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POWDER METALLURGY REVIEW

POWDER METALLURGY IN INDIA

AUTOMOTIVE APPLICATIONS FOR PM

SPARK PLASMA SINTERING

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POWDER METALLURGY REVIEW

India's growing Powder Metallurgy market

Having attended the APMA Conference this year in Pune, India, it was evident that the Indian Powder Metallurgy market is thriving, reporting continued growth that is mirroring the state of the country's expanding automotive sector.

The country's PM structural part makers are not just subsidiaries of leading global PM companies, but also include many locally established enterprises. As the market grows, investment in these companies is continuing, with many reporting facility expansions.

Not content with meeting the needs of the growing local market, a number of the larger PM part manufacturers are also seeking to attract new overseas customers. Reporting from within the industry, Kadambari Gopinath, offers a unique insight into the region, considers the state of its automotive market and identifies the key players in the country's PM structural parts industry.

There are, of course, many applications in the automotive sector for the use of Powder Metallurgy. The process offers numerous advantages over alternative manufacturing routes, from cost savings to novel designs and unique material properties. Much of this innovation has been recognised through industry awards over the years and in this issue, we present award winning PM structural parts from the automotive sector.

Paul Whittaker
Editor, Powder Metallurgy Review

Cover image
ABS sensor rings are just one of the many automotive components suited to Powder Metallurgy (Courtesy Sintercom India)

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POWDER METALLURGY REVIEW





in this issue

regular features

industry news

To submit news for inclusion in *Powder Metallurgy Review* contact Paul Whittaker, paul@inovar-communications.com

Sumitomo Electric Industries acquires PM companies from Sinterwerke Group

Sumitomo Electric Industries Ltd. (SEI), Osaka, Japan, has acquired both European Powder Metallurgy businesses of Sinterwerke Group; Sinterwerke Herne GmbH, Germany, and Sinterwerke Grenchen AG, Switzerland.

Together, the two Sinterwerke businesses produce a wide range of Powder Metallurgy components, primarily for the automotive and power tool markets, with customers said to include Tier1 automotive suppliers and OEMs. The two companies posted combined sales of approximately €71 million in 2018 and jointly list 400 employees at facilities in Germany and Switzerland.

Speaking on the announcement, Sinterwerke Group stated that the acquisition marks an important move towards increasing its global presence and implementing the latest production process technologies. SEI's Powder Metal Products division operates globally, with Sumitomo Electric Sintered Alloy Ltd. headquartered in Okayama, Japan. The division provides a variety of products, primarily for Japanese manufacturers of cars, automotive components and air conditioners.

SEI stated that its latest acquisitions will help to expand its sales channels to include European automakers and component manufacturers, while increasing the presence of its Powder Metallurgy products business in Europe.

Sinterwerke produces a range of PM components for the automotive and power tool industries (Courtesy Sinterwerke)

www.sinterwerke.com
www.global-sei.com

Melrose reports no immediate plans to offload GKN Powder Metallurgy

Melrose Industries PLC, UK, has reported that, despite earlier plans for a quick sale of the GKN Powder Metallurgy division, the company has no immediate plans to sell the business. In its recently published 2018 Annual Report, Melrose stated that, "whilst we will continue to review the position in the months to come, we expect GKN Powder Metallurgy to remain in the group for the present."

Upon taking control of GKN, Melrose stated that it set about removing the duplicate central functions and decentralising the GKN businesses, simultaneously reorganising the Melrose Group into five divisions: GKN Aerospace; GKN Automotive; GKN Powder Metallurgy; Nortek Air & Security; and Other Industrial.

"For the GKN businesses, decentralisation was the first step in bringing about the change in culture we believe is vital to securing long-term improvement," stated Simon Peckham, Melrose's Chief Executive. "For GKN Aerospace and GKN Powder Metallurgy, we worked with incumbent management teams to agree their management plans."

"Having agreed their approach, the GKN businesses have been given the freedom and responsibility to start to deliver on their commitments. Part of this has been a refocus on profitable sales rather than solely on growth. There is also a clear expectation that they be good stewards of their businesses for the benefit of all stakeholders."

In the Annual Report for the year ended December 31, 2018, the company announced statutory revenue for the Melrose group of £8,605 million (2017: £2,092 million) and, despite declaring a statutory operating loss of £392 million (2017: £7 million), primarily as a result of the required accounting for the GKN acquisition, its adjusted operating profit was £847 million (2017: £279 million).

"The former GKN businesses are proving their potential to offer the outstanding opportunities we expected and much has already been achieved in the short period of ownership," added Justin Dowley, Melrose's Non-executive Chairman.

www.melroseplc.net

GKN Powder Metallurgy opens North American PM Headquarters

GKN Powder Metallurgy opens North American PM Headquarters and AM Customer Center (Courtesy GKN Powder Metallurgy)

GKN Powder Metallurgy has opened its new North American Powder Metallurgy Headquarters and Additive Manufacturing Customer Center in Auburn Hills, Michigan, USA. The new facility will house over eighty employees from the three divisions of GKN Powder Metallurgy; GKN Hoeganaes, GKN Sinter Metals and GKN Additive.

The building includes a 3,200 ft^2 Additive Manufacturing Customer Center, equipped with two EOS M290 metal Laser Powder Bed Fusion (L-PBF) systems. EOS's systems are capable of manufacturing functional metal prototypes within a two-week lead time and allow customers to test factors such as usability, ergonomics, manufacturability and materials in the early stages of the development process. It is expected that the full 38,260 ft^2 combined facility will expand the company's global Additive Manufacturing network and the scope of its in-house Powder Metallurgy capabilities.

Reid Southby, President of GKN Sinter Metals Large Segment, stated, "We are excited to start a new journey in Auburn Hills with a space that is dedicated to our team, our community and the advanced technology we create for our customers. This building reinforces our commitment to the North American market and continued global growth."

"GKN Powder Metallurgy is at an exhilarating point in its journey of growth and innovation," Southby continued. "We now have the opportunity to provide our customers and strategic partners with local and exceptional support on all fronts of our business."

www.gknpm.com

Miba reports continued growth as revenue exceeds €985 million

Miba AG, Laakirchen, Austria, has reported strong growth in its fiscal year 2018–2019 (February 1, 2018 to January 31, 2019). Revenue has increased 11% year on year to €985 million, which positions the group closer to its revenue target of €1 billion set out in the Miba 2020 – Dynamic Evolution strategy.

According to the group, its annual revenue has more than doubled since 2010, rising by over half a billion euros. "The past fiscal year saw challenging market conditions in the automotive segment and showed once again that, with its very broad product portfolio and its focus on a number of regional markets, Miba is very well prepared to manage volatility in individual market segments," stated F Peter Mitterbauer, CEO of Miba AG.

The group has reportedly invested €87 million in property, plant and equipment and intangible assets and €41 million in research and development. "By investing in our plants, in research and development and in our employees' expertise, we are creating the basis for our further growth," continued Mitterbauer. "Thanks to our financial stability and our independence as a family-owned company, we are best placed to invest over the long-term and with a steady hand. This enables us to safeguard existing jobs and create new ones."

Miba states that it is in the process of building three new plants in China and India, in order to accommodate growth in Asia. It is also expected to build an eMobility Cluster in Austria, where the Group's expertise from electrification and the automotive sector will be integrated. The company has reportedly created over 1,100 additional jobs in Austria since 2010. "In Vorchdorf, we are planning to build additional capacity for the e-mobility business," added Mitterbauer. "By doing so, we are maintaining our strategy of investing heavily in Austria as well as growing globally."

www.miba.com

F Peter Mitterbauer, CEO (left) and Markus Hofer, CFO (right) (Courtesy Miba AG)

Oerlikon finalises sale of Drive Systems Segment to Dana Incorporated

Oerlikon has announced the sale of its Drive Systems Segment to Dana Incorporated. The agreement to divest was signed and announced in July 2018 and, after receiving the required regulatory approvals and satisfying all closing conditions, the sale is now successfully completed.

"The closing of the transaction marks the next milestone in the execution of our strategy," stated Dr Roland Fischer, CEO of Oerlikon Group. "Following the sale, we will now concentrate our efforts and resources in sustaining the growth and performance of our surface solutions and man-made fibres businesses."

The transaction is said to free up resources for Oerlikon to fund innovation, invest in organic and inorganic growth and to further implement digital and operational excellence initiatives to drive future growth. The transaction has an enterprise value of CHF 600 million (approx €530 million).

www.oerlikon.com
www.dana.com

Bodycote invests in new North American heat treatment facility

Bodycote plc, a global provider of heat treatment and specialist thermal processing services headquartered in Macclesfield, Cheshire, UK, is expanding its capabilities in North America with the launch of a new heat treating facility in Elgin, Illinois, USA. According to the company, the new facility will offer advanced heat treating technologies such as low-pressure carburising and carbonitriding, vacuum nitriding and ferritic nitrocarburising, Bodycote's Corr-I-Dur® process, and traditional carburising of large parts.

Operating from more than 180 accredited facilities in twenty-three countries, Bodycote provides classical heat treatment and specialist technologies including Hot Isostatic Pressing (HIP) to a wide range of industries, including aerospace, defence, automotive, power generation, oil & gas, construction, medical and transportation. The new facility is expected to be operational by late 2019 and will support the automotive, agricultural, mining, construction and other manufacturing supply chains in the USA's Upper Midwest.

Dan McCurdy, Bodycote's President of Automotive & General Industrial, North America & Asia division, stated, "This investment demonstrates Bodycote's commitment to serving the Midwest with the services our customers ask for and require."

www.bodycote.com

Arcast produces fine titanium superalloy powder

Arcast Inc., Oxford, Maine, USA, reports that it has successfully produced a titanium superalloy powder with an as-atomised D50 of 20 µm, with narrow size distribution and with little-to-no oxygen pick-up. The alloy was produced using Arcast's proprietary atomising process.

Arcast's process consumes relatively little gas and has zero risk of ceramic/oxide contamination, the company states, making it possible to process metal alloys which other methods cannot. Powders produced by this method can be used in Additive Manufacturing, Metal Injection Moulding and other Powder Metallurgy processes. The production of powder by this process also does not require specialist feedstock.

Arcast stated that the new alloy is now being produced in significant quantities. With its growing capacity to produce as-atomised, advanced titanium alloys (along with other challenging metal alloys) from a range of low-cost feedstock, Arcast states that it can offer a complete solution for Additive Manufacturing, Metal Injection Moulding and other Powder Metallurgy markets.

www.arcastinc.com

Sandvik completes acquisition of Kunshan Ousike Precision Tools

Sandvik has completed its acquisition of Kunshan Ousike Precision Tools Co., Ltd (OSK), a supplier of solid carbide round tools based in Kunshan, Jiangsu, China. OSK will be part of the Seco Tools division of Sandvik Machining Solutions.

The acquisition is expected to strengthen Seco Tools' position and product offering in the fast-growing Chinese electronics industry. At the time of the acquisition agreement in November 2018, Klas Forsström, President of Sandvik Machining Solutions, stated, "The acquisition is aligned with Sandvik Machining Solutions' focus on growing the round tools business. We are already today well positioned in China but OSK will bring us even closer to customers."

OSK was established in 2006 and in 2017 reported revenues of SEK 120 million and employed a staff of ninety. Both parties have agreed not to disclose the purchase price.

www.home.sandvik
www.secotools.com
www.osktool.com

Horizon Technology discusses durability when selecting metal powders

Horizon Technology, St. Marys, Pennsylvania, USA, recently made available a number of online guides designed to provide an introduction to various Powder Metallurgy processes and applications. The company has now added a new guide, 'Choosing Powder Metallurgy Materials Part 1: Durability'.

This is the first in a series on selecting PM materials and lists what factors should be considered before constructing a PM part, such as corrosion resistance, hardness, tensile strength, impact toughness and fatigue strength.

The guide also covers 'Materials and Their Qualities', breaking down the properties and advantages/disadvantages of stainless steel, copper, nickel, aluminium and titanium.

The guide is available to read for free on the company's website.

www.horizontechnology.biz

MPIF releases updated *Standard 35 for PM Self-Lubricating Bearings*

The Metal Powder Industries Federation (MPIF) has released the 2019 edition of its *MPIF Standard 35–SLB, Materials Standards for PM Self-Lubricating Bearings*. This standard provides the design and materials engineer with the latest engineering property data and information available to specify materials for structural parts made using the PM process.

Each section of the standard is distinguished by easy-to-read data tables (Inch-Pound and SI units) and provides explanatory information for the materials listed. The standard, developed by the Powder Metallurgy commercial parts manufacturing industry, has reportedly been revised to make it cleaner and more concise.

MPIF Standard 35-SLB does not apply to materials for PM Structural Parts, powder forged or metal injection moulded (MIM) products, which are covered in separate editions of *MPIF Standard 35*.

www.mpif.org

Epson Atmix installs new production line for amorphous alloy powder at its Kita-Inter Plant

Epson Atmix Corporation, Aomori, Japan, has launched a new production line for amorphous alloy powder at its Kita-Inter Plant, Hachinohe, Aomori Prefecture, Japan. A division of Seiko Epson Corporation, Epson Atmix has invested approximately 800 million yen (USD $7.4 million) to implement the new line and plans to increase its amorphous alloy powder production capacity to approximately 6,000 tons per year by 2023.

The company's superfine alloy powders are used in the manufacture of high-performance components found in products ranging from automobiles to smartphones to medical equipment and more. Epson Atmix states that the demand from these types of industries has been growing, and this trend is expected to continue for the foreseeable future.

The new production for amorphous alloy powder has begun operation at its Kita-Inter Plant (Courtesy Epson Atmix)

Epson Atmix believes it was the first company in the world to successfully volume-produce amorphous alloy powder using its SWAP (Spinning Water Atomisation Process) production method in 2004.

Amorphous alloy powders are reported to have high magnetic flux densities and low energy loss in addition to excellent high-frequency characteristics. These characteristics make amorphous alloy powders extremely attractive as performance-enhancing, highly functional material powders that enable small, low-power voltage control components and that support high frequencies and large currents.

www.atmix.co.jp

GEA launches its R55 industrial rotary press for powder compaction

GEA Group AG, Düsseldorf, Germany, debuted its new R55 industrial rotary press during Powtech 2019 in Nuremberg, Germany, April 9–11, 2019. The fully-automated R55 is capable of compacting a range of materials for the manufacture of products including hard metals, nuclear fuel pellets, batteries, confectionary and pharmaceuticals.

The new press is said to incorporate the latest technologies to help ensure flexibility, precision, operator safety and minimal maintenance requirements. It is available with a number of optional features, designed to improve and expedite the production process while providing higher levels of control, and is reportedly capable of outputting more than 30,000 products per hour at a maximum compression force of 130 kN.

The system's top and bottom air compensators are designed to enable truly symmetric constant-density compression, while a hold down/hold up system provides a method by which to control vertical stresses during ejection. This enables the R55 to emulate the functionality of both hydraulic and electric single-stroke presses while providing a higher output.

To reduce the risk of damage to products, the press also incorporates a takeoff wheel, replacing the conventional ejection bar, for the removal of fragile parts horizontally from the press directly onto a conveyor belt. In addition, continuous powder flow is said to ensure a narrow weight distribution. Gentle pre-compression also facilitates powder deaeration and prepares the formulation for its final compression between two large compression rollers.

GEA's new R55 industrial rotary press (Courtesy GEA Group AG)

During press operation, GEA's In-line Density Control (IDC) measures the diameter and height of all tablets and weighs up to 100 products per minute. Where variations are identified, through instant density calculations, the press will adjust its compression force and fill depth to keep the average part density and height constant.

www.gea.com


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www.mimete.com

Construction begins on Ceratizit plant extension

Construction is now underway on an extension to Ceratizit Austria GmbH's manufacturing plant in Reutte, Austria. According to Ceratizit's parent organisation Plansee SE, the new build will be ready for occupation by Spring 2022, and will house a staff of up to 300.

The extension to the plant reportedly involves an investment in the double-digit million euro range, and the new facility is set to comprise a multi-storey building with a length of 200 m and width of 80 m. To combine the old plant with the new building, Ceratizit will pave a previously privately-used gravel road to route internal plant traffic away from public roads.

At present, three companies of the Plansee Group operate out of the same industrial park in Reutte. While Plansee SE manufactures semi-finished products and components made of tungsten and molybdenum metals, Ceratizit Austria specialises in the production of carbide tools for machining processes. The new building will house the Grinding Shop and Tool & Die, enabling Ceratizit Austria to meet the strong global demand for hard metal tools.

www.ceratizit.com | www.plansee.com

Arcast metal powders certified for commercial, aerospace & defence

Arcast Inc. and Arcast Materials Division, Oxford, Maine, USA, have achieved certification to ISO 9001:2015 and AS9100D for the manufacture and sale of metal powder and castings for commercial, aerospace and defence applications. Arcast stated that it built its new materials division around these quality management systems to ensure its ability to meet the industry's most demanding requirements.

The new certification means that Arcast's metal powders, as well as its casting products, can now be sold to a wide range of markets, including aerospace, with the confidence that it can meet the quality standards required by its customers. With its growing capacity to produce as atomised titanium alloys (along with other challenging metal alloys) with a D50 of 30-40 μm from a range of low-cost feedstock, Arcast states that it can offer a complete solution for Additive Manufacturing, Metal Injection Moulding and other Powder Metallurgy markets.

"Our ultra-clean and high-performing processing method offers the highest possible quality powder and is now backed up by a quality standard that matches it," commented Sasha Long, Arcast Vice President.

www.arcastinc.com

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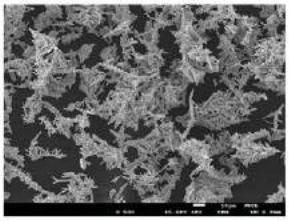
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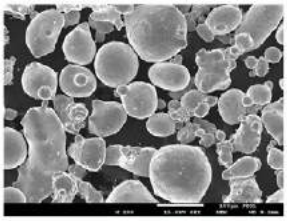
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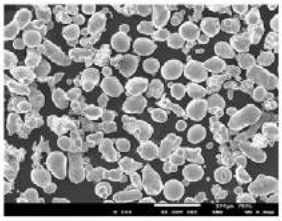
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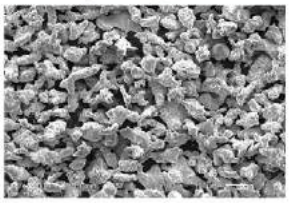
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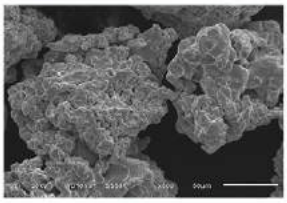
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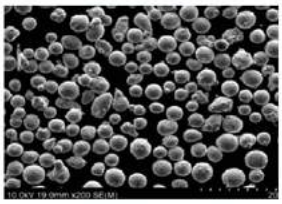
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Sandvik Group reports its best ever earnings in 2018

Sandvik AB, Stockholm, Sweden, has published its Annual Report for 2018. The company stated that 2018 had been a record year, in which it achieved the best earnings in its history and a record-high operating margin, with sales exceeding SEK 100 billion for the first time ever. The group stated that this was partly influenced by a positive economic climate, with favourable demand in all of its segments and on all continents, as well as recent work to decentralise and streamline the company's activities.

The group reported an order intake of SEK 102,440 million (2017: 95,444) with revenues totalling SEK 100,072 million (2017: 90,827). An operating profit of SEK 18,689 million was recorded (2017: SEK 18,073). The adjusted operating margin for 2018 was reported to be 18.6% (2017: 16.1%), with a free operating cash flow of SEK 15,281 million (2017: SEK 15,095 million).

According to the report, Sandvik saw strong development in all customer segments and in all geographical regions in 2018, with order intake showing overall growth of 9% from 2017. A breakdown of revenues by customer segment showed that 34% of the groups revenues came from the mining segment, 23% from engineering, 12% from automotive, 11% from energy, 9% from construction, and 6% from aerospace, with the remaining 5% of revenues coming from other, unspecified segments.

By region, 38% of Sandvik's revenues came from Europe, 21% from North America, 20% from Asia, and a further 9% from Africa/Middle East, 7% from Australia and 5% from South America. Sandvik Machining Solutions represented 53% of the group's total adjusted operating profit, with Sandvik Mining and Rock Technology representing 39% and Sandvik Materials Technology 7%.

In 2018, Sandvik Group concluded the divestment of Sandvik Hyperion and its wire operations (welding wire and stainless wire) and made a new investment in a manufacturing plant for titanium and nickel powder. It also completed several strategic acquisitions, including the metrology software company Metrologic Group and industrial heating company Custom Electric Manufacturing.

www.home.sandvik

Höganäs publishes its sustainability report for 2018

Sweden's Höganäs AB has released its second annual sustainability report, highlighting the company's activities and sustainability performance in 2018. As the leading producer of iron powders, Höganäs employs around 2,500 staff across eighteen production units in eleven countries. Its product portfolio contains more than 3,500 products and the company serves around 3,000 customers globally.

In the report, Fredrik Emilson, Höganäs President and CEO, stated, "2018 was characterised by high demand for our metal powders, organisational changes and integration of new acquisitions. Even though high demand is positive, it also brings challenges. We have done our utmost to balance our customers' needs and deliver according to plan. Our co-workers have accomplished great results despite the high workload."

Höganäs stated that it is on track to decrease energy use by 10% by 2020 compared to energy usage in 2010. The 2018 result was said to show an 8.7% decrease. One of the company's goals is to become a climate neutral operation, minimising its climate footprint through both established and newly developed methods. "We also need to invest in research and innovation to make improvements beyond what is possible today," added Nicklas Lång, Senior Vice President Sustainability, Höganäs Group.

A long term Climate Roadmap, which aims to decouple earnings from climate impact emissions, is reported to be underway. "The Climate Roadmap will guide the strategy and business planning, as well as form the basis for action plans in the years to come. The areas covered in this work are, among others the upstream scope 3 CO_2 emissions, efficient sourcing of raw materials and transports, supply of fuels and energy and internal energy efficiency," added Lång. "To get closer to our vision, the necessary co-operation with industry partners, academia and society's various actors will continue in the years to come."

One such joint activity is a pilot-scale plant for renewable energy gas, which is currently under start-up for testing at the company's site in Höganäs, Sweden. If successful, it will be integrated permanently into operations and replace about 50 GW hours of non-renewable energy per year from 2020.

"As we are convinced that metal powder can improve society, it is natural for us to integrate sustainability in our business. We strive not only to reduce our own negative impact, but also to contribute positively to society through more sustainable solutions. Systematic assessment of our products' life-cycles will help us meet customer expectations and promote the products' sustainability advantages with a knowledge-based approach," added Emilson.

www.hoganas.com

William Rowland in £10m expansion and relocation

William Rowland, recognised as one of the oldest metal trading businesses in the UK, has announced it is relocating to a new £10 million state-of-the-art manufacturing facility in Barnsley, South Yorkshire. The company has operated from its existing site in nearby Sheffield since 1870, and the move to a new 6.5-acre site is expected to allow it continue on its current growth trajectory.

It was stated that several new product lines have been added in the last two years which support its transformation into a manufacturing business, with the addition of several new processes across its refined metals, metal powders and speciality alloys segments.

"It was critical we removed the obstacles to our continued growth and put ourselves in a position to help our customers and suppliers grow their businesses," stated Richard Lowe, MD for William Rowland.

"In selecting the site, we had to consider our strongest asset (employees) first, as without them we cannot provide the outstanding levels of expertise and service our customers are accustomed to. Additionally, we wish to become an employer of choice and, whilst we are renowned for service and stability, a modern place of work will help with that."

William Rowland is owned by Amalgamated Metals Corp (AMC), who operate a variety of non-ferrous metals businesses globally and also offer a range of risk management services to the metals sector. "Our parent company has a stable and balanced portfolio, and long term perspective which enables significant investments of this type, even when the economic climate is uncertain," Lowe continued.

"The site will be fully operational in the first half of 2020, with the No. 1 objective of no disruption to our valued customers. I am really confident we can achieve a move with little disruption, we are in control of the disposal of the current site and have duplicate facilities in the West Midlands from where we can build buffer inventory."

www.william-rowland.com

William Rowland is relocating to a new £10 million state-of-the-art manufacturing facility

Reading Alloys appoints Michael Wilkes as its new Product Manager for Powders

Reading Alloys, a division of Ametek Specialty Metal Products (SMP), headquartered in Robesonia, Pennsylvania, USA, has announced the appointment of Michael Wilkes as its new Product Manager for Powders. Wilkes will be overseeing the ongoing growth of Reading Alloys' range of powder-based products, including high-purity titanium and titanium alloy powders produced via a hydride-dehydride (HDH) process and used for coatings in orthopaedic medical devices, advanced electronics, traditional Powder Metallurgy and metal Additive Manufacturing.

Wilkes previously worked as Director of Global Customer Service at Carpenter Technologies in Reading, Pennsylvania, USA. In that role, he was responsible for leading global customer service quality, inside sales and customer service teams at seven global locations while also supporting multiple brands and products. He holds a BSc in Management and Marketing from Pennsylvania State University and has also completed the Executive Education General Management Program at Harvard Business School.

www.readingalloys.com

Reading Alloys has appointed Michael Wilkes as its new Product Manager for Powders

Nabertherm appoints Timm Grotheer its new Managing Director

Nabertherm GmbH, Bremen, Germany, has announced the appointment of Timm Grotheer as its new Managing Director. Grotheer, who previously served as Managing Director of shipbuilding group Lürssen, succeeds Friedrich-Wilhelm Wentrot, who has served as Managing Director of the company for eighteen years.

Under Wentrot, Nabertherm reported that it has seen global success, employing more than 500 staff and achieving a turnover of more than €60 million ($68 million). A key element has been the consistent internationalisation of the business, which now has an export share of 70%, selling its furnaces and plants around the world.

www.nabertherm.com

Höganäs rebrands H.C. Starck division

Höganäs AB has announced that as of June 1, 2019, it has rebranded its H.C. Starck Surface Technology & Ceramic Powders (STC) division under the main Höganäs brand. Höganäs acquired the STC division from H.C. Starck, along with two production units, in March 2018.

"Together we are a leading provider for all surface and joining technologies, including thermal spraying, hard facing, brazing and welding. As one Höganäs organisation, we utilise our joint forces to invent better solutions for our customers' current needs and future challenges," stated Hans Keller, President Product Area Surface & Joining Technologies at Höganäs.

The company stated that it aims to make surface coating a new and strong business division, alongside its metal powder for press and sinter components. "Now that we are truly one company, Höganäs is one of the largest players in the premium segment of the surface coating market, servicing a broad range of industries, but focusing on automotive, oil and gas, mining and construction, energy and aviation," added Keller.

www.hoganas.com

GKN Sinter Metals begins construction of new facility in Mexico

GKN Sinter Metals has officially begun construction of its new Powder Metallurgy parts making facility in Guanajuato, Mexico. The plant will include almost 6,000 m^2 of roofed area and employ up to 250 people when fully operational.

It was stated that the site is perfectly positioned to support local Mexican customers, adding to GKN Sinter Metals' leading position in automotive and industrial markets, as well as its strategic focus to expand products in electrical systems, solutions in X-by-Wire systems, e-pump technology, connected home technologies, etc.

"We are proud to welcome GKN Sinter Metals in the state of Guanajuato, a company with high technology products and a company with a large global footprint. Our state welcomes GKN with open arms," stated Mauricio Usabiaga Diaz Barriga, Guanajuato Secretary of Economy Development.

During a ground-breaking ceremony with business partners and representatives from the local government in attendance, Peter Oberparleiter, GKN Powder Metallurgy CEO, reconfirmed the company's commitment to its operations in Mexico, stating:

"It is part of our strategy to have operations in our key markets and in close proximity to our customers. Reflecting the strong development of the Mexican automotive and industrial sector over the recent years this investment was a natural step. We are excited to see local production beginning in August with the objective to have full operations and local supply from Guanajuato in 2019."

www.gknpm.com

Breaking ground for construction of GKN's facility (Courtesy GKN Sinter Metals)

Japan's Powder Metallurgy industry remains stable

The Japan Powder Metallurgy Association (JPMA) has reported that the production of Powder Metallurgy structural parts and sintered bearings in Japan remained stable in 2018. Figures released by the Japan Ministry of Technology and Industry (METI) showed that structural (machine) PM part production was 88,605 tons in 2018, up from 88,484 in 2017. Sintered bearing production fell slightly, with 6,704 tons produced in 2018, compared to 6,741 tons in the previous year.

The reported value of both structural PM parts and sintered bearings increased in 2018. PM structural (machine) parts were valued at Yen 112,671 billion in 2018, up from Yen 110,904 billion in 2017, with the value of sintered bearings increasing to Yen 16,033 billion in 2018 from Yen 15,843 billion in 2017.

