Advanced Engineering P. Ltd

Experts in Metallography, Failure Investigation and RLA

Metallurgy for Industries

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Retained austenite

-A boon or curse?

What do you mean by the term "Retained Austenite"?

Austenite that does not transform to martensite upon quenching is called retained austenite (RA). It is that fraction of austenite which remains untransformed at the end of the hardening process. The retained austenite forms when the steel is not quenched to Mf or martensite finish temperature; that is, low enough to form 100% martensite.

How does it form?

Austenite is a phase present in steel at high temperature having face centered cubic (FCC) structure. For hardening, steel is heated beyond upper critical temperature in the austenitic range and quenched to room temperature after adequate holding. Upon cooling, most of the structure is transformed to ferrite with body centered cubic (BCC), or to martensite having a body centered tetragonal (BCT) structure. Depending on the rate of cooling, some percentage of austenite (typically 0-40%) remains untransformed as retained austenite. In the microstructure of a hardened-tempered steel sample, the dark-colored needles are tempered martensite phase whereas the light areas are retained austenite. The amount of retained austenite in steel depends on its carbon content, alloy content (especially austenite stabilizers such as nickel, manganese and nitrogen), quenching medium and subsequent thermal and/or mechanical treatments.

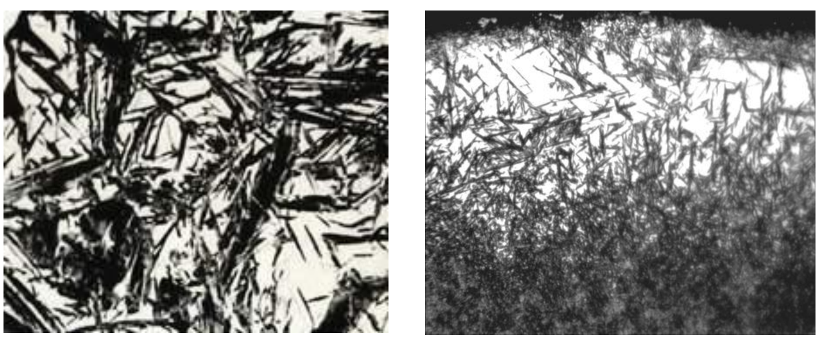


Fig. Microstructure showing martensite needles and retained austenite

What are the effects of retained austenite on properties & performance?

- Elastic limit: Too much retained austenite can result in lower elastic limits.
- Hardness: Higher retained austenite reduces the hardness of steel.
- Dimensional stability: Austenite can transform during service as a result of thermal cycles, plastic deformation, or shock. The transformation of austenite to martensite is accompanied by 4-5% increase in volume and introduction of internal stresses that can lead to cracking.
- Fatigue life: Transformation of austenite during service introduces compressive residual stresses improving rolling contact fatigue life.
- Impact strength: The impact strength increases with increasing austenite content.

TCR News

- Installed a new heat treatment furnace for simulation heat treatment. The furnace is capable of attaining max temperature of 1100 deg C. it is equipped with 8 segment programmable PID controller which can execute simulation heat treatment cycle automatically. The furnace can handle job sizes up to 500x500x150 mm size coupon samples.

- Tested more than 500 microstructures, 400 chemical tests and 250 hardness tests within 2 days time for critical time bound project for customer.
- Developed testing Flexural strength and pull strength of for long fiber bars

EVOLVE by TCR

- Conducted Level II certification course in Penetrant testing during 6th – 10th August. Participants were awarded Level II certification upon successfully clearing mandatory examination requirement as per written practice based on SNT-TC-1A document.
- Upcoming training on basics of metallurgy for engineers on 14th-15th September focuses on providing knowledge of metallurgical aspects in industrial environment for engineers.

Click for more information on upcoming training courses.

- Fracture toughness: Low retained austenite content can result in poor fracture toughness.

What are the benefits of retained austenite in steel?
- Finely dispersed retained austenite in the matrix of tempered martensite resists the propagation of fatigue cracks and improves rolling contact fatigue (RCF) life of components like bearings.
- Retained austenite plays a beneficial role in Non-distorting tool steels. Here enough austenite is retained (by adjusting the composition) to balance the transformational contraction during heating and the expansion corresponding to the formation of martensite during cooling. It imparts the dimensional stability to the component.
- The presence of 30-40% retained austenite makes straightening operation of the components possible after hardening.

What are the deleterious effects of retained austenite?
- Retained austenite is highly undesirable in components for the tool and dies industry. The RA is recognized as a major cause for premature failure.
- Austenite being a softer phase, if the percentage of retained austenite in steel is high, it produces soft spots. These soft spots are detrimental in applications such as cutting tools as they reduce wear resistance.
- Untempered martensite produced due to transformation of retained austenite to martensite during service is hard & brittle leading to premature failures. Hence, retained austenite is considered to be detrimental in applications such as tools and dies, where high impact loading is an essential service condition.

