Heat Treatment Experience of Additive Manufacturing

Furnaces for the Additive Manufacturing Industry
for Metal Applications

Västerås
20th of September 2017

Nabertherm GmbH
Frank Murken

Nabertherm
MORE THAN HEAT 30-3000 °C

Contents

1 Introduction

Additive manufacturing allows for the direct conversion of design construction files to fully functional objects.

With 3D-printing objects from metals, plastics, ceramics, glass, sand or other materials will built-up in layers until they have reached their final shape.

Depending on the material, the layers are interconnected by means of a binder system, by laser or other technology.

Many additive manufacturing processes require subsequent heat treatment of the printed parts. The heat treatment requirements depend on the printed material, working temperatures, the atmosphere in the furnace and, of course, the additive manufacturing method.

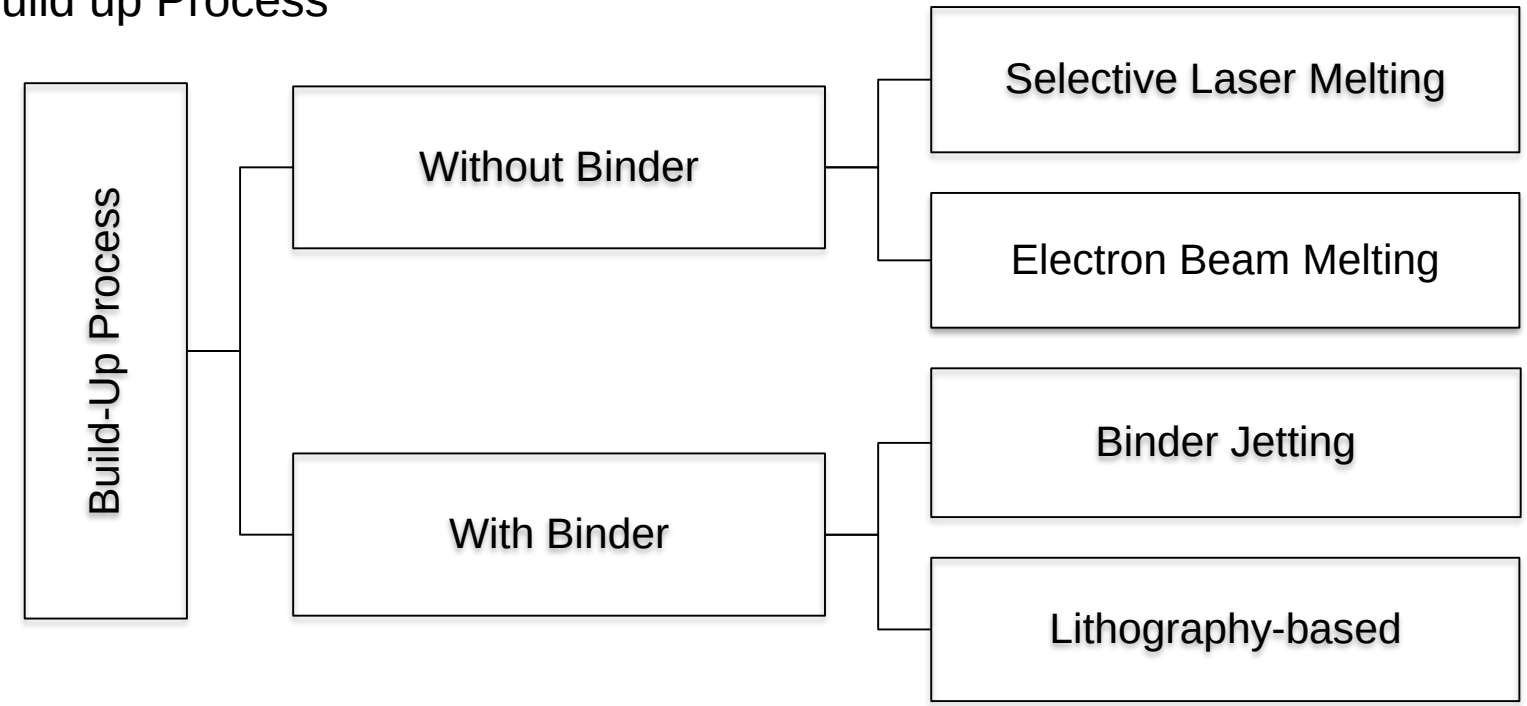
Laser-melted metallic components might need to be stress relieved prior to being separated from the plate to relieve the stress that is generated during the printing process.

