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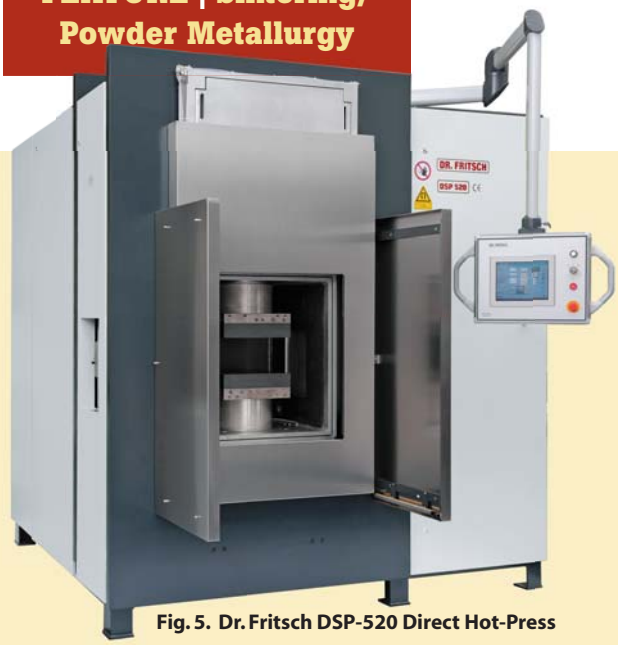

Fig. 5. Dr. Fritsch DSP-520 Direct Hot-Press

FAST Direct Hot-Pressing Brings Sintering Up to Speed

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A unique fast-heating sintering process developed by German sintering pioneer Dr. Fritsch is employed in an increasing number of industries. To date, almost 1,000 sinter presses have been installed worldwide, and new applications are added constantly.

Having its origin in the diamond tools industry, FAST Direct Hot-Pressing has spread into many other industries. Back in 1953, not even the founder of the company, Dr. Fritsch, would have imagined the diverse fields of application for this sintering technique. Today, Dr. Fritsch is an established supplier of sinter presses and related machinery for the diamond-tools and friction-materials industry, sputter-target manufacturers, heat-sink producers, hard-metal and ceramics industry, as well as for universities and R&D institutes. With upcoming new developments, the list will probably never be completed.

Why are so many users switching to FAST Direct Hot-Pressing?

Introduction

Most users are already familiar with traditional hot-pressing techniques before switching to FAST Direct Hot-Pressing. Hot pressing is one of the widely established methods used to consolidate cold-pressed or loose powders. However, most people in the industry associate hot pressing with long sinter cycles and low flexibility.

Normally, large furnaces are heated up via induction coils or graphite heating elements from outside to inside. First, the walls of the chamber are heated up, then the atmosphere inside the chamber, then the mold and in the very end the powder or green compact inside the mold. It is obvious that this sinter cycle takes a comparably long time, and changing the temperature during or between the cycles is a slow and inaccurate process due to the sluggish nature of the system.

FAST Direct Hot-Pressing takes another approach. FAST stands for "Field Assisted Sintering Technique." The mold is directly connected to electric power. The resistivity of the mold material and the powder part or green compact generate the heat directly inside the mold. Neither the furnace nor the atmosphere inside the furnace is heated up. The heat is only generated where it is needed. This results in very high heating rates and, additionally, a significant increase in the sintering activity of fine metal-powder aggregates. Depending on the part size, sinter cycles of only a few minutes can be achieved. Further, this process lowers the sintering temperature and pressure compared to that required in traditional sintering processes.

Field Assisted Sintering Technique (FAST)

The basic idea of sintering with electric current is quite old. Resistance heating of hard metal powders was patented by American inventor George F. Taylor as early as 1933.[1] Since then, the technique evolved, and several variations of Taylor's idea are now available. When applying a standard (unpulsed) current, the technique is often referred to as FAST

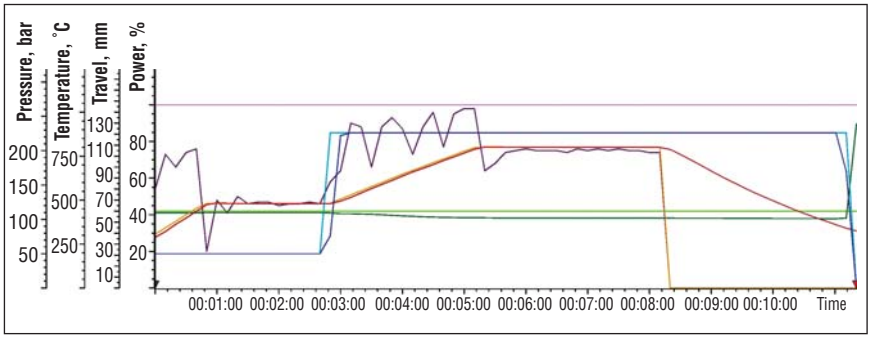

Fig. 1. Typical FAST Direct Hot-Pressing sinter cycle (red/orange: actual/set temperature; green: densification of powder/green compact; dark blue/light blue: actual/set pressure)

