Tempering…

Tempering is a heat treatment process that alters the mechanical properties (typically ductility and hardness) and relieves internal stresses of a steel. Tempering allows carbon trapped in a martensitic microstructure to disperse, and enables the internal stresses to be released from the steel that may have been created from prior operations.

The Tempering Process

Tempering is performed by elevating the steel to a set point below its lower critical temperature, typically following a hardening operation. Once this temperature is reached, it is held there for a specified amount of time. The exact temperature and time depend on several factors such as the type of steel and desired mechanical properties.

To get the steel to its critical temperature, some type of heating device must be used. Common devices include gas furnaces, electrical resistance furnaces, or induction furnaces. Often, this heating is done in a vacuum or with an inert gas to protect the steel from oxidation. Once the furnace achieves the desired temperature, a dwell time occurs. Following the dwell time, the furnace is shut off and the steel is allowed to cool at predetermined rate.

Why Is Steel Tempered?

Tempering steel after a hardening process allows for a middle ground of hardness and strength. This is achieved by allowing the carbon diffusion to occur within a steel microstructure. When steel is hardened, it can become excessively brittle and hard. However, when not hardened, the steel may not have the strength or abrasion resistance needed for its intended application. Tempering also improves the machinability and formability of a hardened steel, and can reduce the risk of the steel cracking or failing due to internal stresses.

When Is Tempering Used?

- Tempering is most commonly used following a quenching operation. Heating a carbon steel and rapidly quenching it can leave it too hard and brittle. Tempering it can restore some of its ductility.
- Tempering can reduce the hardness and relieve the stress of a welded component. Welds can create a localized zone that has been hardened due to the heat of the welding process. This can leave undesirable mechanical properties and residual stress that can promote hydrogen cracking. Tempering helps prevent this.
- Work hardened materials often require tempering. Materials can become work hardened through processes such as punching, bending, forming, drilling, or rolling. Work hardened materials have a high amount of residual stresses that can be alleviated through a tempering process.

What Is Annealing?

While the chemical composition of a metal determines much of the mechanical properties, many metals can have their mechanical properties altered through heat treatment. There are many different types of heat treatment used today, and one of the most popular methods is annealing.

What Is Annealing?

Annealing is a heat treatment process used mostly to increase the ductility and reduce the hardness of a material. This change in hardness and ductility is a result of the reduction of dislocations in the crystal structure of the material being annealed. Annealing is often performed after a material has undergone a hardening or cold working process to prevent it from brittle failure or to make it more formable for subsequent operations.

Why Is Metal Annealed?

As mentioned above, annealing is used to reduce hardness and increase ductility. Changing these mechanical properties through annealing is significant for many reasons:

- Annealing improves the formability of a material. Hard, brittle materials can be difficult to bend or press without creating a material fracture. Annealing helps eliminate this risk.
- Annealing can also improve machinability. A material that is extremely brittle can cause excessive tool wear. Reducing the hardness of a material via annealing can reduce the wear on the tool being used.
- Annealing removes residual stresses. Residual stresses can create cracks and other mechanical complications, and it is often best to eliminate them whenever possible.

What Metals Can Be Annealed?

To perform an annealing process, a material that can be altered by heat treatment must be used. Examples include many types of steel and cast iron. Some types of aluminum, copper, brass and other materials may also respond to an annealing process.

The Annealing Process

There are three main stages to an annealing process.

1. Recovery stage.
2. Recrystallization stage
3. Grain growth stage

Recovery Stage

During the recovery stage, a furnace or other type of heating device is used to raise the material to a temperature where its internal stresses are relieved.

Recrystallization Stage

During the recrystallization stage, the material is heated above its recrystallization temperature, but below its melting temperature. This causes new grains without preexisting stresses to form.

Grain Growth Stage

During the grain growth, the new grains fully develop. This growth is controlled by allowing the material to cool at a specified rate. The result of completing these three stages is a material with more ductility and reduced hardness. Subsequent operations that can further alter mechanical properties are sometimes carried out after the annealing process.

When Are Annealed Metals Used?

Common applications for annealed metals include:

- Work-hardened materials such as sheet metal that has undergone a stamping process or cold drawn bar stock.
- Metal wire that has been drawn from one size to a smaller size may also undergo an annealing process.
- Machining operations that create high amounts of heat or material displacement may also warrant an annealing process afterward.
- Welded components can create residual stresses in the area of the material exposed to elevated temperatures; to recreate uniform physical properties, annealing is often used.

Difference Between Annealing and Tempering

What's the difference between annealing and tempering?

The difference between annealing and tempering comes down to how it is treated. Annealing involves heating steel to a specified temperature and then cooling at a very slow and controlled rate, whereas tempering involves heating the metal to a precise temperature below the critical point, and is often done in air, vacuum or inert atmospheres.

Heat Treatments

Heat treatments are used to alter the physical and mechanical properties of metal without changing its shape. They are essential processes in metal manufacturing which increase desirable characteristic of metal, while allowing for further processing to take place.

Various heat treatment processes involve carefully controlled heating and cooling of metal. Steel, for example, is commonly heat treated for use in a variety of commercial applications.

Common objectives of heat treatment are to:

- Increase strength
- Increase hardness
- Improve toughness
- Improve machining
- Improve formability
- Increase ductility
- Improve elasticity

The cooling stage has different effects depending on the metal and process. When steel is cooled quickly it hardens, whereas the rapid cooling stage of solution annealing will soften aluminum.

While there are many types of heat treatment, two important types are annealing and tempering.

Annealing

Annealing involves heating steel to a specified temperature and then cooling at a very slow and controlled rate.

Annealing is commonly used to:

- Soften a metal for cold working
- Improve machinability
- Enhance electrical conductivity

Annealing also restores ductility. During cold working, the metal can become hardened to the extent that any more work will result in cracking. By annealing the metal beforehand, cold working can take place without any risk of cracking, as annealing releases mechanical stresses produced during machining or grinding.

Annealing is used for steel, however, other metals including copper, aluminum and brass can be subject to a process called solution annealed.

Large ovens are used for annealing steel. The inside of the oven must be large enough to allow air to circulate around the metal. For large pieces, gas fired conveyor furnaces are used while car-bottom furnaces are more practical for smaller pieces of metal.

During the annealing process, the metal is heated to a specific temperature where recrystallization can occur. At this stage, any defects caused by deformation of the metal are repaired. The metal is held at that temperature for a fixed period, then cooled down to room temperature.

The cooling process must be done very slowly to produce a refined microstructure, thus maximizing softness. This is often done by immersing the hot steel in sand, ashes or other substances with low heat conductivity, or by switching off the oven and allowing the steel to cool with the furnace.

Tempering

Tempering is used to increase the toughness of iron alloys, particularly steel. Untempered steel is very hard but is too brittle for most applications. Tempering is commonly done after hardening to reduce excess hardness.

Tempering is used to alter:

- Hardness
- Ductility
- Toughness
- Strength
- Structural stability

Tempering involves heating the metal to a precise temperature below the critical point, and is often done in air, vacuum or inert atmospheres.

The temperature is adjusted depending on the amount of hardness that needs to be reduced. While it varies depending on the metal type, generally, low temperatures will reduce brittleness while maintaining most of the hardness, while higher temperatures reduce hardness which increases elasticity and plasticity, but causes some yield and tensile strength to be lost.

It is essential to heat the metal gradually to avoid the steel being cracked. The metal is then held at this temperature for a fixed period. A rough guideline is one hour per inch of thickness. During this time the internal stresses in the metal are relieved. The metal is then cooled in still air.