Binder containing systems require a thermal debinding to obtain the desired material properties.

1 Introduction

Process Chain

Build up Process



1 Introduction

Selective Laser Melting

A powder coat is selectively melted through laser or e-beam, thereby being fused. In laser melting, if applied to powdered metals the powder is melted and fused. In the case of plastics, this process is called laser sintering, since plastic particles are only partially melted and fused. After finishing the component geometry, loose material will be removed.

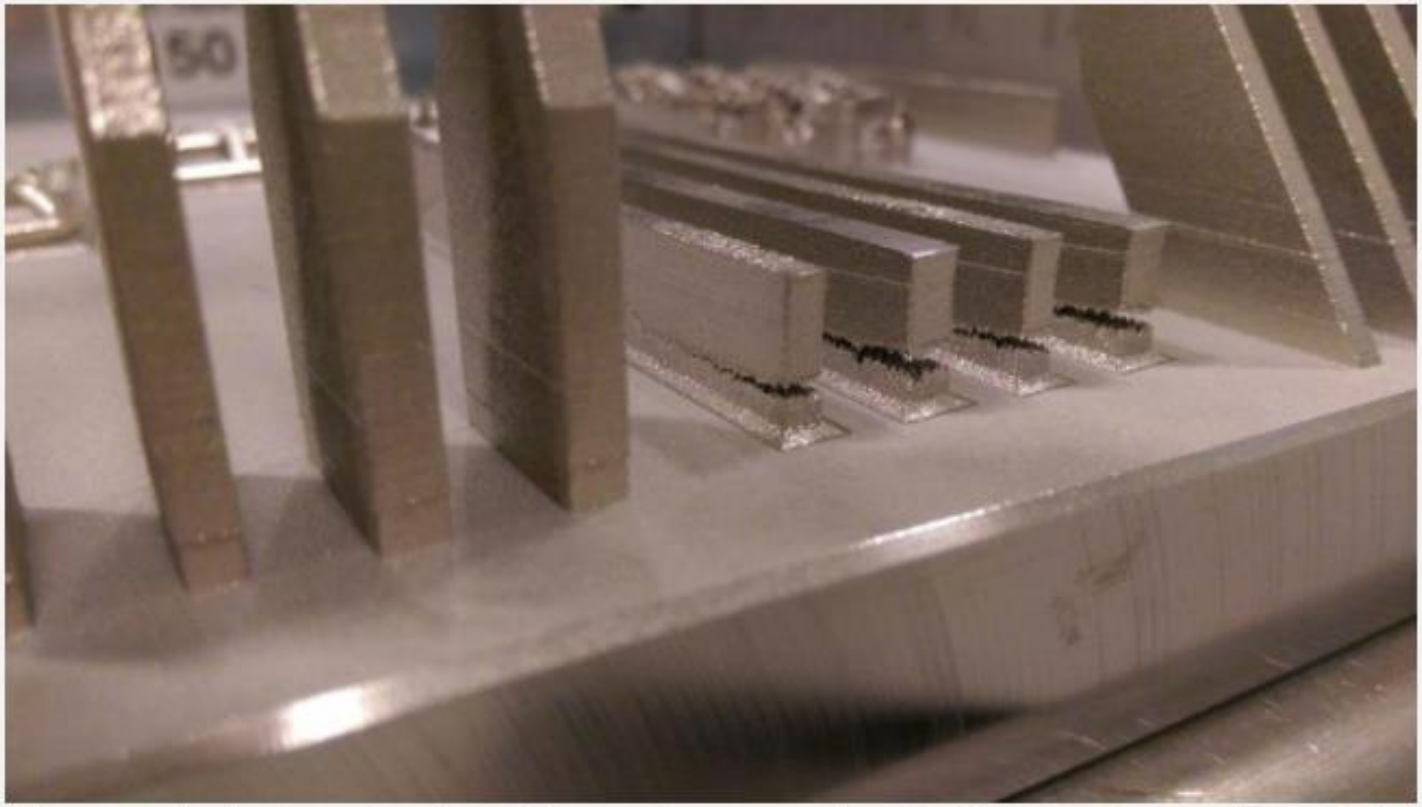
Materials
Metals, Plastics

The most common heat treatment of parts manufactured by a laser-based system is the stress relief treatment to reduce the internal stress, which was introduced into the component during laser melting.