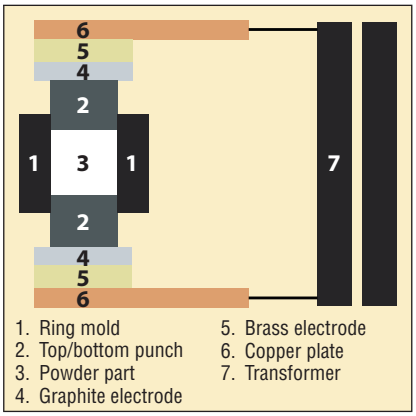

Fig. 2. FAST Direct Hot-Pressing scheme

Direct Hot-Pressing (FAST DHP). Another common term is Rapid Hot-Pressing (RHP). When applying a pulsed current, it is referred to as Spark Plasma Sintering (SPS). Due to the high cost related to generating a pulsed current and the unproven effect of it, this technique is less common for industrial applications.

All these variations of Direct Hot-Pressing are summarized under the generic term "Field Assisted Sintering Technique (FAST)."[2] The latest research suggests that there is no evident difference between sintering with pulsed or unpulsed current (SPS or FAST DHP). The same improved sinter results (compared to traditional sintering) can be achieved by all FAST sintering techniques.[3]

The temperature range of FAST Direct Hot-Pressing is determined by the pyrometer and construction of the sinter chamber. Usually, the machines are available in two versions: a low sinter-temperature version for up to 1100°C (~2000°F) and a high sinter-temperature version for up to 2400°C (~4350°F). The difference is the construction of the sinter chamber, especially the heat insulation, and the temperature measurement devices (thermocouples or pyrometer).

FAST sintering presses normally apply a uniaxial pressing force with a hydraulic cylinder moving the upper or the lower ram (less common) of the machine. Standard pressing forces can be as high as 200 tons. One needs to keep in mind that FAST Direct Hot-Pressing allows most materials to be sintered to full density at lower temperature and lower pressure compared to traditional hot-pressing techniques. Therefore, the high pressing forces of typical conventional presses are not required.

The mold material is normally graphite, a material that is available worldwide at low cost in standard qualities. Using metal powders, the conductivity of the mold is ideal for FAST-sintering of the workpiece. Molds with a big diameter and even with several layers can be heated up very quickly. The process is especially suitable for materials that require high heating rates (e.g., materials that should not be kept at high temperatures). For metal-powder workpieces, a typical sinter cycle takes about 10-15 minutes for small geometries (e.g., 100 x 100 mm). For larger geometries (e.g., 200 mm diameter), a typical cycle takes approximately 45 minutes. Sintering several layers simultaneously does not necessarily prolong the cycle time dramatically. In fact, sintering more than one layer can even have a positive effect on power consumption because working with stacks increases the electric resistivity.

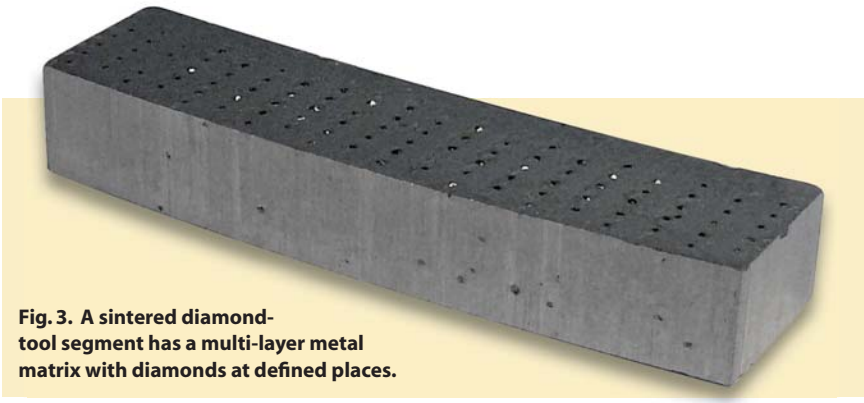

Fig. 3. A sintered diamond-tool segment has a multi-layer metal matrix with diamonds at defined places.

Typical materials and applications of FAST Direct Hot-Pressing are:

- Hard metals and steels
- Multi-layer composite materials
- Functionally graded materials (FGMs)
- High-performance ceramic materials
- Special materials to be sintered with minor grain growth
- Sputter targets
- Friction materials for brakes and clutches
- Diamond tools (metal-diamond alloys)
- Heat sinks (copper-diamond alloys)

Applications

The short sinter cycles of the FAST-sintering process make the technique ideally suitable for sintering all kinds of metal powders. No wonder that this is one of the main applications. The short cycles reduce grain growth to an absolute minimum. This ensures that the material keeps the desired characteristics and helps to achieve the required density.

