Advances in Powder Metal Sintering Technology

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Introduction

The traditional powder metal process, often referred to as "press and sinter", is constantly driven to change by an industry goal of entering new markets through substitution and the development of innovative products for new applications. Although much advancement has been made in the area of compaction, new materials and sintering technology continue to broaden the applications and improve the overall quality and competitiveness of powder metal components.

The goal of any sintering furnace is to provide a consistent, repeatable and economical relationship between the times that a part is in each location of the furnace, the temperature of the part as it travels through the furnace and the atmosphere seen by the part during each stage of the sintering process.

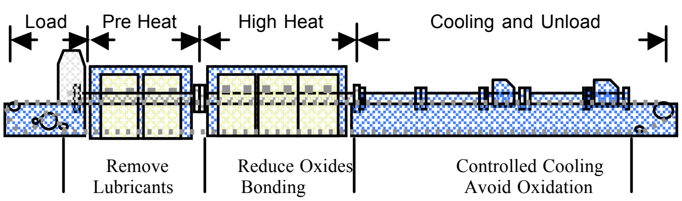

Figure 1. Sintering Furnace Schematic

The process of sintering powder metal components within a powder metal furnace can be summarized by four stages. The product is first brought into the pre-heat section of the furnace. It is here that the lubricants that have been added to the powder to facilitate the compaction step are removed. As the compact enters the high-heat section of the furnace, the compact is brought to the sintering temperature and the oxides on the surface of the powder particles are reduced.

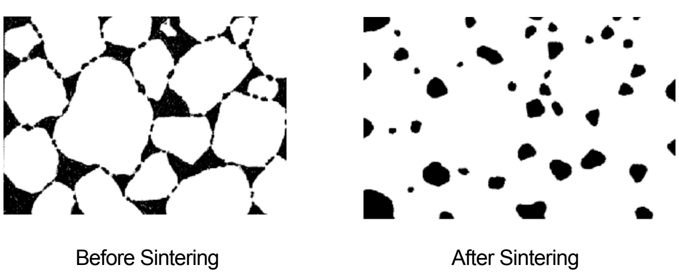

Figure 2. Powder Metal Compact Before and After Sintering

While the compact is in the high-heat section of the furnace, the alloys diffuse and the particles bond together to form a compact with reduced porosity that is more rounded in nature. In an inert atmosphere, the compact is finally cooled to a temperature below which no oxidation will occur.

Advancements

The areas of advancement in sintering technology and equipment can be grouped into five technological groupings.

- De-Lubrication
- High Temperature Sintering
- Sinter Hardening
- Sintering Atmosphere
- Furnace Connectivity and Control

De – Lubrication

Lubricants are blended into the metal powders prior to compaction to reduce inter-particle friction and aid in ejecting the compact from the die of the compaction press. Although these hydrocarbons are beneficial to the compaction process, they must be removed from the compact before sintering can take place.

A great deal of work has been done on the removal of lubricants from compacts. Many devices such as bubblers, humidifiers and auxiliary combustion systems have been developed to aid in the removal of the lubricants. These systems are designed to introduce some source of oxidant, such as water vapor, oxygen and carbon dioxide, into the preheat section of a furnace. This water vapor is a source of oxygen for the reaction of any carbon that results from the decomposition of the lubricant as it is exposed to high temperatures.

The most common problem with such devices is the control of the amount of oxidant that is introduced. The auxiliary combustion systems have proven themselves to work well for large parts and heavy loads. However, the application of this technology has not seen the same degree of success with small parts and light loads.

There is new technology emerging that expands the use of the ***auxiliary combustion technology*** to smaller parts and lighter loads. This new technology incorporates better control of the combustion that forms the oxidant with more flexibility in the amount and location of its injection. With this advancement comes an increase in the range of applications of auxiliary combustion technology. These new devices can now be retrofitted into an existing pre-heat section of a sintering furnace. Initial results from installations of this new technology have demonstrated increased rates of lubricant removal.

Another technology that is becoming more popular is the ***extension of the pre-heat muffle***. These extensions can be as simple as an insulated neck on the front of the pre-heat muffle and as complex as having an oxidant injected into the extension to burn combustibles prior to exiting the furnace.

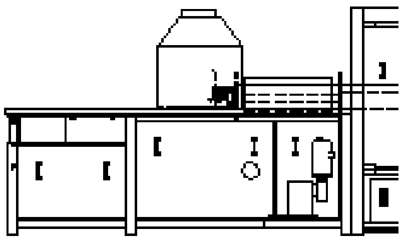

Figure 3. Pre-heat extensions provide more time for de-lubrication

The extended muffle allows the hot gasses exiting the furnace to pre-heat the compact and provides more time for the lubricants to be removed from the compact before it reaches the high heat section of the furnace.

High Temperature Sintering

For many decades, 2050°F has been the standard sintering temperature for ferrous powder metal components. At this temperature the powder metal particles will diffuse together to form a solid component with some degree of porosity. This porosity has proven to be beneficial in applications such as self lubricating bearings. However, the porosity has also limited the application of powder metal components in some designs due to a shortfall in properties when compared to wrought components.

