A Member of The Linde Group

Annealing

Annealing is the commonest of all the heat treatment processes. Every piece of metal has been annealed at least once and some parts many times in the process of getting from raw material to part.

Why anneal?

There are two main reasons for annealing. The first is to soften it and remove stress. The second is to homogenise the structure.

Every time a piece of metal is worked it accumulates stress and gets harder. The harder it gets, the more difficult it is to work again. Take something as simple as a coin as an example. The cast slab of coinage alloy is rolled down to a plate. It becomes so hard that it must be annealed before it can be rolled further. It may undergo several such cycles before reaching the correct thickness. The coin sized blanks are then punched out of the strip. The cut faces are hard so the blanks are annealed again before they can be minted. No final anneal is needed as the hardness from minting process helps with wear in service.

When a metal is cast, the solidification processes result in both macro and micro segregation of the alloying elements present. Macro segregation needs to be broken down by mechanical work, but micro segregation can often be homogenised by annealing.

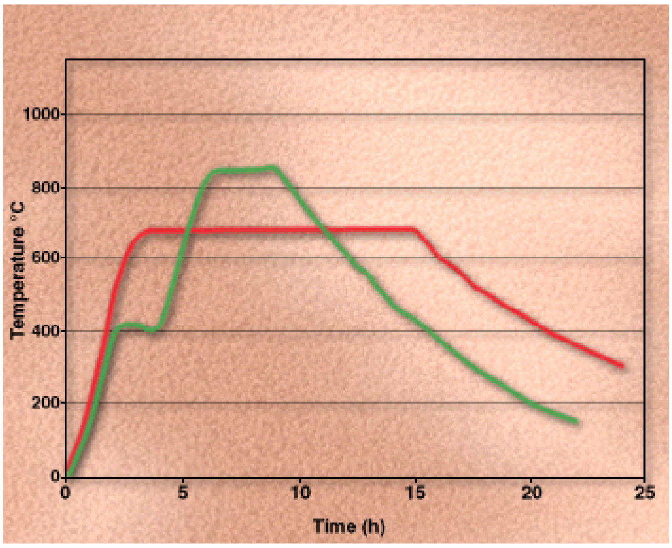

Figure 1. Process (green) and sub-critical (red) annealing cycles

How is it done?

Annealing is basically a very simple process. The metal is heated up, held at temperature for a time, then it is slow cooled. If the condition of the surface does not matter or cleaning takes place later (e.g. castings) then it can be done in air. If the surface finish does matter then a protective atmosphere is used. Typically this would be nitrogen with a small hydrogen addition. Steel is a bit different from the rest of the metals so it will be addressed separately.

Steel

There are two distinct types of steel annealing: process annealing (sometimes called normalising) carried out in the austenitic range above 720°C and subcritical annealing (or spheroidising) which is carried out in the ferritic range below 720°C. Typical time-temperature curves for these processes are shown in Figure 1.

The aim of the process anneal is to produce a soft material in the minimum time. The resulting structure is shown in Figure 2. The lighter grains are soft ferrite and the dark grains are pearlite. Pearlite is made up of alternating layers of hard iron carbide and soft ferrite. If it is thought of as glass plates with plastercine between, then it will be seen as fairly stiff still.

The aim of sub-critical annealing is to coalesce the layers of iron carbide into globules (Figure 3) and so produce the very softest material possible. We now have marbles in plastercine; a much more malleable material.

Atmospheres

Although most steel is annealed in nitrogen/hydrogen, this atmosphere is inherently decarburizing to steels. If it is necessary to avoid decarburization then different atmospheres can be used as shown in the table.

Material	Atmosphere
Cast Iron	Nitrogen
Mild Steel	Nitrogen/2-4% Hydrogen
Alloy Steels	Nitrogen/2-4% Natural Gas
Carbon Steel	Nitrogen/2-4% Natural Gas
Carbon Steel	Nitrogen/0.5-1% Propane
Mild/Carbon Steels	Nitrogen/5-50% Cracked Methanol or Endothermically generated gas

While the nitrogen/hydrocarbon atmospheres require no control the furnace needs to be very leak tight for them to be effective. If carbon control is needed then a mixture of nitrogen with cracked methanol or endothermically generated gas can be used. In many large continuous furnaces a CARBOCAT® gas generator can be used as the source of endothermically generated gas. A CARBOFLEX® control system can be used for carbon control. In large continuous furnaces with no fans atmosphere consistency can be a problem. If this is the case a CARBOJET® high speed gas injection system can be used to improve uniformity.

Non-ferrous metals

Non-ferrous metals are generally annealed at temperature around 50% of their melting point. As for steel the aim is to get a soft, stress-free material. The effect of annealing of a heavily cold rolled material is shown in Figure 4.

