Benefits of Laminar Gas Flow during Debind and Sinter of PIM/MIM Parts

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Two Page Summary

This presentation deals with the benefits of Laminar gas flow in Batch furnaces. Laminar gas flow provides complete debinding, it ensures temperature uniformity during debind and sinter, it eliminates evaporation of key constituents of the part, it provides versatility and flexibility in producing the largest variety of PIM/MIM parts, and it eliminates a separate thermal debind step.

Furnace Design Challenges: MIM parts are made many different metal powders from iron nickels to stainless steel, from titanium to super alloys using a variety of different binder materials to mix different feedstocks. Depending on the metal powder and the binder used the debinding process can be under atmosphere or partial pressure atmospheres of nitrogen, argon, and hydrogen. Sintering process requires the same atmospheres or high vacuum for special alloys.

In order to process MIM parts from any material the furnace was designed with a refractory metal hot zone and retort. Graphite hot zones and retorts create carbon level control problems, and are not suited for hydrogen atmospheres or high vacuum. A controlled gas flow management system was developed in order to address the uneven gas flow resulting in poor temperature uniformity inside contemporary furnaces. This MIM furnace is very flexible allowing the processing of most materials in all the atmospheres mentioned. Typically it works under partial pressure from atmosphere 1010 mbar to 0.10 mbar and has a high degree of temperature uniformity because of the laminar flow of the gas. The furnace may also include an optional a high vacuum system to reach 10^{-7} mbar. The computer controls of the furnace allow for changes to any of the conditions in any of the segments of the process via entry into an Excel spreadsheet.

The Debind Cycle**:** The secondary binder is thermally removed inside this furnace. The rate of binder removal must be carefully controlled so that the part does not crack. To overcome binder deposits on the cold walls of the furnace a virtually gas tight retort with plenums is constructed out of TZM. The gas flow across the parts during debinding and sintering is of great importance. A controlled gas management system feeds the gas at a predetermined flow rate into the plenums of the retort.

The retort is tightly connected to a totally oil free specially designed dry pump which, via a partial pressure valve, allows for partial pressure atmospheres inside the retort. This method enables the gas to flow across the parts towards the pump and in its gas stream carries the evaporated binder into water-cooled traps so that the binders do not deposit on the cold walls of the chamber.

The Sinter Cycle: During the sinter cycle the parts will be brought to high temperatures. For temperature uniformity a rectangular shaped hot zone is fabricated with heating elements evenly spaced around the retort giving maximum uniformity under partial pressure and vacuum. The tungsten heating elements permit temperatures to1,650°C under various gas and vacuum conditions. A six (6) zone control each with its own control thermocouple, SCR and transformer also helps maintain temperature uniformity to ± 5°C during sintering.

Laminar Gas Flows During The Debind/Sinter Cycle: Three flow characteristics of gasses are possible:

Turbulent Flow: At atmospheric pressure the gas molecules flow at high velocities colliding with each other creating uneven flow. Under these conditions, MIM parts may not be either fully debound or sintered.

Laminar Flow: occurs at partial pressures between turbulent and molecular flow. This furnace is designed for laminar flow, where the gas acts much like a fluid; the molecules are tightly packed and move predictably over surface irregularities and guarantees that all parts receive a sufficient amount of gas flow.

Molecular Flow: This is at vacuum levels below laminar flow where the gas molecules collide, mainly with the surfaces of the retort/chamber rather than with each other. In the molecular flow region the molecules move unpredictably. At vacuum levels below 100 milli-Torr, the molecule movement is strictly random. The binder molecules escape on to the cold walls of the chamber and contaminate the furnace.

Experiments were conducted at 350°C, 550°C, 1000 °C and 1200 °C to map the furnace temperature uniformity within the work space of one furnace using different gases and partial pressures and vacuum. Temperatures were measured using the 6 control thermocouples and 12 survey thermocouples. The results clearly indicate that at debinding temperatures, laminar flow results in much improved uniformity over molecular flow. At the sintering temperatures the influence of laminar flow is diminished. Mechanical properties and product characteristics, such as, density, carbon and oxygen levels and surface finishes were influenced positively by the laminar flow characteristics of the furnace.

The furnace presented here has all the advantages of the two conventional furnace methods and brings economy to the MIM process. The furnace allows debinding and sintering in one step of any MIM parts reducing process time, energy consumption, capital equipment cost, floor space requirements to name just a few. At the same time the furnace controls bring flexibility to the process cycle by being freely programmable for any segment in the process. Last but not least, each cycle is recorded to provide a fingerprint of the particular MIM part being processed in order to verify uniformity from run to run, this gives the user the ability to study the effects of different process parameters on his parts.