

POWDER METALLURGY REVIEW

VOL. 5 NO. 1
SPRING 2016



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Submitting news and articles

We welcome contributions from both industry and academia and are always interested to hear about company news, innovative applications for PM, technology developments, research and more.

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Subscriptions

Powder Metallurgy Review is published on a quarterly basis. It is available as a free electronic publication or as a paid print subscription. The annual subscription charge is £85.00 including shipping.

Advertising opportunities

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Design and production

Inovar Communications Ltd.

ISSN 2050-9693 (Print edition)
ISSN 2050-9707 (Online edition)

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POWDER METALLURGY REVIEW

India's Powder Metallurgy industry continues to thrive

India is one of the world's fastest growing major economies and with a reported GDP growth of around 7% a year the country has been one of the few to defy global economic slowdowns. There is increasing demand for vehicles and luxury goods, a fact not lost on many businesses that see opportunities in the huge domestic market, as well as making use of a large, relatively low cost workforce to manufacture those goods.

The global automotive industry is no exception and is investing in India, with many of the major automotive manufacturers now having bases in the country. Increased automotive production of course leads to growth in the supply chain, which is reflected in the growth of India's Powder Metallurgy industry.

There are however still a number of challenges for the country to overcome. As our interview with the President of the Powder Metallurgy Association of India reveals, the region's improving infrastructure is seen as one of the main factors enabling further growth in the manufacturing sector.

Remaining in Asia, China is the world's leading producer of cemented carbides accounting for over 40% of an estimated global production of 65,000 mt in 2014. The President of the Cemented Carbide Branch of the China Tungsten Industry Association reports on the current status, challenges and manufacturing outlook for the cemented carbide industry in China to 2020.

Paul Whittaker
Editor, *Powder Metallurgy Review*



Cover image

Powder Metallurgy sintering furnace (Courtesy Fluidtherm Technology)

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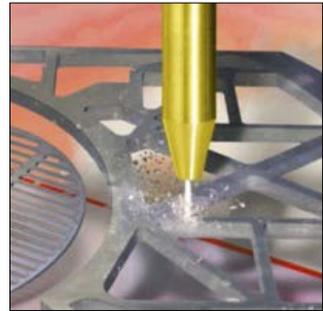
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33 INDIA FOCUS: The challenges and outlook for India's Powder Metallurgy industry

During a visit to India on behalf of *Powder Metallurgy Review*, Dr Georg Schlieper took the opportunity to meet with the President of Powder Metallurgy Association of India. During the meeting questions were answered regarding the current state of India's PM industry and the opportunities for growth in the country.

39 INDIA FOCUS: Fluidtherm Technology, India's innovative furnace manufacturer looks forward to continued growth

Fluidtherm Technology Pvt Ltd is India's largest manufacturer of furnaces for the Powder Metallurgy industry. Dr Georg Schlieper reports on a recent visit to Fluidtherm where he met with the company's founder and CEO, Narasimhan Gopinath.

49 China's cemented carbide industry: Growth prospects for the world's leading producer

China is the leading global manufacturer of cemented carbides with over 40% market share. Zhongjian Zhang, President of the Cemented Carbide Branch of the China Tungsten Industry Association, identifies key players and reports on the current state and outlook for the cemented carbide industry in China.

59 Hagen 2015: Advances in metal powder technologies at Germany's annual PM symposium

The Hagen Symposium, organised by Germany's Fachverband Pulvermetallurgie, is the annual meeting for the German speaking PM community. We report on a number of the key presentations from this year's event.

67 Safety in the PM industry: Steps in reducing the risk of fire and explosion with metal powder dusts

A session on combustible dusts at last year's POWDERMET2015 conference held in San Diego, USA, included two papers which assessed the potential risks with metal dusts and, perhaps more importantly, provided guidance on mitigation strategies to avoid these risks. Dr David Whittaker reports for *Powder Metallurgy Review* on the papers from this session.

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

GKN Powder Metallurgy reports record year for powder sales

GKN plc has reported its results for the year ended 31 December 2015, showing sales for the whole group increased to £7,689 million. Operating profit fell slightly to £679 million (-1%) over the previous year.

"GKN continued to make progress in 2015 and delivered on our expectations. We performed well against our key markets, overcoming some demand weakness and demonstrating once again the strength of our businesses, strong market positions and leading technology," stated Nigel Stein, GKN's Chief Executive.

"Highlights of the year were GKN Aerospace's acquisition of Fokker Technologies, strong market-beating growth by GKN Driveline and good margin advances by GKN Powder Metallurgy. Looking forward, we expect 2016 to be a year of good growth, helped by the contribution from Fokker," added Stein.