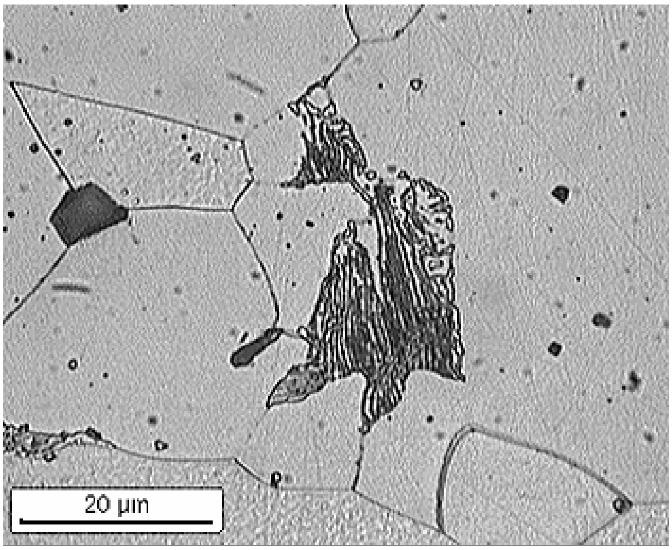

Figure 2. Ferrite and pearlite in a process annealed 0.18% carbon steel

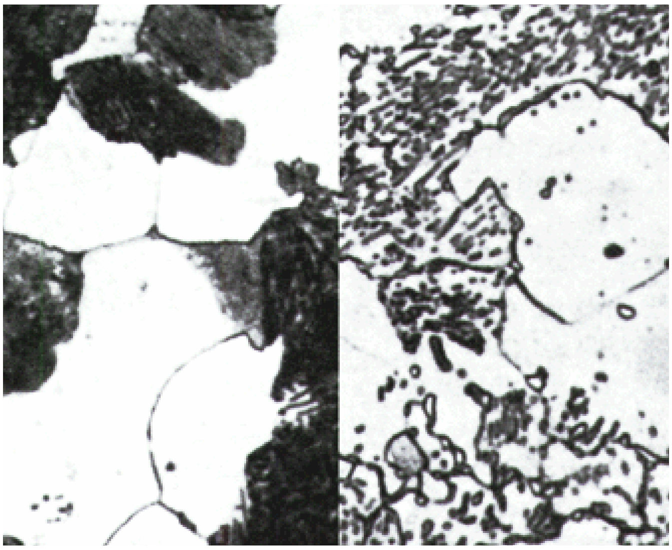

Figure 3. The effect of sub-critical annealing (right) on pearlite

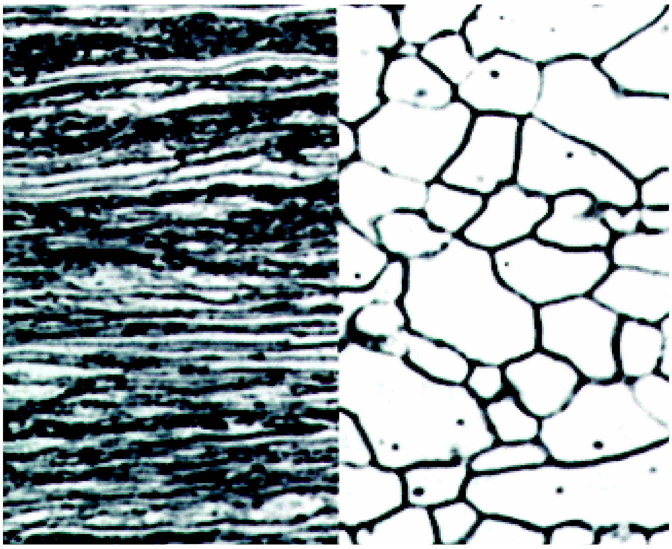

Figure 4. The effect of annealing on a cold worked material

Atmospheres

Some non-ferrous alloys oxidize so readily the hydrogen is ineffective as a protective atmosphere and an inert gas alone is used to reduce oxygen availability. For other alloys hydrogen can be used toi eliminate oxidation. Some examples are shown in the table.

Material	Atmosphere
Titanium Alloys	Argon
Magnesium Alloys	Nitrogen
Aluminium Alloys	Nitrogen
Copper	Nitrogen/1-4% Hydrogen
Bronze	Nitrogen/5% Hydrogen
Brass	Nitrogen/25% Hydrogen
Silver Alloys	Nitrogen/4% Hydrogen
Nickel Alloys	Nitrogen/4% Hydrogen
High Chromium Alloys	Nitrogen/25% Hydrogen to 100% Hydrogen

For accurate control of the annealing conditions a HYDROFLEX® N_2/H_2 atmosphere control system can be used.

What types of furnaces are used?

Anything, from a tiny 50 mm wide by 1500 mm long mesh belt furnaces for jewelry to giant ten stories high by 500 m long continuous annealers at a steelworks for strip, is used. The workhorse of the semi-finished industry has been the bell furnace lately enshrined in the 100% hydrogen bell annealer. In this type of furnace, shown in Figure 5, the work is stacked on a usually circular base and is covered with a hood or bell which contains the protective atmosphere. In this case it is 100% hydrogen – used because its high thermal conductivity shortens cycle times. A furnace is then lowered over the bell and the work heated. On completion of the heating part of the cycle the furnace is removed for use on another bell and the work is left to cool inside the bell in its protective atmosphere.

Figure 5. An 100% hydrogen bell annealing installation (photo courtesy of Ebner)

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