Binderless sintering is very often possible, so the use of nickel and cobalt can be avoided. Due to the good electrical conductivity of the material, all advantages of a FAST Direct Hot-Pressing process are coming into effect. They are:

- High productivity due to short cycles
- Reduction of grain growth
- Effective use of energy because heat is generated where it is needed

When talking metals or metal alloys, most materials are tungsten carbide, pure tungsten, tungsten-titanium or (stainless) steels. Excellent sinter results can be achieved with all of these materials. In some industries (e.g., sputter target industry), a good result is defined as the full densification of the material. For other applications (e.g., stainless steel filters), the material must have an exactly defined

Spotlight on Functionally Graded Materials

Especially in wear-relevant applications, the industry demands materials that increase the performance and lifetime of a product. The combination of sometimes apparently contradictory characteristics cannot be achieved by one material alone. Innovative companies are therefore putting a focus on material combinations, so called functionally graded materials (FGMs). A product may have the characteristics and advantages of material A on one side and of material B on the other side. Between these two sides, there is a material gradient.

In order to achieve this gradient homogeneously, a sintering technique is required that allows all sinter parameters to be controlled precisely and is fast enough to avoid undesired grain growth. FAST Direct Hot-Pressing creates a controlled liquid phase between the different materials, allowing them to bond together. Furthermore, the layers of consolidated loose powder can be sintered onto a carrier. All this can be done in one sinter cycle, eliminating the operating expenses of additional production steps.

Fig. 4. Stack of brake pads inside a Dr. Fritsch DSP-520 FAST Direct Hot-Press

porosity. The exact control of all process parameters is a very important reason why manufacturers switch from imprecise traditional furnaces to modern-style FAST Direct Hot-Presses.

In addition to (hard) metals and steel, typical applications include the sintering of technical ceramics, such as B_4C, AlN, TiB_2, Al_2O_3 and others. For sputter-target applications, AlN with a 300-mm diameter has already been sintered using a Dr. Fritsch FAST Direct Hot-Press, which proves the technology is not only suitable for sintering large dimensions in metals but also in ceramic materials.

The FAST Direct Hot-Presses

Since the early days, Dr. Fritsch always had a focus on the needs of the industry. Although many machines are used for R&D, the industrial focus ensures that an R&D process can be upscaled to industrial dimensions without the need to change the technology or the manufacturer of the equipment.

The range of machines reaches from the R&D-scale DSP-507 with 81 kVA to the big DSP-535 with 370 kVA. The DSP-507 offers a maximum sintering surface of 200 x 200 mm, whereas the DSP-535 provides 350 x 350 mm. The daylight distances vary from 140 mm to 320 mm, depending on the size of the machine. All machines can be operated up to 2400°C (4350°F). The standard sintering atmosphere is vacuum (20 mbar) and inert gas (nitrogen, argon or forming gas with up to 5% hydrogen). If required, most machines can be equipped with a vacuum level of 0.05 mbar. Typical maximum pressing forces range from 260 kN (DSP-507) up to 2,083 kN (DSP-535) with many different hydraulic cylinder sizes available in between.

Altogether, Dr. Fritsch offers five different FAST Direct Hot-Presses, which ensures that there is the right size and performance for all applications. Special software ensures full process control. All relevant process parameters – like temperature, pressure, stroke (densification) and time – are individually programmable and recordable. The machines can be equipped with up to eight thermocouples for temperature control and comparisons. Alternatively or additionally, up to three pyrometers can be installed. This ensures that the machines fulfill the strict legal requirements of safety-relevant industries like the production of aircraft brake pads.

Conclusion

FAST Direct Hot-Pressing is the answer to many issues industries around the world are dealing with. It allows the sintering of materials with exactly pre-defined characteristics and combines this precision with a very fast and energy-efficient manufacturing process. The development of new materials can be accelerated significantly as compared to traditional hot-pressing techniques. In fact, the sinter quality and achievable density comes close or is comparable to hot isostatic pressing (HIP) but at a fraction of the cost. The technique is already an established manufacturing standard in the diamond-tools industry.

Other industries are just about to discover the multiple advantages of FAST DHP, and the number of users is increasing rapidly. But, in some areas, new users can still benefit from the first-mover advantage. **IH**

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References

1. G.F. Taylor, U.S. patent 1896854, "Apparatus for Making Hard Metal Compositions", February 7th, 1933
2. Ref. to Wikipedia, Article on "Hot Pressing", as of August 12th, 2013
3. "International Powder Metallurgy Directory" (January 4th, 2012): 2011 Hagen Symposium. A Review of Spark Plasma Sintering by Prof. Bernd Kieback, Director of Fraunhofer IFAM branch lab Dresden and the Institute for Materials Science at the Technical University of Dresden (Germany). Summary has been published by Dr. Georg Schlieper.