The need to compete with wrought materials has pushed the powder metal industry to seek methods for producing higher density components. Techniques such as double press – double sinter and forging have become common place throughout the industry. However, an increase in the density of components produced through traditional "press and sinter" technology has also become a major area of focus. Much of the research in this area has identified the need to go beyond the traditional sintering temperature to a much higher temperature.

The common difficulty with all furnaces that operate above 2150°F is the means of conveying the product through the furnace. Ceramic belt furnaces have extended this temperature range to about 2350°F. However, these furnaces are limited in there loading to about 10 lbs/ ft^2. Pusher furnaces that have been capable of temperatures in excess of 2600°F can convey much larger loads but use expensive molybdenum elements that are very susceptible to oxidation and are very expensive.

A new style of ***hybrid pusher furnace*** is currently on the market that has a maximum operating temperature of 2350°F. This furnace uses low cost silicon carbide heating elements. It also only pushes the plates through the heated section of the furnace. Prior to entering the cooling section, the plates are transferred onto a mesh belt for the remainder of the trip through the furnace. This allows the heated section to be longer than what was traditionally feasible which results in higher throughputs. The prime application for this technology is the precision gear market that requires higher temperature sintering and high volume production.

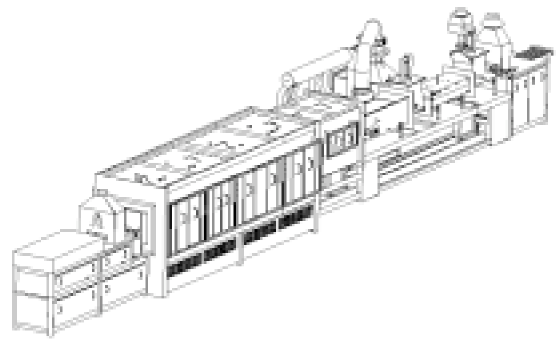

Figure 4. Schematic of hybrid pusher furnace

Sintering Hardening

The use of convective cooling units to rapidly cool sintered component to a high hardness continues to expand the applications and reduce the cost of powder metal components.

The designs of convective cooling units that are used in sinter hardening continue to improve. Higher cooling rates and an improvement in the ability to control the atmosphere flow in the furnace continue to reduce the need for alloys in the materials that were once needed to achieve hardness.

Other improvements have been in the area of application of the sinter hardening technology. High temperature sintering continues to be a direction of improvement in the powder metal industry. However, the combination of ***sinter hardening and high temperature sintering*** has not been widely applied. That is changing. The hybrid pusher furnace is equipped with sinter hardening capability as well as other high temperature sintering furnaces are being equipped with convective cooling systems. The result is a product mix that has new properties and economics to further broaden the powder metal market.

Sintering Atmosphere

One of the major keys to successfully sintering powder metal components is to have an appropriate atmosphere throughout the furnace that is optimized for function and economics. Although the importance of the sintering atmosphere has been known for a long time, the availability of tools and techniques are now providing more information to the part producer so they have better control of the sintering process.

The application of analyzers that can measure the amount of oxygen, hydrogen and dew point in the furnace atmosphere is growing. Sampling throughout the furnace by way of pre-installed sampling locations throughout the furnace and sample probes, can provide a map of the atmosphere from the front of the furnace to the back. Profiling the atmosphere during good times of operation provides a baseline for troubleshooting the atmosphere during those problem times.

Figure 5. Atmosphere sample cart

One tool that is seeing more use through the industry is the ***atmosphere sampling cart***. The cart can be equipped with a range of device that measure oxygen, hydrogen, dew point, carbon monoxide, carbon dioxide and methane. Real-time readouts as well as long term data collection has made this a valuable tool for evaluating the atmosphere in a furnace.

Furnace Connectivity and Control

Control of a sintering furnace can range in complexity from the very simple stand alone controllers to advanced computer systems. In the age of the internet and cell phones, furnace manufacturers and users are beginning to incorporate these technologies into the sintering furnaces.

Real-time remote monitoring systems are being used to record information for both quality control and preventative maintenance. Information about power draw can be automatically sent to the furnace manufacturer on a routine basis for their review and recommendations on maintenance.

The internet is being used hand in hand with sintering furnaces. In the event of an alarm on the furnace, the furnace PLC can use an internet connection to text message a maintenance person's cell phone or send them an e-mail alerting them of the problem. A simple subscription to a service offering PC-to-PC remote connectivity allows the furnace controls and computer system to be remotely accessed. Whether they are in the same building or in another country, data can be gathered or program change can now be made without a technician ever leaving their office.

Future

It is difficult to know just where technology will lead the powder metal industry. Better properties of existing materials and the development of new materials are two goals that will never go away. So only one thing can be said with certainty, the adoption of technology from other industries and the development of new technology within the powder metal industry are essential to the continued growth and competitiveness.