Quenching and Cooling

Quenching and cooling are the other half of the heat treatment cycle from heating. Quenching is mostly applicable to steels where the aim is to convert the soft high temperature austenitic structure to hard martensite. To achieve this, the cooling has to be fast enough to prevent the formation of other phases like pearlite and bainite.

Why use gas?

Conventionally, water, oil or a mixture of water and a polymer are used for quenching. Water is generally to fast for most applications and will crack the steel. Oil is a good quenchant, but has two significant problems. First it boils when the part first enters the oil and cooling is slow, when the film breaks down cooling speed increases. Unfortunately this happens at different times on different areas of the part leading to distortion. Second, it is not very environmentally friendly and must be washed of parts before further processing creating a waste disposal problem. Although the water/polymer mixture has some advantages over oil the parts still have to be washed after quenching and dried to prevent rusting.

Gas does not have these problems. Most of the gases used are very environmentally friendly and there is no waste disposal problem. The gas does not change phase during the quenching process so the heat transfer coefficient is constant minimising distortion. The cleanliness of a heat treatment shop that uses low pressure gas carburising in a vacuum furnace followed by gas quenching can be seen from Figure 1.

Figure 1. A modular vacuum carburising system at BMW (photo courtesy of ALD)

Gas quenching in vacuum furnaces

The lower the hardenability of the steel being quenched, the higher the quenching speed needed to harden it. Higher hardenability is usually associated with higher alloy content. As most carburised and quenched components go into the automotive industry, alloy content has to be minimised to keep down costs. Thus the higher the quenching speed that can be achieved the better.

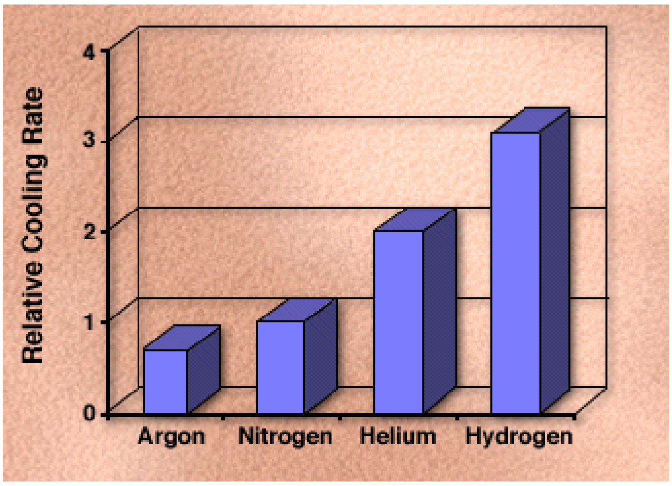


Figure 2. The relative quenching efficiency of various gases

Gas quenching speed is controlled by three main factors; the physical properties of the gas, its pressure and its velocity past the parts. The pressure is limited mainly by cost. Quenching pressure above 20 bar does not seem to be economic and 6 to 10 bar is more typical. Velocity is limited by the furnace design. Furnace manufacturers are striving to increase it, but again there are limits. As for the properties of gases, their relative quenching speeds are shown in Figure 2.

Which gas?

Argon and nitrogen

The use of argon is normally restricted to those tool steels that are sensitive to nitriding, ruling out nitrogen. Nitrogen at pressures up to 10 bar is quite adequate for many low alloy steels, particularly in small section sizes, e.g. 20mm diameter 16MnCr5. However, it cannot achieve the speed required for typical automotive gears in most of the common carburising steels. At 20 bar it is possible to quench a 30mm diameter bar, but for larger parts something more is needed.

Helium

It is technically feasible to use helium. 20 bar helium can quench a 40 mm diameter bar of 16MnCr5. However, helium is a rare gas, hence expensive. It is possible to recycle helium, but even the cheapest recycled helium costs ten times more than nitrogen to achieve the same quenching rate.

Hydrogen

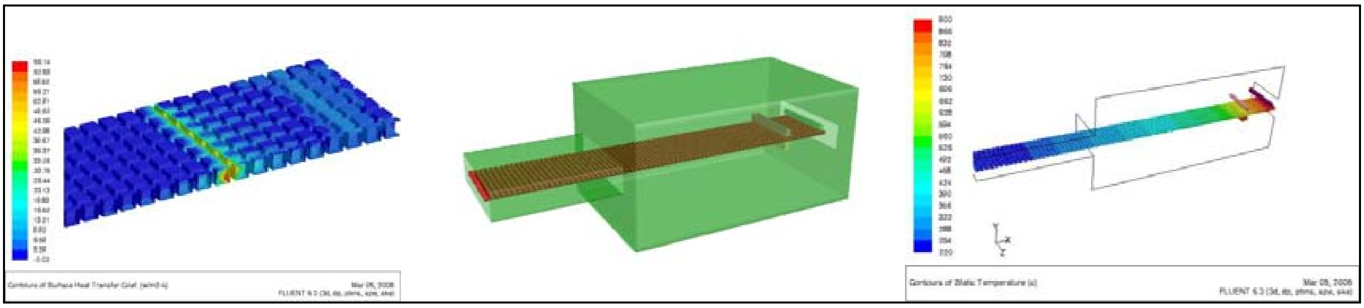
Hydrogen is the fastest quenching gas and also the cheapest in terms of cost of cooling rate even without gas recycle. Hydrogen recycle is, of course, possible using systems such as that developed by Seco/Warwick. Hydrogen has a heat transfer coefficient almost twice that of nitrogen at the same pressure and can give quenching speeds similar to oil.

Gas-jet quenching and cooling

Using gas-jet technology it is possible to get very high gas velocities and therefore high cooling rates with only nitrogen. Sometimes a little hydrogen is added more for oxidation control than for increased speed. Gas-jet cooling can either be used in a separate chamber after either a vacuum or conventional atmospheric pressure furnace in in-situ for applications such as sinter hardening.

Linde FRIOFLEX™ technology can be used to increase the cooling speed in a sintering furnace by using inert gas from a nozzle arrangement. The principle is well known and impingement cooling has been successfully applied to cool or quench metal components.

Basically a cooling nozzle arrangement is directed at the sintered parts as the parts pass on the belt at high temperature. The gas velocity is sufficient to achieve desired cooling rate to ensure the formation of martensite hence achieving the required hardness whilst the furnace atmosphere is still protecting the components from the oxidation, doing its primary duty.



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