The statistics published by the JPMA also revealed that 95% of structural PM parts, and 78% of PM bearings, were used in automotive applications. The consumption of PM parts in a typical car produced in Japan was said to be 8.8 kg.

www.jpma.gr.jp
www.meti.go.jp

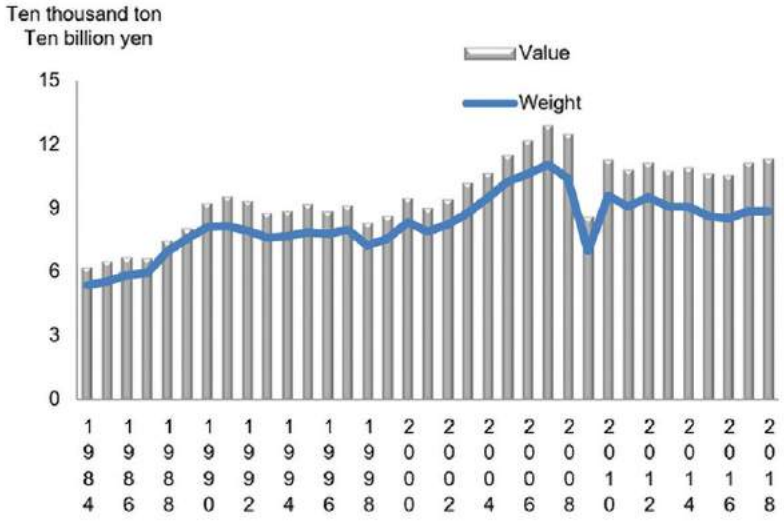

Fig. 1 Structural (machine) PM part production in Japan (Courtesy JPMA)

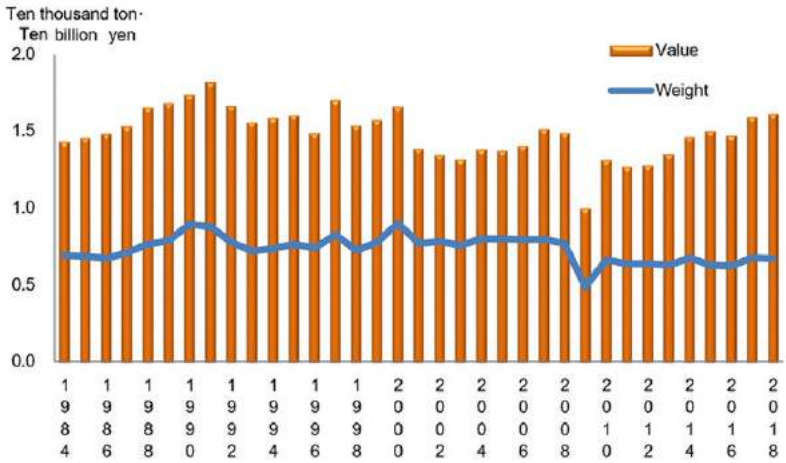

Fig. 2 Production of PM bearings in Japan (Courtesy JPMA)

Sandvik Materials Technology to separate from the Sandvik Group

Sandvik AB, Stockholm, Sweden, is to initiate an internal separation of its business division Sandvik Materials Technology. The decision was made by Sandvik's Board of Directors with the reported aim of increasing the structural independence of Sandvik Materials Technology from the Sandvik Group. It is expected that this will put a significant focus on the business' future development possibilities, as well as creating flexibility.

According to the company, the separation is expected to take at least a year, with no guarantee whether a decision to list Sandvik Materials Technology at the Nasdaq Stockholm Exchange will be taken. "The decision to initiate an internal separation of Sandvik Materials Technology is based on the board's belief that each part will develop more favourably by itself, increasing opportunities for profitable growth and improving long-term shareholder value," stated Johan Molin, Chairman of the Sandvik Board of Directors.

Björn Rosengren, President and CEO of Sandvik, commented, "Sandvik Materials Technology represents the origin of Sandvik and great businesses have sprung out of it to shape the current structure. It is my view that a separation will allow full focus on Sandvik Materials Technology's key strengths and its further improved performance."

www.home.sandvik

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Mimete begins metal powder production at its Italian facility

Mimete S.r.l., Osnago, Italy, a division of the Fomas Group, Osnago, Italy, has begun production of metal powders in its new and customised VIGA (Vacuum Inert Gas Atomisation) facility. Mimete's manufacturing plant has been specifically designed by Fomas to serve the Additive Manufacturing market and will target various sectors, primarily biomedical, power generation, aerospace and racing.

According to Mimete, the first atomisation process was monitored through an advanced production management system and the alloy chosen for the first batch of powder was 316L. Production of IN625 and F75 is currently ongoing. The company stated that it then analysed the powders at its in-house laboratory. Scanning Electron Microscope (SEM) images of the powder produced reportedly showed a morphology that was spherical and homogeneous, and the measured flowability also met the targets set.

Maria Guzzoni, Mimete Strategy & Special Projects Coordinator, stated, "We were all very excited to be together for the first atomisation. It was not about scoring the best result, but it was more about getting to the end of the cycle – the starting point for future challenges and improvements. We studied a lot and we were well prepared for all scenarios, but we were aware that moving from theory to reality always implies a certain level of uncertainty. We were incredibly moved to finally see the successful results of all the hard work and the commitment we went through last year."

Mimete, a division of the Fomas Group, has begun production of metal powders at its manufacturing plant in Italy (Courtesy Fomas Group)

www.mimete.com
www.fomasgroup.com

Höganäs and Dontyne collaborate on PM gear options for the auto industry

Sweden's Höganäs AB is working with Dontyne Gears Ltd, Washington, Tyne and Wear, UK, to offer automotive manufacturers a range of services with the aim of drastically improving driveline solutions. Through a newly formed cooperation, the two companies will showcase how lighter Powder Metallurgy components, with complex designs, can bring substantial cost savings for car manufacturers and system suppliers in the automotive industry.

Lightweighting, both for electric and traditional internal combustion engines and drivelines, continues to be a major focus for the automotive industry, states Höganäs. Improving fuel efficiency and increasing the driving range of plug-in vehicles will be key for carmakers as the industry evolves into the era of electrification.

Transmission gears such as this can offer cost savings and improved performance (Courtesy Höganäs)

"We help car manufacturers and system suppliers design, test and prototype new, light-weight metal powder driveline solutions that are a much better fit for the hybridisation and electrification of the automotive industry," stated Eckart Schneider, Director Powder Metallurgy Business Development at Höganäs AB. "Our cooperation with Dontyne Gears means we can become even better partners for our customers in developing and prototyping PM components in general and drivelines in particular."

Höganäs brings to the collaboration its knowledge of materials and experience of PM component applications for automotive driveline solutions, while Dontyne Gears will offer its expertise in gearing and system design, and manufacturing practices to reduce time and resources and promote efficient production.

"As materials and production techniques continuously improve, there are many applications that benefit from being looked at again to find much simpler and more cost-efficient alternatives," stated Mike Fish, CEO of Dontyne Gears. "Car manufacturers will benefit greatly when switching to components made out of PM instead of solid steel. We see a number of new applications where PM brings big advantages, such as weight and inertia as well as noise reduction."

The two companies have now launched a joint concept development towards hybridising a pick-up truck to take advantage of PM gearing and electrical motor solutions. So far, the project is reported to show promising developments and could potentially have a large impact on the design-optimised drivetrains based on Powder Metallurgy solutions.

www.hoganas.com
www.dontynegears.com

Kennametal to be beta customer for ExOne's new X1 25PRO metal AM system

The ExOne Company revealed its new X125PRO beta system at Rapid + TCT 2019 (Courtesy ExOne)

The ExOne Company, a provider of Additive Manufacturing systems and services headquartered in North Huntingdon, Pennsylvania, USA, revealed its new X1 25PRO™ metal Additive Manufacturing beta system at Rapid + TCT 2019, Detroit, Michigan, USA, in May 2019. The company also announced Kennametal Inc., a supplier of tooling and wear resistant solutions located in Pittsburgh, Pennsylvania, USA, as a beta customer.

During the beta period, ExOne stated that Kennametal will have the opportunity to evaluate the X1 25PRO system and trial new materials and processes. The high-resolution production machine is said to be capable of additively manufacturing parts in metal, ceramic, and other advanced materials, as well as standard industry powders used in Powder Metallurgy and Metal Injection Moulding (MIM).

"We see Binder Jet technology as a key enabler for our differentiated, high-performance wear materials, such as tungsten carbide and Kennametal Stellite™ alloys," stated, Sherri McCleary, Director of Business Development Additive at Kennametal. "Kennametal is uniquely qualified to supply these additive materials and components, and we're pleased to collaborate with ExOne on cutting-edge technology with the potential to help us advance from prototyping to serial production."

John Hartner, Chief Executive Officer at ExOne, commented, "Working with innovative, global companies like Kennametal is another important step towards integrating industrial 3D printing into existing and new production lines. We are excited to bring Kennametal on as a beta user and and look forward to beginning the testing programme."

www.exone.com
www.kennametal.com

Chinese Ministry of Industry and IT pursues hydrogen fuel development

China's Ministry of Industry and Information Technology has reinforced its commitment to develop the country's hydrogen fuel industry as part of its ongoing effort to promote green energy, according to *China Daily*. This year, the development of hydrogen stations for new energy vehicles was included for the first time in Premier Li Kegiang's Government Work Report, released in early April.

In a recent news conference held in late April by the State Council Information Office in Beijing, Huang Libin, Spokesman for the Ministry, stated, "Hydrogen fuel cell vehicles will coexist and complement fully electric vehicles, jointly meeting the people's transportation needs."

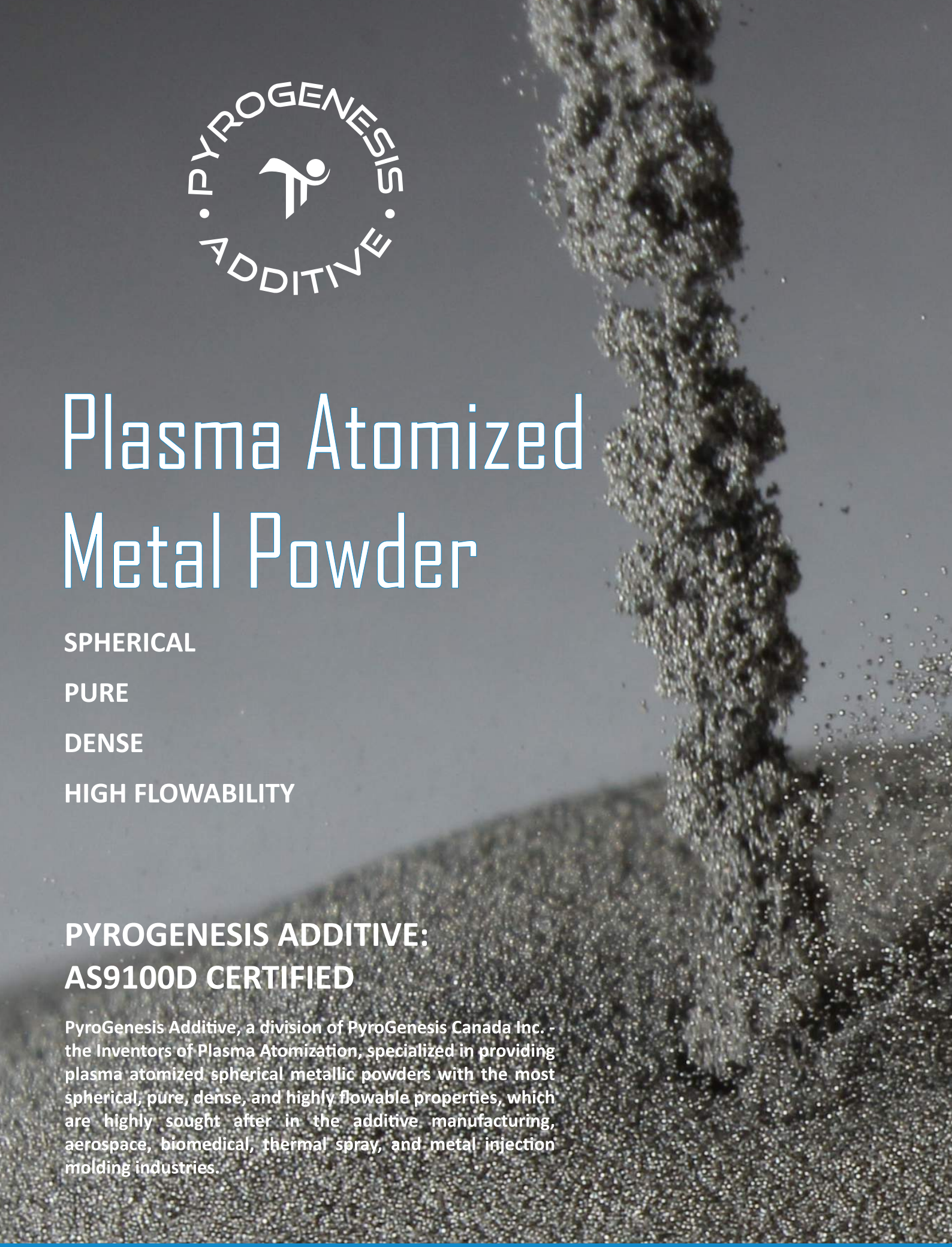
Both hydrogen fuel cell vehicles and fully electric lithium battery vehicles are important technical routes for new energy vehicles, Huang said, adding that based on their technical characteristics and development trends, fully electric vehicles have so far proved more suitable for passenger cars travelling within the city limits, while hydrogen-powered vehicles suit large commercial vehicles, such as buses and trucks, used over longer distances.

Safely storing hydrogen, however, is a key technical challenge for the development of the industry, as is the lack of supporting infrastructure, laws and regulations surrounding the technology. "The Ministry of Industry and Information Technology will carry out demonstration runs of hydrogen fuel cell vehicles together with other departments, with the aim of promoting innovative development in China's hydrogen energy and fuel cell vehicle industries," Huang added.

Japan's Toyota motor group – one of the first automakers to develop hydrogen fuel cell vehicles – established a joint research institute with Tsinghua University on April 21, 2019, working on hydrogen fuel cell technology. On April 22, Toyota partnered with Foton Motor Group and Beijing SinoHytec, a high-tech enterprise focusing on the R&D and industrialisation of hydrogen fuel cell engines.

The cooperation will reportedly see the hydrogen-powered buses produced by Foton Motor coupled with Sino-Hytec's hydrogen fuel cell power system which uses Toyota's hydrogen fuel cell stack and other components and parts. Xu Heyi, Chairman of BAIC, Foton's parent company, stated that Foton's fuel cell bus will serve the 2022 Beijing Winter Olympics.

The collaboration between Toyota and Foton is, according to China Daily, expected to extend to a full range of models, including passenger cars, vans, and light and heavy trucks. Meanwhile, at the 2019 Shanghai Auto Show, SAIC Maxus revealed China's first hydrogen fuel cell passenger car; this model is said to have a driving range of 340 miles (550 km), and reportedly takes just five minutes to refuel from empty to full.



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www.pyrogenesis.com/products-services/contact-pyrogenesis-additive/

Rise of electromobility not a threat to steel demand

During the Handelsblatt Annual Conference on the future of steel, held in Düsseldorf, Germany, March 20–21, 2019, the Handelsblatt Research Institute (HRI) presented a new study, commissioned by voestalpine AG, Linz, Austria, on the role of steel in electromobility. The study found that, although the trend toward lightweighting in automotive construction has enabled materials such as aluminium and plastic to become established in the automotive industry, the demand for steel is predicted to remain high or possibly increase as the automotive industry continues to change.

The study was based on secondary analysis of eighty sources, as well as interviews with six experts. Among its conclusions, it found that the electromobility sector will rely on an intelligent mix of materials in which steel will continue to play a crucial role. Moreover, it was speculated that the trend in electric vehicle development of reducing weight "at any price" is now coming to an end; while carbon-fibre reinforced plastics, for example, are lighter and tougher than steel, they are also significantly more expensive and harder to recycle, giving steel a cost and ecological advantage.

It was stated that steel's advantage could be boosted further by the development of new high- and ultra-high tensile steel grades, which will allow steel to remain a competitive material for electric vehicle production in the long-term. High- and ultra-high tensile steel grades can be lightweight and tough, and steel is also comparatively easy to process and recycle.

Jan Kleibrink, Head of Economic Analysis at the Handelsblatt Research Institute, stated, "There are not only economic reasons for using steel in electromobility, but also comparatively good life cycle assessment and safety aspects."

The study drew on current market and vehicle production data to surmise its picture of the future for steel in the automotive industry, finding that several automotive manufacturers have near-term plans for vehicle construction in which steel continues to play a key role. It was found that the BMW i5 model will be constructed in steel and light alloys from 2021, a shift from the carbon used in the i3.

In the Tesla model 3, the share of aluminium and titanium will be reduced in favour of steel. "The share of high-strength steels amongst the steel grades used in vehicle construction will rise from its current level of 18% to 30%," explained Kleibrink, citing preliminary work by the Posco Research Institute. According to the World Steel Association, this would allow vehicle weights to be reduced by between 25–39%, leading to potential savings of 3–4.5 tons of greenhouse gas emissions over a vehicle's service life.

The study found that steel also plays a crucial role in the motor and drive of electric vehicles, with between 40 and 100 kilos of non-grain-oriented electrical steel reported to be used in the construction of purely electric vehicles. It was speculated that this could increase demand for this magnetically-soft material to over a million tons a year in Europe, depending on demand.

Steel manufacturers were said to be focusing the development of thinner, tougher electrical steels in order to reduce the weight of the motor. However, as the physical limits in this field are believed to have almost been reached, it is thought that in future manufacturers will differentiate themselves primarily through their expertise in bonding, joining and forming technologies.

In addition, special alloys with a higher silicon and aluminium content are capable of reducing heat loss in the motor during magnetic reversal by up to 30%. Manufacturers with expertise in this segment are expected to benefit from the growing electromobility market. By 2025, it was estimated that over 14 million electric vehicles may have been sold in the EU alone. According to the study, this is a trend in which steel as a material will play an important role, as the dominant ingredient in an intelligent materials mix designed to maximise cost efficiency, sustainability and safety.

www.voestalpine.com

ZF to build BMW's new hybrid eight-speed automatic transmission in company's largest ever single order

ZF Friedrichshafen AG, headquartered in Friedrichshafen, Germany, has received a double digit billion euro order from BMW AG for its enhanced eight-speed automatic transmission, said to be the largest ever single order in the company's history. The new transmission will enter series production in 2022 at ZF's plant in Saarbrücken, the lead production facility for ZF's automatic passenger car transmissions, with production for further customers to be undertaken at its locations in Gray Court, USA, and Shanghai, China.

"This business win is the largest single order in the history of ZF," stated Wolf-Henning Scheider, ZF's CEO. "When it comes to the electrification of passenger cars, in addition to pure electric drives, it confirms our strategy to focus on plug-in hybrids as an everyday solution and to develop attractive products in these areas."

The latest upgraded version of ZF's eight-speed transmission, a technology which has been in production since 2009, has been optimised by integrating an electric drive. The transmission can be installed in almost all vehicle classes with a front-longitudinal drive configuration.

"We have consistently optimised our eight-speed automatic transmission according to future e-mobility requirements," stated Michael Hankel, member of the ZF Board of Management responsible for transmission technology and e-mobility. "With a modular construction using various starting elements, the new-generation hybrid transmission offers a flexible solution which is suitable for all passenger cars – both conventional as well as electric."

The order from BMW is expected to run for a period of several years. "The order was based on the fact that the customer sees our technology as a sustainable drive solution for its vehicles which supports them in achieving CO_2 targets. In addition, the possibility to easily change from one transmission variant to another allows our customer the flexibility to react to market requirements."

"Alongside the significant CO_2 savings potential, this high degree of flexibility is resulting in strong interest in our transmission. We are in very promising discussions with other customers," added Hankel.

www.zf.com

Powering electric vehicles using water, CO_2 and cobalt

Researchers at the University of Massachusetts Lowell, USA, report that they have developed a new way to power electric vehicles by using water, carbon dioxide and cobalt to produce hydrogen gas on-demand at low temperature and pressure. The research team is led by Prof David Ryan, Chemistry Department Chairman, and believes that its new technology could enable vehicles of all sizes to run for longer while maintaining zero emissions.

Because the majority of electric vehicles currently in use are powered by batteries which must be recharged periodically, and which have limitations such as storage capacity, the time required to recharge, and cost, much current electric vehicle technology is only practical for small cars and not for larger vehicles such as trucks and busses. Prof Ryan, however, believes that the technology developed by his team could be used to power vehicles of all sizes.

In an electric vehicle using this technology, all hydrogen created would go directly into a fuel cell, where it would be mixed with oxygen from the atmosphere to generate electricity and water. The generated electricity would then power the system that operates the vehicle's motor, rechargeable battery and headlights.

"This process doesn't store any hydrogen gas, so it's safe and poses no transportation issues, greatly minimising the possibility of a fire or explosion," commented Prof Ryan, adding that the hydrogen generated by the technology is more than 95% pure. "Hydrogen burns completely clean; it produces no carbon dioxide, only water. And, you don't have to burn hydrogen to generate electricity. Hydrogen can be used in fuel cells, in which it combines with oxygen from the air to produce electricity at up to 85% efficiency."

Further, "since hydrogen is not mined or pumped out the ground like fossil fuels, we have to produce it," he added. "Current methods of doing that are expensive and inefficient. This, coupled with the lack of needed infrastructure, has hampered the transition from a petroleum to a hydrogen economy. Our hope is that the catalytic hydrogen technology we have developed would help solve all of these challenges."

www.uml.edu

Prof David Ryan (right) and graduate student Ahmed Jawhari examine a prototype of their invention (Courtesy University of Massachusetts Lowell)

Ricardo partners with Geely to develop advanced hybrid transmission

Global strategic engineering and environmental consultancy Ricardo plc, Shoreham-by-Sea, West Sussex, UK, has partnered with Geely Auto Group, a leading manufacturer of new energy vehicles based in Hangzhou, China, to develop a new advanced transmission for range-extended plug-in hybrid vehicles.

According to Ricardo, the development approach will be collaborative and flexible with co-located, joint teams consisting of Geely and Ricardo engineers based in China and the UK. This is expected to support the internal communications and decision-making processes.

In addition to the core engineering team, support will also be available from Ricardo's technical centres, which are based in various locations around the world, including the Czech Republic. The companies state that the key requirements for the transmission are high efficiency and competitive cost for high-volume A and B-segment products

"Ricardo is pleased to have been selected by Geely for this important, new transmission programme," stated Gary Tan, President of Ricardo Asia. "Geely is one of China's most respected manufacturers for new energy vehicles, and it is a company that shares the Ricardo ethos of excellence in technology, engineering and innovation. We look forward to working in partnership to deliver this impressive range-extended plug-in hybrid transmission to market in Geely's future products."

www.ricardo.com

www.geelyauto.com.hk

Three new BMW all-electric vehicles undergo testing in Arctic conditions

BMW Group has entered cold testing of its three new all-electric vehicles, the BMW iX3, BMW i4 and BMW iNEXT, expected to launch in 2020 and 2021. According to the group, it is currently testing prototypes of the new models under arctic conditions at the winter test centre on Arjeplog, Sweden, situated on the edge of the Arctic Circle.

Within the framework of comprehensive vehicle testing, the vehicles' drive and suspension components are being put to the test under extreme weather and road conditions on the icy surfaces of frozen lakes, on snow and in very low temperatures, as the manufacturer aims to prove the reliability and performance of the electric motors, high-voltage batteries and power electronics of the BMW eDrive technology.

Starting next year, the BMW iX3 will feature the fifth generation of BMW eDrive technology for the first time. This electric motor and high-voltage storage unit is said to feature state-of-the-art battery cell technology to facilitate purely electric driving in a new dimension. With a reported range of over 400 km and the possibility to use DC charging stations with a capacity of 150 kW to charge its battery, this Sports Activity Vehicle (SAV) is reported to be suitable for both day-to-day use and long-distance travel. The BMW iX3 will be the first model produced for the entire global market by the BMW Brilliance Automotive Joint Venture production unit in Shenyang, China.

The BMW i4 is a four-door coupe positioned in the premium midrange segment and will also feature the fifth-generation BMW eDrive technology featured by the BMW i4, with a reported range of over 600 km. The BMW i4 will be produced at the BMW Munich plant from 2021.

BMW electric vehicles undergo winter trial tests (Courtesy BMW Group)

The BMW iNEXT will feature the BMW Group's future modular construction system, reportedly combining innovations in the areas of design, automated driving, connectivity, electrification and services (D+ACES) defined by the group's Number One > Next corporate strategy. The iNEXT also has a reported range of over 600 km and will be produced at the BMW Dingolfing plant as from 2021.

www.bmwgroup.com

ZF to acquire vehicle braking solutions specialist WABCO

ZF Friedrichshafen AG, Germany, has entered into a definitive agreement to acquire WABCO, a global supplier of braking control systems, technologies and services. Together, ZF and WABCO state that they will form a leading global integrated mobility systems provider for commercial vehicles. The planned acquisition, at $136.50 per share for a total equity value of approximately $7 billion, has been approved by ZF's Management Board and Supervisory Board and WABCO's Board of Directors.

WABCO's products and services include integrated braking systems and stability control, air suspension systems, transmission automation controls, aerodynamics, telematics, and fleet management solutions. WABCO reported €3.3 billion in revenues in 2018 and employs some 16,000 people across forty countries.

Wolf-Henning Scheider, ZF CEO, stated, "We believe that, together with WABCO, ZF can form the world's leading integrated systems provider for commercial vehicle technology, creating long-term value and security for its customers, employees and owners. For ZF the acquisition of a specialist and leader for commercial vehicle braking systems means adding a stable and growing business segment and enables our existing commercial vehicle division to expand its expertise in vehicle dynamics control."

"This will create the foundation for ZF to offer comprehensive systems for safe and automated mobility solutions for passengers and goods to our customers," he continued. "This is also in the best interest of our owners, the Zeppelin Foundation and the Dr Jürgen and Irmgard Ulderup Foundation, as the transaction will result in a sustainable strengthening of ZF."

Jacques Esculier, Chairman and CEO of WABCO, added, "Joining forces with highly respected ZF will create a leading global technology company well positioned to capitalise on future demand for autonomous, efficient and connected commercial vehicles. We have a long history of successful collaboration to develop innovative technologies with ZF with both companies sharing an uncompromising drive for excellence, passion for innovation, and exceptional customer focus."

The planned acquisition is part of ZF's Next Generation Mobility strategy and will expand the company's expertise to include commercial vehicle braking solutions for the first time. ZF expects to close the transaction at the beginning of 2020.

The combined company is expected to have annual sales of approximately €40 billion.

www.zf.com

Toyota makes available nearly 24,000 royalty-free patent licences for vehicle electrification

Toyota Motor Corporation has announced that it will grant royalty-free licences on nearly 24,000 of its patents for vehicle electrification-related technologies in an effort to further promote the widespread use of electric vehicles. The company also plans to provide fee-based technical support to other manufacturers developing and selling electrified vehicles when they use Toyota's motors, batteries, PCUs, control ECUs and other vehicle electrification system technologies as part of their powertrain systems.

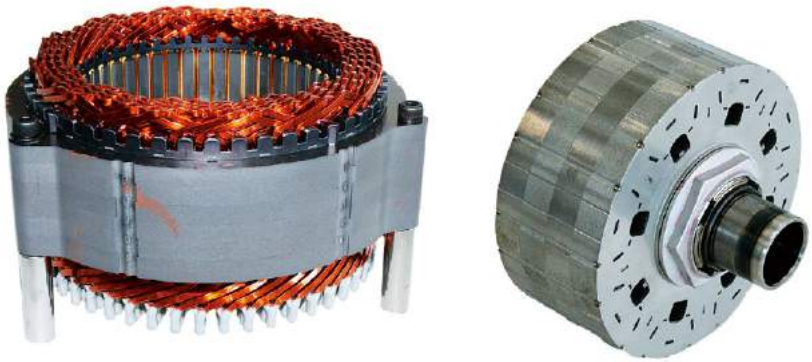
Toyota stated that it aims to help governments, automakers, and society at large to accomplish goals related to climate change. Shigeki Terashi, Member of the Board and Executive Vice President of Toyota Motor Corporation, explained, "Based on the high volume of inquiries we receive about our vehicle electrification systems from companies that recognise a need to popularise hybrid and other electrified vehicle technologies, we believe that now is the time for cooperation. If the number of electrified vehicles accelerates significantly in the next ten years, they will become standard, and we hope to play a role in supporting that process."

The royalty-free patents are said to be for advanced technologies found in electrified vehicles, particularly those used in hybrid electric vehicles (HEVs), that have helped Toyota to realise enhanced performance, reduced size and cost reductions. More specifically, the patents included are for parts and systems, such as electric motors, power control units and system controls. These are core technologies that can be applied to the development of various types of electrified vehicles including HEVs, plug-in hybrid electric vehicles (PHEV) and fuel-cell electric vehicles (FCEV).

Together, Toyota stated that it will offer approximately 23,740 patents awarded over its more than twenty years of electrified vehicle technology development, with the grant period beginning immediately and lasting through the end of 2030. Contracts for the grants may be issued by contacting Toyota and discussing specific licensing terms and conditions.

Toyota already offers 5,680 patents related to its FCEVs as of January 2015. Now, it will add approximately 2,590 patents related to electric motors, 2,020 patents related to PCUs, 7,550 patents related to system controls, 1,320 engine transaxle patents, 2,200 charger patents and 2,380 additional fuel cell patents.

www.global.toyota



Toyota has released almost 24,000 patents relating to vehicle electrification (Courtesy Toyota Motor Corporation)

Weissgärber appointed provisional manager of Fraunhofer IFAM Dresden

Dr Thomas Weissgärber has taken over the provisional management of the Dresden branch of the Fraunhofer Institute for Manufacturing Technology (IFAM) and Advanced Materials IFAM. He succeeds Prof Bernd Kieback, who retires after many years as head of the institute.

Dr Weissgärber, a long-time employee of the institute, previously served as deputy head of Fraunhofer IFAM Dresden and has conducted research in various fields of Powder Metallurgy. He is said to have contributed significantly to the development of the institute into one of the leading application-oriented research institutes in the field of PM technologies and materials, and to the strengthening of ties between science and applied research. In addition, he is involved in various committees in the field of PM.

By organising scientific events internationally, as well as at the Dresden location itself, he reportedly aims to contribute to the transfer of knowledge within the field and grow the general perception of PM, and to further strengthen and expand Dresden's location as a leader in PM in Europe and worldwide. In November, he was awarded the Skaupy Prize for his achievements to date.

