RETAINED AUSTENITE STABILIZATION

IN CARBURIZED SAE 8620 ALLOY STEEL

Case-hardened components made of low-alloy steels often have retained austenite in the case after quenching, which can be transformed to martensite by further cooling of the component, even if the austenite stabilizes during aging at room temperature.

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The phenomenon of retained austenite stabilization in tool steels is well documented[1,2]. When a steel with a martensite finish temperature (M_f) below room temperature is quenched, some austenite is retained in the microstructure. If cooling is immediately continued to a temperature below the M_f, virtually all the austenite present at room temperature can be transformed to martensite. However, if there is a delay between quenching to room temperature and the further cooling, the austenite can stabilize and cannot then be transformed by subsequent cooling[3].

It is important to know if this phenomenon also applies to carburized low alloy steels used to make gears. As well as reducing hardness and wear resistance, retained austenite in the case of such components can later be transformed by applied stress, causing distortion during service. Retained austenite has also been reported to lead to cracking during grinding after heat treatment.

There is no agreement in the literature on the occurrence of stabilization, with some reports suggesting that it does not occur in carburized low alloy steels[4]. Others, however, report that it does occur[5, 6]; and some even suggest that its onset is very rapid[7]. Where stabilization is reported, it is generally associated with high alloy content, particularly nickel, and with

Cold treating gears after quenching.

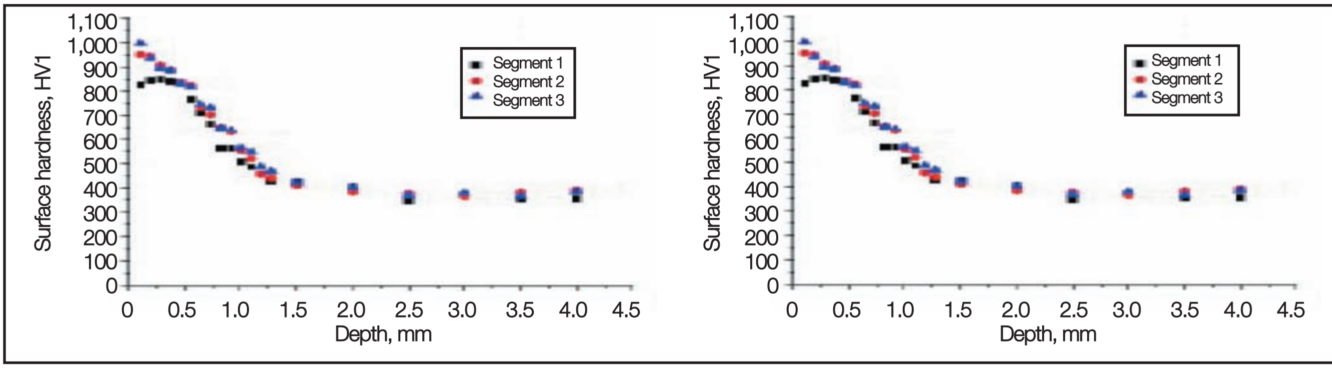

Fig. 1— Hardness profiles after cold treatment with different time delays.

Table 1 — Properties of the case before and after cold treatment

Treatment	Case depth at 550 HV, mm	Surface hardness, HV1 @ 0.1 mm	Retained austenite, %
As quenched	0.93	827	27.4
Cold after 2 min	1.01	951	10.4
Cold after 1h	1.07	997	8.8
Cold after 12 h	0.97	901	11.3
Cold after 24 h	1.02	956	11.6
Cold after 168 h	0.88	953	9.4

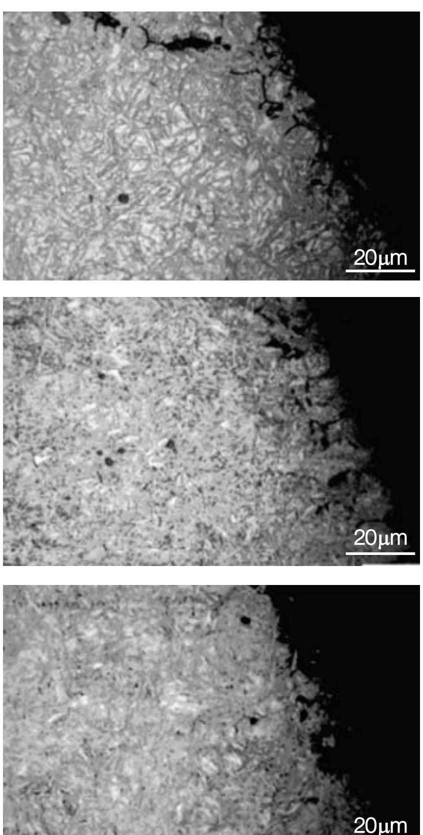

Fig. 2 — Microstructure of the near-surface case before and after cold treatment; (top) as-quenched; (middle) cold treated after 2 min; (bottom) cold treated after 168 h.

the presence of nitrogen in the case. The work reported here set out to show the effects of stabilization on a typical carburizing steel (SAE 8620) after carburizing in a typical industrial cycle without any added nitrogen.

Experimental Conditions

The SAE 8620 material for the tests was in the form of gear teeth. They were carburized in an industrial sealed quench furnace with the following cycle:

- Heat to 930°C with a carbon potential of 0.4% and soak for more than 190 minutes.
- Carburize at 930°C for 345 minutes at a carbon potential of 0.9%.
- Diffuse at 850°C for 150 min at a carbon potential of 0.75%.
- Oil quench until the samples reach 70°C.
- Cold treat at -120°C for 1hour, after delays of 2 minutes, 1 hour, 12 hours, 24 hours, and 168 hours.

After treatment, each sample was examined for microstructure, retained austenite (by x-ray diffraction) and hardness profile.

