The advantages of Field Assisted Sintering Technology (FAST) – a high degree of product homogeneity and extremely short processing times at a high compacting rate – have been discussed and generally acknowledged in numerous scientific studies. In addition to the classic applications of sintering technology, FAST has been used in the past 10 years primarily for the development of new materials and the selective improvement of known material properties.

FCT Systeme GmbH (FCT), a company of the German FCT Group in Frankenblick/Thuringia, looks back on more than 40 years of experience in the development and construction of maximum temperature systems. For the past 8 years the company has been working on SPS/FAST systems for the development of new materials, primarily composite metal-ceramic based materials. Until recently the FAST technology, an in-house development, focused on classic R&D applications. So far, about 100 systems have been delivered to customers around the world, where they operate successfully. About 10% of these systems are used in industrial environments and this figure is rising.

From the start FCT worked determinedly on further developing the basic, long-established technology, which is also known as spark plasma sintering, with the goal of improving the production of specific components. It quickly became apparent that systems for electrically conductive and non-conductive materials required substantially different designs, especially for larger components. To meet this necessity, a hybrid concept was developed a few years ago that combines the FAST technology with the classic hot pressing technology (Joule heat): FCT Hybrid-
FAST technology. Initial projects with components having diameters up to 150 mm confirmed the effectiveness of this technology and achieved promising results: improved material properties due to the extremely short sintering times, as well as enormous economical benefits due to the high production speed.

For years now, this has made it possible to compact binderless tungsten carbide parts with a diameter of 240 mm to 99.7% of the theoretical density in a total cycle time of 45 min, at a maximum temperature of 2100 °C and a pressing force of 250 t. The components produced by this process have an extremely even, fine microstructure, with the result that this technology soon became standard in the manufacture of sputter targets. Several semi-continuous production systems customised especially for this application are in use in Germany and abroad.

Moreover, a semi-continuous production process can substantially increase the efficiency of the Hybrid-FAST technology. In specific cases the moulds – due to the required clean conditions – are filled in separate rooms and then transported to the FAST system via an airlock, with the help of handling systems in some cases. Once inside the system, they are heated rapidly at an even temperature, uniformly compacted and then transported via another air lock to the cooling area.

Under optimal conditions, i.e. controlled heating, holding and cooling times, it is possible to implement a very simple semi-continuous production system that is economical also for much larger components than previously possible.

In field assisted sintering the compact is heated evenly by means of uniformly distributed energy input. The high uniformity of the temperature throughout the material volume rapidly reduces the risk of internal tensions – a significant advantage over classic hot pressing technology. In the same manner, suitable cooling devices are used to uniformly dissipate the heat over the mould surfaces, which likewise minimises tensions in the material, since there is no radial heat dissipation with high gradients in the component.

An example for non-conductive materials: for years, special rolling bearings have been manufactured from gas pressure sintered silicon nitride/SiAlON materials. Many processes depend on this time-proven application. However, the relatively long cycle times during gas pressure sintering limit the possibility of controlling fine-grained structures, especially when it comes to components with a larger volume. Bearing assemblies for wind turbines, for example, consist of rollers with a diameter of 45 mm and a length of 65 mm. With the Hybrid-FAST technology they can be fully compacted within 15 min and have an unprecedented fine-grained, homogeneous structure, as well as outstanding rolling behaviour.

A cooperation with research facilities resulted in the need for a more efficient power supply system. This was achieved with an integrated hybrid heating system. Today it is possible to combine up to 500 kW pulsed power supply systems with an integrated hybrid heating system, likewise with an output of 500 kW, and to achieve usable heating capacities of up to 800 kW through the variable use of both systems.

This makes it possible to manufacture large components with a diameter of 500 mm or dimensions of 400 mm x 400 mm. Ideally, the FAST technology is used for direct heating of the compact – which is no problem in the case of metals, although a certain minimum conductivity is necessary – and the hybrid heating is used for compensation of energy losses through radiation as well as for input of the energy to the press tool shells.
Especially powder metallurgy parts require maximum performance from the FAST pulses for optimal operation – also with respect to the material properties, e.g. the oxide layers, and the microstructure parameters. Another challenge is the high power input in the required short cycle time, without the unwanted effect of insufficient uniform heating of the starting powder due to an uncontrolled path of the electric current. These problems can be considered solved, although the power properties have to meet certain requirements, especially in the case of composites and powder mixtures.

