

Furnaces for additive manufacturing

Rapid prototyping, rapid tooling and 3-D printing

For 3D printing and rapid prototyping different materials (plastics, metals, ceramics) can be used. When using metals and plastics it has to be distinguished, if the material is sintered directly in the 3-D printer by lasers or if the material is mixed with the organic binder (wax, polyacrylics, etc.). A so called feedstock develops. This can be processed then with low-cost 3-D printers like plastics. The binder will subsequently be removed (burn out up to 700 °C, decompose catalytically 110 °C - 140 °C [Catamold process] or washed out). This technique has been taken over from powder metallurgy (MIM =metal injection moulding).

In contrast to casting, injection moulding or conventional powder metallurgy production methods the manufactured parts in the 3-D printer are often unique, for example prosthetic parts and small series. The parts themselves are also mostly small due to the comparatively slow print process. Therefore rather small furnaces are needed. It can start at one litre. The users of the 3-D printing often come from sectors that previously had less to do with heat treatment and sintering. There is a strong demand for preferably low-cost, multifunctional furnaces. Besides, companies such as foundries or aluminium injection moulders can be interested in small furnaces for 3-D printing parts in order to avoid using large production furnaces.

1. Plastics

- a. Hardening: Parts which were made of plastics sometimes require a thermal hardening. Drying oven of the LHT series can be used for this purpose.
- b. Drying: If support structures made of water-soluble polymers are used which should be later washed out, drying oven of the LHT series are used too.
- c. Casting: Plastic models often act as the master form. They are used to manufacture silicone moulds. Casting cores can be manufactured through these moulds. With LINN tiltable casting machines or inductive heated centrifugal casting machines of the series Supercast/ Titancast the master form can be arbitrarily often produced in metal.



LHT drying oven (Tmax 300°C). Furnace for drying and hardening



Supercast. Induction centrifugal casting machine



Induction tiltable casting machine

2. Metal / hard metal / ceramics

- a. Stress relief heat treatment, annealing, heat treatment: Parts which were sintered directly with the laser in the printer often require a thermal post treatment under protective gas up to 1100 °C for improving the mechanic properties. Furnaces of the series HK with gas purging are suitable for ferrous alloys. For sensitive metals such as titanium which will be treated subsequently at approx. 950 °C in vacuum or in very clean argon (99,999 % = N5 quality), furnaces of the series KS-S/Vac or VMK-S/Vac are suitable. These are used also for stainless steels. For aluminium parts circulation can be used air furnaces of the series LHT up to 300 °C, furnaces of the series AK or in case of high requirements for temperature uniformity furnaces of the series KK-U or KK-UL up to 550 °C.
- b. Melting: Sometimes, only a porous part is manufactured which will be infiltrated afterwards in a metal melting. For this purpose furnaces of the series HK with the option gas purging device and metal shell can be used or in case of induction melting the middle frequency generators of the series MFG can be used. For sensitive metals furnaces of the series KS-S (Tmax 1150 °C) are necessary or for temperatures above 1150 °C furnaces of the series HT which can work under protective gas and/or vacuum are required.
- c. Hard metals parts are often repressed in the furnace under over pressure. In this case, overpressure furnaces of the series FKH/GKH/Rubistar (Tmax 2400 °C, 60 - 100 bar) can be considered. However, it is usually operated at pressures around 1000 bar (HIP, heat-insulated presses which are not included in our product range.)



VMK-135-S (Tmax 1050 °C). Protective gas and vacuum tight, different sizes



KS-S 240 (Tmax 1200°C). Protective gas and vacuum tight, different sizes



KK-U 75 (Tmax 850 °C). With air circulation insert in different sizes



HT-1600-G-Graphite (Tmax 1600 °C, optional up to 2200°C). Protective gas and vacuum tight, different sizes



HK 30 (Tmax 1300 °C). Almost gas tight for operation with N₂ or Ar, different sizes



Rubi-Star 60 (Tmax 2400 °C, Pmax. 60 Bar, optional higher). High pressure furnace, different sizes

3. Feedstock (metal/hard metal/ceramic)

Debinding: The binder usually consists of 2 components. The main component (proportion up to 95 %) will be burnt out during debinding, decomposed catalytically or simply washed out with solvents. The residual binder content of approx. 5 % causes that the component still has certain mechanic strength for transport and handling.

