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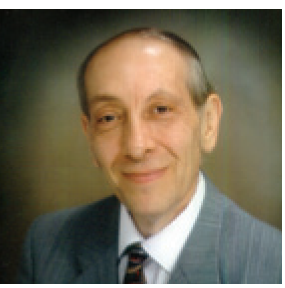
A Discussion of Retained Austenite

What is retained austenite and how does it affect the properties of a component? How much, if any, retained austenite should be present in a particular component microstructure? Is the presence of retained austenite in a microstructure a good thing or a concern? These are questions that metallurgists have spent countless hours debating. What do we as heat treaters need to know about retained austenite and how is retained austenite viewed by various industries? Let's learn more.



What is retained austenite?

Austenite that does not transform to martensite upon quenching is called *retained austenite* (RA). Thus, *retained austenite* occurs when steel is not quenched to the M_f, or martensite finish, temperature; that is, low enough to form 100% martensite. Because the M_f is below room temperature in alloys containing more than 0.30% carbon, significant amounts of untransformed, or retained austenite, may be present, intermingled with martensite at room temperature (Fig. 1). Retained austenite is a specific crystalline form of iron and steel. The dark-colored needles shown are tempered martensite crystals and the light-colored areas are retained austenite crystals. The amount of retained austenite is a function of the carbon content, alloy content (especially nickel and manganese), quenchant temperature and subsequent thermal and/or mechanical treatments.

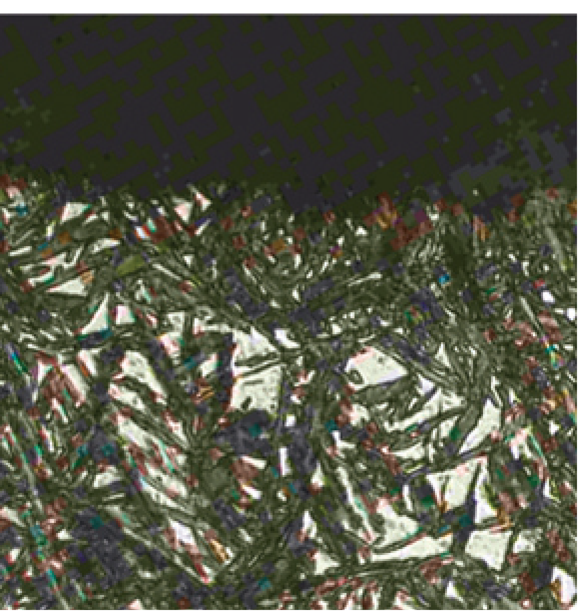


Fig. 1. RA present in a case carburized component [1]. Photomicrograph courtesy of Alan Stone, Aston Metallurgical Services (www.astonmet.com). Etchant: 2% nital. 1,000×

Depending on the steel chemistry and specific heat treatment, the retained austenite level in the case can vary from over 50% of the structure to nearly zero. 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%.

Why is retained austenite problematic?

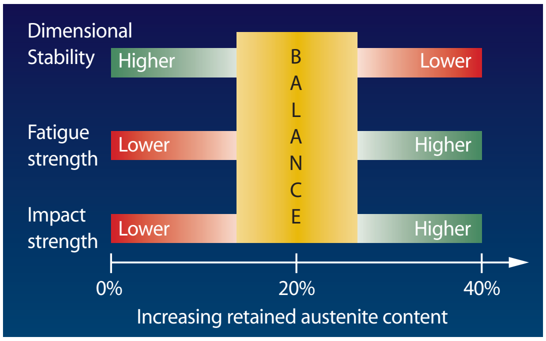
The very characteristics that give retained austenite many of its unique properties are those responsible for significant problems in most applications. We know that austenite is the normal phase of steel at high temperatures, but not at room temperature. Because retained austenite exists outside of its normal temperature range, it is metastable. This means that when given the opportunity, it will change or transform from austenite into martensite. In addition, a volume change (increase) accompanies this transformation and induces a great deal of internal stress in a component, often manifesting itself as cracks.

How does RA behave?

Martensite is hard, strong and brittle while austenite is soft and tough. In some instances, when combined, the mixture of austenite and martensite creates a composite material that has some of the benefits of each, while compensating for the shortcomings of both.

