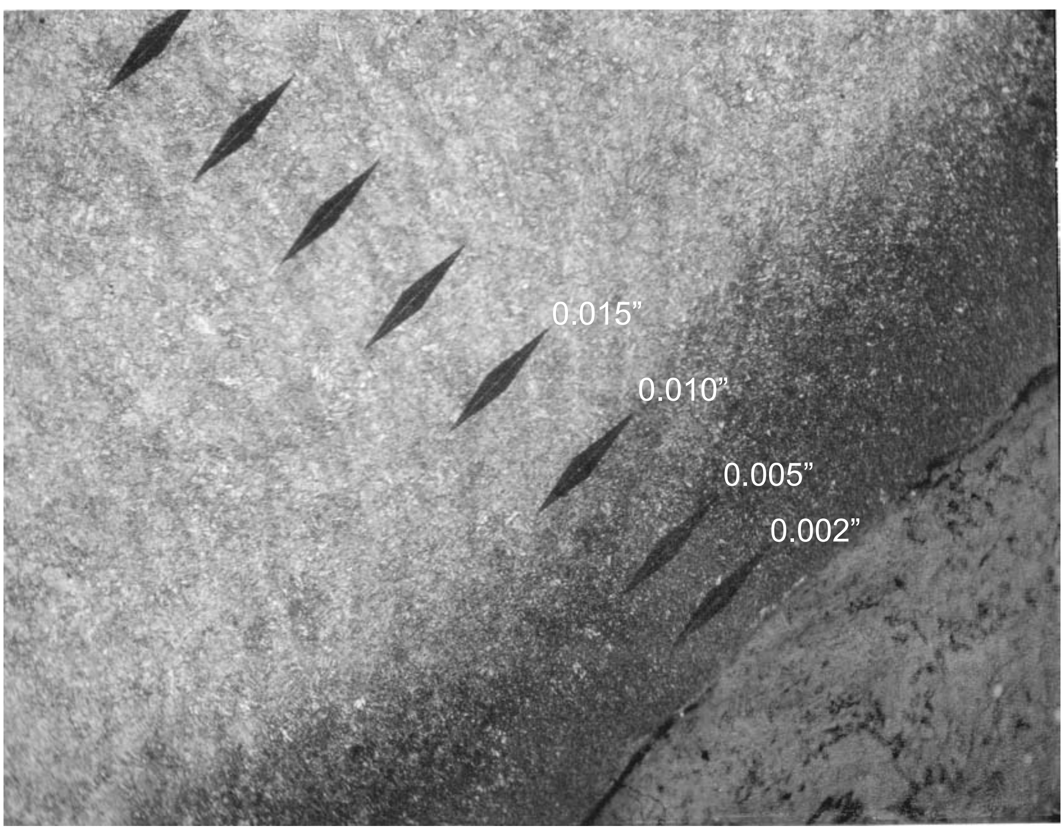


~30X Mag.

2% Nital Etch

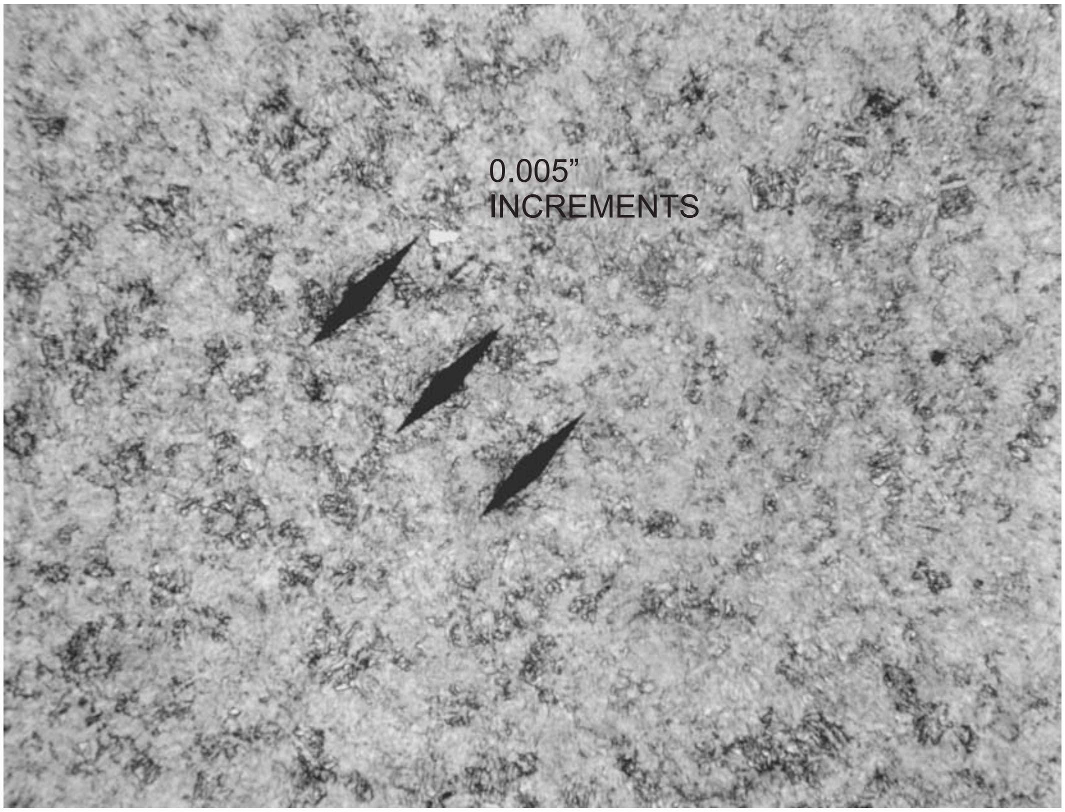
FIGURE 1. Random area selected for microhardness testing & scratch testing.



~125X Mag.

2% Nital Etch

FIGURE 2. At this mag., the carbon restoration extends into the metal ~0.010".



~125X Mag.

2% Nital Etch

FIGURE 3. This is a normal appearing martensitic microstructure expected when the metal has been normalized, quenched and tempered. The measured hardness is identical with that of the carbon restored surface.