

Retained Austenite Analysis

Application Note

Background

Hardening of steels requires that the material be heated treated at a high temperature followed by a quenching and tempering process. The goal of the heat treating process is to develop the desired microstructure containing the phases offering the best combination of desired properties. During the heating cycle, the room temperature body-centered cubic Ferrite phase is transformed into the face-centered cubic structure known as Austenite. By quenching from the heat treatment temperature, the Austenite will then transform into the metastable phase Martensite, which is a very hard, but brittle phase. While the high hardness can be favorable for applications like cutting and tooling, Martensitic steels can be so brittle that they have limited use. Thus, a tempering process is almost always undertaken to reduce the brittleness of the steel at the expense of a slight loss in hardness. However, because of compositional and kinetic effects, the quench and heat treatment process does not always go to completion, and Austenite can be retained after quenching and tempering, which can lead to a degradation in the material's performance. This is due to the fact that the retained Austenite can be transformed into fresh, untempered Martensite by applied stresses while in use. This transformation is accompanied by a volume change and subsequently increases the internal stress in the part and can lead to cracking problems.

Analysis Method

Since Austenite has a different crystal structure from Martensite and the other forms of steel (Ferrite, Bainite and Pearlite), the resulting diffraction pattern will also be different. Thus, we can estimate the amount of Retained Austenite by comparing the intensities of diffraction peaks arising from each of the phases. In the absence of significant undissolved carbides and preferred orientation, there is a good correlation between the intensity ratio and the volume fraction of retained Austenite.

Two standards (ASTM E975 and SAE SP-453) for Austenite measurements are in common use. Both assume that the material has a nearly random orientation and has few carbides. The method is described below and illustrated in Figure 1, which compares the 200 Ferrite/ Martensite (200) peak with the Austenite 200 and 220 peaks (A200 & A220, respectively). In order to check for preferred orientation, the ratio of the integrated intensities of the two Austenite peaks is compared to the theoretical value of 1.475. If the ratio is between the limits of 1.2 to 1.8, then the sample is considered to be free of preferred orientation. The Direct Comparison Method then allows the calculation of the retained austenite by use of the intensity ratios of the Austenite (γ phase) and Ferrite (α phase) and correction factors that account for the different scattering powers of each phase. The formula used to compute the volume fraction f^γ of the Austenite phase is as follows:

$$f^\gamma = \frac{I_1 R_2 / I_2 R_1}{(1 + I_1 R_2 / I_2 R_1)}$$

where f_v = volume fraction of Austenite;

I_1, I_2 = Intensity of hkl peak of Austenite and Ferrite, respectively;

R_1, R_2 = Correction factors for Austenite and Ferrite, respectively.

The I_i values are measured directly from the diffraction scans while the R_i values are itemized in several published tables, the relevant portion of which is reproduced below for Cu radiation:

Ferrite Phase (α)		Austenite Phase (γ)	
hkl	R_α	hkl	R_γ
110	250	111	184
200	36	200	83
211	71	220	47
220	25	311	58

For the example shown in Figure 1, the following intensities were collected:

Austenite 200 689

Martensite 200 6784

Austenite 220 336

After the corrections are applied, the volume percent retained Austenite can be computed:

a) using Austenite 200 reflection: vol% = 4.2%

b) using the Austenite 220 reflection: vol% = 3.7%

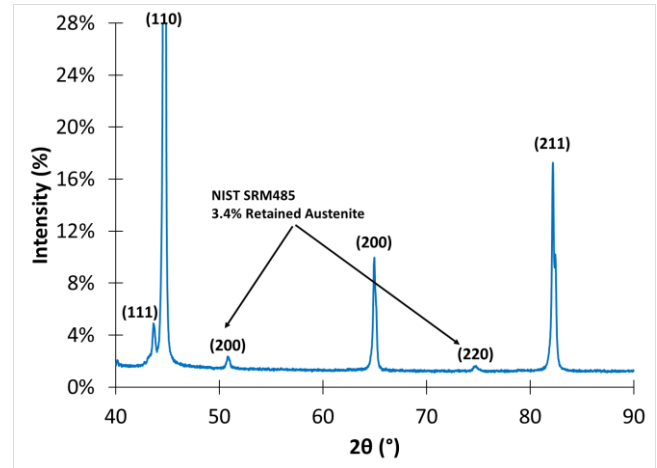


Figure 1. Diffraction pattern used for retained Austenite analysis.

Two problem areas are likely to come up when doing retained Austenite analysis. The first arises when a significant amount of undissolved carbides is present, while the second occurs when either the Austenite or the Martensite has a preferred orientation. In general, both problems are difficult to solve using conventional methods, such as those outlined in the ASTM and SAE standards. To overcome these problems, the preferred way today is to use the Rietveld whole pattern method whereby the entire diffraction pattern is analyzed instead of just the three peaks shown in Figure 1. The Rietveld refinement is a fundamental parameters method in which the diffraction patterns from each phase (with or without texture) is modeled and scaled to provide a least square fit to the observed diffraction pattern. With the simplified method where there are no carbides or preferred orientation, the ASTM/SAE methods can be accurate to levels as good as 1% with a sensitivity level of about 0.5%. In the more complicated cases where the Rietveld method is required, similar results can be expected, even in the presence of carbides and texture.

Applications

- Dimensional controls
- High speed tool steels
- Forgings
- Optimizing heat treatments
- High toughness alloys
- Bearings
- Case hardening
- Failure analysis