Heat Treating with Salts

Heat treating is a process in which metal is heated to a certain temperature and then cooled in a particular manner to alter its internal structure for obtaining a desired degree of physical and mechanical properties. The purpose is to increase the metal's hardness, as well as to obtain maximum strength and durability in the material.

Numerous industries utilize heat treated parts, including those in the automotive, aerospace, information technology and heavy equipment sectors. Specifically, manufacturers of items such as saws, axes, cutting tools, bearings, gears, axles, fasteners, camshafts and crankshafts all rely on heat treating to make their products more durable and to last longer.[1]

The heat treating processes require three basic steps:

1. Heating to a specified temperature.
2. Holding at that temperature for the appropriate amount of time.
3. Cooling according to prescribed methods.

Understanding the Part Material

According to the ASM International's Heat Treating Society, about 80 percent of heat treated parts are made of steel, such as bars and tubes, as well as parts that have been cast, forged, welded, machined, rolled, stamped, drawn or extruded.[1]

Successful heat treating begins by understanding the make-up of the steel that is to be treated. The American Iron and Steel Institute (A.I.S.I.) and the Society of Automotive Engineers (S.A.E.) utilize a four-digit system to code various types of steel used in manufacturing. The alloying element in the AISI specification is indicated by the first two digits, and the amount of carbon in the material is indicated by the last two digits. The first digit represents a general category of the steel groupings, meaning that 1xxx groups within the SAE-AISI system represent carbon steel. The second digit represents the presence of major elements which may affect the properties of steel; for example, in 1018 steel the zero in the 10xx series depicts no major secondary element. The last two digits indicates the percentage of carbon concentration. SAE 1018 indicates non-modified carbon steel containing 0.18% of carbon, while SAE 5130 indicates a chromium alloy steel containing 1% chromium and 0.30% carbon.

SAE designation	Type
1xxx	Carbon steels
2xxx	Nickel steels
3xxx	Nickel-chromium steels
4xxx	Molybdenum steels
5xxx	Chromium steels
6xxx	Chromium-vanadium steels
7xxx	Tungsten steels
8xxx	Nickel-chromium-vanadium steels
9xxx	Silicon-manganese steels

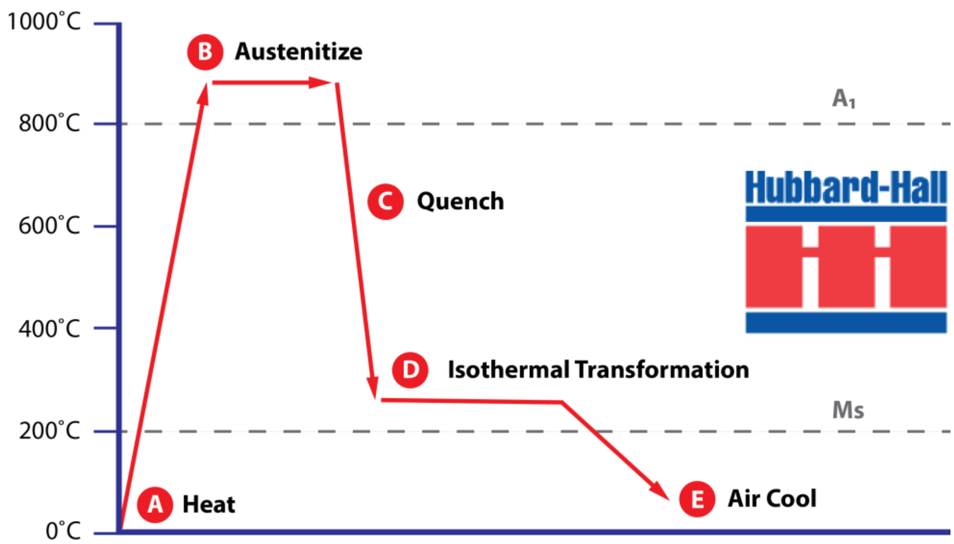
Carbon steel has a main alloying constituent of carbon in the range of 0.12% to 2.0%. Plain carbon steel is usually iron with less than 1% carbon, plus small amounts of manganese, phosphorous, sulfur and silicon. Carbon steel is broken down into four classes based on carbon content:

- Low Carbon Steel: up to 0.21% carbon content
- Medium Carbon Steel: 0.3 - 0.6% carbon content
- High Carbon Steel: 0.6 - 1.0% carbon content
- Ultra-High Carbon Steel: 1.25 - 2.0% carbon content

The Austempering and Quenching Process

Austempering is a heat treatment that is applied to ferrous metals and is defined by both the process and the resultant microstructure of the work. In steel, it produces a bainite (or a plate-like) microstructure, which is made up of packets of parallel plates in the morphological packet.