Weissgärber stated that he sees his new role as motivation to continuously expand and build on existing competencies at Fraunhofer IFAM Dresden and to utilise the institute's knowledge, especially in materials, PM and AM, for innovative, future-oriented solutions to generate optimal solutions in core areas such as energy technology, mobility and medical technology.

www.ifam-dd.fraunhofer.de

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ZF strengthens its commitment to Chinese automotive market

ZF Friedrichschafen AG, Germany, is set to introduce production of its 8-speed 8HP automatic transmission to its plant in Shanghai, China, as it seeks to expand its presence in the country. The group currently offers its Chinese customers a number of high-tech solutions for e-mobility and autonomous driving, and is now said to be enlarging its customer base with Chinese manufacturers and new mobility providers.

By enabling the development and manufacture of its complete product portfolio within China, ZF hopes to better support the local market. The group opened its first Chinese production site in 1994, and now operates thirty-two, with several additional plants planned and significant expansions to its development capacity within the country underway.

"Our strategy for the Chinese automotive market is called 'local for local'," explained Dr Holger Klein, ZF Board Member responsible for the Asia-Pacific region, with China as its core market. "Almost all of our customers will expand their business in China in the coming years. We will support them in this by offering our entire portfolio locally – from development services to local just-in-sequence delivery."

"We will increase our degree of localisation in China up to 100% in the coming years," he continued. "With our innovations and high-tech products, we will have an even stronger presence in the future."

Introducing production of its 8-speed 8HP automatic transmission to the Shanghai plant, where automatic transmissions have been produced since 2004, will enable ZF to supply local customers with its flagship product for passenger cars, as well as variants of the 8HP for plug-in hybrid drives. In the future, ZF stated that it will endeavour to produce purely electric drives in China; production facilities for this are currently under way.

Further, to meet local production demand for passenger car electric power steering systems in China, ZF is reported to be building a new steering plant in Zhanjiagang – set to be the largest of ZF's thirty-two plants in China to date. ZF will also serve the commercial vehicle market more locally from China: a joint venture with commercial vehicle manufacturer Foton will see production of ZF's TraXon automatic and hybrid commercial vehicle transmission begin in the near future. To support this venture, a joint production plant has been built south of Shanghai. ZF currently employs around 15,000 staff in the country.

www.zf.com

Höganäs in teardown of plug-in hybrid to establish opportunities for PM

A team of engineers from Höganäs China is undergoing a project to tear down a hybrid SUV (Courtesy Höganäs)

In order to establish a better understanding of the use of Powder Metallurgy components in a modern plug-in hybrid vehicle, a team of engineers from Höganäs China has undertaken a project to tear down a BYD Tang DM hybrid SUV. The team in Shanghai dismantled the car to identify components that are either made using Powder Metallurgy, or which could be converted to Powder Metallurgy production.

The BYD Tang is a plug-in hybrid crossover sport utility vehicle developed by Chinese automaker BYD. Its 18.4 kWh lithium iron phosphate battery pack is said to deliver an all-electric range of 80 km (50 miles) from two electric motors, front and rear. The Tang has a 2.0 litre internal combustion engine and is fitted with a Dual Mode (DM) system, allowing drivers to switch between all-electric mode (EV mode) and hybrid electric mode (HEV mode).

The teardown follows on from a similar project in 2017, where a team of engineers from Höganäs stripped back three new vehicles to their component parts. The full report can be read in the Summer 2017 issue of *Powder Metallurgy Review* magazine.

www.hoganas.com

EPMA announces new President and Council Members

The European Powder Metallurgy Association (EPMA) announced a number of leadership changes during its General Assembly on March 21, 2019, in Brussels, Belgium. Every three years, the EPMA Statutes require an election to be held to form a new EPMA Council, as well as a new EPMA President and Treasurer (both subject to a maximum of two terms). The new EPMA Council was elected by a ballot of Full Member companies in advance of the General Assembly for the period of 2019–2022, with representatives of both Pometon SpA and Polmo Lomianki SA joining the council for the first time.

As the tenure of the current EPMA President and Treasurer came to an end, the newly formed council announced during the General Assembly its choice for the EPMA's new President and Treasurer. Ralf Carlström, Digital Metal AB, was elected as EPMA President (2019–2022), succeeding Philippe Gundermann. Pierre Blanchard, Erasteel Kloster AB, was elected as EPMA Treasurer (2019– 2022), succeeding Peter Kjeldsteen, Sintex A/S.

During the assembly, outgoing EPMA President Philippe Gundermann reported on PM industry trends and statistics, highlighting the various PM sectors. Lionel Aboussouan, the EPMA's Executive Director provided updates on the various EPMA projects and activities undertaken by the association during 2018, and Kate Blackbourne, EPMA Congress Manager, gave insight into last year's Euro PM2018 Congress & Exhibition. Andrew Almond, EPMA Marketing Manager, provided an overview of marketing and promotional work in 2018 and the EPMA's new Technical Manager, Bruno Vicenzi, explained the various EU projects the EPMA has been involved with during the last twelve months.

Ralf Carlström, Digital Metal AB, was elected as EPMA President

Keynote speeches, presented towards the end of the assembly, saw Guy Thiran, Executive Director, Eurometaux, provide an update on 'Regulatory developments of interest to the Powder Metallurgy Industry', and Prof Thilo Bein, Fraunhofer LBF / Chairman for Materials, Design and Production Task Force, European Automotive Research Partners Association (EARPA), discuss 'Advanced Lightweight Design – Challenges and Trends'.

www.epma.com

Sintex publishes PM case studies

Sintex a/s, Denmark, has published a number of Powder Metallurgy case studies highlighting the capabilities of PM technologies for a range of applications. The case studies are available on the company's website in English, German and Danish, and include the following:

High strength requirements fulfilled using MIM

Looking at the use of Metal Injection Moulding (MIM) technology to enable a customer to fulfil the high strength requirements of a sensor housing, in the same geometry as plastic but with the same strength as steel.

Surface treatment strengthens joins

Looking at the production of a wear-resistant coating for friction plates consisting of a wolfram carbide hard metal coating. The friction plates are used in wind turbines and the aim of their development was to reduce friction during use. Further key benefits of the new wear-resistant coating were the achievement of higher friction plate strength and extended lifetime.

Powder Metallurgy fulfils high requirements

In this case study, Sintex presents the development of a custom PM solution for an automotive customer with strict material and quality requirements. The customer required higher corrosion resistance without a significant cost increase. Sintex's case study examines how the company met this requirement through new material development and proposals for design enhancements, such that the higher material price was offset by mass savings, and the development of a fully automatic production line.

Stator design with SMC

This case study looks at the benefits of SMC in the production of stators for cheaper, smaller and more efficient motors. An example is provided of the production of a stator with an outer diameter of 80 mm, length of 20 mm, six stator teeth, outer rotor diameter of 28 mm and four poles.

World-class sound using innovative SMC solution

Looking at the use of SMCs in a loudspeaker produced by a Danish speaker manufacturer. SMCs are an attractive solution for applications that require low losses, in particular at high frequencies, as the advantages of SMCs increase at higher magnetic frequencies.

The loudspeaker produced through this collaboration was said to be the first loudspeaker to contain a magnetic system made of SMC.

www.sintex.com

Zyfra offers digitalisation solutions to PM industry

Zyfra, a specialist in digitalisation systems focusing on the machinery, metallurgy, mining, oil & gas and chemical sectors, has reported on the opportunities that the introduction of such systems could offer the Powder Metallurgy sector. According to the company, headquartered in Helsinki, Finland, the Powder Metallurgy industry has been lagging behind other sectors, such as the automotive industry, when it comes to implementing such processes. However, as the demand on data collection and monitoring options increases, it reports that there will be opportunities to embrace digitalisation and implement Artificial Intelligence to improve the Powder Metallurgy supply chain.

Over the past few years, Zyfra states that the Powder Metallurgy sector has picked up pace in digitalisation. There have been significant innovations in automation, data collection and analytics. Companies that are hesitant to embark on digital transformation, will have to do it soon, the company reports. According to GKN Powder Metallurgy's Chief Digital Officer, Paul Mairl, such companies will be missing an opportunity and, if they don't act soon, even large firms might soon see small but fast market players pass by.

Citing a 360 Research Reports market study, Zyfra commented that, over the next five years, the Powder Metallurgy market will be growing at a solid 3.6% CAGR in terms of revenue. The global market size will, it was reported, reach $9.72 billion by 2024, from $7.85 billion in 2019.

Powder Metallurgy is backed by the needs of several industries, especially the automotive industry. Both have been expanding since the 1950s and, nowadays, around 90% of Powder Metallurgy products are used in the transportation market, according to Tadayuki Tsutsui from Hitachi Powdered Metals. It means that Powder Metallurgy can't ignore various challenges that the motoring industry currently faces, including, for example, subscription-based access and demand for green vehicles. To meet these challenges, Powder Metallurgy has to embrace digital transformation and smart technologies, states Zyfra.

"AI solutions for casting powder mixtures have been in place for quite a long time, and most of them can be applied in Powder Metallurgy as well," stated Konstantin Gorbach, ZYFRA Head of Intelligent Applications. "Those smart technologies allow you to control the level of consumption and improve production efficiency by better managing the manufacturing process and assessing the product quality."

"They also minimise manual handling and reduce powder contamination, manage data across multiple locations and monitor the production status," continued Gorbach. "Smart solutions for Powder Metallurgy are able to develop unique production with set properties for each client and smoother distribution of production capacities. As a result, the producer will offer its customers not just a product, but a complete solution, a combination of new alloys with unique properties and engineering solutions for their application."

It was stated that usually, during the manufacturing process, a large amount of data is accumulated that directly or indirectly affects the quality of the company's product. Powder Metallurgy is no exception; data is collected and stored for all key processes, from mixing ingredients to quality control, including pressing and especially the process of sintering.

"When you connect all meaningful factors together, you create a model that allows the prediction of mechanical properties in the future product, as well as the probability of defects," continues Gorbach. "If any adjustments are required, the operator will know about it in advance, making it is possible to improve the quality proactively."

Computer vision technologies make it possible to automatically distinguish many types of defects. Zyfra is reported to be implementing a pilot project whose task is to find defects in plastic manufacturing, but a similar technology can be applied to Powder Metallurgy, the company added.

www.zyfra.com

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www.fluidtherm.com
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Sino-Euro expands its portfolio of titanium powders

Sino-Euro Materials Technologies of Xi'an Co., Ltd. (SMT), a subsidiary of the Northwest Institute for Non-ferrous Metal Research located in Xi'an, Shaanxi Province, China, has expanded its range of titanium powder with the introduction of BT20, Ti1023, Ti6242 and Ti6Al7Nb. The company will produce the new materials using its Supreme-Speed Plasma Rotating Electrode Process (SS-PREP™).

BT20 titanium alloy, also referred to as TA15 in China, is said to be widely used in aerospace engines, nuclear structures and other industries in China and Russia. The nominal chemistry of BT20, with alpha and beta phase comprised of Ti-6.5Al-1Mo-1V-2Zr (weight percentage), reportedly offers excellent mechanical properties at both elevated temperatures and at room temperature.

Ti1023 is a TIMET-developed, high-strength, hardenable forging alloy used in airframes, landing gear components and engines. It is said to be suitable for near-net shape forging techniques due to its excellent combination of strength and toughness.

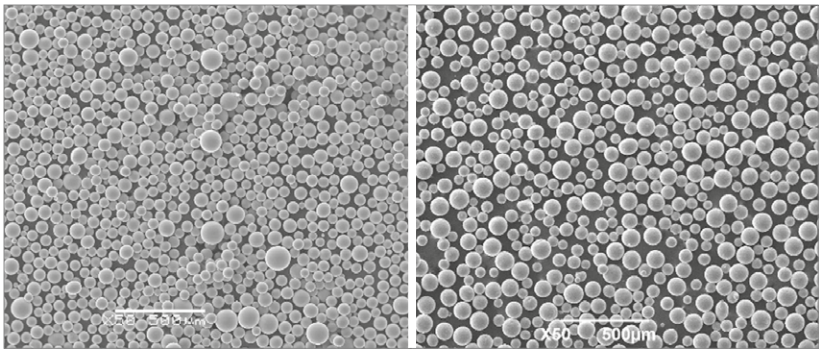
Ti6242 is said to offer a highly desirable combination of tensile strength, creep strength, toughness and high-temperature stability for long-term applications at temperatures of up to 530°C. Its primary application area is in gas turbine compressor components, such as blades, discs and impellers.

Ti6Al7Nb is said to offer an ideal substitute for Ti6Al4V in medical applications, as it does not contain vanadium. Vanadium has been found to be toxic to humans at high levels, and has also been identified as a possible carcinogen, making it unsuitable for use in medical implants or tools.

Speaking on the expansion to Sino-Euro's titanium portfolio, Dr Liang Shujin, the company's General Manager, stated, "Based on the SS-PREP technique, Sino-Euro could make any kind of titanium alloy into spherical powder just as easy as Ti-6Al-4V. Unlike the sophisticated correlation between alloy and parameters during gas or plasma atomisation, SS-PREP owns the similar parameters for different kind alloy, including titanium, nickel-based and iron-based alloy."

According to Sino-Euro, its powder business achieved revenues of around $6 million in 2018.

www.c-semt.com



Sino-Euro has added Ti1023 (left) and BT20 (right) to its portfolio of spherical metal powders (Courtesy Sino-Euro Materials Technologies of Xi'an Co., Ltd.)

Plansee Composite Materials appoints new Managing Director

Plansee Composite Materials GmbH, Lechbruck, Germany, part of the Austrian-based Plansee Group, has appointed Mathias Hochstrasser as its Managing Director. Hochstrasser has worked for the Plansee Group for thirteen years, having joined the company in Switzerland in 2006.

After joining Plansee as a Production Planner, Hochstrasser relocated to China in 2011 as Project Leader for the construction of a new plant. He is said to have managed and incrementally expanded the plant in Shanghai since its successful commissioning in 2013. At present, Plansee has more than 400 employees in China.

On his appointment to Managing Director of Plansee Composite Materials, Hochstrasser stated, "Plansee in Lechbruck is very well positioned – with great employees, competitive products, good capacity utilisation and outstanding machinery."

Plansee Composite Materials is Plansee Group's competence centre for tungsten heavy metals as well as metallic and ceramic composite materials. The site manufactures a number of products from the group's tungsten heavy metal alloys, as well as metal and ceramic composites based materials such as on titanium and aluminium.

Among other products, Plansee Composite Materials develops sputtering targets and cathodes for hard material coatings. Its Lechbruck site was founded in 1975 and is certified to ISO 9001 for quality management systems in the development, production and distribution of powders, semi-finished products and products made of refractory metals.

www.plansee.com

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(8) Cold forging mould;
(9) CNC powder molding press;
(10) Rotary type powder molding press;
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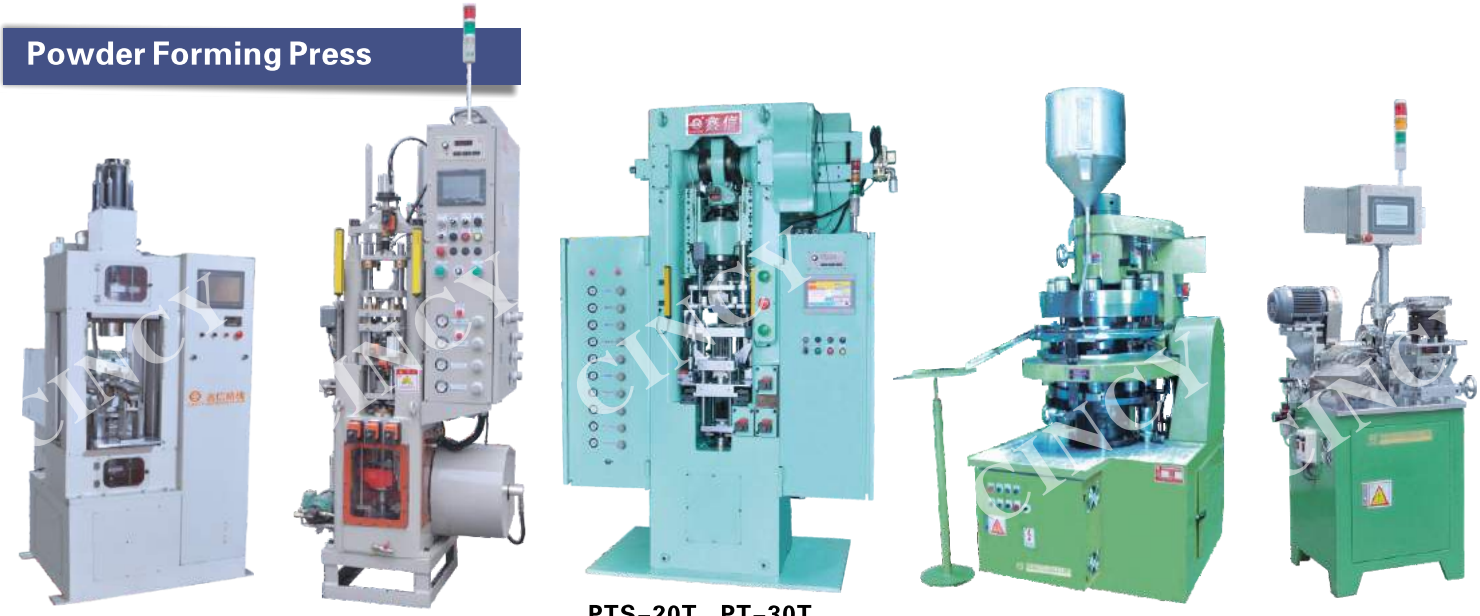

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China announces new tungsten and rare earth quotas for first half 2019

Roskill Information Services, London, UK, has reported on China's new rare earth and tungsten mine production quotas for the first half of 2019. In March, China's Ministry of Natural Resources and the Ministry of Industry and Information Technology set tungsten quotes for the first half of the year at 49.8 kt (65% WO3 basis), while rare earth quotas were set at 50.4 kt of light rare earths and 9.6 kt of medium and heavy rare earths.

According to Roskill, the new tungsten quotas has left a degree of uncertainty in the market. Usually, two quotas are given by the ministry – one for mines where tungsten is the primary (or sole) product and a second for mines with tungsten as a by-product. The quota for H1 2019 is said to be some 22% lower than the overall quota for H1 2018 (63.9 kt) and 3% lower than the primary tungsten quota (51.3 kt), with a 12.6 kt quota also outlined for by-product tungsten in H1 2018. In 2017 and 2018, the overall tungsten quota increased because of a rise in the by-product quota.

Historically, Roskill added that the quota has lagged behind actual mine production; between 2011 and 2018, tungsten mine output exceeded the quota every year. This has reportedly been addressed in China's National Mineral Resources Planning (2016–2020) document, which caps tungsten mine output at 120 kt/year of concentrates on a 65% WO_3 basis (61.6 kt contained W) by 2020, and is said to be more reflective of production in recent years.

Despite increasing by nearly 30% compared to the H2 2018 quota allocation, the H1 2019 quota for rare earths has caused little uncertainty, as the MIIT has indicated that the H1 allocation will represent 50% of the 2019 annual quota. This would result in there being no overall change in the mining quota between 2018 and 2019. Inner Mongolia continues to hold the largest portion of the light rare earth mining quota, with 34.6 kt REO assigned to China Northern Rare Earth Group, which operates the Baiyun Obo mine in Baotou.

Rare earth mining in H1 2019 is reportedly expected to remain far below the quota, particularly in southern provinces where imports of mineral concentrates and semi-processed products are said to have increased significantly since early 2018. Rare earth concentrates imported by China in 2018 and early 2019 have been sourced largely from Myanmar, the USA and monazite concentrates imported from Russia, Brazil and other Asian countries. Rare earth production from imported concentrates and compounds is not included in separation quotas for RE companies and also avoids the resource tax applied to Chinese domestic mining of rare earths.

Roskill's full report on *Rare Earth: Global Industry, Markets and Outlook* was published in December 2018. Both the company's Tungsten and Rare Earth reports are available to download via its website.

www.roskill.com

Dr Leo Prakash posthumously awarded 2019 Ivor Jenkins Medal

The UK's Institute of Materials, Minerals and Mining (IOM[3]) has named Dr Leo Prakash the recipient of its 2019 Ivor Jenkins Medal, posthumously. The annual award is presented to individuals in recognition of a significant contribution that has enhanced the scientific, industrial or technological understanding of materials processing or component production using Powder Metallurgy and particulate materials.

Dr Prakash, who passed away aged sixty-nine in February 2019, was a renowned authority in the field of cemented carbides and other hard materials. His pioneering work in the late 1970s and early 1980s on iron-based binders for hardmetals led to the commercialisation of several alternatives to pure cobalt and laid the foundation for the wave of recent research into and development of low cobalt and cobalt-free hardmetals, an important topic considering the status of cobalt as a critical raw material as well as the current strict classification issues.

From the mid-late 1980s and into the 1990s, his fundamental studies into the mechanisms of grain growth inhibition and sintering of the very finest grained tungsten carbide hardmetals at the time were also of great significance for the industry, as were his studies of material properties and performance in both laboratory tests and practical applications.

For the last ten years, Dr Prakash was Co-chairman of EuroHM, the European hard materials group within the European Powder Metallurgy Association (EPMA). He authored or co-authored over forty publications in international journals, conferences and textbooks.

www.iom3.org

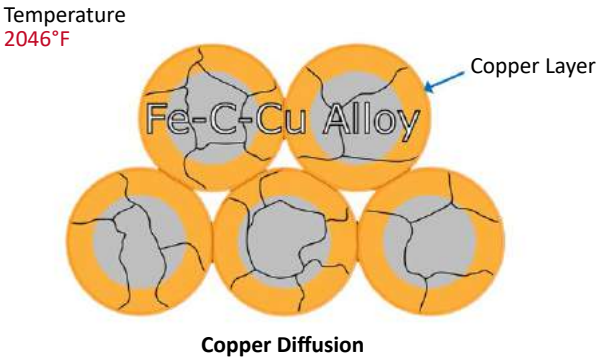
Dr Leo Prakash has been awarded the 2019 Ivor Jenkins Medal, posthumously

TAT Technologies announces August dates for its sintering courses

TAT Technologies has announced August 2019 dates for its sintering courses, held at the company's training centre in St. Mary's, Pennsylvania, USA. The courses are aimed at employees in the Powder Metallurgy industry who want to learn more about the necessary fundamentals of the sintering process.

Course 1: Preparation for Better Sintering
August 20–23, 2019

Covering all aspects of preparation of parts and the furnace before sintering, this course will give attendees a clear understanding of what is needed to ensure parts will be properly and thoroughly delubed, oxide reduced and graphite diffused, before proceeding to the sintering section of the furnace.



The course will explain what happens inside a PM part as it proceeds through the furnace (Courtesy TAT Technologies)

Course 2: Sintering-Ferrous PM
August 26–29, 2019

Building on the knowledge and skills gained in Preparation for Better Sintering, this course will teach students how to guide their well-prepared part through the furnace and achieve a quality sintered result with the least property variation and at higher production rates. Course one is a pre-requisite for this course.

An Early Bird Discount is available until June 28, with savings of $1000 for students attending both courses.

www.tat-tech.com

PM China 2019 concludes after another successful event

The PM China 2019 exhibition hosted 464 exhibitors, a rise of 11% over the previous year

The 12th Shanghai International Exhibition for Powder Metallurgy, Cemented Carbides and Advanced Ceramics (PM China 2019) was held at Shanghai World Expo & Convention Center, China, March 25–27, 2019. The organisers reported that the exhibition hosted 464 exhibitors, a rise of 11% over the previous year, and welcomed 22,637 visitors across the four days of the event, an increase of 19.5% over last year.

Exhibiting companies were present from a large number of countries including China, the USA, Germany, the UK, Italy, France, the Netherlands, Sweden, Switzerland, Austria, Russia, Canada, Japan, South Korea, Poland, Singapore, India, Hong Kong and Taiwan, covering various fields such as powder raw materials, products, mechanical equipment, Additive Manufacturing, testing instruments, gas and process solutions. Approximately 210 equipment companies, accounting for 45% of exhibitors, exhibited at the show, as well as 114 material suppliers, accounting for 24%; approximately 120 product companies, accounting for 26%; and approximately twenty Additive Manufacturing companies, accounting for 5%.

A number of academic forums and exchange meetings were also held at the show, including the 2019 China Summit Forum on Cutting-edge Technology Application and Development in Advanced Ceramic Industry & Academic Annual Meeting of the Industrial Ceramics Committee of Chinese Ceramic Society, The 8th Shanghai International Injection Molding Forum, the Academic Annual Meeting of China Powder Metallurgy Alliance & 2019 Shanghai International Powder Metallurgy Forum, and more.

The 13th Shanghai International Exhibition for Powder Metallurgy, Cemented Carbides and Advanced Ceramics will be held at the Shanghai World Expo & Convention Center from March 24–26, 2020.

www.en.pmexchina.com

Gopinath named as Fellow of PMAI

During APMA 2019, the 5th International Conference on Powder Metallurgy in Asia, held in Pune, India, February 19-21, N Gopinath, Managing Director of Fluidtherm Technology and past-president of the Powder Metallurgy Association of India (PMAI), was conferred with the title Fellow of PMAI (FPMAI) for his service to the Indian PM industry.

Fellowship of the PMAI is conferred upon individuals who have demonstrated significant contributions to the science and practice of Powder Metallurgy, the growth of the Indian PM industry and the growth of PMAI.

"Gopinath has met these criteria in abundance by developing unique processes and world-class furnaces for Powder Metallurgy, making these available in India and around the world, and for his efforts that made PMAI an internationally respected body," stated Aniket Gore, President of PMAI.

Fluidtherm is a manufacturer of sintering and heat treatment furnaces, as well as fluidised bed reactors and chemical/mineral processing plants. In addition to facilities for plant design, procurement, manufacture, start-up and after service, Fluidtherm operates a versatile thermal processing test facility where process and product development, as well as client services such as failure analysis, process selection/optimisation, trouble shooting and contract R&D are carried out.

www.pmai.in
www.fluidtherm.com

N Gopinath, Managing Director of Fluidtherm Technology, was conferred with the title Fellow of PMAI (FPMAI) for his service to the Indian PM industry

EPMA announces PM Life training course dates for 2019–20

The European Powder Metallurgy Association (EPMA) has announced upcoming course dates for PM Life in 2019-20. PM Life is a training programme organised by a variety of partners in the European PM industry, which aims to provide life-long learning in Powder Metallurgy.

PM Life delivers comprehensive training to participants, who have the choice of attending the full five-week course or picking specific modules which relate to their field of interest.

Each one-week course module will be hosted in a different venue across five European countries, offering participants a wide range of experience and contacts within the European Powder Metallurgy industry. An optional internship is also offered by PM Life, which can be undertaken in either a factory or university, so that participants can practice what they have learnt during the course in a working environment.

The PM life training programme is made up of the following modules:

Powder and Hardmetals
June 3-7 2019 - Sweden
The Powder and Hardmetals module will provide a comprehensive overview of the fabrication and use of metal powder and hard metals. The module will cover both fundamental aspects of the technology and industrial practices, in sessions led by experts from academia, research and industry.

Press and Sinter
June 17-21 2019 – France
The Press and Sinter module will go into both fundamental and practical facets of the conventional powder processing route comprising pressing and sintering operations. Sessions will be held on topics including modelling, the numerical design of parts and tools for pressing, pressing machines, material selection, types of sintering process, the mechanical properties of sintered steels and more.

Hot Isostatic Pressing
TBC, 2020
Course details to be confirmed by the organisers

Additive Manufacturing
August 26-30 2019 – Germany
The Additive Manufacturing module will begin with a general introduction to AM of metals, ceramics and polymers as well as the fundamental aspects of the industry.

Metal Injection Moulding
September 9-13 2019 – Spain
The Metal Injection Moulding (MIM) module will include both fundamental and practical aspects of Powder Injection Moulding (PIM) technology, from part and mould design, to powder and feedstock development, to debinding and sintering.

The EPMA is the acting point of contact for enquiries regarding the course and for registration. Further information and course details are available via the PM Life website.

www.pmlifetraining.com

Formnext + PM South China: A new trade show for AM and PM

The first ever Formnext + PM South China trade show for the Additive Manufacturing and Powder Metallurgy industries will be held in Shenzhen, China, from September 9–11, 2020. Organised by Mesago Messe Frankfurt GmbH, Germany, Guangzhou Guangya Messe Frankfurt Co Ltd, China and Uniris Exhibition Shanghai Co Ltd, China, the new trade show will showcase the metal powder industries to an international audience.

Petra Haarburger, Managing Director of Mesago Messe, the organiser of the annual Formnext show in Frankfurt, stated, "Formnext + PM South China offers both Chinese and international additive manufacturers an exceptional platform in the highly dynamic southern China region." The Greater Bay Area around Shenzhen is said to be a key location for innovation in science, technology, electronics, manufacturing, automotive manufacturing, robotics and automation in China, and a major driver for the economy.

According to Sascha Wenzler, Vice President for Formnext at Mesago Messe, added, "Formnext has been a resounding success in Europe and we are confident that the combination of Additive Manufacturing, materials, and innovative process technologies will also perfectly address the current and future needs of the Chinese manufacturing industry."

Uniris Exhibition Shanghai Co Ltd previously organised the Powder Metallurgy Expo South China. With the support of Messe Frankfurt's extensive global network of branch and sales offices, it was stated that the new trade show will be widely promoted on relevant national and international media channels, online portals and social media. Exhibitors are also expected to benefit from Uniris' experience in markets related to the PM industry.