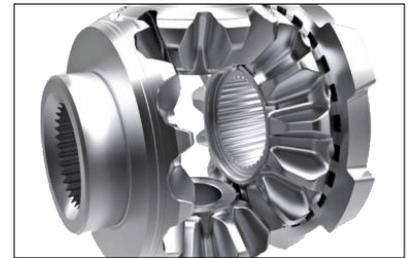
GKN Powder Metallurgy

GKN Powder Metallurgy, comprising GKN Sinter Metals and Hoeganaes, reported 2015 sales of £906 million with a trading profit of £109 million (up 6% on previous year). The company announced record sales of powder for the year. Underlying sales growth was achieved in North America, China and Europe but sales in Brazil fell sharply due to weaker automotive and industrial markets.

The divisional trading margin was 12.0% (2014: 11.0%), reflecting the move towards higher value "design for Powder Metallurgy" parts and a small margin benefit from lower raw material prices passed through to customers.

During the year, GKN stated that its Powder Metallurgy division achieved a number of important milestones, which included:

- Winning around £185 million of annualised sales in new and replacement business



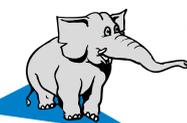
Around 80% of GKN Powder Metallurgy sales are to the automotive market. The Ford F-Series trucks are using GKN forged PM gears in open differentials and transmissions (Courtesy GKN)

- Its position in China being further enhanced by forming a new venture to produce metal powders, subject to approvals
- Development of new technically enhanced powders continuing with a new research titanium atomiser being commissioned at the Powder Innovation Centre, in the USA and the attainment of AS9100 Certification for the AncorTi™ range of gas atomised titanium powders for aerospace applications.

www.gkn.com ●●●



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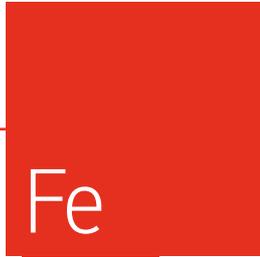
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Metalvalue and Asco Industries to construct world's largest gas atomised metal powder plant

France's Metalvalue SAS and Asco-Industries have set up a joint venture forming Metalvalue Powder, to produce gas atomised metal powders in what they claim will result in the building of the world's largest gas atomising plant. Studies are underway to finalise the location of the site.

Following the acquisition of Swedish company Bofors Bruk, parent company of Metec/Hydro-pulsor, Metalvalue acquired patents relating to the Scanpac® MMS

Powder Metallurgy process. The Scanpac® MMS process has already been licensed to a number of companies and the new atomising plant will supply metal powders to these clients, as well as supplying those using current PM processes.

Metalvalue also announced it is establishing a parts manufacturing plant in Etain, Meuse, France, that will initially double the production capacity of the Bofors Bruk facility in Sweden.

www.metalvalue.fr ●●●

Numanova Srl to manufacture range of powders for PM and AM applications

Italian investment group Italeaf has announced it has established Numanova Srl to produce metal powders suited to a range of Additive Manufacturing and Powder Metallurgy applications. The production plant will be located at Italeaf's facility in Nera Montoro, near Rome, and the company plans to have operating offices in Milan, London and Hong Kong.

Numanova states it will be active in the production of high-quality metal powders for Additive Manufacturing (3D printing), Metal Injection Moulding (MIM) and Hot Isostatic Pressing (HIP). The metal powders will be suited to advanced uses in areas such as aerospace, energy, mechanical and biomedical.

Investment of some €12 million has been announced and the company will be equipped with advanced gas atomised metal powder production technology. It will also use plasma atomisation technologies and total production capacity is expected to be around 500 tons/year of metal powders.

"The production of metal powders and the research and development activity to make new alloys are attracting interest and growing expectations on the global market," stated Paolo Folgarait, Numanova's Executive Director and General Manager.

"The versatility of the techniques of Powder Metallurgy can help to create complex and innovative metallic materials (and ceramic) and introduce new forms of production in advanced sectors with high added value," added Folgarait

Numanova added that it has concluded a number of framework agreements for business collaboration and technical-scientific cooperation with metal Additive Manufacturing systems providers and companies operating in the metallurgical sector. It has also signed agreements with national and international universities and research centres.

www.italeaf.com ●●●

Powder Metallurgy gearbox on show

Höganäs AB, Sweden, has reported that there was great interest shown in Powder Metallurgy gear technology at last year's CTI International Transmission Symposium and Expo, Berlin, December 8-10, 2015. The world's first six-speed manual transmission demonstrator car equipped with PM gear technology was on display.