Typical Austempering Heat Treatment Cycle in Ductile Iron



Source: Akbarzadeh, Elina & Rahimi, M. & Yazdani, Sasan. (2016). Dry sliding wear of Ni alloyed austempered ductile iron. 13. 10.1007/s41230-016-6072-0.

When heated to temperatures below 730°C, the pure metal iron has a body-centered cubic structure; if heated above this temperature the structure will change to a face-centered cubic. On cooling, the change is reversed and a body-centered cubic structure is once more formed. The importance of this reversible transformation lies in the fact that up to 2.0% carbon can dissolve in a face-centered cubic, forming what is known as a "solid solution." While in a body-centered cubic iron state, no more than 0.02% carbon can be dissolved this way. The solid solution formed when the carbon atoms are absorbed into the face-centered cubic structure of iron is called austenite.

When quenched, carbon is precipitated from austenite not in the form of elemental carbon (graphite), but as the compound iron carbide Fe3C, usually call cementite. Like most other metallic carbides, this substance, is usually very hard; as the amount of carbon increases, the hardness of the cooled steel will also increase.

The temperature of the quench tank is set so that the material is rapidly cooled down through the pearlite phase and quenched at a temperature that falls within the bainite region, but staying above the marentsitic phase. The austempered bainite microstructure of the work imparts high ductility, impact strength and wear resistance for a given hardness; a rifle bolt was one of the first uses for this process.

The salt quench also provides low distortion of work with repeatable dimensional response. It increases fatigue strength and is resistant to hydrogen and environmental embrittlement.

Heat Treat with Salt Baths

Salt bath heat treatment is a heat treatment process comprising an immersion of the treated part into a molten salt, or salts mixture.[2] There are numerous benefits of heat treatment in salt baths, the most prevalent is that they provide faster heating. A work part immersed into a molten salt is heated by heat transferred by conduction (combined with convection) through the liquid media (salt bath).[2] The heat transfer rate in a liquid media is much greater than that in other heating mechanisms, such as radiation or convection through a gas.[2]

Using salt baths also helps with a controlled cooling conditions during quenching. In conventional quenching operation, either water or oil are used as the quenching media and the high cooling rate provided by water/oil may cause cracks and distortions. Cooling in molten salt is slower and stops at lower temperature.[2]

Salt baths also provide low surface oxidation and decarburization, as the contact of the hot work part with the atmosphere is minimized when the part is treated in the salt bath.[2] There are additional advantages to salt heat treat:

- Wide operating temperatures: 300°F -1100°F
- Most of the heat is extracted during quenching by convection at a uniform rate.
- Salt gives buoyancy to the work being processed to hold work distortion to a minimum.
- Quench severity can be controlled or manipulated by a greater degree by varying temperature, agitation and water content of the salt.
- Excellent thermal and chemical stability of the salt means that the only replenishment required is due to drag-out losses.
- Nonflammable salt poses no fire hazard.
- Salt is easily removed with water after quenching.

Want to Learn More?

Hubbard-Hall has a lot of information for you to learn more about neutral salts, quenching and tempering salts, rubber curing salts and solution heat treating/annealing of aluminum and descaling salts.

Neutral Salts: designed to provide excellent fluidity and great stability, Hubbard-Hall's neutral heat treatment salts are formulated with a balanced mixture of chlorides. The Neutral Salts highlighted in this section include only 1 non-barium product (neutral salt B). Selection of neutral salts is generally based on operating range.

Quenching and Tempering Salts: this line of heat treatment salts is composed of nitrate-nitrite salts for use as steel tempering or quenching media. All are completely water soluble, easily washed and have similar high-transfer rates and heat capacity.

Solution Heat Treating/Annealing of Aluminum: molten heat treatment salts provide a high degree of temperature uniformity required for the satisfactory heat treatment of aluminum alloys. Hubbard-Hall's aluminum heat treatment salts are free-flowing and high purity products.

Descaling Salts: molten descaling salts can be used to remove oxide scales from both ferrous and non-ferrous metals. Molten Descaling Salts have the ability to produce clean, scale-free surfaces without base metal loss, pitting or etching.

Rubber Curing Salts: rubber curing heat treatment salts are high purity, eutectic mixture of nitrate and nitrite salts. They are formulated specifically for curing extruded rubber profiles at the lowest possible temperature ranges. All chemicals used in these rubber curing salts are water-soluble and do not form any insolubles. Therefore, the solidified salt is easily removed from the surface in a hot water spray rinsing station at the end of the trough just after emerging from the salt trough.

References:

1. ASM International; https://www.asminternational.org/web/hts/about/what-is
2. https://www.substech.com/dokuwiki/doku.php?id=salt_bath_heat_treatment

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