Formnext + PM South China will target visitors from a wide range of sectors, including architecture, automation, automotive, aerospace, construction, dental technology, home appliances, electrical engineering and electronics, packaging technology, medical technology and toolmaking. The event will be held at the Shenzhen World Exhibition and Convention Center, which is currently under construction and which, when completed, is expected to be one of the largest exhibition centres in the world.

www.messefrankfurt.com

R&D programme launched for Powder Metallurgy helical gears

mG miniGears Spa, Padova, Italy, a manufacturer of precision parts, drive components, gear kits and complex system solutions and a company of hGears Holding GmbH, has launched a research & development programme to investigate the use of Powder Metallurgy for the production of helical gears. The programme will aim to expand the advantages of PM technology to the most demanding automotive applications, where low Noise Vibration Harshness (NVH) properties are requested.

According to the company, PM helical gears are characterised by elements that must be produced with helical motion movement of the punches, and elements where this movement is not allowed (typically a splined central hole or weight-reducing slots in the gear body). The combination of these requirements means that a new approach must be taken to the design of compaction tooling for the gears' production.

A first prototype has been produced by the company which reportedly meets these requirements. To increase its knowledge of the stress and strain level of the tool, the company utilised strain gauges on the critical elements. The information gathered by this method will be used for the next generation of the tool, where the helix angle of the gear teeth will be increased to the maximum value currently used in the industry.

The main outcome of this research programme is expected to be the production of a cheap, light, strong and geometrically complex gear. By drawing on its knowledge and technology for gear manufacturing, mG miniGears expects to be able to meet the highest quality requirements with its helical gears.

www.hgears.com

The prototype PM helical gear produced by mG miniGears

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The Powder Metallurgy market in India: Potential for continued growth as auto industry advances

India produced a total of 31 million vehicles last year, including passenger and commercial vehicles as well as three and two-wheelers, making it the fourth largest automotive manufacturer in the world. Domestic sales and exports are increasing year-on-year, with the country offering huge potential for growth. The domestic market for sintered components is growing at a CAGR of 22%, with many businesses reporting further investment and new product lines. In this review, Kadambari Gopinath, Fluidtherm Technology, reports on the current state of India's automotive market and provides an insight into the country's growing PM industry.

The inflection point for the Indian Powder Metallurgy industry came at the turn of the century, driven by general economic growth, an opening up to foreign investments in the automobile sector through a Foreign Direct Investment (FDI) programme, and the introduction of emission standards by the government. Since then, the fortune of the country's PM industry has been strongly interwined with that of its automobile sector, which today accounts for around 80% of all PM sales in the country.

India's automotive sector

The automobile industry in India has shown strong growth over the last three years, in spite of a temporary upset following demonetisation in November 2016, where the government of India effectively removed 86% of cash from circulation in an effort to tackle tax-free cash, known in India as 'black money'. Although affected by this, the automobile sector bounced back and enjoyed peak production in 2018, reporting 14.8% growth year-on-year. However, after a seemingly strong first quarter, production rates for FY 2019 dropped to a modest 6.3% growth compared to FY 2018 (the Indian financial year runs from April 1 to March 31 of the following year. Therefore FY 2019 refers to the period from April 1, 2018 to March 31, 2019).

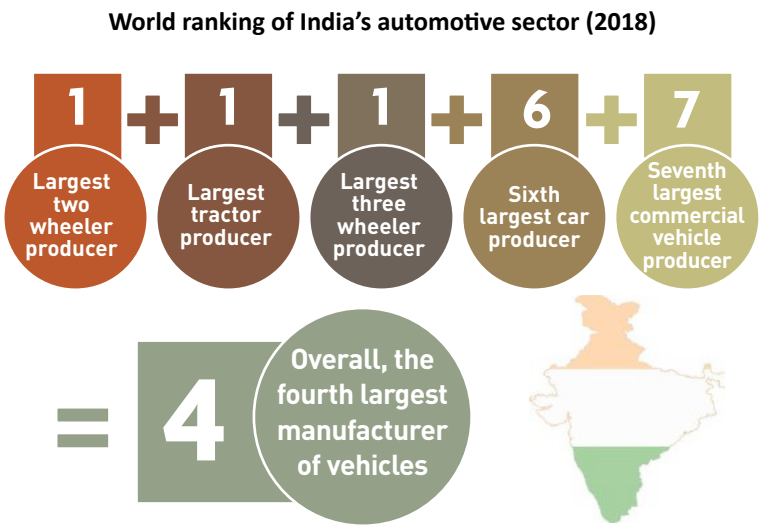

Fig. 1 India's automotive industry is the fourth largest in the world, with capacity for significant growth

Fig. 2 India's auto industry is working to meet BS-VI (Euro-6 equivalent) emission standards, due to come into force in April 2020 (Courtesy Mahindra Group)

The country's automobile associations have forecast single-digit domestic sales growth of around 3–5% in FY 2020, owing to a host of factors including high interest rates on loans, rising commodity prices and poor monsoons (resulting in lower agricultural output). The outcome of parliamentary elections in May, and the monetary policies that follow, will also affect vehicle sales.

This slowdown could not have come at a worse time. Automobile manufacturers are currently facing an enormous challenge in transitioning to the BS-VI emission standards (which will come into force from April 1, 2020) from the current BS-IV standards, having skipped BS-V altogether. While new models are easier equipped to meet BS-VI requirements, the challenge lies in upgrading existing models.

The problem is not technology. Many Indian manufacturers have been exporting vehicles and parts to Europe, which has the same emission requirements (BS-VI is similar to Euro-6). The challenge is in modifying these technologies to suit an Indian market which demands smaller and lighter vehicles, smaller engines, and where fuel efficiency and cost are critical factors in the purchase decision.

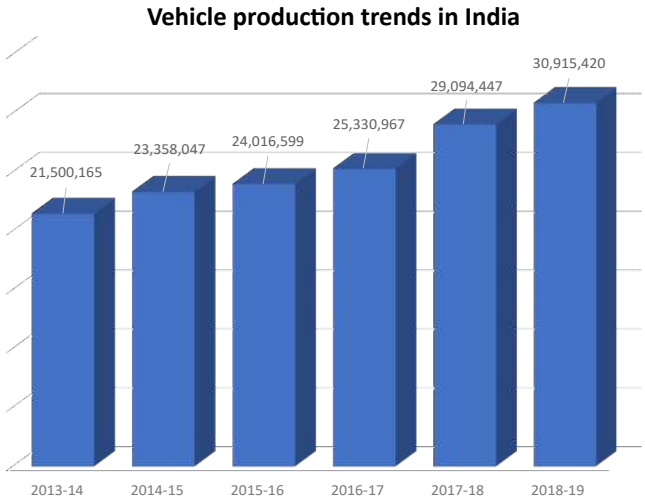

Fig. 3 Auto production, including passenger and commercial vehicles as well as two and three wheelers (Courtesy SIAM)

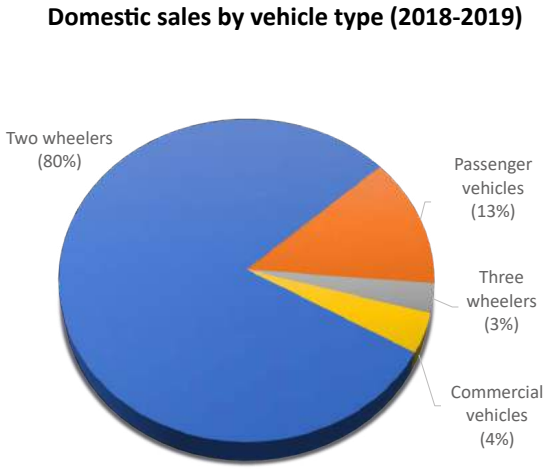

Fig. 4 Two-wheelers account for the vast majority of automobiles sold in India (Courtesy SIAM)

Small capacity diesel engines (less than 1.5 litre) also appear to have taken a major hit. Maruti Suzuki has announced that it will phase out its diesel models by April 2020. The increase in costs to make these cars BS-VI compliant, especially in the small car segment, would price them out of the reach of their buyers. Mahindra & Mahindra will discontinue its 1.2 litre diesel lines, while continuing to sell its higher capacity diesel engine variants. Tata Motors will also close down production of the 1.05 litre diesel engine that drives two of its recently launched hatchback and compact sedan models.

However, in spite of this uncertainty in the short-term, the Indian automobile industry remains the fourth largest in the world, and significant growth is seen as inevitable.

Fig. 5 The production of two-wheelers accounts for 80% of India's domestic vehicle sales (Courtesy Yamaha India)

The automotive market in India

Domestic sales (across all vehicle categories) account for about 85% of India's total vehicle production. Most automobile manufacturers prefer to set up production facilities in India to combat high import duties.

The two-wheeler market contributes 80% of total domestic vehicle sales by volume

India is the largest market for two-wheelers in the world, and production in this sector grew by 4.86% in FY 2019, compared to the previous year. Two-wheelers constitute a large percentage of vehicles exported out of the country.

India has eleven motorcycle and seven scooter manufacturers. Motorcycles contribute about 63% of total two-wheeler sales, scooters about 33% and mopeds less than 5%. Rural markets are dominated by the sales of sub 110 cc two-wheelers. The biggest growth in the urban areas has been in the mid-capacity segment (250-500 cc).

Passenger vehicle category	Market share (sales vol)	Leading manufacturers (in category)	Market share (in category)
Hatchbacks	33%	Maruti Suzuki	62.85 %
		Hyundai Motors	21.2%
		Tata Motors	11.2%
Compact sedans	17.6%	Maruti Suzuki	57.9%
		Honda Cars	19.4%
		Hyundai Motors	8.6%
Mid-sized sedans	7.1%	Maruti Suzuki	26%
		Honda Cars	23.1%
		Hyundai Motors	22.3%
Compact SUVs	13.2%	Maruti Suzuki	47.9 %
		Tata Motors	16.7%
		Ford India	14%
Executive & mid-sized SUVs	14.7%	Mahindra & Mahindra	42.7%
		Hyundai Motors	34.1%
		Maruti Suzuki	10.3%
MPVs and vans	14.4%	Maruti Suzuki	68.2%
		Toyota Kirloskar	21.8%
		Mahindra & Mahindra	8.2%

Table 1 Market share for automotive vehicles in India, highlighting top three manufacturers in each category (Courtesy SIAM/Economic Times)

Fig. 6 The market for three-wheelers in India remains strong, with manufactures now also offering electric versions (Courtesy Piaggio)

Fig. 7 India is the largest producer of tractors in the world (Courtesy Mahindra Group)

Passenger vehicles account for 13% of domestic sales volumes

This category was negatively impacted in FY 2019. Hatchback sales are the largest and most competitive; India is the largest producer in the world of cars less than 3600 mm in length (Segment A cars). Maruti Suzuki is the market leader (51% marketshare), followed by Hyundai Motors (16.1%), Mahindra & Mahindra (7.5%) and Tata Motors (6.8%). Honda Cars, Toyota Kirloskar and Ford India have smaller shares. It was a tough year for Renault, Nissan Motors and Volkswagen, who reported significant drops in sales in the country.

Luxury cars accounted for about 1.2% of the total domestic sales in FY 2018. Mercedes Benz has the largest share (38%), followed by BMW (26%). Others include Audi, Jaguar, Volvo and Porsche.

Commercial vehicles demonstrate robust growth

Sales of commercial vehicles increased by 17.5% in FY 2019 compared to the previous year, crossing the one million mark. Medium & Heavy Commercial Vehicles increased by 14.6% and Light Commercial Vehicles grew by 19.46% in the same period. Tata Motors is the dominant player in this segment and accounts for 44.2% of the market. Mahindra & Mahindra accounts for 22.6% and Ashok Leyland accounts for 16.8%. Other major players include Force Motors (7.8%) and Eicher Trucks & Buses (5.8%).

Three-wheelers maintain popularity

Sales of three-wheelers increased by 10.27% in FY 2019, when compared to the previous year. Passenger carrier sales registered a growth of 10.62% in this period, up from the previous year, and goods carriers grew by 8.75%.The market leader in this segment is Baja Auto, followed by Piaggio and Mahindra & Mahindra.

Exports of Indian-manufactured vehicles see steady growth

In FY 2019, the export of automobiles manufactured in India accounted for $18.2 billion and 15% of total automobile production in the country. Exports increased from the previous year in all segments except passenger vehicles.

Electrification of vehicles lags behind

The government of India has set a difficult target of 30% of all vehicles to be electric by 2030. Scooter manufacturers are at the forefront of this technology. Two-wheeler giants like Hero, TVS Motors and Honda have all launched their variants of electric scooters. There are also a number of start-ups who have entered the electric scooter market such as Ather Energy, Okinawa and Avon.

The electric three-wheeler segment is also gaining momentum. Mahindra and Lohia Auto both have electric three-wheelers. Piaggio has announced the launch of its electric three wheeler this year. However, the charging infrastructure, high prices and lack of subsidies are some of the issues that plague widespread adoption of electric vehicles.

The passenger vehicle segment has been lagging behind with Mahindra & Mahindra being the only manufacturer which offers fully electric vehicles (EVs) in the country.

"India is not ready for electric vehicles. I see hybrid and CNG vehicles more in public transport (buses)," stated Sharath Vijayraghavan of Sundaram Motors. It is expected that the transition from IC engines to electric vehicles in India will only really pick up speed by about 2025.

PM components in India's automotive sector

The total tonnage of PM parts manufactured in India in FY 2019 was approximately 38,000 tons. The domestic market for sintered components is growing at a CAGR of 22% and is expected to reach US $275 million in FY 2020. Approximately 20% of PM components manufactured in the country are exported.

The percentage of sintered parts in a vehicle still remains low when compared with global averages. While Japan and Europe are estimated to have 12 kg of sintered parts for every vehicle, India has a mere 4 kg per vehicle. This represents a huge opportunity and keeps PM part manufacturers optimistic.

Fig. 8 Applications for PM include components in synchroniser systems (Courtesy Sintercom India)

Increase in the use of PM parts to meet BS-VI emission standards

Indian PM part manufacturers are excited by opportunities arising from BS-VI standards, which require monitoring and control of tailpipe emissions of pollutants in running conditions. This translates to a significant increase (more than double) in the number of sensors being used, both before and after the catalytic converter. "The sensor holder is a part that is perfectly suited for manufacture through PM as opposed to machining," stated Jignesh Rawal of Sintercom India. BS-VI also requires reductions in noise, vibration and harshness (NVH). This could drive conversion from conventional forged to sintered components. Components such as mass balancers and anti-backlash gear drives are already produced by sintering.

The CAFE (Corporate Average Fuel Economy) norms, expected to come in 2022, will create more opportunities for PM manufacturers as lightweighting and fuel efficiency will become key points of discussion with OEMs.

Reduced popularity of diesel engines impacts Indian PM part manufacturers

In FY 2018, around 40% of engines produced in the country were diesel. However, this is expected to change significantly in the coming years. With the new BS VI standards coming into play from April 1, 2020,

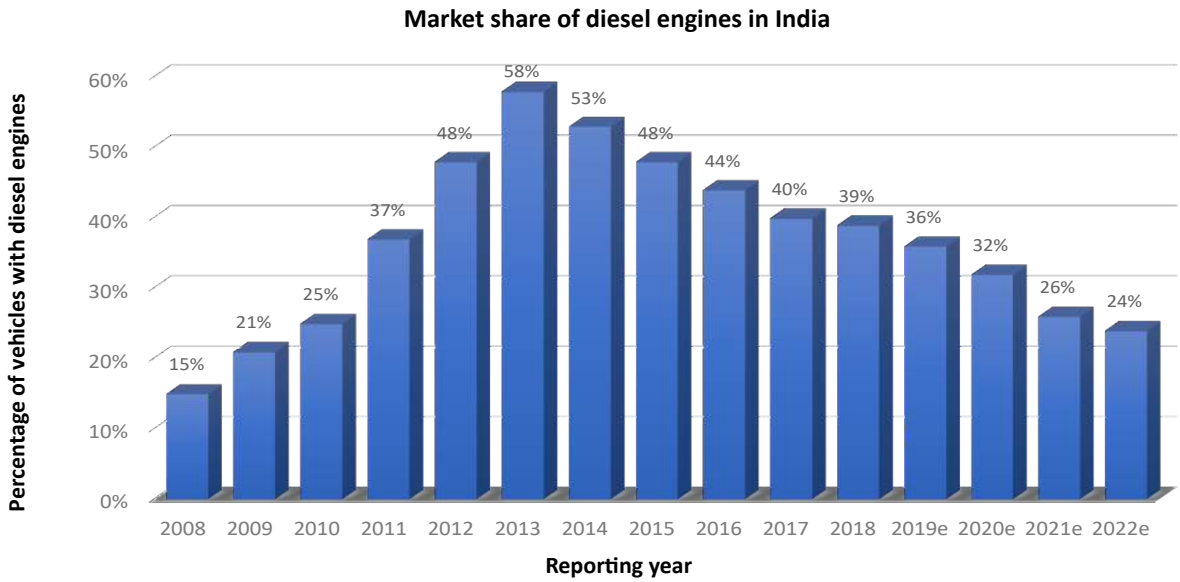

Fig. 9 Penetration of diesel engines in the Indian market (Courtesy ICRA Research)

Fig. 10 Powder Metallurgy is used to manufacture ABS sensor rings (Courtesy Sintercom India)

Vehicle category	Average local sourcing in top selling models (with > 80% market share)
Hatchbacks, compact sedans, SUVs	90–95%
Premium sedans	98–90%
Commercial vehicles	> 90%
2 wheelers	> 90%
Tractors	> 95%

Table 2 Tier 1 levels of locally sourced components across vehicle segments (Source: IHS, McKinsey)

many automobile manufacturers are revisiting their portfolio. OEMs have already stopped manufacturing small capacity diesel engines (less than 1.5 litre). Close to a dozen small diesel cars have been discontinued.

PM part manufacturers with product portfolios heavily skewed to diesel engine components (turbochargers for diesel engines, fuel injection systems, diesel filters, etc.) have been significantly affected. However, if OEMs continue to focus on high capacity diesel engines in newer models, the diesel PM component market is expected to recover.

Emerging opportunity for turbocharged compact petrol engines

In India, while over 90% of diesel engines are equipped with turbo chargers, very few petrol engines have them. There is, however, a shift to Turbocharged Gasoline Direct Injection (TGDI) from Multi Port Fuel Injection (MPFI) technology to boost power.

At the moment, there are only two manufacturers that offer three-cylinder engines, namely Ford & GM. However, companies such as Hyundai are looking to launch more fuel efficient turbocharged petrol engines for their compact hatchbacks and sedans.

Introduction of TGDI technology will also become mainstream in the compact SUV segment – a very popular category in the country. Turbochargers will be used by OEMs to reduce the overall weight of vehicles. These trends are good news for PM manufacturers, who expect to see a positive impact on production volumes.

Variable Valve Timing (VVT)

Currently, all major OEMs meet BS-IV standards without using VVT systems in their engines. This will not be possible when the country switches to BS-VI. Petrol engines are being equipped with single or dual VVT/ VCT to meet emission standards. VVT is expected to add 1 to 2.7 kg of PM components per vehicle by 2020, depending on which component manufacturer you talk to.

Local sourcing remains key

Due to the price sensitivity of the Indian market, automotive suppliers are working closely with part manufacturers to source high levels of locally produced components. To further encourage this localisation, the government recently introduced its FAME (Faster Adoption and Manufacturing of hybrid and Electric Vehicles) II Initiative. Under this scheme, incentives are available to makers of EVs where local sourcing exceeds 40% of the ex-factory price of electric buses and 50% for all other categories.

The increased need for local sourcing for the two-wheeler and commercial vehicle segments also offers a key opportunity for Indian PM part manufacturers.

High-density parts needed

To date, the Indian auto market has demanded PM parts with densities of around 7.2 g/cm^3 or less. However, a new wave of localisation is expected to increase the demand for higher density parts. Many part manufacturers have already invested in plant and machinery to manufacture components with densities of up to 7.4 g/cm^3, and one PM manufacturer reported that it has been achieving 7.6+ g/cm^3 densities as it caters to a large export market. However, the consensus is

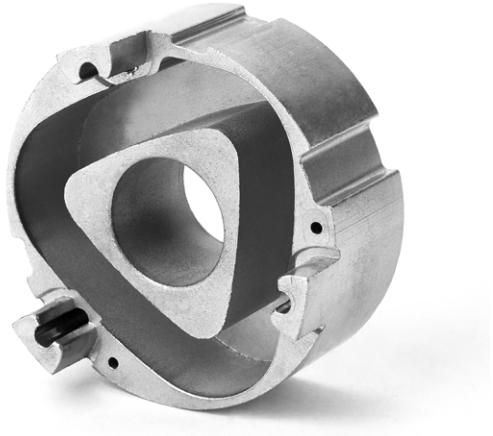

Fig. 11 This magnet housing, used in the assembly of electromagnetic clutches and brakes, won Best PM Product Award at APMA 2019 (Courtesy Speciality Sintered Products)

Fig.12 Couplings, such as this manufactured by Pricol India, are used in agriculture and industrial water pumps to couple motor and pump assemblies (Courtesy Pricol India)

that PM parts with densities greater than 7.4 g/cm^3 are mostly imported at the moment, and this market offers a good opportunity for Indian PM part manufacturers.

Growing demand for automatic transmissions

The use of automatic transmissions (AT) in India today represents a small market, but has potential for growth. The high cost, lower fuel efficiency and India's poor road conditions, are just some of the reasons why AT vehicles have not gained significant popularity in the country. In 2015, the market share of automatics was reported to be less than 5%.

However, some auto analysts believe this will change, and that ATs could even reach a market share of 40% in the next four years. Reinforcing this potential, Hyundai Motors recently reported a significant increase in sales of its automatic transmission vehicles, stating that ATs now account for 10% of its total sales, compared to just 4% in 2015.

Many components in automatic transmissions, such as fluid couplings, are currently being imported into the country, but Indian PM part manufacturers believe this could easily change. The growing popularity of automatic vehicles could lead to new product lines being manufactured by PM companies in the country.

Electrification of vehicles

Nine of the ten most polluted cities in the world are in India, and the Indian government is betting heavily on electric vehicles to counteract this. It has developed a framework to expedite the purchase of electric vehicles for public transport and official use in eleven large cities. There is also a growing consumer market for electric two- and three-wheelers, as well as light commercial vehicles.

Many PM part manufacturers have expanded their product portfolio to cater to the electric vehicle segment. Niranjan Nalkhade of Speciality Sintered Products says that his company has added three EV parts to its portfolio and, in addition, its R&D team is working on creating entire solutions for electric vehicles, which comprise multiple sintered parts. Other major PM part manufacturers are also investing in R&D to introduce new lines of PM components for EVs, such as rare earth magnets.

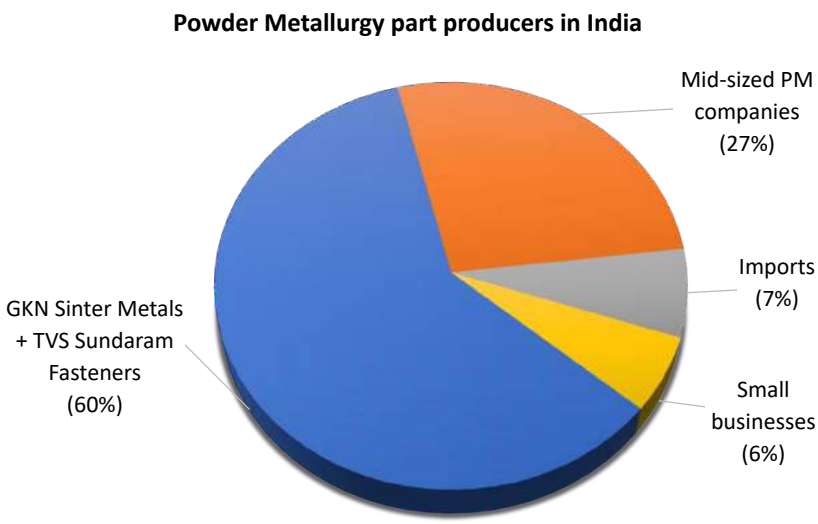

Fig. 13 The production of PM components in India is dominated by GKN Sinter Metals and TVS Sundaram Fasteners (Courtesy Powder Metallurgy Association of India)

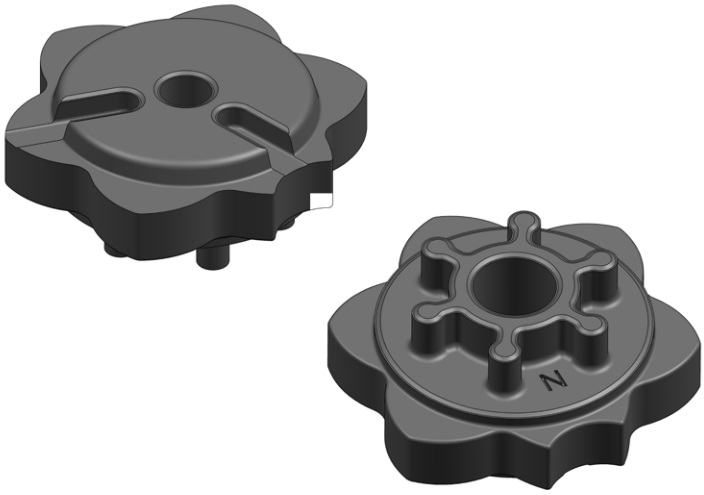

Fig. 14 Plate, gear shift cam (Star Index) manufactured by GKN Sinter Metal, used in transmission gears (Courtesy GKN Sinter Metal)

Major PM part producers in India

The two largest PM part manufacturers in India are GKN Sinter Metals and TVS Sundaram Fasteners, which together account for an estimated 60% of the market. Other major manufacturers include Federal Mogul, Hitachi Chemical, Motherson Sintermetal, Nippon Piston Ring, Porite, Pricol, Singhal Sintered, Sintercom India, Speciality Sintered Products, Star Sintered and Tenneco. These companies account for about 27% of the market. Imported PM parts (mainly from Japan and the USA) account for another 7% of the market. The small business sector (including bush manufacturers) accounts for around 6% of the market (Fig. 13).

Fig. 15 Camshaft left hand gear manufactured by Sintercom India (Courtesy Sintercom India)

Federal Mogul

Now part of Tenneco, Federal Mogul entered India's PM market with the acquisition of the Brico + Goetze India joint venture. The company manufactures sintered components from its facility in Bhiwadi, Rajasthan, and has the capacity to manufacture 12 million valve seats and 13 million valve guides.

GKN Sinter Metals

GKN Sinter Metals is the single largest PM part manufacturer in the country. The company originally entered India through a joint venture with Mahindra Sintered Products, a company it later acquired in 2002. GKN Sinter Metals has two manufacturing plants in India, one near Pune and another in Ahmednagar. The company manufactures sintered parts for engine, transmission, shock absorber, G-Rotors, VVT & VCT Parts. Its total production capacity is estimated to be about 12,000 tonnes per year.

Recent changes in GKN management policy are reported to have seen a rationalisation of its product portfolio. This is said to have created a number of opportunities for other PM part makers, especially those located in the Pune region.

Hitachi Chemical

Hitachi Chemical began its operations in India in 2011, with a capital investment of USD 17 million, and has been expanding its facilities at regular intervals ever since. The company caters predominantly to Japanese vehicle manufacturers in India. It manufactures structural parts such as gears and bearing caps, as well as valve guides.

Motherson Sintermetal

As part of the US $10.5 billion Samvardhana Motherson Group, Motherson Sintermetal was formed when it acquired Sintermetal in

Spain, in 2012. Since then, it has established a greenfield manufacturing facility in Puducherry to manufacture parts for suspension and powertrain applications. The plant was set up with a production capacity of 5000 tonnes per year, and the company primarily caters to export markets in Europe.

Nippon Piston Ring
Japan's Nippon Piston Ring has a PM manufacturing facility near Bangalore. Components produced here are thought to include valve seats, although exactly what else is manufactured, and at what quantity, is unknown.

Porite Group
Porite entered India in 2015 and earmarked a significant investment of US $28.6 million for its expansion in the country. Since then, the company has been growing at a steady rate, investing in plant and machinery, and is expected to become a dominant player in the Indian PM market.

Pricol
Pricol's PM sales account for around 5% of its total turnover. The company's PM manufacturing facility is in Coimbatore, where it manufactures PM gears, hubs, G-rotors, valve plates, oilless bearings, gear shifter parts, pistons and slack adjuster pads. The company reported a production capacity of 1000 tonnes per year for its PM plant. Of this, 50% is utilised for the production of components for its pumps division. Over 20% of the company's PM production is for export markets.

Singhal Sintered
Operations began in 2007 with the establishment of a PM manufacturing plant near New Delhi. Singhal Sintered manufactures PM components for the automotive and non-automotive industries. The automotive industry accounts for 50% of produced parts. The company has a reported capacity of 900 tonnes per year for PM parts.

Fig. 16 Exhaust side gear manufactured by Sintercom India (Courtesy Sintercom India)

Fig. 17 Bearing caps are manufactured by Sintercom India (Courtesy Sintercom India)

Sintercom India
Sintercom India is a joint venture with Austria's Miba AG. The company began commercial production in June 2009 and is today publicly traded on the Indian stock exchange. Sintercom's engine product portfolio includes engine drive gears, chain sprockets, belt pulleys, cam to cam gears and engine shaft bearing caps for engines ranging from 800 cc to 2000 cc.

Sintercom manufactures a broad range of components for transmission hubs from 60 N/M to 400 N/M for both petrol and diesel vehicles. It also manufactures stainless steel sintered parts for use in exhaust manifolds. The company's manufacturing plant near Pune has a reported production capacity of 3600 tonnes per year, which it will increase to 4980 tonnes per year by FY 2021. Less than 5% of the company's revenue comes from export markets.