Printed aluminium part, heat treated in model N 250/85 HA (Manufactures CETIM CERTEC on SUPCHARD platform)

1 Introduction – Without Binder

Why heat treatment of laser melted parts?



Here, stress buildup shows the collapse of four metal bars created through additive manufacturing. [Photo Credit: Albert To / University of Pittsburgh's Swanson School of Engineering]

1 Introduction

Binder containing process - Binder Jetting

Inkjet print heads apply a liquid bonding agent onto thin layers of powder. By gluing the particles together, the part is built up layer by layer.

Materials

Metals, ceramics, plastics, sand

Why heat treatment of binder containing parts?

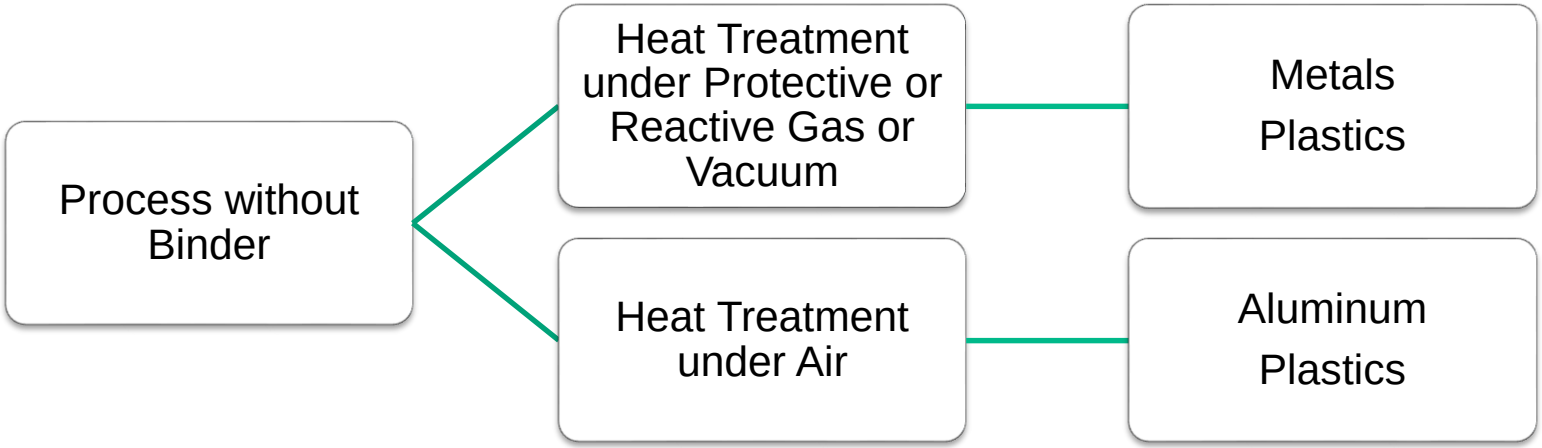
Debinding

Most of the organic binder is removed during debinding. There are various debinding methods. Such as thermal debinding, catalytic debinding or solvent debinding.

Sintering

In the next step, the component is sintered at above 1300°C. Depending on the feedstock, the component shrinks by up to 20%.

2 Heat Treatment – Process without Binder



The different heat treatment processes are defined by various parameters and requirements :

- Material (Aluminum, stainless steel, titanium,…)
- Additive Process (Laser Melting)
- Purpose of heat treatment (Stress relief, material strength,…)
- Requirements for the final product (Surface,…)
- Manufacturer (System provider, powder,…)

2 Heat Treatment – Process without Binder

2.1 Protective Gas Atmosphere or Vacuum

Heat treatment under protective gas or vacuum are usually made for metals, to prevent or minimize oxidation of the components.

Selection criteria's furnace atmosphere

- Manufacturer or material specification
- Purpose of the heat treatment
- Requirements for the component and the surface
- Further requirements

2 Heat Treatment – Process without Binder

2.1 Protective Gas Atmosphere or Vacuum

What is the result the customer expects after the heat treatment?