The CTI Symposium and Transmission Expo is the largest transmission event in the world. The show attracts participants from all of the major automobile and transmission manufacturers, as well as suppliers from all over the world. Höganäs exhibited as part of the Powder Metal Gearbox Initiative, the unique PM industry collaboration to prove the concept, potential benefits and implementation readiness of PM gear technology in modern automotive transmissions. "We made a lot of new connections into the automotive industry and the transmission engineering expert community," stated Eckart Schneider, Director Global Development PM Components at Höganäs.

The final conference day included a test drive at a race track. There were some 15 different vehicles ranging from Porsches to Opels available. The consortium's demonstrator vehicle was one of the cars and demonstrated the performance of the PM gears. "Everything went well," added Anders Flodin, PMC Höganäs. "The drivers could not notice that there was any difference between a regular transmission and a PM geared transmission, which is what the Höganäs led PM gear consortium wanted to achieve."

www.hoganas.com ●●●



Makin Metal Powders appoints new Managing Director and expands team

Makin Metal Powders, based in Rochdale, UK, has announced that Jonathan Hood has been appointed Managing Director following the retirement of Dr John Boden on January 1st 2016.

Hood, whose previous role was that of Sales and Technical Director for the company, is a highly qualified metallurgist and is said to have a clear idea of how the company can continue to grow and develop under his leadership over the next decade. It was announced that as a first step he is expanding the leadership team by adding two new faces to the board.

On January 4th, Michael Yan, who was previously responsible for sales in East Asia, joined the board as Marketing Director. Yan has a technical background as well as considerable experience in Marketing and Sales for both Makin and parent

company GRIPM. Yan will retain responsibility for East Asia Sales.

In February 2016 Steve Ellis was appointed as the new Sales and Technical Director. Ellis has a degree in materials science as well as experience in metal powders and will represent a significant boost to the technical expertise available at Makin. Ellis has also operated at senior levels with companies in manufacturing and copper metals and will bring great operational and customer service knowledge and expertise to his new role.

Other changes announced include the appointment of Phil Wilcock as Finance Director after the retirement of Brian Hope in October 2015. Wilcock was previously Makin's Management Accountant.

www.makin-metals.com ●●●

Abbott Furnace announces departure of its President

Abbott Furnace Company, based in St. Mary's, Pennsylvania, USA, has announced that Jose M Medina has tendered his resignation as President, effective February 5, 2016. Abbott Furnace added that its Directors will take over responsibility for the day to day running.

"We are thankful for Mr Medina's leadership over the past year as the company has undergone a successful transition in ownership. We appreciate the support he has given to our employees and wish him success as he moves forward," the company stated.

Abbott Furnace manufactures a range of industrial furnaces for a number of applications.

www.abbottfurnace.com ●●●

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(*Elnik Systems will charge for 2 trial runs on DSH production equipment. Should a furnace be purchased within 1 year of these trial runs, Elnik will provide full credit for 2 trial runs off the price of the purchased equipment.)



SHW AG on target as Powder Metallurgy sales increase 8%

Germany's SHW AG, a leading automotive supplier of automotive pumps, engine components and brake discs, has published its preliminary, unaudited key performance indicators for the fiscal year 2015.

"We achieved major progress in the final stage of the fiscal year," stated Dr Frank Boshoff, Chief Executive Officer of SHW. "We reduced the tailbacks further in the Powder Metallurgy at our Aalen-Wasseralfingen plant and in the pump assembly at our Bad Schussenried plant. I am positive that the measures to enhance capacity at our Aalen-Wasseralfingen plant will be implemented by the end of the first quarter 2016 as scheduled, thereby sustainably enhancing our profitability in the Pumps and Engine Components business segment."

Due to the lasting high level of customer call-offs, particularly in the Pumps and Engine Components business segment, in the fiscal year 2015, SHW stated that it was once again able to disconnect itself from the general market trend and boost its group sales by 8% to €463.5 million (previous year: €430.0 million). Incoming orders at the group's domestic companies totalled €445.0 million, almost reaching the previous year's record amount of €453.5 million.

Adjusted consolidated earnings before interest, taxes, depreciation and amortisation (adjusted EBITDA) improved by 7% from €40.6 million to €43.5 million and was therefore within the target range of €42 million to €46 million publicised last September. The corresponding margin of 9.4% was at the previous

year's level. The reported net income for the year was €14.4 million, an increase of 34% on the previous year's figure of €10.7 million.