Speciality Sintered Products
Founded in 2001, Speciality Sintered Products has shown remarkable growth in the last five years. The company has two manufacturing

facilities near Pune and a third large facility is being planned. It has an in-house design centre and tool room.

Speciality Sintered Products reported a production capacity of 8,000 tonnes per year and is in the process of expanding this to 10,000 tonnes per year. Around 40% of its revenue comes from export markets.

Star Sintered

Founded in 1992, Star Sintered has two PM manufacturing facilities near New Delhi, with a reported production capacity of 2000 tonnes per year. Around 20% of the company's revenue comes from auto components, with the rest coming largely from the white goods sector.

Tenneco India

Tenneco India has one PM part manufacturing plant in the country, from which it manufactures shock absorber parts.

TVS Sundaram Fasteners

TVS Sundaram Fasteners is a powder to parts vertically integrated manufacturer. The company's PM division accounts for about 9% of the company's total revenue. The company caters to both the OEM and aftermarket sectors in India as well as globally, reporting around 30% exports.

PM parts are manufactured out of three plants located in Hosur, Madurai, and Uttarkhand, with total production capacity estimated to be around 10,000 tonnes per year. The company's iron powder (pre-alloyed and pure iron) plant near Hyderabad is under expansion, and is expected to have a production capacity of 15,000 tonnes per year.

India's non-automotive PM component market

A total of 8% of PM parts manufactured in India are reported to be for consumer goods (household appliances, air conditioners, etc). Many PM part manufacturers catering to the auto industry also have a small presence in the non-automotive PM component industry. As mentioned, around 10% of TVS Sundaram Fasteners' revenues, and some 20% of GKN Sinter Metals' production come from non-automotive PM components. Star Sintered is largely focused on the non-automotive sector, with 80% of their production catering to this market.

In addition to these companies, there are PM part manufacturers who exclusively manufacture parts for the non-automotive sector. These include sintered bearings, bronze filters and PM bushes. There are over twenty small companies that compete in this segment.

The Indian diamond tool industry is also thriving. Major suppliers of diamond tools for cutting stone include StaySharp, Optima, SD Tools and Diabu, who own about 50% of the market. The concrete cutting sector is dominated by players like Hilti and Wendt.

The Indian tungsten carbide market is amongst the largest in Asia, right up there with South Korea and China. The highest users of Tungsten Carbide in the country are manufacturers of cutting tools, wear parts (die inserts) and mining tools. Automobile companies are the largest users of cutting tools (60% market share), followed by aerospace, oil & gas, power generation and general engineering companies. Aerospace is the fastest growing segment of users due to the increased number of aerospace part manufacturers setting up facilities in the country. Major manufacturers of cutting tools include Kennametal, SECO Tools, Iscar and Sandvik Coromant, which is the market leader with about 15% market share.

Fig. 18 Sandvik Coromant works closely with its customers in India to provide a wide range of solutions (Courtesy Sandvik Coromant)

Additive Manufacturing in India

Aerospace

The Additive Manufacturing industry in India is still in its nascent stages. However, the industry expects to see significant growth within the next five years, driven mainly by the country's aerospace industry. Most aerospace companies report using AM in the alpha stage (pre-production). However, there have been some high profile case studies of AM parts being used successfully by the Indian aeronautics and space agencies.

Hindustan Aeronautics Limited has used additively manufactured components in the Hindustan Turbofan Engine-25 (HTFE25).37. It has also used AM to develop a fuel system elbow for the Su-MKI aircraft, now certified and in preparation to begin serial production of the part. The Indian Space Research Organisation (ISRO) used Additive Manufacturing to produce a component of its satellite communication systems.

Fig. 19 High pressure compressor stator, manufactured by Wipro 3D in Ti6Al4V, is used to convert kinetic energy into static pressure through diffusion and redirects the flow direction of fuel (Courtesy Wipro 3D)

Medical/dental

AM parts for medical/dental applications are another fast growing segment and here, in addition to the prototyping and pre-production stage, AM is being used for the manufacture of patient-specific implants. A case has also been established for the Additive Manufacturing of titanium implants, as the cost of imported implants is high. IIT Mumbai, CECRI and CSIO are a few organisations currently involved in the production of patient-specific implants.

Automotive

The Indian automobile industry also has the potential to drive growth of AM, especially with the recent localisation requirement by the government for electric vehicles (40–50%, depending on vehicle type). For the moment, however, AM is being used primarily for prototyping (proof of concepts). A few auto part manufacturers that have invested in metal AM systems include Bajaj Auto, Hero Motors, Wabtech and Honeywell.

Installed systems

There are an estimated fifty metal AM systems installed in the country, with EOS taking the lion's share of the market at 65%, followed by Renishaw at about 18–20%. Other players include SLM Solutions and the GE-owned Concept Laser. New entrants in the market include Desktop Metal and The ExOne group.

Service providers

A large percentage of Indian AM part producers are service providers such as Wipro 3D, Objectify, Intech DMLS, 3dpd, Rapid DMLS, Think3D, IGTR-Aurangabad, CTTC-Bhuwaneshwar, Nashik Engineering Cluster and BharatForge. In addition to these, there are government run research labs that also fall in this category. These companies differ vastly in their abilities and the value they provide. Most work on a pure outsourcing model where they additively manufacture a component based on a design provided by a customer. They may optimise the design for the AM process, but rarely make further design changes. A few companies, like Wipro 3D and Intech DMLS, are able to offer value engineering services – developing, testing and building a prototype or component for specific applications.

Materials

Around 5 tons of AM powders were imported into the country in FY 2019, representing a 5% increase from the previous year. Most AM part manufacturers and solution providers work with a range of materials including aluminium (AlSi10Mg), titanium alloys (Ti64, TI64 ELI & TiCP), nickel alloys (Inconel 718, 625, HX), SS alloys (17-4 PH, PH1, 316L), maraging steels (300grade), and cobalt chrome (MP1-F75, SP2- CE certified dental alloy free of Ni, Be & Cd).

MIM parts manufacturers in India

The MIM manufacturers in India cater largely to export markets, with about 95% of MIM parts manufactured destined for global markets. The small domestic market is mainly in the defence, automotive & textile industries, with a smaller contribution from medical devices.

Indo-MIM is the largest MIM manufacturer in the world and dominates the Indian market, producing 98% of all MIM components in the country. The company has two manufacturing plants in India and one in the United States.

Indo-MIM's in-house tool room can produce over sixty moulds per month, with each tool producing between one to thirty-two parts per one shot. The company has been growing at 30% CAGR for the last five years.

Fig. 20 Stopper slide, manufactured by Indo-MIM, acts as a slide stopper in 9 mm pistols. This part won the Best MIM Product Award at APMA 2019. Material used: Hardened and tempered steel MIM 430 (Courtesy APMA)

Indo-MIM shipped an estimated 400 million parts in FY 2019, and around 92% of parts produced at are exported to the US, Europe and the Far East.

Automobile and fire arms parts constitute 67% of the company's revenues. Another major chunk is generated by parts for consumer products. Parts for medical equipment form a small portion of the company's revenues but are the fastest growing.

Other MIM manufacturers include Bangalore MIM Components, JJ Orthodontics, Meetu-Raj industries, VDR Metals and Inmet Technology (a new division of the mammoth Bharat Forge).

Traditional press & sinter PM parts have had a negligible presence in the Indian defence and aerospace industries so far. The three large manufacturers of small arms in the country have begun using metal injection moulded parts, and the aerospace industry has begun experimenting with additively manufactured components. The overall size of the component market in India for these two sectors is estimated by McKinsey at USD $8 billion and $11 billion respectively.

India's metal powder producers

India has a number of mid-sized metal powder production facilities. In 2018, an estimated 44,900 tons of metal powder was produced in India for PM applications (Table 3). Of this, iron-based powders account for 80% of total powder production in the country. Whilst iron-based powders are used primarily in the automobile sector (80%), copper based powders are used in appliances (60%), friction elements (18%) and diamond tools (15%).

Höganäs India remains the largest source of Fe metal powders in the country and accounts for about 65% of the market. The company has a plant in Ahmednagar that caters to domestic markets and has a production capacity of 35,000 tonnes per year. The company manufactures both pure iron powders and premixed alloys. Around 70% of powders sold by the company are to automotive component manufacturers. It imports about 15% of the metal powders it sells in India from its sister companies across the world.

Estimated tonnage of metal powder shipments for all PM applications in India										
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Iron-base	26,500	31,200	35,400	37,000	30,000	37,000	30,500	30,000	32,050	36,000
Copper-base	12,500	13,700	14,500	14,500	13,700	12,100	10,000	6,000	7,250	8,900
Total	39,000	44,900	49,900	51,500	43,700	49,100	40,500	36,000	39,300	44,900

Table 3 Powder Production in India (Source: Powder Metallurgy Association of India)

With growth slowing down in the European PM markets and plateauing in the North American markets, metal powder manufacturers are looking to Asia to fuel their growth. While China remains their largest market at present, India has been identified as a growth market, and many large powder manufacturers are looking to either establish manufacturing facilities or expand their existing footprint in the country.

Rio Tinto and Pometon have a significant presence in India. They do not manufacture powders in the country, but do have a large sales presence. TVS Sundaram Fasteners manufactures powders that it uses largely for its own production. The company manufactures water atomised iron and pre-alloyed powders of a wide density range.

Smaller Fe-based powder manufacturers account for about 15% of the market. SLM and Innomet Powders are two such companies. SLM manufactures sponge iron and atomised iron powders. Innomet specialises in manufacturing customised grades of metal alloy powders containing iron, copper, tin, zinc and cobalt.

Other major manufacturers of copper powders in India include PP Patel and Sarda Industrial Enterprises. GKN Sinter Metals manufactures copper powder for its own consumption out of its plant in Ahmednagar (80–100 tonnes per year).

MIM and AM powders

Indo-MIM commissioned a powder manufacturing unit in 2017, where it manufactures MIM powders primarily for its own consumption. Its atomisation facility consists of vacuum induction melting with inert gas atomisation. The company recently began manufacturing AM powders in stainless steel, Co-Cr and Inconel grades.

Midhani, a government owned manufacturer of superalloys, plans to begin manufacturing titanium and nickel superalloy materials through gas atomisation in 2020.

Outlook for the Indian PM community

The uncertainty in domestic demand from the automotive sector has had a mixed impact on the country's PM part manufacturers. Around 75% are expecting increased production in the quarter April–June 2019, and expect to see continued growth in the following quarter as well. They did not face any shrinking in their margins and do not expect to in the near term.

The remaining 25% of PM part manufacturers who reported reductions in production volumes typically have product portfolios that are heavily skewed towards diesel engine components, and export contributions of less than 10%. These companies, however, are all investing in plant and machinery in the coming quarter (July –September 2019) that will help them alter their product mix and open new markets. The after-market will continue to offer a steady revenue stream for diesel engine components, but it is insufficient to sustain the larger PM companies.

Many PM parts manufacturers believe that the speed of recovery of the automobile segment is dependent on the fallout from the coming government elections and any subsequent changes to interest rates in the country. Predictions of growth of the domestic PM market in the next full year have been conservative. Almost all PM part manufacturers believe that growth will be between 4–6% in the coming year. Many companies plan to supplement domestic growth by trying to increase their share of exports. Some 40% of Indian PM part manufacturers expect exports to grow moderately by 5–10%, while another 10% expect it will grow even faster.

The overall sentiment seems to be positive and almost all PM part manufacturers are making investments in plant and machinery in the coming quarter (July–September 2019). Even with the recent drop in growth rate for the automobile sector, there is a great deal of optimism in the Indian automotive industry. The next six months are expected to be tough on the industry, as it battles with fluctuating demand and new emission standards, but according to McKinsey, India's consuming class is expected to expand to 89 million households by 2024. The pace of infrastructure development is also encouraging, with an average of 40 km of road added per day.

As OEMs demand more R&D investment from automotive parts manufacturers, there can be inconsistency in component volumes. Although overall auto production volumes in India are expected to remain the same, variants and new platforms are increasing. In some cases, this can lead to unprofitable PM applications. To retain margins, a number of larger PM part manufacturers are moving to more complex and higher density parts. This transition may open up opportunities for smaller PM firms to form partnerships with larger players to supply the lower volume components required by OEMs.

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Sources of data

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[2] Investment data, including infrastructure data etc., from India Brand Equity Foundation (www.ibef.org)
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Award winning automotive applications showcase potential of PM

There are many applications in the automotive sector where the use of Powder Metallurgy offers numerous advantages over other metal working processes. From reduced manufacturing costs to improved properties and unique material characteristics, Powder Metallurgy can be used to produce a wide range of automotive components. Over recent years, many of these parts have been the recipient of industry awards, and in this article, Dr David Whittaker highlights a number of the winning parts to showcase the potential for PM in the automotive sector.

PM technology's strength lies in the manufacture of geometrically complex components in high production volumes. As the automotive industry is the leading consumer of a wide range of such components, it is unsurprising that this sector has historically emerged as a dominant driver for the continued growth of PM applications.

Globally, the proportion of Powder Metallurgy components destined for automotive applications is generally understood to be around 80% of total press and sinter PM production. The established automotive PM applications are widely spread around the vehicle, but, as seen in Fig. 1, engine and transmission components have emerged as dominant sources of demand. The actual quantity and total weight of PM components found in each vehicle does, however,

Typical applications for Powder Metallurgy components

Shock absorber
valves
pistons
rod guides

Power steering
pump rotor
drive pulley
yoke
cam rings

Door/roof
hinges
bushings

Braking system
disc brake pads
ABS sensor rings
friction materials
bushings
pistons

Camshaft
assembly lobes
bearing caps
pulleys
sprockets

Turbocharger
gears
vanes
bearings
rings
bushings

Parking
gear
sensor

HVAC
bearings
plates
hubs

Valve components
guides
seat inserts

Clutch components
hub
backing plate

Crankshaft
bearing caps
pulley
sensor
sprockets

Oil pumps
gears
gerotors
sprockets

Fuel system
pumps
gears
gerotors
sprockets

Planetary carrier
frame
gears
spacers

VVT systems
cam lobes
sprockets
rotor

Transmission
sensor rings
end caps
bearings
differential gear
hubs
stators
one-way clutch
sun gear
sprockets
thrust washers

Steering column
drive pulley
cams
gears
bushings

Engine
connecting rods
armatures
heat sinks
lever arms
lock plates
rocker arm
spark plugs
sprockets
pulleys
stator
thrust plate
sensor rings

Synchroniser
housing
hub
rings

Water pump
flange
impellers
pulley

Fig. 1 A selection of automotive components that can be produced by PM

Fig. 2 Powder Forged connecting rods, such as this one produced by Metaldyne (now AAM), demonstrate the use of powder metal technology in critical and demanding applications

vary considerably depending on auto manufacturer and world region. Typically, in North America around 13 kg of PM parts are found in the average sedan, rising to 20 kg in a mid-range crossover and around 34 kg in a large SUV. In Asia the figure is estimated to be near 9 kg for the average car, with Europe slightly lower at 8 kg. It should be noted that vehicles in North America do tend to be larger than those models found in Europe or Asia, but it is clear that there is still potential to expand the market for PM in many world regions.

Fig. 3 Duplex cam sprocket manufactured by NetShape Technologies (Courtesy MPIF)

Award winning parts

The Powder Metallurgy industry's trade associations play an important role in promoting the use and further adoption of PM technology. From cost savings and environmental impact, to novel applications and unique properties, the Powder Metallurgy process has much to offer the industries of today as well as the technologies of tomorrow.

The automotive industry is one such industry and is certainly not overlooked when it comes to recognition through industry awards. Many of the trade associations, such as the Metal Powder Industries Federation (MPIF), Japan Powder Metallurgy Association (JPMA) and European Powder Metallurgy Association (EPMA), regularly include automotive components in their award presentations.

This article provides a review of award-winning PM structural part applications as presented in recent years by regional trade associations. Many of the awards demonstrate the continuing dominance of PM engine and transmission components for internal combustion engines.

However, it should be recognised that the trend towards vehicle drive electrification may affect this balance in the medium term and, therefore, some commentary is provided on potential PM functional part applications in electric vehicles, driven by this development trend and highlighted in a recent seminar organised by the EPMA.

Automotive engine parts

Over the years, many automotive engine components have been recognised for their use of Powder Metallurgy in meeting the increasing demands of the automotive industry. Components such as the Powder Forged connecting rod, shown in Fig. 2, have been pivotal in the acceptance of powder metal parts in critical applications. Recent engine part awards have included PM sprockets and valve seats, as well as main bearing cap components.

Sprockets

A 2017 MPIF Award of Distinction was presented to NetShape Technologies, Floyds Knobs, Indiana, USA, for a copper steel duplex cam sprocket made for US Tsubaki Automotive, LLC (Fig. 3). This part goes into the 4.4 litre Big Lion diesel engine in Land Rover's flagship vehicle. An original PM design, the part offers an estimated 30% savings over the cost of machining it from wrought material.

In 2016 the MPIF made an Award of Distinction to Cloyes Gear & Products, Inc., Division of HHI/MPG, Subiaco, Arkansas, USA, for three PM steel sprockets made for Iwis Engine Systems LP (Fig. 4). The components, a rubberised crankshaft sprocket and two rubberised oil pump sprockets, are used in a General Motors Generation II High-Feature V-6 Engine, currently installed in the Cadillac CT6 and ATS, GMC Acadia and Chevrolet Camaro. The patented rubber design used on the crankshaft sprocket provides improved noise, vibration and harsh-

Fig. 4 Cloyes Gear & Products, Inc. produced these rubberised engine sprockets for use in General Motors' Generation II V-6 Engine (Courtesy MPIF)

Fig. 5 Hitachi Chemicals Co. Ltd use die wall lubrication in the compaction stage to achieve high density (Courtesy JPMA)

Fig. 6 A matrix toughened material, developed by Fine Sinter Co. Ltd and Toyota Motor Corporation, is used in these valve seats (Courtesy JPMA)

Fig. 7 These valve seats from Fine Sinter Co. Ltd offer cost savings by minimising the amount of wear resistant material used (Courtesy JPMA)

ness characteristics that exceed the engine manufacturer's demands. Fabrication via PM provides an estimated 30% saving over parts machined from steel bar or forgings.

The JPMA presented an award to Hitachi Chemicals Co. Ltd in 2015 for a high density PM steel sprocket (Fig. 5) which was produced using die wall lubrication in compaction. The developed technology provides products with sintered densities of 7.5 g/cm^3 and higher shape complexity, whilst eliminating the compacting speed rate-determining step in the die lubricant coating process. In lubricant coating using the conventional spray method, reduction of compacting speed and the ability to respond to the incorporation of lightening holes were significant challenges. To solve these problems, Hitachi Chemicals developed a new die wall lubrication compacting method in which coating of the lubricant is completed in the die operation cycle from ejection after the compacting process to return for filling, thereby achieving the same compacting speed as in conventional compacting. In addition, in the spray method, the die is generally heated for the purposes of increasing the adhesion between the die wall surface and a solid lubricant, or drying the solution of a solid-liquid mixed lubricant. The newly developed method makes it possible to obtain the desired high-density product properties in PM sprockets without heating the die, and has resulted in higher productivity in comparison with the tooth flank form rolling method and the conventional warm die wall lubrication compacting method.

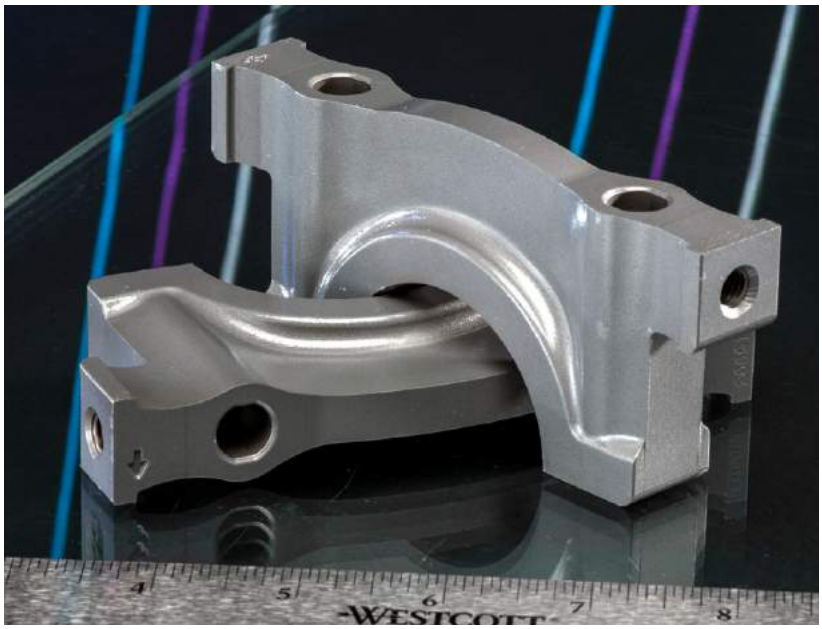

Fig. 8 Main bearing caps, made by GKN Powder Metallurgy, are used in the turbocharged four-cylinder engine in the Alfa Romeo Giulia (Courtesy MPIF)

Valve seats

In 2016 and 2015, the JPMA made awards for two valve seat applications that were both enabled by novel material developments. Fine Sinter Co. Ltd and Toyota Motor Corporation received a prize for the development of a valve seat material (Fig. 6) with improved anti-adhesive wear properties by distributing fine hard particles in the matrix. Valve seats for automobile engines are required to have high anti-wear properties and hard

particles are added and distributed in the matrix to obtain a 'cobblestone effect' to achieve this requirement.

Additionally, the combustion heat from engine operation produces oxides, whose major components are Fe, on the surface of the valve seat. These oxides also improve the anti-adhesive wear with the valve and they create a synergetic effect with the conventional hard particles in the matrix material. However, recent improvements in engine efficiency have created more difficult conditions for Fe oxide formation, and other means are needed to strengthen the valve seat against adhesive wear. One option is to increase hard particle content. However, this option could cause degradations in compactability, machinability and machined surface roughness of the valve seat material. The development by Fine Sinter uses hard particles with an increased austenite diffusion phase compared to conventional materials. These hard particles improve adhesive properties with the matrix, solve the concerns over surface roughness after machining by detachment of hard particles, and provide a 35% cost reduction compared with the conventional material.

A year earlier, Fine Sinter Co. Ltd received an award for a modified design concept for valve seats (Fig. 7). This valve seat provided an improvement in cost effectiveness by minimising the amount of highly wear resistant material used through the reviewing of the layer boundary angle. The valve seat has expensive, highly wear-resistant material (seat material) on the seat surface where the valve impacts, because impacting the valve wears the seat. Therefore, in order to improve cost effectiveness, the developed valve seat has two layers with a cheaper material (base material) on the cylinder head side because wear resistance is not required on this part of the component. This development improved the layer boundary angle to 45°, which is parallel to the valve-impacting surface angle. The amount of expensive material in the valve seat is therefore reduced.

Fig. 9 AAM Powertrain manufactures this sprocket for a VVT sub-system in GM's three and four cylinder engines (Courtesy MPIF)

It was also found that the use of highly wear resistant material as the seat material reduces heat conductivity because of the hard layer, which includes carbide. Therefore, decreasing the proportion of highly wear resistant material in the valve seat improves total heat conductivity and provides a heat reduction effect – an essential requirement in modern higher efficiency engines which operate at higher temperatures.

Main bearing caps

In 2018, an MPIF Grand Prize was presented to GKN Powder Metallurgy for a copper steel PM main bearing cap made for FCA US LLC (Fig. 8). The part is used in the 2.0 l all-aluminium turbocharged four-cylinder engine in the Alfa Romeo Giulia.

Although PM main bearing caps have dominated engine design for more than two decades, the design of this part is said to break new ground. Requirements for engine weight reduction drove the designers to an 'upside down' sculpted version. This novel design delivers a part that is said to be around 23% lighter than previous versions and offers 10% better fatigue strength.

Powder Metallurgy parts used in engine ancillary sub-systems

Recent developments in this category have been dominated by applications in Variable Valve Timing (VVT) and Variable Cam Timing (VCT) sub-systems, with components for turbochargers also featuring.

VVT sprocket

In 2018, an MPIF Award of Distinction went to AAM Powertrain, Detroit, Michigan, USA, for a pre-alloyed steel VVT sprocket (Fig. 9), which is used in overhead camshaft GM inline three- and four-cylinder engines in cars such as the Buick Encore and Envision and the Chevrolet Cruze and Malibu, among others.

The six pitch inverted tooth was specifically selected to address concerns with NVH (noise, vibration and harshness) as well as with durability and rotating mass. The part demands very consistent powder filling to achieve the extremely tight tolerances required.

Fig. 10 Complex pulley with high-accuracy non-circular gear teeth for a VCT sub-system manufactured by Sumitomo Electric Industries (Courtesy JPMA)

VCT pulley

In 2017, Sumitomo Electric Industries Ltd. received a JPMA prize for a pulley with non-circular – in this case, triangular – gear teeth, which is a part of a VCT system in a 3-cylinder engine (Fig. 10). The part was developed to achieve a reduction in vibration. To deliver the required improvements in function, high dimensional accuracy, especially to the extremely tight geometrical tolerances of the non-circular external teeth (the outer diameter, the whole circumference, profile and squareness), was needed. Uneven density after compaction and deformation due to sintering were identified as factors affecting external tooth accuracy. These were resolved by optimising the sizing conditions. In relation to the shape requirements for subsequent assembly, the female screw holes and four oil passing slots had to be formed using side cores in compacting.

VVT rotors

Sumitomo Electric Industries Ltd. had earlier been awarded a JPMA Process Development Prize, in 2016, for a manufacturing line used to produce Variable Valve Timing (VVT) parts (Fig. 11). Although not an award for a component, this prize is of interest as it highlights some of the unique manufacturing capabilities of PM. The set-up provides the simultaneous green machining of holes and grooves, and the attachment of a two-dimensional barcode to ensure high quality. Also, the line provides successful touchless manufacturing of parts, from compacting to sizing.

VVT systems control the timing of valve opening and closing by changing the phase of the rotor with oil pressure, enhancing power output and reducing fuel consumption. VVT parts are rapidly developing, with, for example, the rotor becoming unified with oil control valve, and the demand for holes and grooves, which cannot be moulded in compaction, has increased. Therefore, the increase in machining cost, including deburring after sintering, has become a problem area.

To solve this problem, Sumitomo Electric has applied green machining, enabling rapid machining without burr formation, and has sought to decrease cost. The company developed a multi-machining technology for holes and grooves in one operation and succeeded in building a consistent higher productivity line. This line can prevent the risk of cracks and chips, due to offline handling, by in-lining the green machining equipment, linking it with the compaction process, and machining with a touchless and stockless concept. In addition, traceability has been enhanced by attaching a two-dimensional barcode by laser beam to each product before sintering, enabling the tracing of product quality and manufacturing information, and the risk of cracks and chips in green machining has been decreased.

VVT control plate

Sumitomo Electric Industries Ltd received a further JPMA prize in 2016 for the development of a laser quenched multistage, complicated shape side plate, adapted to the high torque phase control system of a VVT rotor (Fig. 12). High torque was necessary for the controlling phase of the rotor and, in the conventional model, several springs were attached to the rotor itself to control phase. However, in the developed model, a system which controls phase from outside the unit was adopted. Therefore, a large spring, which slides with the side plate, was attached and the previously used aluminium casting could be replaced with a sintered iron part. Regarding the product shape, the side plate was difficult to compact, due to the many tangs required to fix the spring to the surface and the deep oil groove on the opposite surface. In order to maximise the benefits of using PM, multistage compaction was successfully designed in at an early stage. Furthermore, the side surface of each tang demanded good wear resistance, due to the sliding of the spring. Although the surface was uneven, laser quenching could be applied to achieve the required hardness without decreasing accuracy by using a simple jig and program, instead of induction hardening with a complicated coil design.

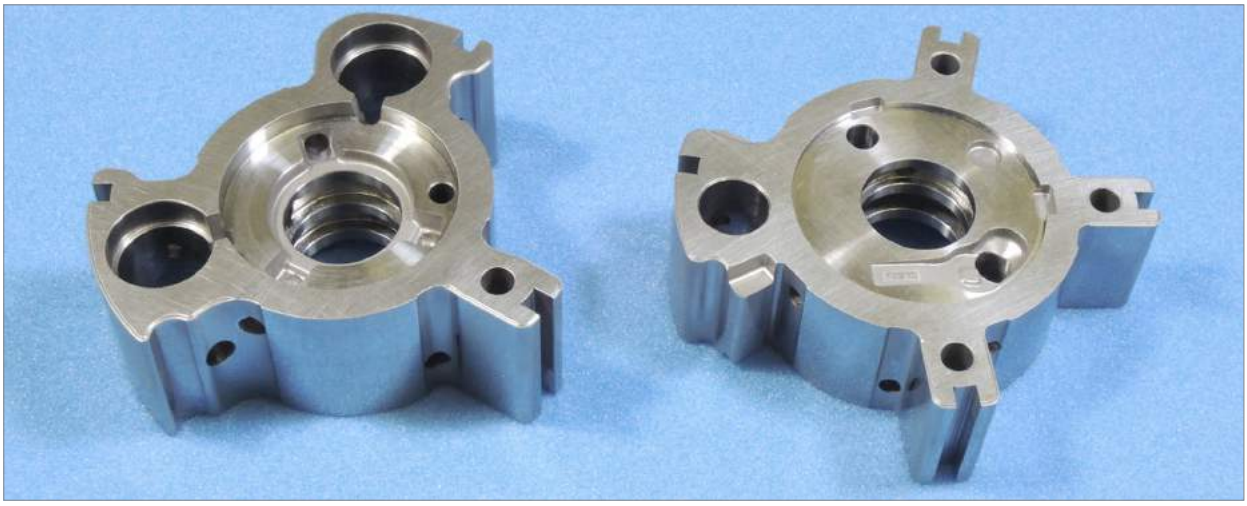

Fig. 11 Sumitomo Electric Industries Ltd's VVT parts manufacturing-line allows the simultaneous green machining of holes and grooves (Courtesy JPMA)

Turbocharger valve bushings

Finally in this application category, Hitachi Chemical Co. Ltd. received a JPMA award in 2015 for the development of an austenitic sintered material with excellent heat and wear resistance and for use in the valve bushing in a turbocharger (Fig. 13). Turbochargers have conventionally been used in diesel engine vehicles, but their usage has now also been expanding into gasoline engines. Since the exhaust gas temperatures in gasoline engines are higher than those in diesel engines, austenitic materials tend to be used as turbocharger parts because of their superior heat resistance. To respond to these requirements, a new austenitic sintered material with higher wear resistance has been developed.