- Surface without oxidation → no further mechanical treatment
- Oxidation allowed → parts will get a surface finishing or further treatment

Process recommendations for oxide free surfaces

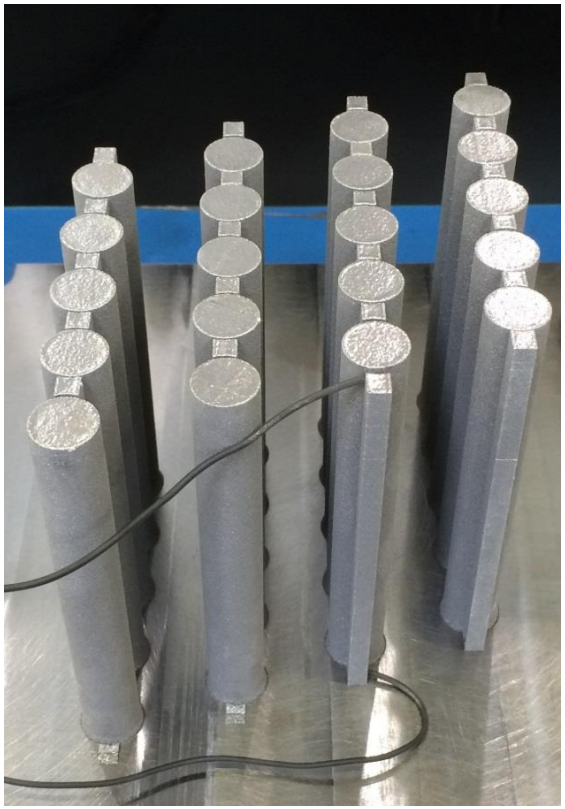
- Proper cleaning of the parts
- Argon with low dew point
- High vacuum (10^{-5} mbar)

