

# Sintering and Sinter Hardening

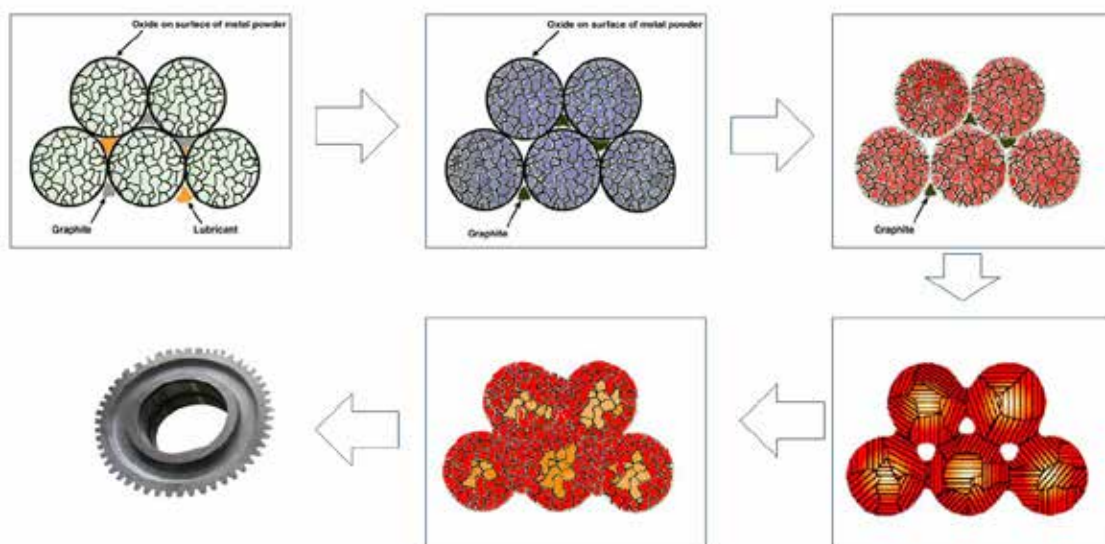
Sintering and sinter hardening are parts of the process that turns metal powder (P/M) into useful components. Powdered metal is compacted (generally at room temperature) in a press that has a die that is shaped like the final component. After the mass of powder is compacted into a shape and ejected from the press (a green component), it is fed slowly through a special high temperature furnace to bond the particles together. The green component goes through a series of processes during P/M production. The key two processes are sintering, where parts become metal components ready for service, or sinter hardening, where parts become solid metal components and are then hardened in the same process cycle.

## How does the green component become a solid piece?

The compacted powder particles are metallurgically fused without melting, a phenomenon called "sintering". Sintering is bonding of adjacent surfaces in a mass of particles by molecular or atomic attraction during heating at a high temperature below the melting temperature of any constituent in the material. The following figure briefly explains how process progresses. Firstly, oxides are reduced to allow bonding between the particles and then diffusion removes the pores and forms a metal solid piece.

## What is the function of the sintering furnace and atmosphere?

Sintering atmospheres perform two major functions. First, they provide a protective atmosphere that keeps detrimental oxygen away from the parts (oxidation). Second, the atmosphere supplies the chemically reducing force to remove metal oxides already present on the powder. The oxide reduction potential is a function of the hydrogen to water ratio. Once the oxide has been reduced, the atoms of the metal particles will interact and sintering will begin. The sintering of iron-based materials is accomplished in many different atmospheres. Most recently furnace atmosphere have been employed as the hardening medium using impingement gas cooling.



## What are the furnace atmosphere mixtures for different alloys?

Furnace atmosphere composition is entirely dependant on the material being treated. Different alloying elements will lead to a change in the hydrogen to water ratio to give the reducing power needed to produce oxide free surfaces. The following table gives examples of different atmospheres used in different alloy systems.

### Sintering Atmosphere Overview

Standard Iron based	5 – 10% H <sub>2</sub> and balance N <sub>2</sub> DA mixed with N <sub>2</sub> to form 5 – 10% H <sub>2</sub> Endothermic gas N <sub>2</sub> methanol mixture
Copper based Materials (Bronze, Brass, etc)	5 – 10% H <sub>2</sub> balance N <sub>2</sub> DA mixed with N <sub>2</sub> to form 5 – 10% H <sub>2</sub> Endothermic gas, N <sub>2</sub> methanol mixture Exothermic Gas
Stainless Steel and Ni/Cr alloys	50 – 100% H <sub>2</sub> and balance N <sub>2</sub> Dissociated Ammonia
Alloys containing Cr, Ti, Zr	50 – 100% H <sub>2</sub> and balance Ar Must be sintered in N <sub>2</sub> free atmosphere
Aluminum Alloys	100% N <sub>2</sub>
Tungsten, Molybdenum	100% H <sub>2</sub>
Titanium	Vacuum Furnace required
Tungsten Carbide and Cobalt	100%

It is therefore recommended that the sintering furnaces is optimised based on the function of the atmosphere expected of that particular zone. This will reduce costs by reducing consumption of expensive furnace constituents as well as giving flexibility to the furnace operator to operate under different conditions for different materials.

## What is sinter hardening?

Sinter hardening is the process by which the P/M parts are rapidly cooled after sintering to form a mostly martensitic microstructure. Traditionally sinter hardening is a separate process by which parts are sintered in a sintering furnace and slowly cooled. Then these parts are taken into a batch furnace, reheated and then quenched. This process has disadvantages in terms of costs, particularly reheating, and quality. As parts are quenched in oil or other chemicals and quenching chemicals tends to be trapped in the porous structure of sintered parts causing loss of performance of the parts and the requirement for a thorough cleaning of parts, increasing the total costs of the production even higher.