The technical success of this material was said to depend on dispersion of carbides in the matrix, introduced to improve wear resistance. Increasing the amount of carbide through an increase in the carbon content does improve wear resistance but also leads to the deterioration of oxidation resistance because of the lower Cr content in the matrix. However, it was found that using finer carbide could improve wear resistance without decreasing oxidation resistance. The developed material has proved to be successful in penetrating the market for turbocharger bushings for gasoline engines.

Fig. 12 This complex side plate is manufactured by Sumitomo Electric Industries for a high torque control system of a VVT rotor (Courtesy JPMA)

Fig. 13 Hitachi Chemical Co produced these valve bushings for turbochargers (Courtesy JPMA)

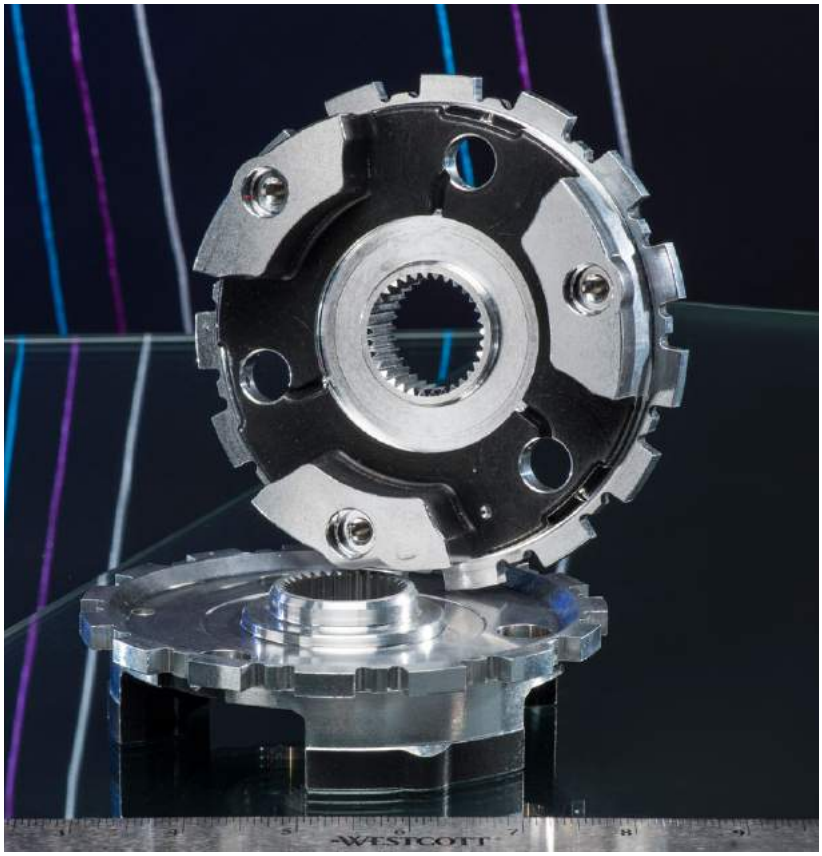

Fig. 14 GKN Powder Metallurgy manufactures this aluminium planetary reaction carrier for GM's 9T50 nine-speed transmission (Courtesy MPIF)

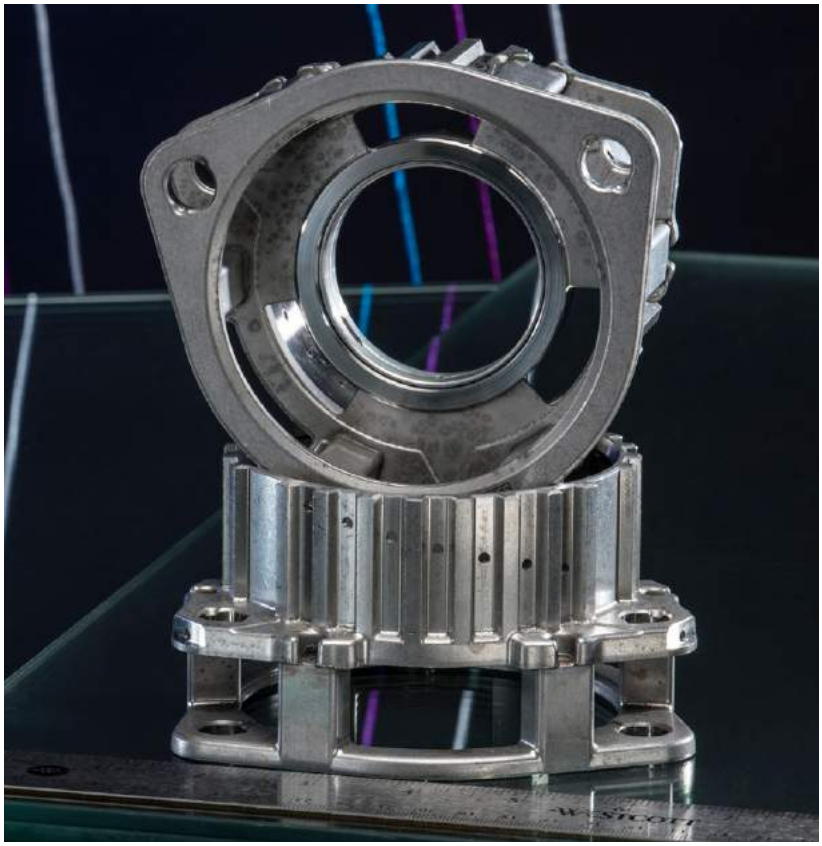

Fig. 15 Rear planetary carrier made by Stackpole International (Courtesy MPIF)

Transmission component applications

Planetary carriers

Recent new PM applications in automotive transmissions have been dominated by planetary carriers.

In 2018, the MPIF Grand Prize was awarded to GKN Powder Metallurgy for an aluminium PM planetary reaction carrier, which it produces for General Motors (Fig. 14). The carrier goes into the all-new GM 9T50 nine-speed transmission, offered in such vehicles as the Chevrolet Malibu and the Equinox crossover. Made from a unique metal matrix composite (MMC) aluminium alloy system and mated to an overdrive carrier, this first-of-its-kind two-piece design required extremely tight tolerances.

Also in 2018, MPIF made an Award of Distinction to Stackpole International, Canada, for a PM copper-steel rear planetary carrier (Fig. 15). The component is used in a new ten-speed automotive transmission, developed jointly by Ford and General Motors and found in such vehicles as the Ford Mustang and GM Camaro. The assembly consists of a clutch hub and a spider, which are joined using a novel sinter- brazing concept. The creative design of the ferrous carrier enabled it to win out over an aluminium casting design by delivering lighter weight and superior strength.

In 2017, an MPIF Grand Prize also went to GKN Powder Metallurgy for a planetary carrier assembly made for Ford Motor Company (Fig. 16). The sinter-brazed copper-steel assembly, comprising a cage and a flanged hub, goes into the all-new ten-speed transmission for the Ford F-150 pickup. The finished carrier assembly requires only simple milling and turning operations to hold the tight tolerances on the bearing bores, pinion pin shaft holes and thrust faces.

Fig. 16 This planetary carrier assembly, produced by GKN Powder Metallurgy, is used in Ford's F-150 ten-speed transmission (Courtesy MPIF)

Fig. 17 Stackpole International make this sinter brazed planetary carrier for ZF's nine-speed automotive transmission (Courtesy MPIF)

In the same year, the MPIF also presented an Award of Distinction to Stackpole International for a sinter-brazed planetary carrier made for ZF, Germany (Fig. 17). The assembly, consisting of a guide plate and a spider, goes into a new nine-speed automotive transmission. The PM design solution for a lightweight carrier met all the customer's design and durability requirements. This same application had received an award from the EPMA at the 2016 PM World Congress, Hamburg.

The final example of a recent JPMA award for a planetary carrier was made to Toyota Motor Corporation for a ravigneaux planetary carrier developed for a new high-efficiency automatic transmission. It consists of a PM carrier A, a PM carrier B, a steel sleeve and a steel hub (Fig. 18). The carrier design was optimised for PM to provide a significant reduction in manufacturing costs compared with forging and stamping. The stress to be applied to the ravigneaux carrier was reduced to below the fatigue limit by optimising the shape of the part at the points where stress was concentrated. The average density of this PM carrier is 7.05 g/cm^3. For forming of the different heights of the legs, green machining was adopted to provide further cost benefits.

In this application the two PM carriers A, B (each made from Fe-2Cu -0.9C) and a steel sleeve, having an optimal joint design, were brazed during the sintering process. After brazing, the steel hub was welded to the sleeve. For the purpose of cost reduction, a completely automatic production line from compaction to machining was developed and the number of operators was halved. Productivity was improved through the introduc-

Fig. 18 Toyota Motor Corporation manufactures this low-cost sintered ravigneaux planetary carrier in-house (Courtesy JPMA)

Fig. 19 Burgess-Norton manufactures this pocket plate for a controllable clutch (Courtesy MPIF)

Fig. 20 Powder Forged electronic locking differential gear set made by GKN Powder Metallurgy for Ford (Courtesy MPIF)

Fig. 21 FMS Corporation produces this thrust washer and back-up washer for a ten-speed automatic transmission (Courtesy MPIF)

tion of a new filling method to stabilise filling density, and tool change-over time was reduced to less than 160 seconds. These developments contributed to substantial improvements in cost competitiveness. It is expected that these technologies will be applied to global production in the future.

Clutch component

There have also been a number of recent awards for PM transmission applications other than planetary carriers. In 2017, an MPIF Award of Distinction was given to Burgess-Norton Mfg. Co. Inc., Geneva, Illinois, USA, for a sinter-hardened steel pocket plate made for Means Industries Inc. (Fig. 19). The part is a major component of a controllable clutch, a new design for multi-speed transmissions.

Locking differential gear

In 2016, a Grand Prize was awarded to GKN Powder Metallurgy for a powder forged electronic locking differential gear set made for Ford Motor Company (Fig. 20). Comprising five components, namely a side gear, two pinion gears, a locking side gear and a locking plate, the gear set is used in the rear axle differential of the Ford F-150 light truck, the first time forged PM differential gears have been used in such an application. The higher performance delivered by the forged PM differential gears compared to that of competing metal-forming processes will help usher in downsized gear systems, satisfying a critical need in future automotive design.

Thrust washer

In 2015, FMS Corporation, Minneapolis, Minnesota, USA, was awarded a Grand Prize for a thrust washer and two back-up washers made for its customer Allison Transmission (Fig. 21). The components play a critical role in the function of Allison's new TC10 automatic transmission for Class 8 (18-wheel) tractors. A first of its kind for the trucking industry, this

ten-speed automatic transmission enables even inexperienced drivers to achieve 5% fuel savings over typical manual transmissions, thus contributing to a significant lowering of CO_2 emissions.

Fabricated from a proprietary low-alloy PM steel, the three parts are warm compacted to achieve high green density, then vacuum sintered at high temperature, gas-pressure quenched and tempered. They are produced very close to net shape, with only precision machining of some surfaces performed to improve the micro-finish as well as for dimensional accuracy. While these washers were an original PM design, they are estimated to save 30% over the cost of comparable forged/machined components.

Oil pump drive sprocket

A 2017 MPIF Award of Distinction was presented to Keystone Powdered Metal Co., St. Marys, Pennsylvania, USA, for an oil pump drive sprocket made of prealloyed steel and fabricated for Linamar Corporation, Canada (Fig. 22). The part is used in a new ten-speed automatic transmission that goes into the Ford F-150 truck.

The part passed extensive durability testing with particular emphasis on noise, vibration and harshness requirements, so critical in automatic transmissions.

Drive transmission gear

Finally, although not a prize winning component, this fourth drive transmission gear developed by Sweden's Höganäs AB, was a notable entry in the 2016 EPMA Awards (Fig. 23). With a density of 7.3 g/cm^3 and a tensile strength of 990 MPa, this component was designed to exploit and demonstrate the full potential, and enduser benefits, of PM in this application.

Together with twelve technical partners and suppliers from the entire PM value chain, a further project resulted in the world's first optimised six-speed manual transmission designed for PM gear technology.

Fig. 22 Oil pump drive sprocket made of prealloyed steel by Keystone Powdered Metal for its customer Ford (Courtesy MPIF)

Fig. 23 Fourth-drive transmission gear developed by Höganäs demonstrates the potential for PM in this application (Courtesy Höganäs AB)

Fig. 24 GKN Powder Metallurgy make this output pulley for rear seat reclining mechanism (Courtesy MPIF)

Fig. 25 Keystone Powdered Metal Company's steering column cams and guides are used in GM models (Courtesy MPIF)

Fig. 26 Multiple PM components made by Keystone Powdered Metal Company are used a steering column (Courtesy MPIF)

Powder Metallurgy in many other automotive systems

There have also been recent developments for new PM applications in other automotive systems.

Car seat component

In 2017, an MPIF Grand Prize was given to GKN Powder Metallurgy for a copper-steel output pulley made for Nidec Automotive Motor Americas (Fig. 24). The part goes into an electric reclining mechanism in a minivan rear seat application. The part offers a high level of functionality in the small footprint mechanism and includes the groove for cable retention, the cam for radial movement and stops at both ends.

Steering column

The MPIF Grand Prize in 2015 went to Keystone Powdered Metal Company, for a rake cam, right-hand and left-hand guides and an eccentric cam made for its customer Nexteer Automotive (Fig. 25). The diffusion-alloyed steel components are used in Cadillac ATS and CTS, Chevrolet Impala and GM Holden Commodore (Australia) steering columns. They are key elements of the column's tilt and telescope adjustment feature, serving a vital role in maintaining the column's position during a crash event.

The multi-level parts are fabricated to net shape, with in-line heat treatment and tempering being the only secondary operation preformed to ensure the required hardness and strength. The rake cam and guides have features that allow for a mechanical lock of the plastic over-mould, in an operation performed by Agapé Plastics, Inc. The economic targets of the customer's preferred design for the steering column tilt/telescope adjustment and lock—with a "pin pocket" that gives a positive detent feel—could be met only with the flexibility offered by PM.

In 2016, the MPIF Grand Prize was again presented to Keystone Powdered Metal Co., St. Marys, Pennsylvania, USA, this time for a total of seven PM components used in the steering column of the Chevrolet Colorado and GMC Canyon trucks (Fig. 26).

The rake cam, left-hand inner cam, retainer guide, right-hand rake teeth energy-absorbing eccentric strap cam, column mounting insert teeth and left-hand rake teeth are made for Nexteer Automotive. The heat-treated diffusion-alloyed steel components are key elements of the steering column's tilt and telescope adjustment feature, serving a vital role in maintaining the column's position during a crash event. The rake cam has features that allow for a mechanical lock of the plastic lever, which is over-moulded in an operation performed by Agapé Plastics, Inc.

Power steering systems

In 2016, two separate MPIF Awards of Distinction featured drive and driven pulleys for electric power steering systems. The first went to Capstan Atlantic, Wrentham, Massachusetts, USA, for a drive pulley (Fig. 27). The iron-copper part is used in assemblies found in the Ford Focus and Escape vehicle platforms.

This unique six-level component requires tight tool-wear control. Powder Metallurgy was chosen as the fabrication method because it offered far better precision than the die-cast alternative at a competitive price.

The second award went to GKN Powder Metallurgy for a copper-steel driven pulley for an electric power steering system made for Nexteer Automotive (Fig. 28). The pulley is a complex net-shape-compacted part with a unique helical geometry and tight tolerances.

Close collaboration with the customer in the design of the part, which includes net-formed lightening holes, yielded savings of more than 10%.

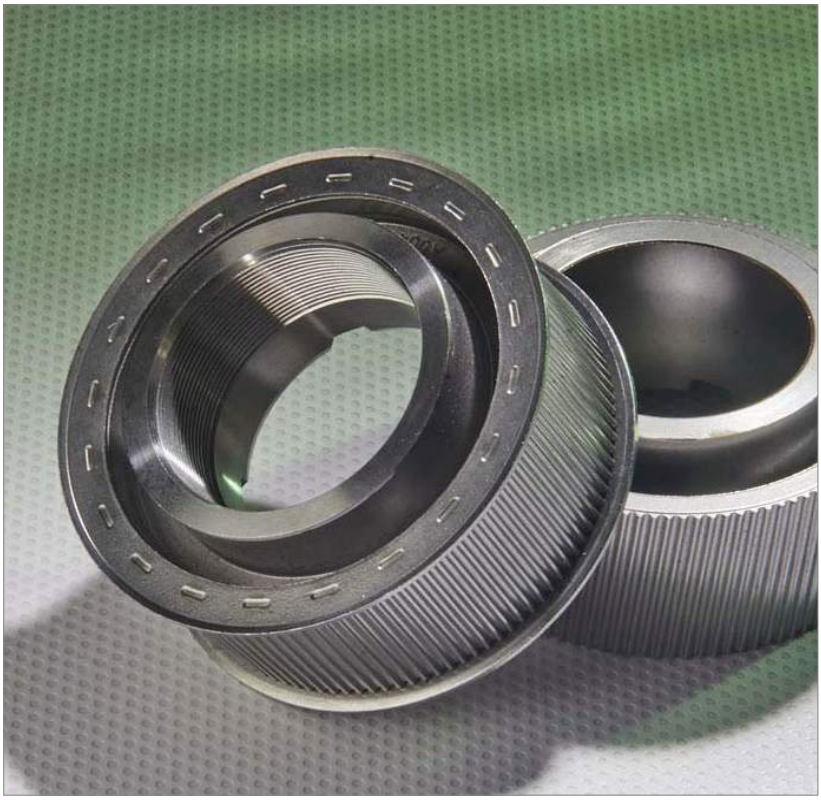

Fig. 27 This award-winning drive pulley is manufactured by Capstan Atlantic for an electronic power steering system (Courtesy MPIF)

Fig. 28 GKN Powder Metallurgy manufactures this copper-steel driven pulley for an electric power steering system (Courtesy MPIF)

Fig. 29 Diamet Corporation make this sprocket drive for a next-generation automatic transmission oil pump (Courtesy JPMA)

Fig. 30 Bearings produced by Diamet Corporation for an electronically controlled wiper motor (Courtesy JPMA)

Sprocket drive for automatic transmission oil pump

The JPMA has also made awards in this category. Firstly, Diamet Corporation was awarded a prize for its development of a sprocket drive for a next-generation fuel consumption AT oil pump (Fig. 29). From a cost point of view, an Fe-Cu-C based sintered sprocket with 6.8g/cm^3 density was used for this unit, instead of a fine-blanked sprocket. Although induction hardening treatment is often used for gear tooth surface hardening, post-processing is required since dimensional accuracy deteriorates. In order to achieve both mechanical strength and low cost, Diamet has tried to improve the dimensional precision of an as-induction hardened body. By setting the sizing conditions to minimise residual stress, it was possible to reduce the deformation during induction hardening and to achieve the required parallelism, with a dimensional accuracy of 50 µm, without post-processing.

Wiper motor self-lubricating bearings

Diamet Corporation won a further award for the development of a PM self-lubricating bearing that is designed to form part of the armature used in an electronically controlled wiper motor, as a typical application example (Fig. 30). In order to improve pressure and wear resistance, the company targeted excellent sliding and lubricating performance with higher hardness and strength than conventional Fe-Cu system oil-impregnated sintered bearings.

For better sliding characteristics, the developed bearing material incorporated a large amount of copper (exceeding the solubility limit in iron) and had a microstructure with a large fraction of copper phases. In addition, as a result of optimising the raw material particle size of the copper powder and graphite and the sintering conditions, the material developed an Fe-Cu system composite structure, in which undissolved copper phases and free graphite are dispersed and distributed, resulting in high hardness and high strength. Diamet also succeeded in securing the dimensional accuracy of the sizing process by achieving almost zero (< 0.1%) dimensional change rate in sintering.

The developed bearing material is said to achieve a wear resistance of more than four times that of a conventional bearing, under the electronically controlled wiper motor operating conditions. The company claims that there is no other example of this type of PM bearing material in the marketplace.

Electric motor applications

In the late 1990s, the EPMA gave an award to Höganäs AB, Sweden, for a new high-purity water atomised iron powder called Somalloy. This powder is chemically treated to provide an electrically insulated inorganic layer on each particle and was aimed at new soft magnetic applications in electric motors. The powder could be compacted to high densities, thereby improving magnetic properties, and, by heat treating, or curing, in air at around 650°C, a bond was developed between the powder and the insulating layer to give the component adequate strength. PM bonded magnets are simple to produce, are more energy efficient and offer 3D design for new motors.

Soft magnetic components have been produced from this type of powder since the late 1990s, including some for applications in hybrid and electric cars. It was the ability to achieve 3D magnetic properties and the net-shape capabilities of the SMC iron powder that prompted YASA Motors in Oxford to choose the SMC Somalloy material for its new compact axial flux e-motors (Fig. 31). Their modular design allowed for stackability – up to four motors in parallel, which can generate a power of 400 kW – and direct drive. YASA stated that this eliminated the need for costly and inefficient transmissions, further reducing overall weight of the vehicle and cutting production and maintenance costs.

PMG Fussen, Germany, has also developed SMC-based components for transversal flux electric motors made by Compact Dynamics GmbH (Fig. 33). Toyota and Honda in Japan are already using SMC iron powder cores for power inductors, also called reactors or choke coils, for switching power supply in hybrid vehicles. So applications for SMC magnets are growing and there is much potential here for the PM industry.

Fig. 31 The YASA P400 electric motor is produced using SMC iron powder components (Courtesy YASA Motors)

Fig. 32 YASA motors can be used to power a number of electric vehicles (Courtesy YASA Motors)

Fig. 33 SMC components produced for electric applications (Courtesy PMG Füssen GmbH)

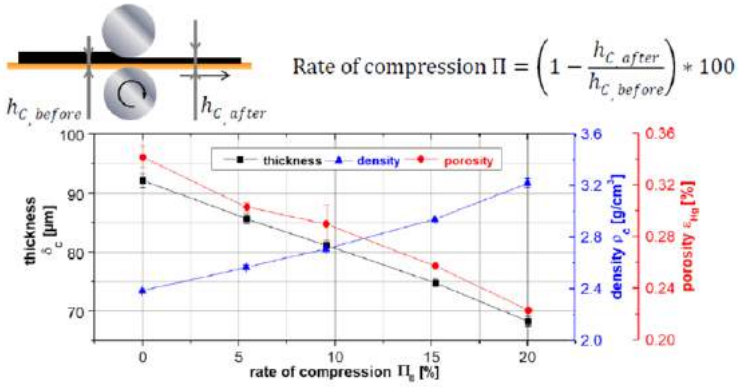

Fig. 34 Influence of rate of compression in calendering of lithium-ion battery electrodes

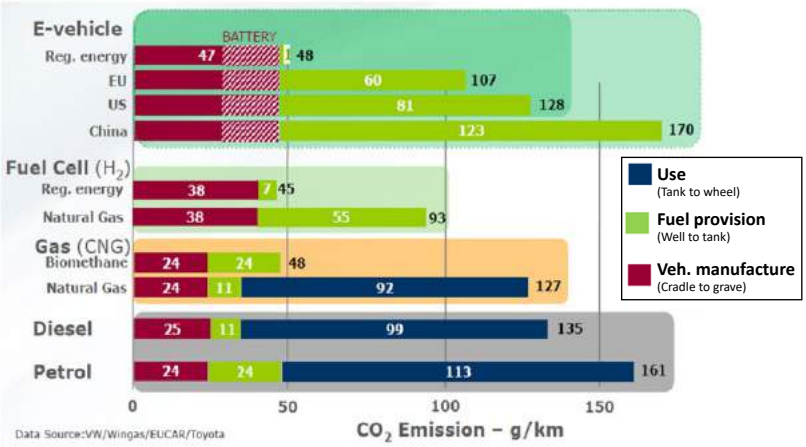

Fig. 35 Lifecycle CO_2 emission comparisons, including "cradle to grave" data

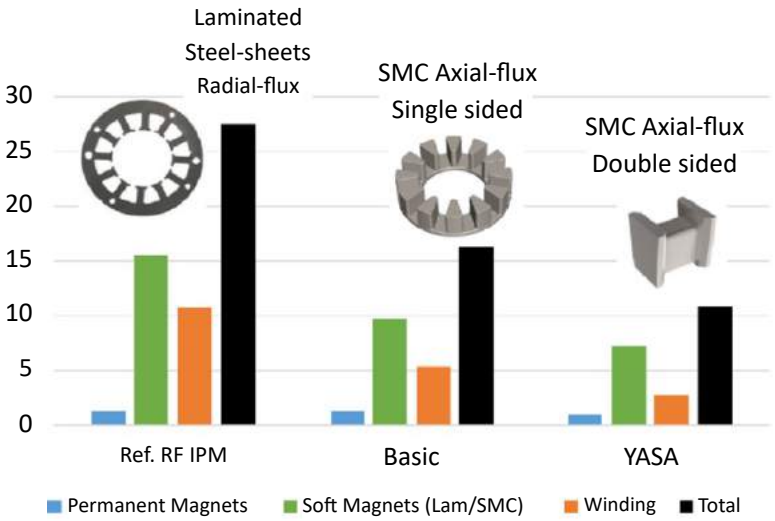

Fig. 36 Use of SMC components in designing for high power density (kW/kg) in axial-flux motors

PM Functional materials to meet the needs of next-gen auto applications

A seminar organised by the EPMA in 2018 discussed a number of Powder Metallurgy processed functional materials with potential applications in next generation electrified vehicles. These included the following topics.

High-energy density battery electrodes and electrolyte
The process steps for lithium-ion batteries are mixing and dispersing, coating and drying, calendering and assembly and electrolyte filling. In the calendering process, the influences of the rate of compression have been assessed in relation to a number of parameters: the tortuosity of the pathways through pores, density level and conductivity, porosity level and diffusion coefficient and discharge capacity (Fig. 34).

Fuel cells
Probably the most reasonable CO_2 footprint comparisons for fuel cell usage vs. internal combustion engines would be the full vehicle 'cradle to grave' figures shown in Fig. 35, which include the embedded carbon contents for vehicle manufacture.

Magnetic material (soft and hard) applications in electric motors and ancillary systems
The use of SMC components for the design for high power density using axial-flux motors (single sided and double sided) is summarised in Fig. 36. This technology is used in electric traction drives.

Transmission gears for electrified transmissions
There is a wide variety of possible transmission architectures for hybrid and BEV drives (Fig. 37). It is envisaged that ultimately the

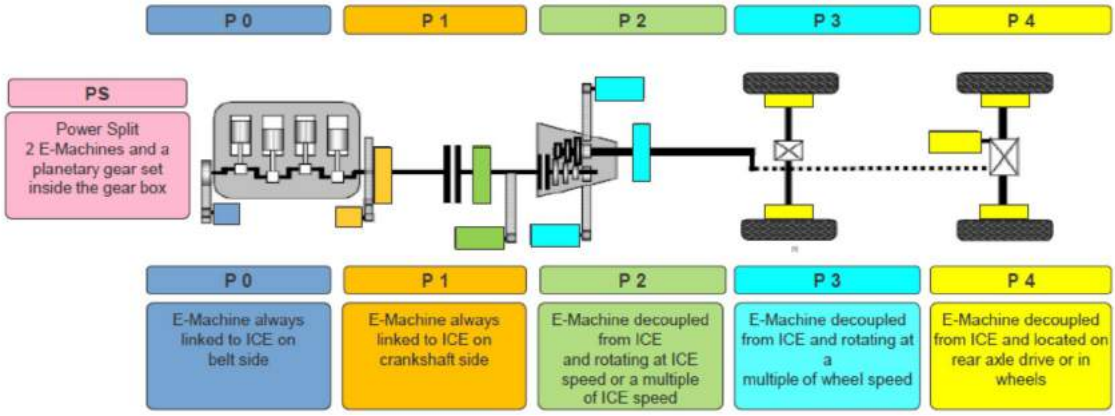

Fig. 37 The high variety of possible hybrid and BEV drive architectures

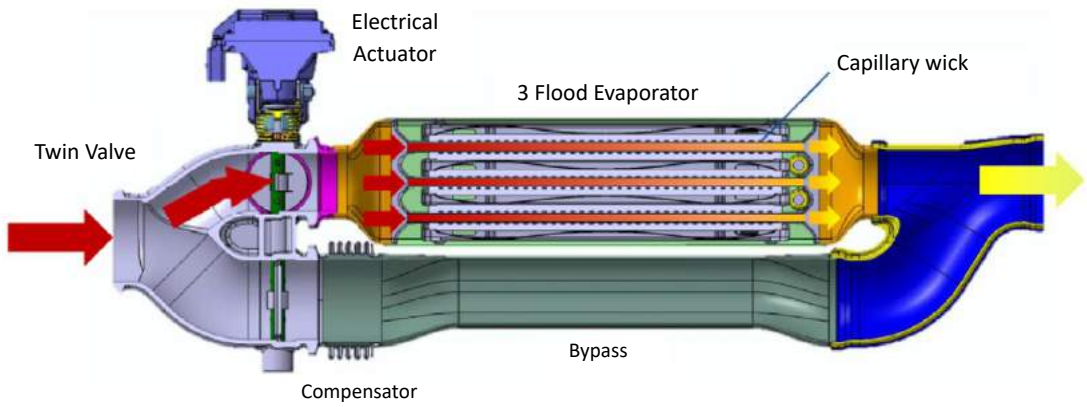

Fig. 38 LHP arrangement for exhaust heat recovery in hybrid vehicles

trend will be towards placing the 'e-machine' in the P4 position where it would be de-coupled from the ICE and put on the rear wheel axle. In such an architecture, the gearbox would be of significantly simplified design compared with a current, conventional gearbox.