How to minimize the amount of retained austenite in steel?
Austenite, being a metastable (un-stable) phase has tendency to transform to martensite. It transforms to martensite when the steel is rapidly cooled (quenched) from austenitization temperature.
- **Tempering treatment:** Tempering is used to transform retained austenite to martensite. Multiple tempering is often performed to ensure that the maximum amount of retained austenite is transformed to martensite.
- **Sub-zero or Cryogenic treatment:** It involves cooling the component to a temperature below its Mf point, typically in the range of -85 C to -195 C. Sub-zero treatment is more effective, if it is carried out immediately after quenching (to room temperature) operation. Sub-zero treatment is usually followed by multiple tempering cycles to bring down the level of retained austenite to a minimum.

Methods of determination of retained austenite in steel:
The main methods developed to measure the amount of retained austenite in steel are based on metallographic, magnetic and x-ray diffraction techniques.

Metallography: Selective etching is used to produces different colors in the metallographic sample to distinguish martensite, retained austenite and carbides. The conventional metallographic point and linear counting methods used to determine the percentage of retained austenite present in steel are tedious and are subject to large errors when the retained austenite content is less than 10%. However, this problem is reasonably overcome by coupling Image analysis tools with conventional optical metallograph.

Magnetic technique: It is possible to determine the amount of retained austenite by method based on magnetic principle, because austenite is non-magnetic and the structural magnetization of ferrite and martensite are similar. However, reliable measurement is possible only if the cementite is completely absent.

X-ray diffraction method: While large amounts of retained austenite (>15%) can be detected and estimated by optical microscopy, specialized equipment and techniques, such as x-ray diffraction methods, are required to accurately measure the amount of retained austenite to as low as 0.5%.
X-ray diffraction is considered to be the most accurate method of determining the amount of retained austenite in steels. ASTM E975 standard is used to determine the amount of retained austenite in steel. Austenite, due to its structural differences from other phases in steel, produces diffraction peaks at different locations in the X-ray diffraction pattern than ferrite and martensite as shown in following figure. The integrated intensities of the austenite (200) and (220), and the ferrite (200) and (211) diffraction peaks are measured on the automated diffractometers, providing four austenite/ferrite peak intensity ratios. The amount of a phase in steel is proportional to the integrated intensity of its diffraction peak.

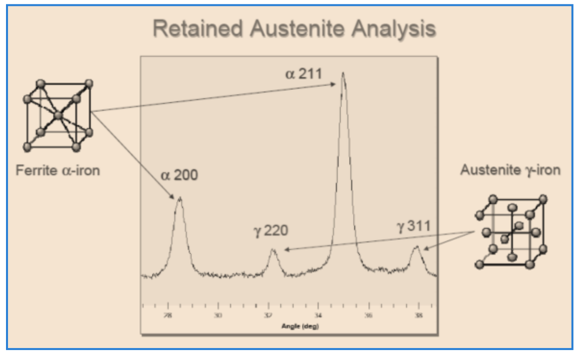
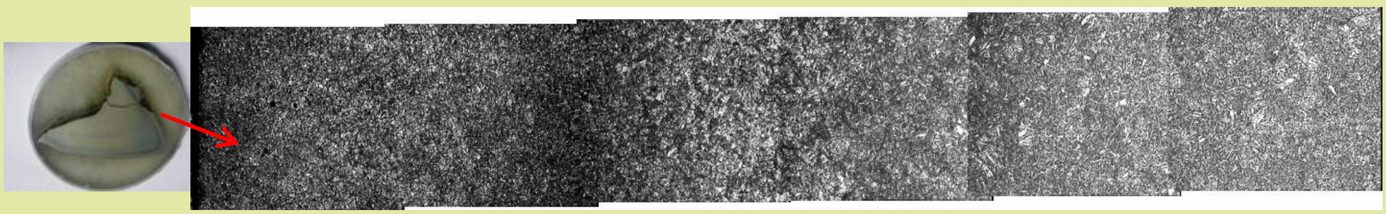


Fig Shows measurement setup and XRD profile of steel sample showing diffraction peaks of ferrite and retained austenite

Whether the retained austenite should be present in any steel, and if yes how much, thus depends on the application of the component.

Microstructure of the Month



Magnification: *500X* **MOC:** 17CrNiMo 4 **Component:** Gear **Etchant :** 2% Nital

Observation: Microstructure in etched condition shows panoramic view starting from surface to core. Case depth is etched dark. The tempered martensite morphology gradually changes as we move towards core.

Cause: The presence of metallurgical notches created by uneven hardness and retained austenite on surface layer that has resulted in fatigue cracks initiation. Further the presence of un-tempered martensite at layer acted as stress risers and cracked at inter granular manner. The final failure was a brittle mode under operation loads.

Useful hints: There should be gradual reduction in surface hardness values when moved from edge to core. Heat treatments cycle may be devised in such away that the case may be comprised of tempered martensite on the surface and retained austenite within stipulated requirements. The Retained austenite shall have fine uniform distribution and not lumps. A test sample should be kept with heat treatment to check microstructure /micro-hardness profile and retained austenite morphology. The RA shall be restricted up to 5-7% in the case.

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