Testing Results

The hardness profiles for the different delay times are shown in Fig. 1. Photomicrographs of the case for one of the as-quenched samples that was cold treated within 2 minutes of quench and one cold treated after a delay of 168 hours are shown in Fig. 2. The structure within 20 µm of the surface has been affected by the migration of alloying elements through internal oxidation, which is normal for carburizing treatments carried out in endothermically generated atmospheres. There is no visible difference between the sample cold treated after 2 minutes and that cold treated after 168 hours.

The case depths obtained from the hardness traverses, the surface hardness, and the retained austenite levels obtained by x-ray diffraction are summarized in Table 1.

Discussion of Test Results

Retained austenite is thought to be stabilized by a pinning mechanism. During aging, carbon is redistributed by diffusion out of the martensite. The structure is then stabilized by interstitial carbon atoms pinning the austenite-martensite interface[5]. As pinning increases with the length of time after quenching, more energy is needed to restart the transformation to martensite; i.e., a lower cold treatment temperature is needed[8].

In general terms, some alloying additions are known to promote stabilization, particularly nickel, carbon, and nitrogen[5, 9]. Thus, the austenite in the cases of higher alloy carburizing steel with high carbon or carbonitrided cases will have a greater tendency to stabilize.

In industrial practice, the transformation temperature available is fixed and the stabilization effect is usually characterized by the time until the available cold treatment temperature will be able to restart the transformation. Assessing reports on the stabilization time must therefore take into account not only the composition of the austenite, but the cold treatment temperature used.

In the case of SAE 8620, under the experimental conditions using cold treatment at -120°C, this temperature was sufficient to restart transformation after all the stabilization times tested.

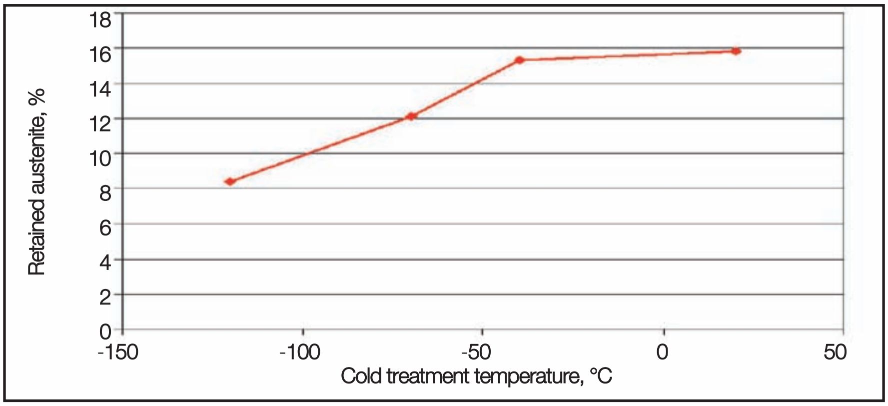

Fig. 3 — The effect of various cold treatment temperatures on the retained austenite in the case of SAE 8620 after l,680 h of stabilization.

This effect probably explains the disparity in the results found in the literature. It is likely that for low alloy carburizing steel, -120°C will always be sufficient to restart transformation, but any higher temperature may not be.

To test this theory, a second as-quenched sample gear was allowed to stabilize for 1,680 hours, and was then subjected to cold treatment at temperatures in the range -40 to -120°C for one hour. The results are shown in Fig. 3. Although not completely conclusive, as the same effect might have been found in samples immediately after quench, the results suggest that a cold treatment temperature of between -40 and -70°C was needed to restart transformation in this steel.

The quantity of retained austenite in this second sample gear in the as-quenched condition was found to be significantly lower than in the original sample gear, when it was tested shortly after quenching. To check if the retained austenite could have been reduced as a result of the time that elapsed between the two measurements, a second sample from this gear was checked. This sample was also found to contain less retained austenite (15.8%). To confirm that this was not simply a difference between the two gears, a sample from the first gear was retested and was found to contain 19% retained austenite, significantly less than when it was originally tested. The microstructure (Fig. 4) appears to contain some small bainite laths that could have formed during extended aging at room temperature. This suggests that the effect is real and is probably caused by isothermally reaching the bainite start condition after protracted aging at room temperature.

Conclusions

For carburized SAE 8620, cold treatment at -120°C is sufficient to restart the transformation of retained austenite to martensite after any stabilization period. The temperature necessary to restart the transformation after stabilization is probably in the range -40 to -70°C.

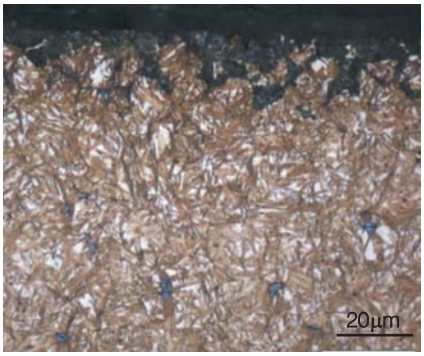

Fig. 4 — Microstructure of the case of a sample aged for 1,680 h at room temperature.

Recommendations

The results of this study were combined with a review of the available literature to develop a number of recommendations for best industrial practice for the cold treatment of case carburized components to remove retained austenite. It is obviously impractical to test every carburizing steel over a range of case compositions and available cold treatment temperatures, so the following guidelines can be used:

- The higher the alloy content (particularly nickel), the shorter the stabilization time and the lower the cold treatment temperature that should be used.
- The higher the case carbon content, the shorter the stabilization time and the lower the cold treatment temperature that should be used. Preemptive treatment of all components is preferable to attempting to recover components after over carburizing is discovered.
- The shorter the delay between quenching and cold treatment the better.
- The colder the treatment temperature the better. **HTP**

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