Capillary wick materials for loop heat pipe application in electric vehicles

Such materials can be used for exhaust heat recovery in hybrid vehicles for shortened cold starts and shortened ICE running times. The evaporator is placed in the exhaust line and the condenser in the coolant circuit (Fig. 38). The benefits of using LHP technology in this application are fast response times, highly efficient heat transport and the absence of an electric pump.

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www.mpif.org

Japan Powder Metallurgy Association
www.jpma.gr.jp

European Powder Metallurgy Association
www.epma.com

Spark Plasma Sintering: Method, systems, applications and industrialisation

For around thirty years, Spark Plasma Sintering (SPS) has been of great interest to the Powder Metallurgy industry and academia alike, for both product manufacturing and advanced material research and development. Today in Japan, a number of components made using SPS are already in production, with the process moving from the R&D stage to practical industrial use. In this article, Dr Masao Tokita, of NJS Co., Ltd., introduces the latest in SPS technology, discusses the development of SPS systems and highlights a number of industrial applications.

It is widely recognised that the Spark Plasma Sintering (SPS) method is an advanced processing technology, used to produce a homogeneous, highly-dense, nanostructural sintered compact, as well as in Functionally Graded Materials (FGMs), fine ceramics, composite materials, wear-resistant materials, thermo-electric semiconductors and biomaterials. Originating in Japan, the technology, also referred to as a pressure-assisted pulse energising process, Field-Assisted Sintering Technology (FAST), Electric Current Activated/assisted Sintering (ECAS) or Pulsed Electric Current Sintering (PECS), is today finding new applications in many global regions.

As of January 2019, over five hundred SPS systems are installed in Japan alone, located in universities, technical colleges, national institutes and private companies for use in both the R&D and manufacturing sectors. It is estimated that around one thousand SPS systems are currently installed globally, including those found in Europe, the USA, Russia, China, Korea and others.

SPS technology is seen as a promising technology for innovative processing in the field of advanced new materials fabrication in the 21st century [1-3]. Today's fifth generation SPS systems are capable of producing parts of increasing size, offering improved functionality, reproducibility, productivity and cost effectiveness.

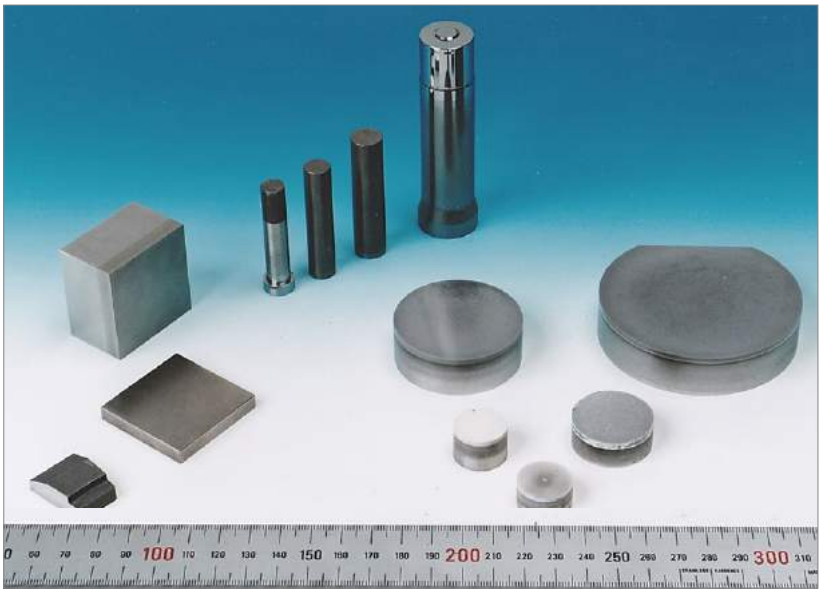


Fig. 1 Spark Plasma Sintering (SPS) can be used to produce a variety of components, from FGMs to porous filters

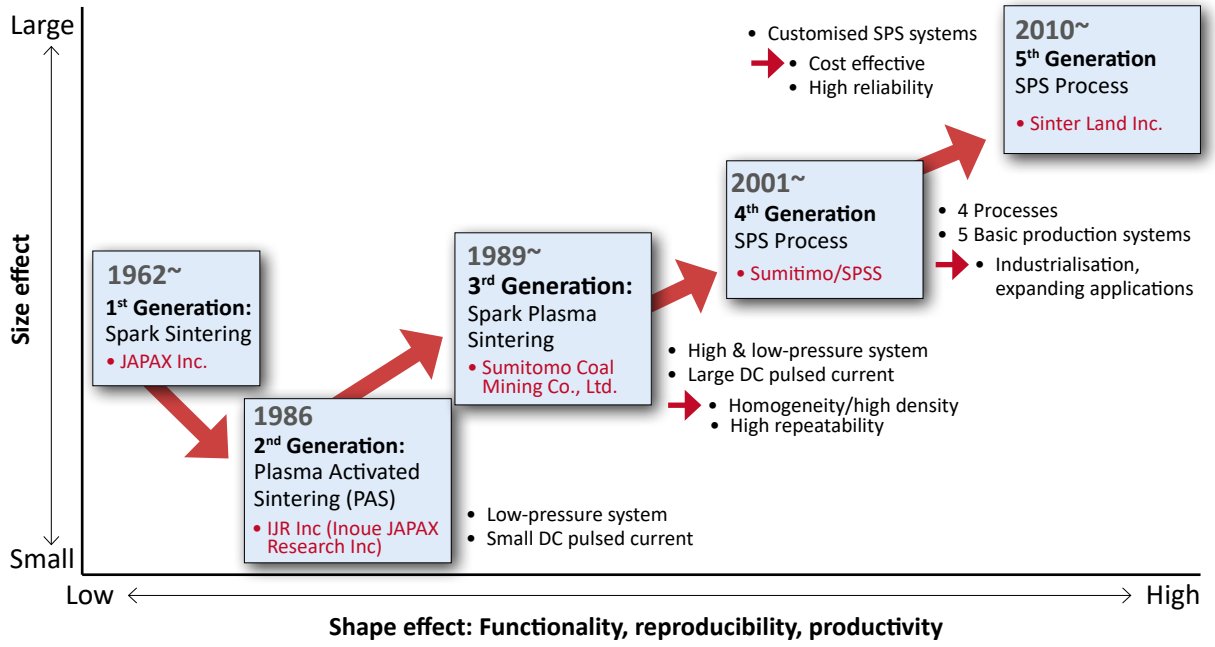


Fig. 2 Historical progress of the Spark Plasma Sintering method and technology

A story of continual innovation

Initial studies, dating back to around 1910 in Germany, report a process where an electric energising technique was applied to consolidate a powder material. In the USA, a few years later in 1933, G F Tayler patented the first resistance sintering method for sheet metals [4]. These processes are considered as the origin of the Hot Pressing (HP) technique, where a high-frequency induction heating method is applied.

It was in the 1960s that a method of Spark Sintering (SS) was developed by Dr Kiyoshi Inoue of JAPAX Inc., Japan [5, 6]. As shown in Fig. 2, this is now referred to as a first generation SPS system. The process was further developed by Inoue, resulting in a second generation technique known as Plasma-Activated Sintering (PAS) released in 1986. Thereafter, in 1989, the Spark Plasma Sintering method was introduced by Sumitomo Coal Mining Co., Ltd, Japan [7], being recognised as the third generation of large DC pulse applied sintering techniques.

Ongoing R&D for the implementation of SPS methods and systems was initiated to design practical hardware and software for industrial applications. The development of small- to medium-sized box-type experimental use SPS systems for new materials preparation, and single-head open-type limited production systems, followed. From 2001 to 2009, as the fourth-generation technology developed to accommodate for product manufacturing, five basic styles of SPS production systems emerged to suit medium- to mass-production scales [8]. In addition to sintering, SPS technology also found application in solid phase diffusion bonding and joining [9], surface modification (treatment) [10] and a synthesis technique, for example, of a single-crystal fabrication.

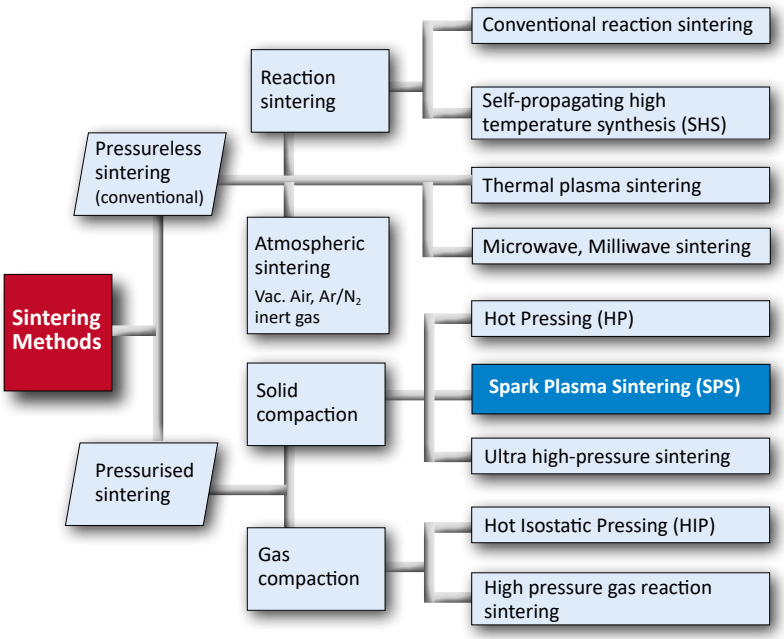


Fig. 3 Typical classification of sintering methods

After 2010, the progress of SPS technology was such that new, advanced SPS systems are now seen as being fifth-generation machines. Customised SPS apparatus, along with more practical manufacturing applications, offer high reliability and reduced production costs.

A further interesting technology, derived from the ongoing development of SPS, is the emergence of Flash Sintering and Flash-SPS, a category of Electric Current Activated/assisted Sintering [3,11]. Still under research, Flash Sintering could prove an innovative future technology.

The Spark Plasma Sintering process

The Spark Plasma Sintering process enables sintering and sinter-bonding, at low temperatures and at high speed. The technique, a form of pressurised sintering as seen in Fig. 3, involves the application of a high-energy, low-voltage electrical current, believed to result in a 'spark plasma' phenomenon in the powder. Although the precise mechanism of the spark plasma remains unclear, many years of research by many different material researchers has resulted in a number of theories [12-16].

One of the most accepted explanations is based around the illustration in Fig. 4 where, once compacted and still under pressure, an on-off DC pulse voltage, at high current, is applied to the powder using a special pulse generator. It is understood that the electrical discharge results in a high-temperature spark plasma, up to several thousand degrees centigrade, generated momentarily at the initial stage of energising. This forms uniformly throughout the compact and the generated heat fuses, purifies and activates the surface of the powder particles (Fig. 5).

The initial stage of the pulse energising results in a discharge between the powder particles and between the powder and the graphite die wall surface (Fig. 6). When sparking occurs, a high-temperature sput-

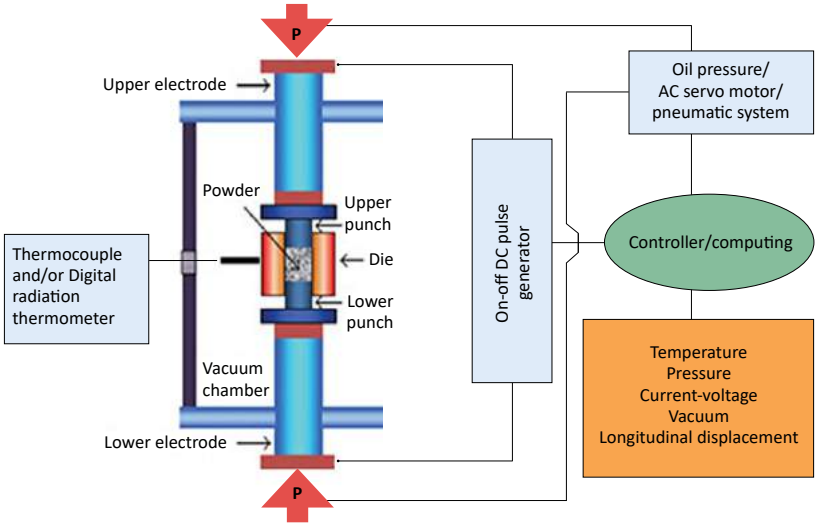


Fig. 4 Basic theory of the SPS process

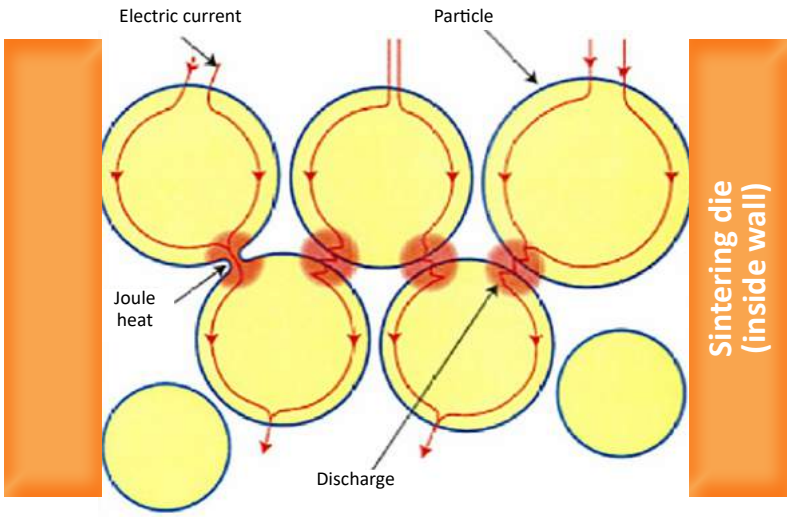


Fig. 5 ON-OFF DC pulsed current path and pulsed current flow through powder particles

Fig. 6 The sintering stage in a graphite mould and vacuum chamber

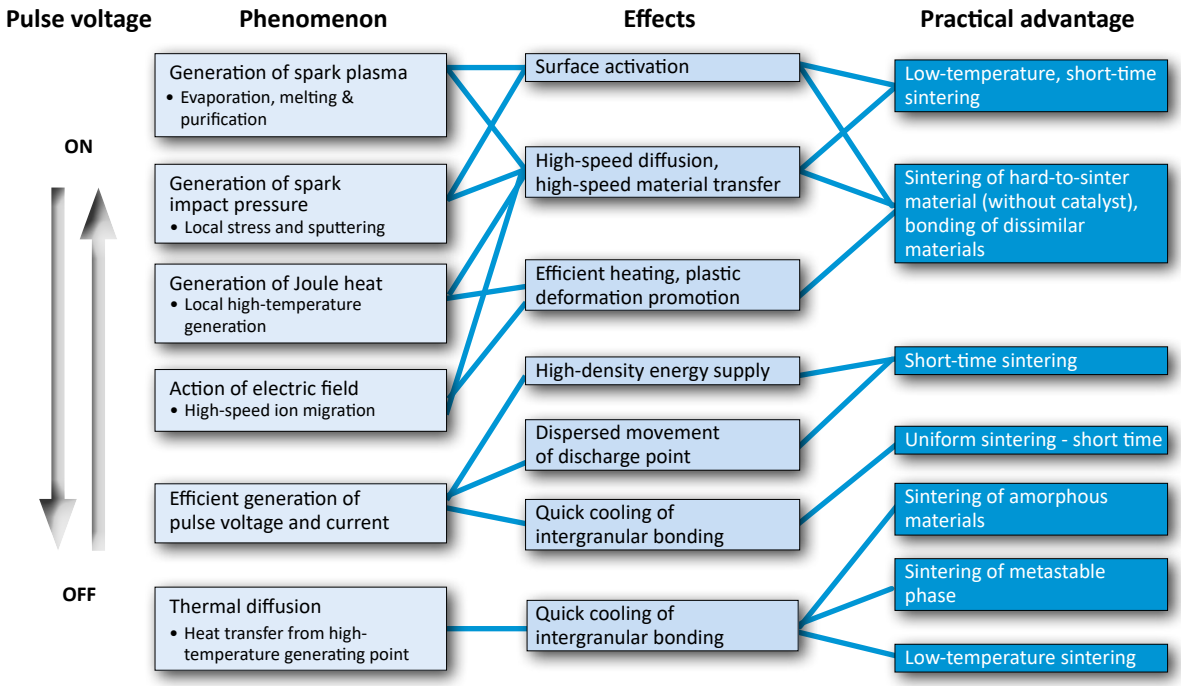


Fig. 7 Effects of ON-OFF DC pulse energising

Fig. 8 This medium-sized 5th Generation SPS system produced by Sinter Land Inc, Japan, offers high-precision process control and short cycle times. Systems such as this can be used with multiple materials and offer wide temperature ranges (Courtesy Sinter Land)

tering effect is generated by spark plasma and spark impact pressure. This works to eliminate adsorptive gases and oxide films and impurities existing on the surface of the powder particles. The action of the electro-magnetic field enhances high-speed diffusion due to the electro-migration effects of ions.

A Joule heating stage, caused by the passage of electric current through the powder whilst under mechanical pressure, further assists in the SPS process. The intense joule heating effect can often result in localised high-temperature generation, and therefore leads to localised vaporisation or cleaning of powder surfaces. Such a phenomenon ensures a favourable path for current flow. Further effects of the on-off pulse DC voltage are shown in more detail in Fig. 7.

Configuration of an SPS system

The configuration of a typical SPS system consists of a compacting press with a vertical, single-axis pressurisation mechanism, incorporating specially designed punch electrodes made from graphite. The system can

Fig. 9 World's largest semi-tunnel type automatic SPS production system has three vacuum chambers, 6 MN press with a pallet-type special conveyer, and inverter-type 40,000 A DC pulse generator (Courtesy Sinter Land)

incorporate a water-cooled vacuum chamber, a vacuum/air/argon-gas atmosphere control mechanism, a special DC-pulsed power generator, Z-axis position measuring and control unit, temperature measuring and control units, an applied pressure display unit, a data analysing unit and various safety interlock devices. A typical 5th Generation medium-sized system can be seen in Fig. 8. This model is ideally suited to R&D work, as well as prototype and product manufacture.

Production-scale SPS systems

Custom built SPS systems are also available today, as well as large production-based machines such as the example seen in Fig. 9. The move to production-scale SPS systems requires consideration of many factors. The cost and development of optimum systems will depend on production strategies, including the required cycle time, technologies to support scale expansion, mass-production, automation and numerical control systems. There is also the development of process technologies for high functionality, reproducibility, uniformity and structural control. In addition, pre- and post-processes for manufacturing must be considered.

In order to meet different productivity levels, there are typically five options to consider. These include: multi-head, batch, tunnel, rotary and shuttle-type SPS systems. In addition to these, scaling-up process, automatic handling and powder stacking equipment for materials and process optimisation have also been developed [17].

Development of pulse generators

Presently, there are two basic types of DC pulse generator for SPS apparatus, thyristor-type and invertor-type power supply. Fig. 10 shows examples of typical on-off pulse waveforms and different pulse width and ratio. The waveform, max./min. on-time/off-time pulse width, peak current, frequency, duty factor settings, control system

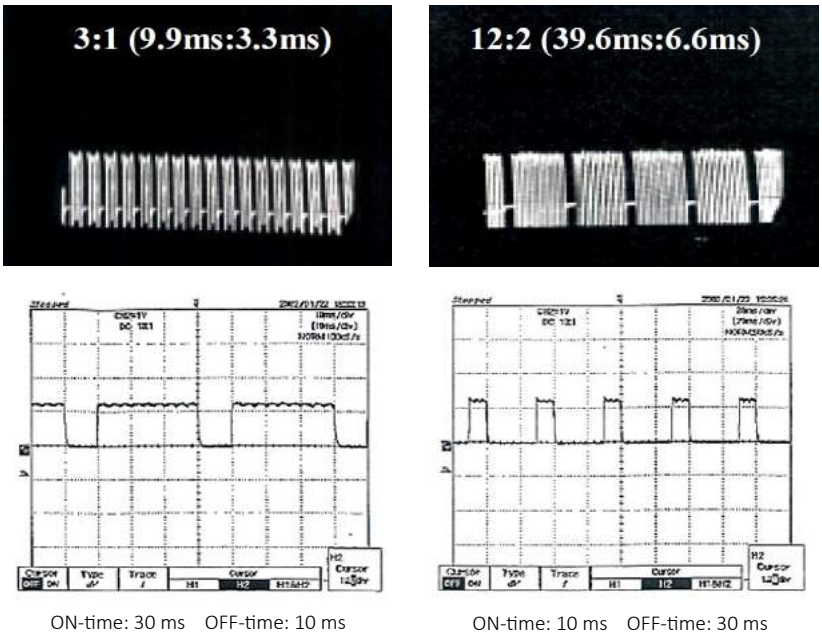
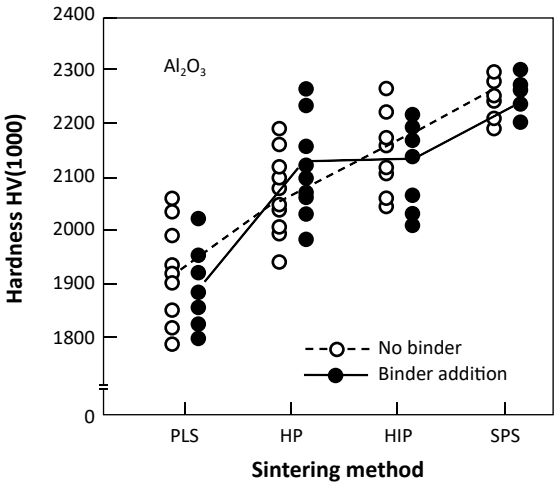
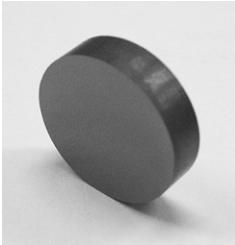


Fig. 10 Typical wave form of a thyristor-type pulse generator (ON-OFF ratio in 50 Hz)

Classification		Materials for SPS processing	
Metals		Fe, Cu, Al, Au, Ag, Ni, Cr, Mo, Sn, Ti, W, Be, C	Virtually any metal possible
Ceramics	Oxides	Al_2O_3,Mulite, ZrO_2, MgO,SiO_2, TiO_2, HfO_2	
	Carbides	SiC, B_4C, TaC, TiC, WC, ZrC, VC	
	Nitrides	Si_3N_4, TaN, TiN, AlN, ZrN, VN	
	Borides	TiB_2, HfB_2, LaB_6, ZrB_2, VB_2, MgB_2	
	Fluorides	LiF, CaF_2, MgF_2	
Cermets		Si_3N_4+Ni, Al_2O_3+Ni, ZrO_2+Ni	
		Al_2O_3+Ti, ZrO_2+stainless steel, Al_2O_3+stainless steel	
		WC+Co, WC+Ni, TiC+TiN+Ni, BN+Fe,	
Intermetallic compounds		TiAl, $MoSi_2$, Si_3Zr_5, NiAl	
		NbCo, Nb_3Al, $LaBaCuSO_4$, Sm_2Co_{17}	
Other materials		Organic materials (polyimide, etc.), FRM, FRC, CNT composite materials	

Table 1 Suitable materials for SPS process





Pure nano-SiC
Powder particle size: 30 nm
R.D: 99.4%
mHV: 2380
Diameter: 20 mm
Grain size after SPS: 100 nm

Fig. 11 Nano-SiC compact by SPS and Al_2O_3 HV hardness distribution behaviour sintered by various methods

		SPS	HP Sintering
Temperature gradient sintering		◎	×
Grain boundary controlled sintering		◎	×
Fine crystalline structure controlled sintering		◎	×
Temperature rise rate		◎	×
Sintering time	Temperature rise time	Fast	Slow
	Holding time	Short	Long
Homogeneous sintering		○	○
Expandability		◎	△
Productivity		◎	△
Investment in equipment		○	△
Running cost		◎	△
(◎ excellent | ○ good | △ fair | × difficult)			

Table 2 Comparison of the characteristics of SPS and HP sintering

and energy consumption vary between each system. Each pulse generator has its own advantages and should be chosen based on the desired purpose and usage of the SPS system.

The majority of SPS systems installed in universities, national institutes and private companies employ the thyristor-type pulse generator, due to a rich reference database on SPS and higher reliability of power supply hardware. The invertor type, with a Pulse Width Modulation (PWM) control, offers a lower power consumption and a more compact size, which could make it a more attractive option for economical low-cost production. The development of pulse generators is still ongoing.

Materials

The SPS process is suited to a number of materials, including conductive and non-conductive powders. An example of suitable materials for SPS is provided in Table 1; these include metals, ceramics, cermets, intermetallic compounds and others.

When using non-conductive materials, where no sparking occurs between powder particles, it is considered that the effect of on-off DC pulse current still exists, energising particles, which results in an enhancement of the sinterability and densification rate of the material. The large pulsed energy generates an electro-magnetic

field effect, such as an electro-migration, and preferential orientation of crystalline structure [18].

Comparing traditional sintering processes to Spark Plasma Sintering

The method of applying heat directly to the compact results in extremely high heating and cooling rates, and is therefore capable of reducing sintering time from hours to minutes. Compared with conventional sintering, the SPS method has demonstrated superior material properties, as it can offer a structure tailoring effect, minimise grain growth, enhance electro-migration and provide a strong preferential orientation effect.

A comparison of various sintering techniques and the resulting HV Vickers hardness is shown in Fig. 11 for an Al_2O_3 example. The results indicate that SPS offers hardness equal to and greater than processing by HIP or conventional hot press sintering. A comparison of specific characteristics of the SPS method, against conventional Hot Press (HP) sintering, is shown in Table 2.

As a sintering technique, SPS has drawn considerable attention as one the newest rapid sintering methods. The novel process also benefits from low power consumption of between 1/5 and 1/3 that of conventional sintering techniques, such as pressureless sintering, hot press sintering and Hot Isostatic Pressing (HIP).

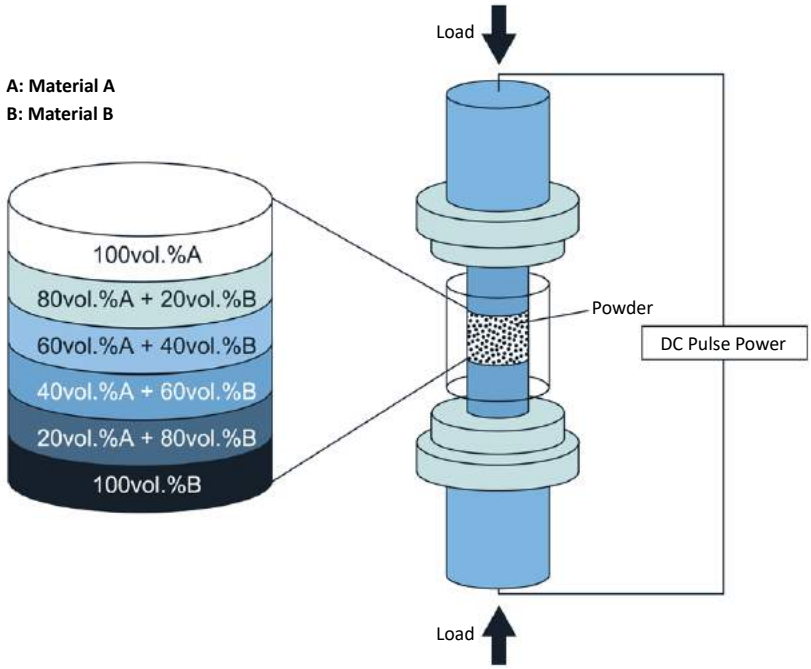


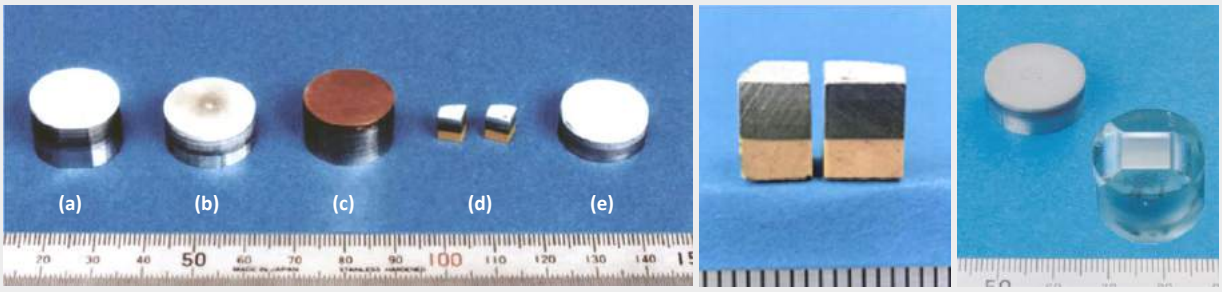
Fig. 13 A typical fabrication process for FGMs by Spark Plasma Sintering

Examples of SPS process applications

Functionally Graded Materials

Functionally Graded Materials (FGMs), often referred to as having 'dream' properties, are advanced materials characterised by a gradual variation in composition and structure, resulting in changes to the properties of the component. The original concept of FGMs was proposed in 1984 by material scientists in Japan during an aerospace research project.

