Heat treatment for high-performance alloys

One of the special features of the manufacturing process for austenitic high-performance alloys is the importance of heat treatment. This is because heat treatment is used to adjust important material properties.

VDM Metals forms the high-performance alloys (HPA) Division of Acerinox. Both flat and long products that the company supplies to its customers are generally heat-treated, because in addition to their particularly high corrosion resistance, many of the products are also characterized by high mechanical strength even at high operating temperatures. The heat treatment process, which is mainly used for austenitic grades, but also duplex steels, is solution annealing. In this process, the carbide precipitates present in the microstructure and other phases in the solid solution are dissolved and prevented from re-precipitating by rapid cooling. Furthermore, solution annealing of austenitic materials serves to recrystallize cold-worked microstructural areas and thus to reduce work hardening. Typical properties that can be achieved with these processes are mechanical strength at room temperature and higher temperatures as well as corrosion and oxidation resistance.

Depending on their chemical composition, non-ferrous metals can also be soft annealed. This is actually a recrystallization annealing process to remove cold-formed areas in the structure, which may make further processing, usually forming processes, more difficult or impossible.

One material that is available in both variants is VDM® Alloy 625, a nickel-chromium-molybdenum-niobium alloy that offers excellent corrosion resistance to a wide range of corrosive media. The alloy is used in the soft annealed condition (annealed at 950 to 1,050 °C) for wet corrosion applications and is TÜV-approved for pressure vessels in the temperature range from -196 to 450 °C. The solution-annealed variant (annealed at 1,080 to 1,160 °C) is generally used for high-temperature applications with operating temperatures above approx. 600 °C and up to approx. 1,000 °C.


Water cooling of annealed plate

HPA Division


Outlet area of VDM Metals' plate annealing furnace in Altena, including water cooling unit

Customers need to be mindful

Even processors of high-performance materials from VDM Metals generally have to carry out heat treatment after hot and cold forming. This is because cold or hot forming changes the mechanical and corrosion-chemical properties of the material as it is delivered to the processor. These can only be restored through targeted heat treatment. However, heat treatments are complex and often not easy to carry out on a component.

Before heat treatment, the workpiece surfaces must be cleaned of contaminants such as grease, oil, marking paints etc. using chlorine-free solvents such as acetone or isopropanol. However, the use of trichloroethylene (TRI), perchloroethylene (PER) and carbon tetrachloride (TETRA) should be avoided under all circumstances. Impurities may include sulphur, phosphorus and low-melting-point metals, which can form low-melting-point phases in combination with nickel. These can lead to the destruction of the material structure and thus to damage when the component is used. Heat treatments should therefore preferably be carried out in electric furnaces under vacuum or inert gas due to the absence of impurities and close temperature control.

Low-sulphur furnace atmosphere

Achieving the lowest possible sulphur furnace atmosphere also requires that the fuels used have the lowest possible sulphur content. Natural gas should contain less than 0.1% sulphur by weight. Heating oil with a maximum sulphur content of 0.5% by weight is also suitable. Workpieces made of high molybdenum alloyed materials should be heated quickly and should therefore be placed in a furnace that has already been heated to the setpoint. These materials include the 6% molybdenum stainless steels VDM® Alloy 926 and Alloy 31 as well as the nickel-based alloys Alloy 625, Alloy C-276 or Alloy 59. The temperature at which heat treatment must be carried out varies from material to material and should be requested from the material manufacturer if in doubt.

Rapid cooling in water or air

The molybdenum-rich austenitic stainless steels and nickel-based alloys must be cooled quickly in order to avoid undesirable precipitation. Delayed cooling - for example in a furnace - must be avoided under all circumstances. This results in precipitates that preferentially form on grain boundaries or along areas close to grain boundaries. Such precipitates impair the corrosion resistance and toughness properties of a material. Cooling rates of ≥ 150 degrees Celsius/min from material-specific solution annealing temperatures to below around 500 degrees Celsius have proven to be effective. While thin-walled workpieces cool down quickly even in still air, thick-walled workpieces can only be cooled by quenching in water or using a fan blast. As a rule of thumb, the cooling process should be set up so that the workpiece turns black within three minutes.