Another example: shortly after the start of the development work at FCT there was great interest in manufacturing large-format components using Al-Si composites, with the addition of SiC submicron powders, carbon nano-tubes, etc. The latter are intended as preforms for later forming processes and are manufactured as plates or cylinders using Hybrid-FAST technology. Such components are used in aerospace applications as well as in disc brakes, although the latter application is still in the development stage.

The adaptation of the semi-continuous Hybrid-FAST technology to continuous production processes – similar to the development of FAST technology for small-format components – is currently under development at the conceptual level and is being implemented for specific components. FCT calls this advanced process FAST² (pronounced FAST squared). The tools are heated in pre-heating channels upstream of the FAST system until the powder compact “softens”.

Consequently, the FAST system needs only the energy required for the actual compacting process and the component can be cooled afterwards to room temperature in a thermally controlled cooling channel. Especially materials sensitive to thermal shock can be compacted safely and economically in this manner. For components made of boron carbide and silicon carbide and their composites, this offers an unrivalled alternative to conventional processes, not only significantly increasing production capacities, but also improving the quality of the product. These systems feature state-of-the-art multistage compacting, which enables up to 10 layers per cycle at a thickness of 8 mm.

Since the start of the development work, the FCT Technology Centre has been equipped with a FAST lab system with a pressing force of 250 kN, which is used for in-house development and is also available for customers and cooperation partners.

Two FAST hybrid systems that represent decisive development milestones at FCT have meanwhile been delivered to customers. Both systems have an efficient hybrid heating capacity of 800 kW. The first system, with a pressing force of 250 t, was installed in Great Britain, where it is used for development of large-format components made of non-oxidic materials.

The second system, with a pressing force of 400 t, was delivered to a Spanish company specialising in nano composite materials and is used for the manufacture of components with a diameter of up to 500 mm, especially in the sector for composite and nano materials. With an overall height of 9 m it is considered the world’s largest system of its type and the power management (max. 80 000 A) presented a challenge to the FCT engineers (Fig. 1 and 2).

Motivated by positive customer feedback, it was decided to build a similar system for the company’s own Technology Centre in Rauenstein, which is used primarily for testing new basic concepts together with potential customers. It features more than 320 t pressing force, 800 kW hybrid heating power (2 × 400 kW) and rapid cooling (Fig. 3 and 4). This system can sinter large-format components with a diameter of up to 450 mm at a maximum temperature of 2300 °C. The design of the control technology incorporates the experience of both FCT and its customers, with user-friendliness and computer-controlled process data analysis as standard features. A special focus is on the acquisition of information about the electrical characteristics of the compact with respect to the compaction state and temperature, as well as the automatic measurement of the respective efficiency ratios for determining an extremely high temperature uniformity field, i.e. before applying the full pressing force. That is why precise temperature measurement is of utmost importance. The axial temperature measurement is conducted directly in the sample, both at the centre and near the edge of the compact. Adaptations of the measurement technology include the acquisition of information on the compaction pressure in the sample with the pressing force applied.

Fig. 1 FAST hybrid system for 400 t (800 kW hybrid heating) in final assembly

Fig. 2 Satisfied faces of both customers and FCT technicians after successful commissioning of a FAST hybrid system (H-HPD 400) with a maximum pressing force of 400 t. The 9 m high system had to be brought in through the roof of the hall.
tive regulation allows control of the temperature gauges in relation to the temperature of the shell surrounding the press tool. The resulting temperature uniformity enables a high degree of homogeneity in the structure and material properties, even in the case of large-volume components. By determining the compaction dynamics during the pressing process, neglecting any elastic changes in the pressing system itself, it is possible to acquire valuable information on the actual compaction processes in the compact. The process data analysis presents this information in the form of a so-called “net curve”. Despite these successes FCT is not resting on its laurels. Having become the world market leader for large production-related FAST hybrid systems with the delivery and commissioning of the 400 t system in Spain, the company is now working on even larger systems that can handle component diameters larger than 1000 mm, as well as 600 mm × 600 mm blocks. The Hybrid-FAST technology has achieved a high status, with particularly good prospects in applications requiring semi-continuous operation. Future challenges will include improvements in tool manufacturing, minimisation of tool costs and economical aspects in the construction of the systems themselves.

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