Examples of bulk FGM compacts, produced by Spark Plasma Sintering, are demonstrated in Fig. 12. Seen from the left, (a) ZrO_2(3Y)/stainless steel compact with six interlayers, (b) ZrO_2(3Y)/nickel compact with seven interlayers, (c) copper/stainless steel compact with five interlayers, (d) aluminium/polyimide compact with three interlayers and, on the right, (e) Al_2O_3/titanium compact with three interlayers. The SPS process resulted in full-density sintered compacts, with no micro-cracks detected.



Examples of bulk FGM compacts
a) ZrO_2/stainless steel,b) ZrO_2/Ni, c) Cu/stainless steel,
d) Al/Polyimide and e) Al_2O_3/Ti

Enlarged cross-section of Al/Polyimide FGM

ZrO_2(3Y)/410L stainless steel 6 layers (left) and 21 layers

Fig. 12 Typical examples of bulk FGMs

Utilising a temperature gradient sintering technique of SPS, the process has successfully created a wide range of bulk FGMs with multiple layers, including various systems of ZrO_2/stainless steel, ZrO_2/TiAl, ZrO_2/Ni, Al_2O_3/stainless steel, Al_2O_3/Ti, Al_2O_3/Ti-6Al-4V, WC/stainless steel, WC/Co, WC/Ni, Cu/stainless steel, SiO_2glass/stainless steel, Al/polyimide resin, Cu/phenol resin and Cu/polyimide resin materials, etc. [19-22].

Fig. 13 shows a schematic illustration of an SPS temperature gradient die assembly and an example of multi-layered ZrO_2(3Y)/stainless steel FGMs compact, which contains a 3 mol.% yttrium partially stabilised zirconia (PSZ) powder, a 410L stainless steel powder and mixed powders of the two as intermediate layers with a different volume fraction. The FGM powders were stacked in a graphite temperature-gradient die of 20 mm internal diameter. The stainless steel powder has an average particle size of 9 µm while the PSZ powder is of granulated particles with an average particle size of 50 µm (its crystalline size is 350 Å). The sintering pressures used were 20–40 MPa, SPS temperatures of 1243–1293 K, with a temperature rise rate of 50 K/min measured near the stainless steel layer [20, 21].

Horn-tip tool for an ultrasonic homogeniser

Ultrasonic homogenisers act through the rapid vibration of a titanium probe, or horn, transmitting ultrasonic energy to the sample. The vibration causes homogenisation directly through the ultrasonic forces as well as through cavitation, where the rapid formation and collapse of bubbles occurs as a result of the vacuum formed when the probe retracts. Conventional titanium horn-tips, although chemically stable and mechanically easy to produce to the desired shape, result in low wear resistance, can lead to contamination and have a short life span. Alternative options, such as brazed ZrO_2 plates on a Ti body, can result in weakness at the brazed layer. Monolithic ceramic horn-tips have good hardness, but are brittle and can result in a short life span.

The FGM horn-tip shown in Fig. 14 is based on the optimised sintering conditions of Al_2O_3/Ti-Ti, with a five layered ZrO_2/Ti/Ti-6Al-4V alloy FGM developed for the structure. The ceramic-metal material achieved a hardness of HV 1364 and, due to the the high hardness at the surface, offered greatly improved corrosion resistance during the cavitation process. A sintering temperature of 1573 K, at a pressure of 30 MPa, resulted in the lowest 17 mg wear amount following a 50 h homogenising operation test.

The life span of the new horn-tip has proved to be around eight-to-ten times greater than conventional options, without cracking, peeling or breakage. It is expected that remarkably less contamination will present a highly reliable production process, and the available large-sized horn-tip encourages higher output power oscillation with much better productivity.

Sputtering target fabrication

With the SPS process, highly-dense sintered products can be fabricated at a much lower temperatures and with shorter heating up and holding times, compared with hot pressing and HIPing. Thus, sputtering target materials are another application field for SPS that can provide positive results. Indeed, several companies have developed a profitable business using SPS in this way.

Fig. 15 shows a typical example of a large-sized metallic sputtering target with a diameter of 350 mm produced by a large-size SPS system. When producing this part by SPS, productivity was approximately seven-to-eight times higher than conventional sintering of HP and HIP

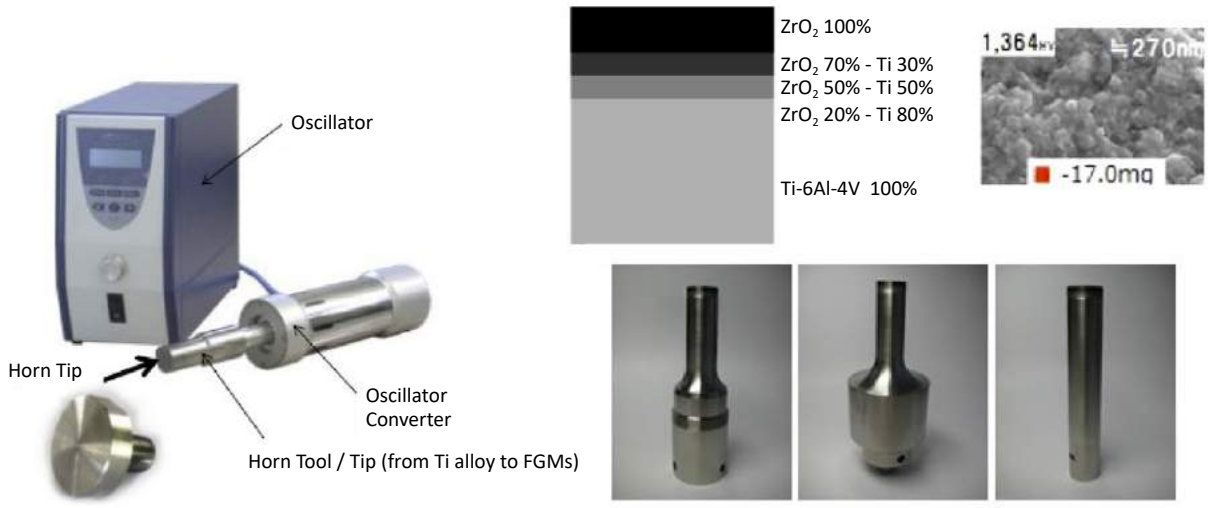
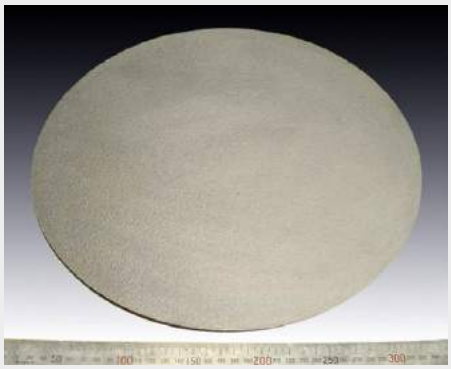
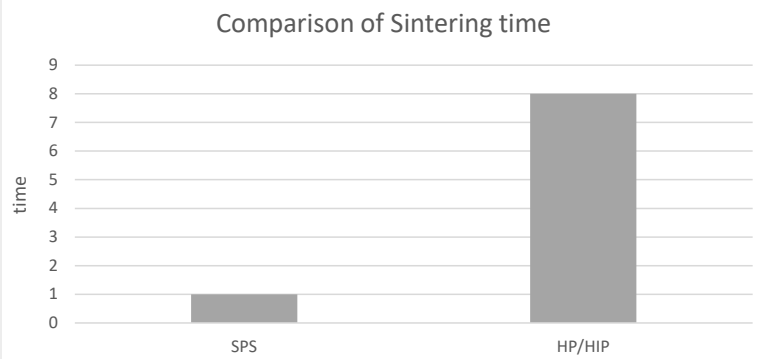


Fig. 14 Ultrasonic homogeniser and ZrO_2/Ti alloy system FGM horn tip tool (manufactured by Mitsui Electric Co.,Ltd, Japan)

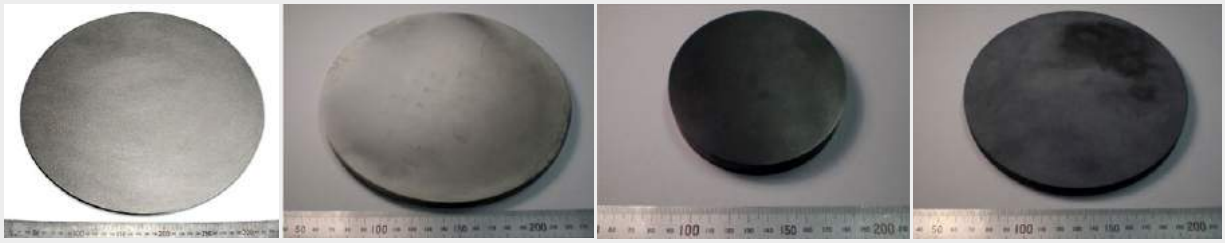




SPS Sintering temperature: 1373-1473 K
Relative density: 99-100% Material: Ru

Materials example: CrB_2, CrB, SiC, SiO_2, Ta_2O_5, ITO, $BaTiO_3$, $PbTiO_3$, TiN, TiAl, Ti-Al-Si, TiTa, Mg_2Si, Ru, RuCo, NiCr, others

Fig. 15 Example of Ø350 mm large-size metallic sputtering target material



Material: Al_2O_3
R.D: 98-99%
Dimensions: Ø 300 x 10 mm

Material: Al_2O_3
R.D: 99-100%
Dimensions: Ø 200 x 10 mm

Material: pure WC (no additives)
R.D: 99-100%
Dimensions: Ø 100 x 16 mm

Material: SiC (with additives)
R.D: 99-100%
Dimensions: Ø 150 x 12 mm

Fig. 16 Example of large-size ceramics by SPS

processes. Also, due to the obtained finer grain size of the SPS sputtering target materials, superior sputtering performances can result where, for example, no splashing phenomenon occurs in the coating process.

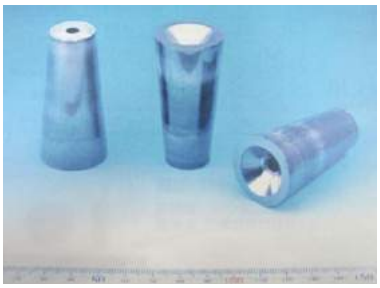
Large-sized oxide (Al_2O_3, ZrO_2, SiO_2), carbide (WC, SiC, B_4C), nitride (Si_3N_4) and boride (TiB_2) ceramic materials have also been fabricated homogenously with finer grain size and almost full density. The samples shown in Fig. 16 were investigated by SEM and it was observed that almost no residual micro pores and no cracks were present in the sintered compacts.

Pure WC (tungsten carbide) aspheric glass lens mould

The growing demand for in-vehicle camera systems for monitoring road conditions, as well as general surveillance and security cameras, has greatly increased the need for the cost-effective production of high performance aspherical glass lenses used in the digital cameras. To meet this need, SPS has been utilised in the production of moulds used to form the aspherical glass lenses. The mould consists of three pieces; an upper punch, lower punch and sleeve die part. Fig. 17 shows examples of such moulds used commercially in the optics industry, which are made from a binderless pure-tungsten carbide (WC single phase, HV 2600) material.

The SPS moulds were homogenously consolidated in nano-structured fine grain size material. By using an ultra-fine grinding machine, a superior mirror surface finish, with a roughness of Ra 2-6 nm, can be obtained. The advantages of SPS pure WC are that no

Fig. 17 Examples of pure WC Aspheric glass lens mould materials



Material: Al_2O_3 Length: 60mm
Outer dia. (Tapered):30/15mm
Inner dia. (Straight):6mm

	General commercial products	SPS sintered nozzle	Advantage of SPS sintered nozzle
Vickers hardness (HV)	900 - 1100	2100 - 2200	High hardness
Relative density (%)	91	100	High density
Surface	Rough	Mirrored surface	Mirror finished surface by near-net shape
Lifetime	One day	Ten days	Ten times longer lifetime

Fig. 18 Comparison of SPSed nozzle and other commercial product

additives are used in the solid-phase sintering and a finer grain size as well as higher oxidation resistance is achieved, compared to conventionally produced binderless WC materials. By running a 10 h oxidisation test in an atmospheric furnace at 973 K, a 30-60% better oxidisation rate in volume (g/cm^3) was demonstrated.

Complex near-net shape forming of Al_2O_3 blasting nozzle

An example of an Al_2O_3 ceramic nozzle, used in sand-blasting apparatus, is shown in Fig. 18. Comparative testing between a conventionally manufactured nozzle and one made using SPS process, was undertaken in real-time blast operating conditions. The SPSed Al_2O_3 nozzle achieved ten times longer life span than a conventionally sintered one produced in an atmospheric pressureless sintering furnace.

The SPS nozzle is produced without post processing and has Vickers hardness of HV 2100-2200, compared to a conventional nozzle with HV 900-1100. Produced to near-net shape accuracy, a Ra 0.64 µm surface roughness was obtained.

Emerging super-plasticity and high specific strength of aluminium-Si alloy materials

The SPS process can be used to achieve nanostructured dense high-silicon/aluminium alloys. The rapidly solidified Al-Si powder, of average particle size 120-150 µm, silicon content 12–17% or higher and nanocrystalline structure, was successfully consolidated into Ø 60–120 mm x 40–60 mm cylindrical compacts with between 600–800 nm grain size as shown in the TEM micrograph in Fig. 19. The sintered compacts, with relative density of almost 100%, were obtained at temperatures of 723–773 K, applied pressures of 100–150 MPa and heat up and holding time of 20 min. When the Ø 60 mm x 40 mm nanostructure SPSed bulk body was formed into a three dimensional shape for an automotive engine piston component, by a high-speed forging press machine, it was demonstrated to provide full forming for lengths of 75 mm within 15–20 seconds per stroke with the strain rate of $10^{-2}S^{-1}$ or higher. The results indicate the phenomenon of 'super-plasticity' occurred, improving the ductility and elongation of the sintered compact. The tensile strength was 350 MPa and it was approximately 1.5 times stronger than a conventionally forged component. This Al-Si alloy with nanostructural material is expected to find wide applications in various electric appliances, electronics and automotive components [23].

Porous materials prepared by SPS

The fabrication of both metallic and ceramic porous structures is another application where SPS could offer advantages over existing sintering methods. In this example, the pure titanium and ZrO_2(3Y) bead struc-

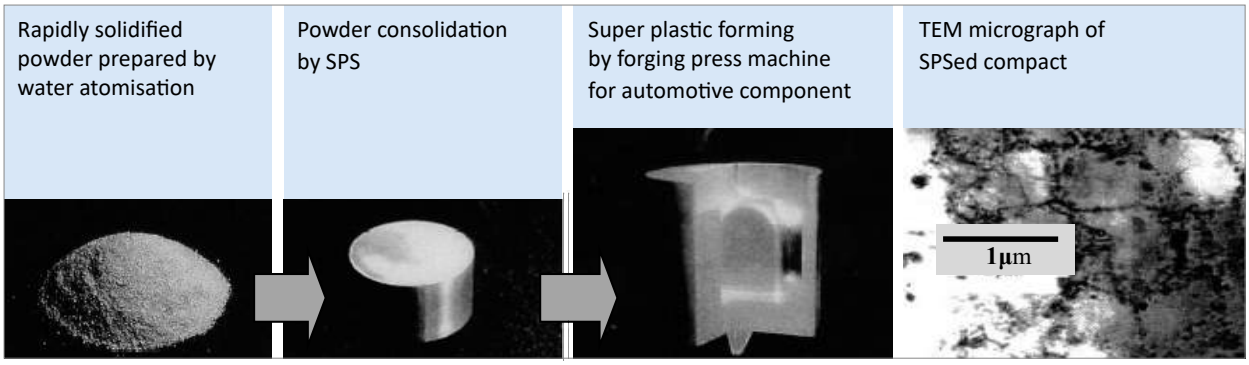


Fig. 19 Appearance of Super-plasticity on automotive component

tures seen in Fig. 20 are formed by applying a low sintering pressure in the range of 0–5MPa, demonstrating that it is possible to obtain high porosity with higher bonding strength at the neck portion.

Potential commercial applications for this process include materials for a bio-reactor, filters, artificial bone joints, vent core materials for a plastic moulding die, electric and hybrid-electric vehicle applications, solid oxide fuel cell (SOFC) batteries, thermo-electric semi-conductors, heat spreaders for thermal conductive components and others.

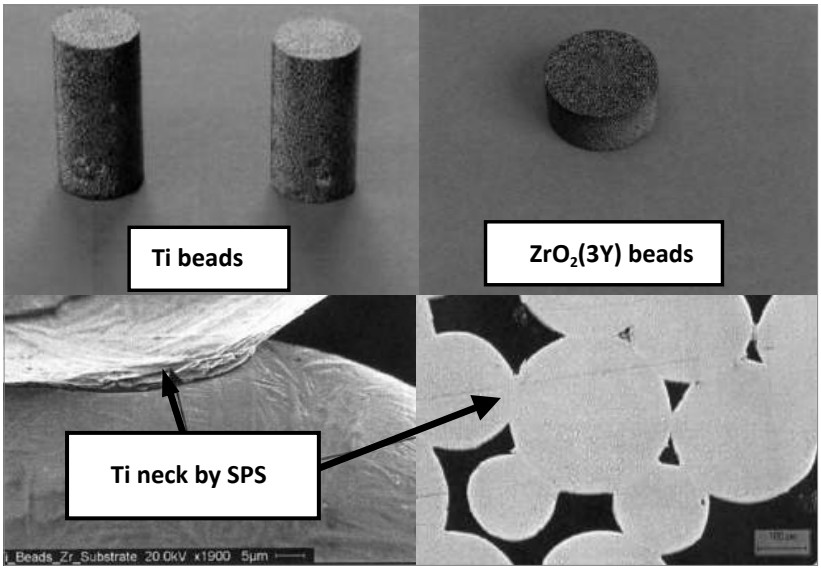


Fig. 20 Examples of porous material

Fine-WC/Co hard alloy FGMs for die & mould and wear-resistant materials industries

As a typical high-wear resistant material, WC/Co or WC/Ni system cemented carbides are now widely used in various press-stamping dies and cutting tools for industrial applications. Although the fabrication of WC/Co hard alloys usually takes many hours, with the development of new automated SPS systems, it is proving possible to sinter such materials in a significantly shorter period, taking advantage of the characteristics inherent in SPS rapid sintering technology.

Table 3 highlights the typical mechanical properties of SPS fine WC system hard alloy products. Fig. 21 shows the production machine's system configuration and an outside view of the fully-automated five-stage chamber-type continuous SPS system. Using this full tunnel automated system and optimised conditions, large square-shaped WC/Co cemented carbide hard alloys, with dimensions of 70 mm × 100 mm × 5-20 mm, were homogeneously fabricated in a shorter sintering time and with a finer grain size than conventional sintering methods. The fine-WC/Co hard alloys obtained by SPS show higher hardness, transverse rupture strength and fracture toughness, than those obtained by conventional methods.

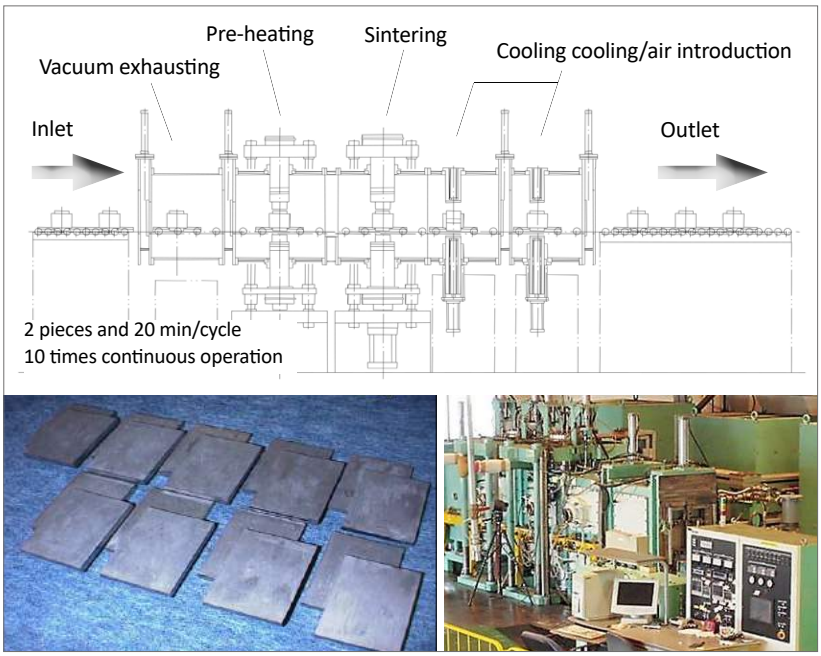


Fig. 21 System configuration and outside view of tunnel-type SPS and large-size 100×70 mm WC/Co cemented carbide hard-alloy compacts fabricated in 10 times continuous operation

Product code name	Co content wt.%	WC pdr. grain size µm	Density g/cm³	Hardness mHV	Transverse rupture strength MPa	Fracture toughness K1C
TC-05	<2	<0.5	15.2	2350	2300	6.2
TC-10	<4	<0.5	15.0	2150	2640	6.5
TC-20	<6	<0.5	14.8	2050	2940	7.3
M78	0	<0.2	15.4	2600	1500	5.1
WC100	0	<0.08	15.6	2700	1470	5.6
NC100	0	<0.5	15.4	2570	1180	5.4

Table 3 Typical mechanical properties of Fine WC/Co hard alloys by SPS

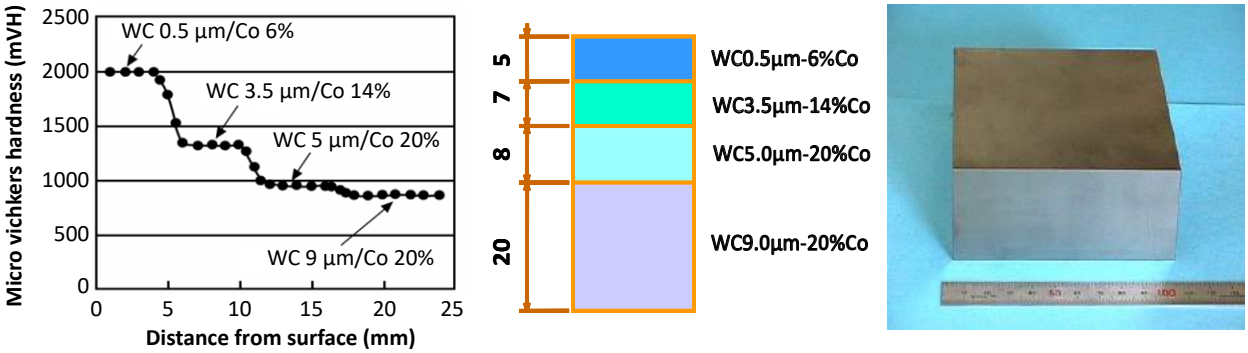


Fig. 22 Large-size WC/Co FGM fabricated by SPS (100 mm × 100 mm × 40 mm) and profiles of micro-hardness on Co content graded cemented carbide by SPS

WC/Co and WC/Co/Ni FGMs for industrial applications

In the first example, a WC/Co FGM block, compositionally graded by cobalt content and measuring 100 × 100 × 40 mm, was produced using SPS within an hour (Fig. 22) [32, 33]. The FGM was then machined by numerically-controlled wire-cut electrical discharge machine to remove smaller pieces of the material. As shown in Fig. 23, the smaller piece of WC/Co FGM was ground to form the specified profiles. The fine WC/Co FGM hard alloy demonstrated high hardness in the top layer and higher strength and fracture toughness in the bottom layer than a monolithic WC/Co hard alloy material. When assembled to form a press stamping progressive die set, the FGM sample achieved an approximately three and a half to ten times longer life time compared with conventional commercial WC/Co cemented carbides.

In a further project, a weldable WC/Ni FGMs screw, used in an extruding machine, was also produced using the SPS process (Fig. 24). The working life proved to be over three times longer than that of the conventional screw, resulting in more than 3000 h service compared to around a typical 800 h in the conventional screw. This FGM screw has proved a successful example of SPS manufacturing and has now been in operation for a number of years at Japan's Hokkaido Electric Power company [24].

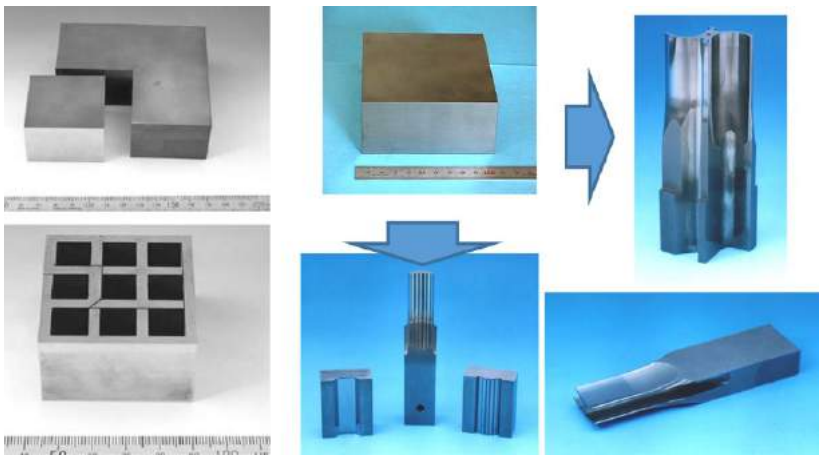


Fig. 23 Example of press stamping die and punch made of WC/Co FGMs for electronic component

Fig. 24 Weldable WC/Ni FGMs tile and the FGMs screw product for the extruding machine

Diamond dicing blades for cutting tool industry

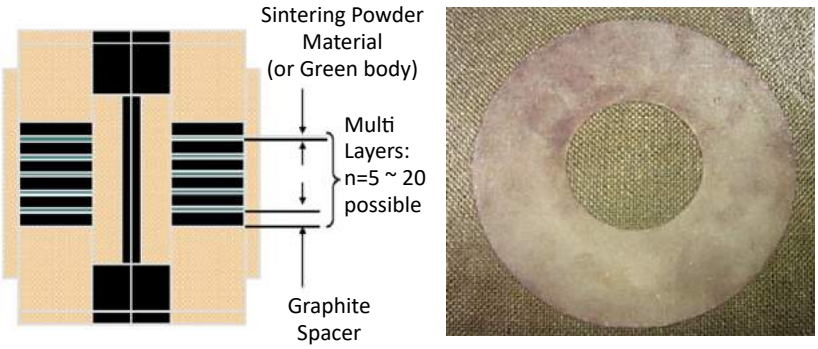
The manufacture of diamond dicing blades, for use in the cutting tool and wear-resistant materials industry, is a further example of how the SPS process can offer distinct advantages. As shown in Fig. 25, metal bonded dicing blades of 100/150 mm diameter and 0.35/0.4 mm thickness can be produced with a flatness level within ± 20 µm and minimal residual stresses. Obtaining such flatness by SPS eliminates a grinding process. The sintered WC/Co plate has relative density 99-100% and a Young's modulus

500-580 GPa was attained under SPS temperature of 1473–1523 K. To achieve series production, in this example continuous SPS operation through multiple work shifts per day resulted in the simultaneous fabrication of 15–20 plates per batch.

Other Industrial Applications

Although not discussed in this article, research into the use of SPS in other categories of materials includes MMC/FRC/FRM composites, thermoelectric semiconductors of SiGe, Bi_2Te_3, $FeSi_2$, $CoSb_3$, $MnSi_2$, Mg_2Si systems for clean energy generation, Nd-Fe-B, Sm_2Co_{17} and ferrite for magnetic materials, MgB_2 superconducting materials [25], $BaTiO_3$ [26], $PbTiO_3$ dielectric materials, shape memory alloys, solid cell materials, glassy metals, optically functional materials and nanocrystalline materials [27]. All could be promising candidates for industrial SPS applications [28].

Applications for SPS 3D forming methods and titanium/hydroxyapatite (HAP) for biomedical applications could also move from the R&D/prototype level into practical use in the near future [29,30].



Outer Diameter	Ø 100/150 mm
Inner Diameter	Ø 40/60 mm
Thickness	0.35/0.40 mm
SPS sintering temp.	1473 ~ 1523 K
Sintering Pressure	40 ~ 50 MPa
Relative Density	99 ~ 100%
Young Modules	500 ~ 580 GPa
Flatness	**<± 20 µm**

Fig. 25 WC/Co sintered very thin plate with diamond of Dicing Blade

Summary & outlook

In this article, the history and fundamentals of SPS, as well as the wider availability of SPS systems and related industrial applications have been discussed. Typical advantages of SPS processing are indicated in the synthesis of FGMs, nanocrystalline materials and wear-resistant hard materials. Due to the versatility of SPS, the remarkable and rapid growth in the number of presented papers and patents in the last decade should be noted, resulting from a new, worldwide adoption of SPS technology in both the scientific community and the industrial sector.

SPS features an electrical energy concentration at areas where current flows easily. In terms of the high energy density of dynamic sintering, further study of these characteristics will lead to the successful advancement and expansion of SPS applications for commercial production. The SPS process has the potential to become a major manufacturing tool in the automotive, electronics, mould & die, tooling, clean energy and aerospace industries, to name just a few, with opportunities in both high-value added, small scale and mass-production markets.

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