- a. Catalytical debinding: LHT can also quote furnaces for the catalytic debinding. These furnaces are protective gastight (N₂) and have a gas circulation to be able to heat up the good faster and to distribute the catalyst homogeneously (nitric acid). A post combustion is necessary because toxic and flammable substances develop during decomposition (see appendix Catamold). For small design sizes gas tight drying cabinets of the series LHT up to 200 °C with gas circulation, dosing pump for the catalyst and post combustion are appropriate. For higher volumes furnaces of the series KH up to 400 °C are available.
- b. Thermal debinding: For the thermal debinding of metals and hard metals furnaces of the series VMK-S und KS-S can be used. Due to high temperature up to 1050 / 1150 °C parts

can be debinded completely in VMK-S or KS-S furnaces respectively because already a „pre-sintering“ is done with the most metals through which the parts get sufficient stability for further process steps. For thermal debinding of parts made of oxide ceramics furnaces of the series KK, KS or LM with post combustion can be used. Thermal debinding requires relatively long time. In case of suitable binder systems the times can be shortened significantly via LHT microwave hybrid furnaces with hot air heating and microwave heating (T_{max} 550 °C) of the series MKST or resistance and microwave heating (T_{max} 1800 °C) of the series MHT, the last is also suitable for sintering.

- c. Sintering: For sintering of oxide ceramics furnaces of the series VMK, VMK1600 / 1800 or furnaces of the series HT Super Eco can be used. Hard metal will mostly be manufactured in furnaces of the series HT graphite. For metals HT furnaces with hydrogen and forming gas atmospheres are suitable. Titanium and refractory metals such as molybdenum and tantalum are sintered in high vacuum cold wall furnaces of the series KKH / KKV.
- d. Liquid Silicon Infiltration: If parts should be made of SiSiC or SiC furnaces of the series KS-S and VMK-S can be used for pyrolysis and furnaces of the series HT or GHV graphite furnaces can be used for graphitization up to 2200 °C and silicon infiltration up to 1600 °C.



Special furnace for catalytic debinding (T_{max} 180 °C), 800l



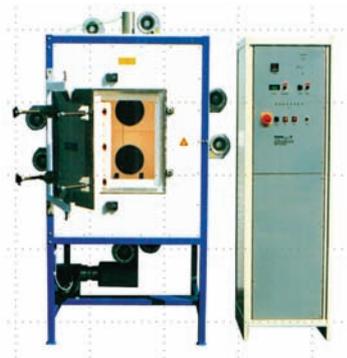
GHV (T_{max} 2200 °C), different sizes



*VMK 1400 - 1800 (Tmax 1820 °C),
different sizes*



*KKV (Tmax 2500 °C), protective gas and
vacuum tight, different sizes*



*MKST 6,4 / 10 (Tmax 550 °C), different
sizes and power levels*



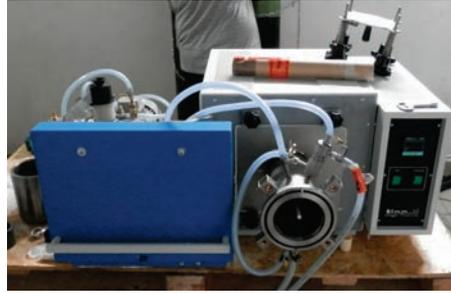
*MHT-G (Tmax 1800 °C) microwave hybrid
furnace, protective gas and vacuum tight,
different sizes*

Cost-effective special solutions:

Universal and cost-effective furnaces for heat treatment and for sintering of parts, manufactured by rapid prototyping processes, made of ferrous alloys, non-ferrous metals, stainless steels, titanium or aluminium under protective gas or vacuum atmosphere are based on our series LM/HK or VMK.

Debindered MIM parts can herewith be sintered as well.

These furnaces can be operated selectively with metallic insert tube (Tmax 1260 °C) or ceramic insert tube (Tmax 1350 °C). The temperature on the sintered part can be controlled and checked via a charging element. Due to use of two insert tubes or end caps respectively for debinding and sintering impurities of the sinter, caused by binder condensates, can be excluded.



HK / LM special

The unique principle of catalytic debinding

BASF has developed a patented polyacetal binder specifically for Catamold[®], the new powder injection moulding technology. This binder can be removed using a method that is completely different from conventional processes. catamold@basf.com.

Green parts manufactured with Catamold[®] are debound in a gas proof furnace at a temperature of 110 to 140 °C, in a nitrogen atmosphere containing a small amount of gaseous nitric acid. We exploit the decomposition of the polyacetal by the acidic atmosphere to achieve very short process times.

The low temperature prevents the component from softening.

Because the nitric acid cannot penetrate into the part of the component that contains the binder, it only reacts with the surface. The gas exchange is therefore limited to the porous zones from which the binder has already been removed. This method of debinding from the outside inwards prevents pressure buildup on the inside. In parts with a wall thickness of up to about 20 mm, the debinding front moves into the component at a rate of 1 or 2 mm per hour. This makes catalytic debinding around ten times faster than conventional technologies.