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RETAINED AUSTENITE IN STEELS

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ELECTRON-METALLOGRAPHIC IDENTIFICATION OF RETAINED AUSTENITE IN STEELS

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Recently it has been discovered\(^1\) by electron microscopy that even in medium carbon steels (\(M_f \geq 200^\circ C\)) small quantities of interlath retained austenite (\(\gamma\)) is present in as-quenched structures. It is speculated that this small quantity of retained \(\gamma\) can have a profound influence on the mechanical properties of steel. This austenite is severely deformed and in most cases the amount is so small that detection by x-ray analysis becomes impossible. However, sophisticated electron microscopic techniques involving careful selected area diffraction, bright field and dark field imaging can unequivocally establish the presence of such small quantities of austenite. Extremely useful morphological and microstructural information on the austenite can also be obtained from the electron metallography.

Fig. 1 illustrates the systematic identification of retained austenite occurring at the lath boundaries of martensite in Fe/4Cr/0.4C steels. Commonly, the martensitic (\(\alpha\)) laths in a packet occur in alternate \(<111>\) and \(<100>\) \(\alpha\) orientations. By tilting carefully, the thin films of austenite are brought into good diffracting condition whereby they appear dark in the BF picture of Fig. 1(a). The diffraction pattern for the matrix and for the austenite corresponds to a non-symmetrical orientation and only \{111\}_\gamma and \{110\}_\alpha reflections [Fig. 1(a) insert] are strongly excited. The DF picture [Fig. 1(b)] is obtained from \{111\}_\gamma reflection whereby only the austenite reverses contrast. Also faint streaking in the diffraction pattern at \{110\}_\alpha reflections along a direction normal to the \(\gamma\) films is discernible [Fig. 1(a) insert], indicating that these films are indeed very thin. Often, however, the unequivocal identification of the austenite phase is complicated by the presence of reflections from auto-tempered carbides, from martensite substructure (twinning) and double diffraction. The BF and DF images of Fig. 2 illustrate clearly that even with the smallest aperture available, closely lying carbide reflections are included along with austenite reflections particularly if \{111\}_\gamma reflections are used for imaging. The DF picture clearly shows the continuous film of interlath austenite and intra-lath auto-tempered carbides exhibiting \{110\}_\alpha habit (Widmannstatten). The indexed SAD pattern of Fig. 3 which is obtained from a different area, clearly illustrates the most common orientation relationship (K-S) observed between \(\alpha\) and \(\gamma\).

Similar to earlier observations\(^2\), retained \(\gamma\) was also identified conclusively in steels subjected to low temperature (-900°C) austenitizing treatments. In addition, extremely narrow inter-lath films of stabilized \(\gamma\) have been identified (Fig. 4) in Fe/0.5Mn/0.1C steel, which is quite surprising, since the occurrence of this phase in such low carbon steels has been overlooked by earlier investigators. Due to preferred orientation within a given martensite packet x-ray analysis may not detect these small quantities, depending on prior \(\gamma\) grain size. While the amount of retained \(\gamma\) in a steel can vary with the heat treatment it received, its occurrence seems to be a rule rather than exception, and its detection requires sophisticated electron metallography.

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Fig. 1a and b. BF and DF of 0.4C steel showing retained austenite.

Fig. 2a and b. BF and DF obtained from superposition of FCC γ and carbide reflections.

Fig. 3. SAD pattern showing Kurdjumov-Sachs orientation relationship:

\[
\begin{align*}
&[110]_\gamma \parallel [111]_M, (\overline{1}1\overline{1})_\gamma \parallel (\overline{1}0\overline{0})_M \\
\text{----} [111] & \text{Martensite orientation} \\
\text{-----} [110] & \text{Austenite orientation} \\
\text{-------} [100] & \text{Martensite orientation}
\end{align*}
\]

Fig. 4a and b. BF and DF of 0.1C steel showing reversal of contrast of stabilized austenite.
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