2 Heat Treatment – Process without Binder

2.1 Protective Gas Atmosphere or Vacuum

Sealed Furnace

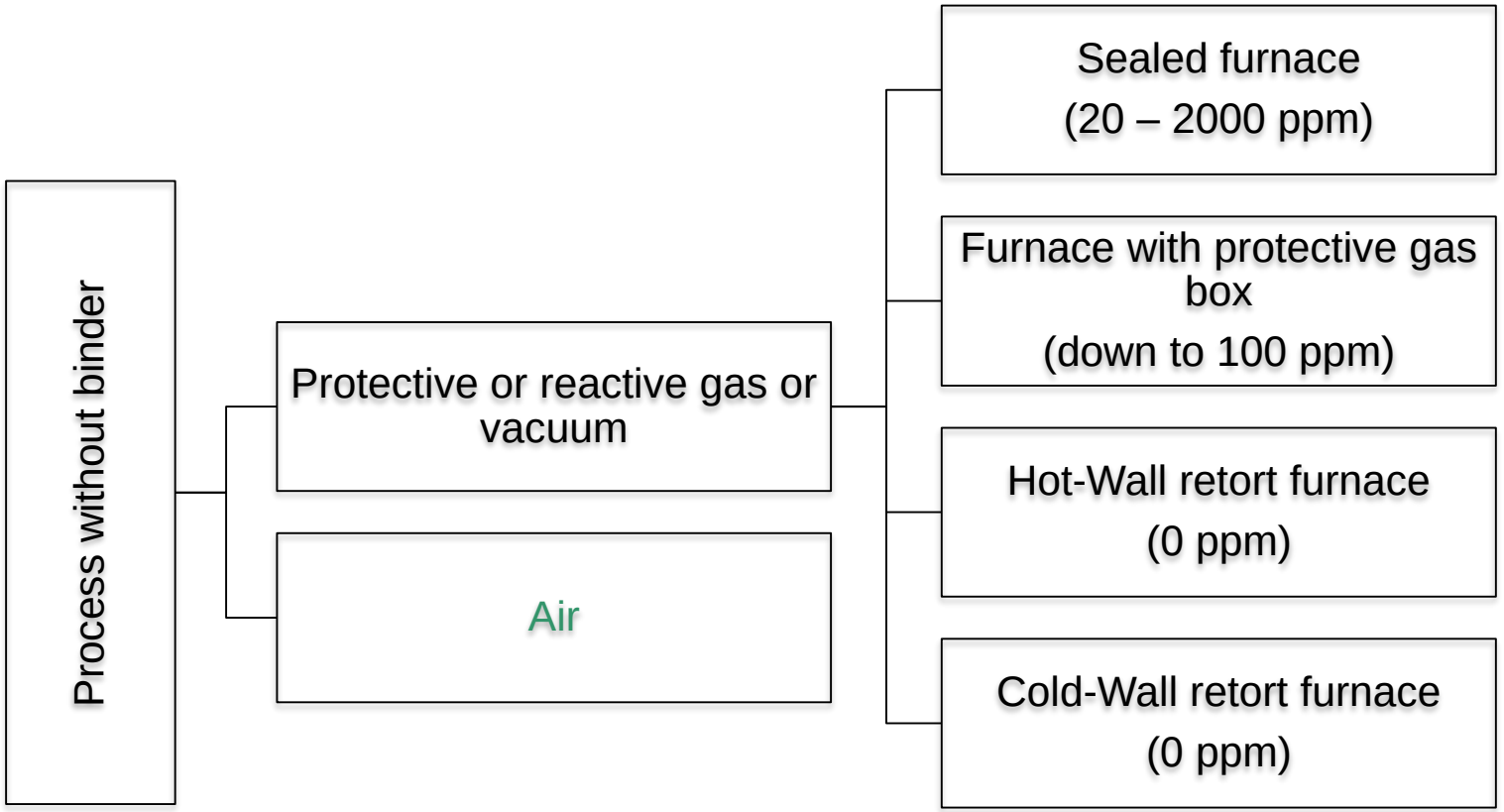
Hot-Wall Retort Furnace



Examples: Titanium parts for tensile strength

2 Heat Treatment – Process without Binder

2.1 Protective Gas Atmosphere or Vacuum



2 Heat Treatment – Process without Binder

2.1 Chamber Furnace with Protective Gas Box

Chamber furnaces represent a good price / performance ratio for applications that are carried out under a non-flammable protective gas atmosphere.

By using a protective gas box with the corresponding gas a standard chamber furnace can be converted into a protective atmosphere furnace. Depending on the process gas, gas flow rate and condition of the box, the residual oxygen contents can be achieved in a low ppm range.

For batches with complex shapes and holes or ever for bulk goods or for parts made of titanium, the use of a box with an evacuation lid in combination with a vacuum pump is recommended. The heat treatment process takes place under a protective gas.

Available for temperatures up to 1150°C

LH 216/12

NW 220

2 Heat Treatment – Process without Binder

2.1 Retort Furnaces

If the process requires a very low oxygen content or a defined protective or reactive gas atmosphere, a retort furnace type is recommended.

NRA 150/09

Hot-wall Retort Furnaces for applications up to 1150°C

These gastight retort furnaces are ideal for heat treatment processes requiring a defined protective or a reaction gas atmosphere.

Cold-wall Retort Furnaces for vacuum applications or above 1150°C with process gas

The vacuum-tight retort furnace enables heat treatment processes either in protective and reaction gas atmospheres above 1150°C or in a vacuum down to 10^{-5} mbar above 600°C.

VHT 100/12 MO

2 Heat Treatment – Process without Binder

2.2 Heat Treatment in Air

Many kinds of materials like aluminum, some steel alloys as well as plastics have to be heat treated in air in order to achieve the required material properties.

For operations below 850°C furnaces with a forced air convection like dryers (TR), chamber ovens (KTR) and forced convection furnaces (NA, SAL, W/HA) are the best choice.
Due to the very good temperature uniformity, forced convection chamber furnaces are suitable for processes such as tempering, aging, stress-reliefing or preheating.