For any given application, mechanical properties are affected by a high percentage of retained austenite content. For example, retained austenite affects the following properties of bearing steels:

- Dimensional stability: Retained austenite will transform to martensite if the temperature drops significantly below the lowest temperature to which it was quenched, or if the room temperature austenite is subjected to high levels of mechanical stress. Martensite, a body centered tetragonal crystal structure, has a larger volume than the face centered cubic austenite that it replaces. Where transformation occurs, there will be a localized 4-5% increase in the volume of the microstructure at room temperature and a resulting dimensional change in the geometry of the component. If great enough, this dimensional change could lead to growth and in severe instances, crack initiation.
- Fatigue: Low retained austenite content and fine austenitic grain sizes, which create a microstructure of finely dispersed retained austenite and tempered martensite, prevent nucleation of fatigue cracks, or retard fatigue crack initiation until very high stress levels are reached. In contrast, low-stress applications that fracture at low cycles are related to high retained austenite levels and coarse austenite grain sizes. For example, one type of fatigue strength of interest



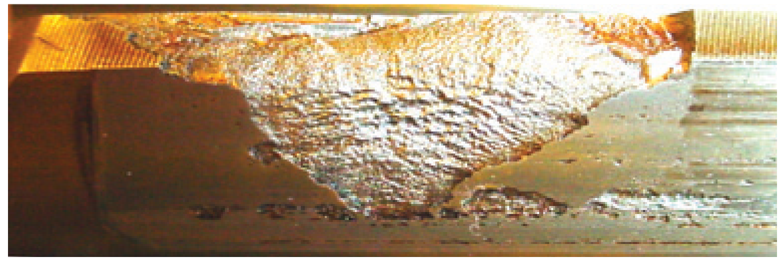


Fig. 2. (left) Balancing properties and RA content [2]

Fig. 3. (above) Gear tooth failure due to spalling (macropitting)

to many users is rolling contact fatigue. Two aspects of retained austenite can improve rolling contact fatigue life. First, the inherent ductility of retained austenite helps to delay crack growth by blunting the tips of cracks as they form. Second, as retained austenite transforms during service, compressive residual stresses increase in the case. These compressive stresses delay crack growth by functioning like a vise and clamping cracks closed. These benefits are not present in a part with insufficient retained austenite.

- Impact: Impact strength is the measure of the ability of a steel to resist fracture when subjected to a sharp blow. Austenite is not only very tough, but also it has higher impact strength than martensite. The steel's impact strength increases with increasing austenite content. Higher impact strength can provide extra protection against cracking, which, in turn, helps prevent such problems as spalling.

It is important to recognize that a balance must be created between the mechanical properties of a component and the optimum percentage of retained austenite for a given application (Fig. 2).

How some industries view retained austenite

Retained austenite is highly undesirable in components for the tool and die industry. RA is recognized as a major cause for premature failure. The low hardness of RA is also incompatible with most applications that require the maximum attainable hardness to resist wear.

The bearing and gear industries have a more favorable view toward having some retained austenite (5 to 30% determined by optical metallography, usually by comparison to known standards). While some of the same mechanisms that affect tooling applications also affect gears, there are some major differences. Gears are typically made of case-hardened steel, which has high impact strength. While most tools fail by wear or fracture, many gear failures are the result of spalling in the tooth area. Spalling is progressive macropitting that occurs when pits coalesce and form irregular craters, which cover a significant area of the tooth surface (Fig. 3). Spalling occurs when the surface of a metal component is subjected to repeated cyclic loads. A crack forms and grows until a small portion of the surface breaks loose, damaging the surface and adding debris to the system. The gear industry balances the amount of retained austenite in a gear tooth to delay the onset of spalling by suppressing crack growth.

How is the percentage of RA reduced?

Tempering is one method used to transform retained austenite. A key is to hold for an adequate amount of time at temperature. Multiple tempers are often performed to ensure the maximum amount of retained austenite has been transformed. Other popular methods include cold treatment at -120ºF (-85ºC) or cryogenic treatment to -320ºF (-195ºC). It is well documented that as the temperature is lowered the degree of transformation increases.

Conclusion

By controlling the level of retained austenite, its beneficial effects can be realized without suffering from its negative influences, such as excessive dimensional growth. Many industries have found a "sweet spot" exists for retained austenite content to achieve a balance of fatigue/impact strength and dimensional stability.

To obtain the optimum level of retained austenite requires a delicate balance of controls and must take into account such items as material chemistry and heat treatment process variables. These variables include steel chemistry, carbon content, austenitizing temperature, quenching rate and tempering temperature. **IH**

References

- Private correspondence, Technical Forum 00-1 Retained Austenite: It's Impact on Bearing Performance, BRENCO Inc. (www.brencoqbs.com)
- Krauss, G., *Steels: Heat Treatment and Processing Principles,* ASM International, 1990
- Private correspondence, Dr. Jeff Levine, Applied Cryogenics (781-270-1180)

Additional related information may be found by searching for these (and other) key words/terms via BNP Media LINX at www.industrialheating.com: retained austenite, metastable, untransformed austenite, martensite finish temperature, dimensional stability, rolling contact fatigue, impact strength, spalling, macropitting, tempering, cryogenic treatment.