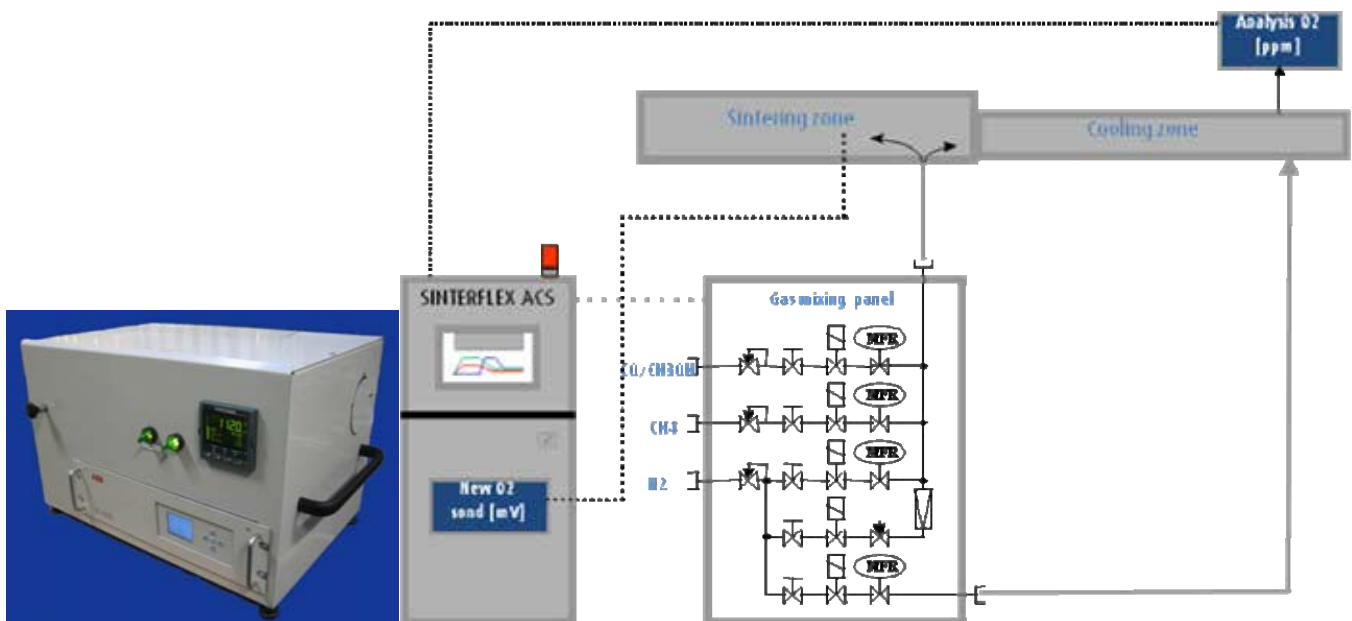
Sinter hardening therefore consolidates this multi-sequence operation into a single run process by which the parts are sintered and then hardened and discharged ready for service.

## Importance of carbon control during sinter hardening

It is very important to control carbon within the furnace to achieve desired mechanical properties for P/M components. Hardness of a ferrous component is directly related to its carbon content. Therefore decarburisation is undesired during sinter hardening.

Increasing the C-potential at the sintering temperature by changing the gas composition has been impractical and led to production of high carbon potential at lower temperatures, leading to sooting and excessive carbide formation.

Linde SINTERFLEX™ technology is able to control the carbon potential by using special external atmosphere analysis equipment and using gases that would control the potential strictly within the required levels.

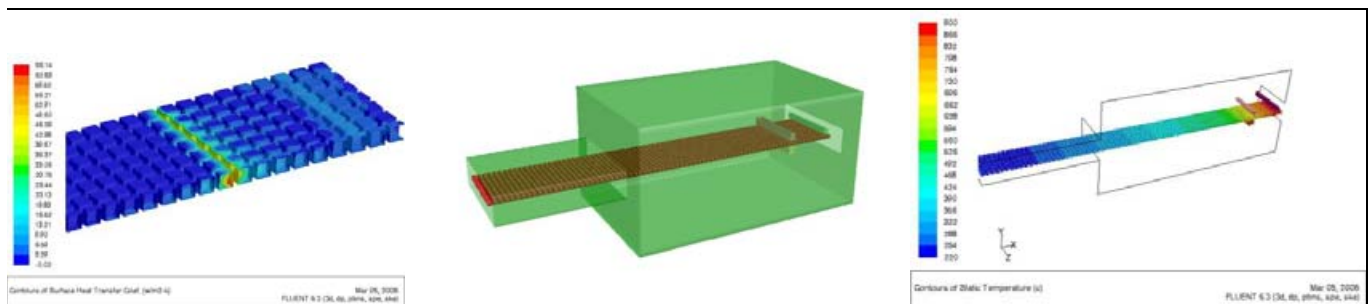


## How quenching is done within the furnace?

Cooling rate is as important as hardenability of the steel in achieving a hardened part. Although some alloying elements will promote the formation of a martensitic structure without forced cooling, in most of the cases, cooling needs to be improved to reduce the cost of alloying elements. Alloying elements will play the key role in determining the atmosphere composition and the method used for furnace atmosphere control and the quenching speed.

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 of the idea is well known and impingement cooling has been successfully applied to cool or quench metal components.

The basic process is to employ the cooling nozzle arrangement so that the sintered parts at high temperature would pass through the high-speed gas cooling zone at the line speed and achieve cooling rate to form 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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