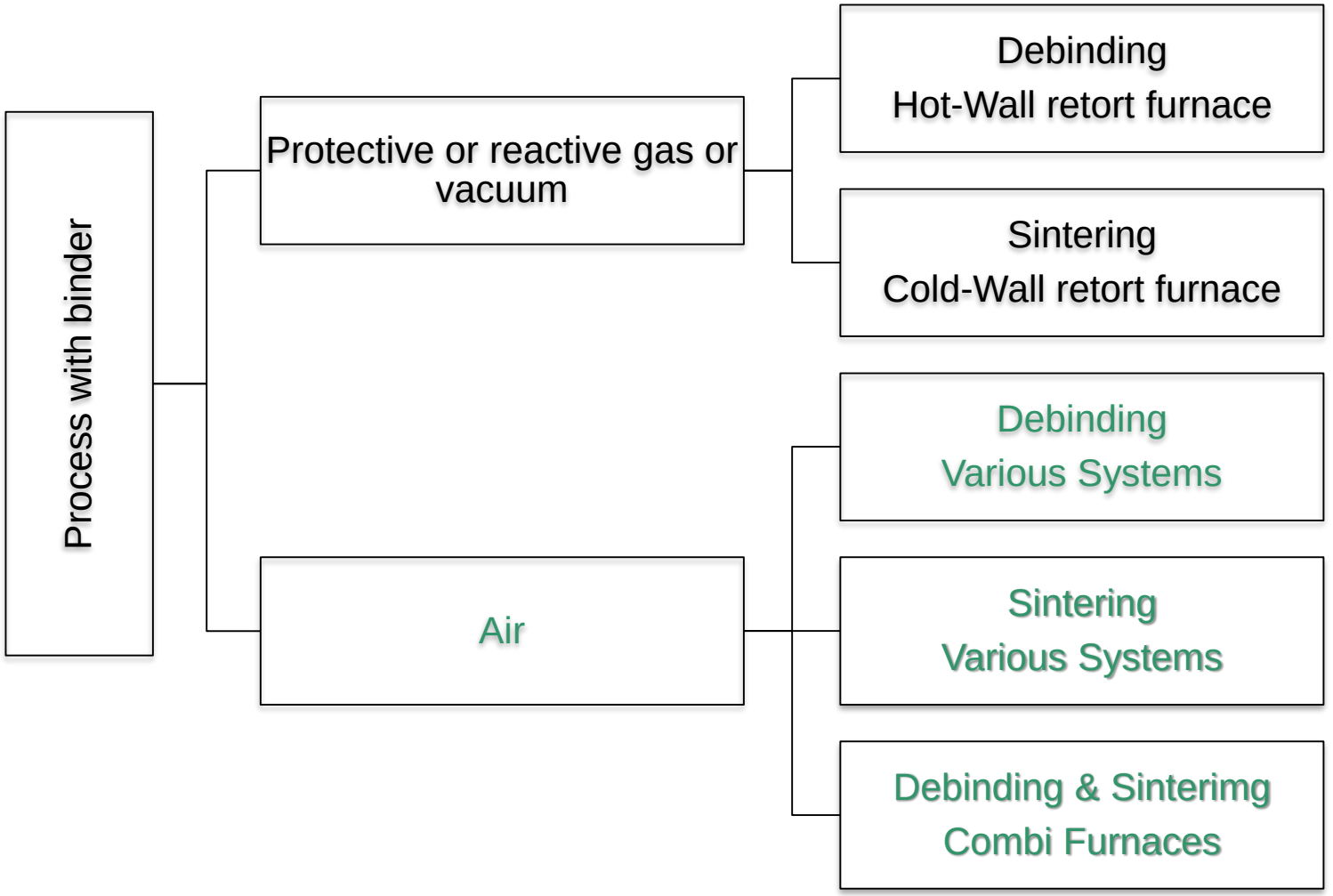
If the process temperature is above 850°C radiation furnaces will be use. Hardening of steel under ambient atmosphere with an external quench bath is just one example.


KTR 4500 LS


NA 250/45


N 41/H

3 Heat Treatment – Process with Binder



3 Heat Treatment – Process with Binder

3.1 Thermal Debinding / In Gas Atmosphere

Debinding is a critical process due to the released hydrocarbons which subject to the corresponding concentration can cause a formation of an ignitable mixture inside the furnace. Depending on the process and the quantity of binder, Nabertherm offers tailored safety packages to ensure a safe operation of the furnace.

Conditions for critical atmosphere inside the furnace:

- Flammable organics (binder, wax, solvents,..)
- Oxygen (ambient atmosphere)
- Ignition source (heating system)

Safety Concept:

No oxygen inside process chamber before the heating process can be started!

3 Heat Treatment – Process with Binder

3.1 Thermal Debinding / In Gas Atmosphere

IDB = Inert Debinding under nonflammable gases like argon, nitrogen or nonflammable forming gases at an overpressure of approx 35 mbar relative

H2 = Debinding under hydrogen atmosphere at an overpressure of approx. 35 mbar rel.

CDB =The polyoxymethylene (POM) of the binder will be removed from the green part and chemically decomposed under the influence of nitric acid.

NRA 400/03-IDB

NRA 40/02-CDB

3 Heat Treatment – Process with Binder

3.2 Sintering / In Gas Atmosphere or under Vacuum

Cold-wall retort furnaces are used for the residual debinding step, followed by the final sintering cycle.
The furnace chamber is equipped with an additional process box that has a direct outlet to the exhaust gas torch through which the exhaust gas can be directly vented. This system enables a substantial reduction in the amount of furnace chamber contamination caused by the exhaust gases generated during debinding.

VHT 40/16 MO H2

VHT 500/22 GR H2

Nabertherm
MORE THAN HEAT 30-3000 °C

Thank you for your attention

www.nabertherm.com