Efficiency programmes in Powder Metallurgy and pump assembly delivered initial successes

The Pumps and Engine Components business segment recorded an increase in sales of 9% to €365.2 million in the fiscal year 2015 (previous year: €333.6 million). Sales in its Passenger Car division grew by 13% to €306.6 million (previous year: €272.0 million) due to strong customer demand for variable oil/vacuum pumps, electrical auxiliary pumps for the start-stop function and camshaft phasers. The Industry division contributed €27.7 million to sales (previous year: €29.8 million). The Powder Metallurgy division boosted its total sales (including internal sales) in the fiscal year 2015 by 8% from €53.1 million to €57.5 million.

www.shw.de ●●●

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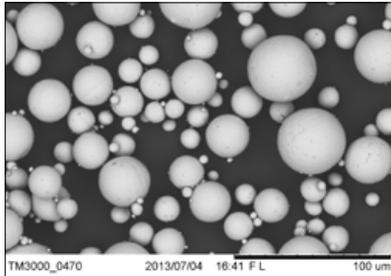
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LPW commences Plasma Spheroidisation of metal powders



LPW Technology has announced that its Plasma Spheroidisation equipment is now operational and producing metal powders for use in the Additive Manufacturing industry. The process uses high energy plasma to produce cleaner, highly spherical and dense metallic powders with greater flowability, reducing down time on the machine and speeding up the manufacturing process.

"We are hugely excited to have this next generation equipment on site for the benefit of our customers. LPW are constantly reacting to solve our customer's problems and ensure that we have the right solution to keep them on track," stated Mike Ford, LPW's Sales Director. "Our Plasma Spheroidisation can produce the best metal powders on the market. They are more spherical and cleaner than those currently available."

The most significant benefit of this novel technology is perfectly spherical powder with no satellites, which increases the flowability and packing density of the powder, especially on AM machines where finer powder is required. In addition, levels of surface contamination, compared to conventional gas-atomised powders, are reduced. This has the potential to enhance mechanical properties in the finished AM component.

www.lpwtechnology.com ●●●

EPMA PM Summer School 2016

The European Powder Metallurgy Association (EPMA) has announced that its 2016 PM Summer School will take place in Valencia, Spain, from June 27 to July 1, 2016. The five-day residential training course will be a mix of lectures, given by experts drawn from both industry and academia, laboratory work, group discussion, problem solving and a

factory tour. Topics to be covered include the manufacture of metal powders, MIM, modelling, sintering, HIP, magnetic materials and AM.

The Summer School is designed for young graduate designers, engineers and scientists from disciplines such as materials science, design, engineering, manufacturing or metallurgy. Graduates under 35 and who have obtained their degree from a European institution are eligible to apply.

www.epma.com ●●●



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China aims to complete restructure of its rare earth industry by mid-2016

The Chinese government has announced that its plans to restructure the country's rare earth mining industry will be completed by summer 2016. As the world's largest producer and exporter of rare-earths, China has had a number of problems managing its resources. Companies flooding the market have led to over-capacity, which is blamed for falling prices, and there have been issues with illegal mining and smuggling.

"But beyond excess capacity, illegal mining and illegal production also have a huge impact on the industry. Certain raw ores are illegally dumped by individuals as recyclable materials, then later extracted. This has formed an illegal industry chain which has a very bad influence on the development of China's rare earth industry. So, we need to crack down on that," Chen Zhanheng, Vice Secretary General of China's Rare Earth Industry Association, is reported by news service CRI as saying.

In 2014, the Chinese government singled out six different rare-earth industry leaders, promising them support to create large rare-earth producers by buying up small scale operations.

At a recent meeting, Xin Guobin, China's Vice-Minister of Industry and

Information Technology, is reported to have said that consolidation is already underway. "To deal with current problems in China's rare earth industry, we are consolidating and upgrading the industry in terms of production and mining procedures. So far, three firms have already formed rare-earth blocs, while another three are still working on it."

Xin Guobin stated that it is the government's hope this will be completed by the summer. "By the end of June we must complete the consolidation of all rare earth mines and firms in China. While this happens, we will continue to work with the companies through our various ministries to support the newly formed rare earth blocs, especially those who finish their consolidation on time."

The Ministry of Industry and Information Technology has stated that it expects there will be a reduction of rare-earth smelting this year through improved output controls and increased competitiveness. It was also reported that Chinese authorities stated that the country's rare-earth industry will have the world's best technology in use by the end of 2020. ●●●

EPMA launches 2016 PM Thesis Competition

The European Powder Metallurgy Association has announced the launch of its 2016 Powder Metallurgy Thesis Competition at both Diploma (Masters) and Doctorate (PhD) levels. The aim of the competition is to develop an interest in Powder Metallurgy, including Metal Injection Moulding, among young scientists at European academic establishments, and to encourage research at undergraduate and post-graduate levels.

The competition is open to all applicants who have graduated from a European university and who have had their theses approved during the 2013/2014, 2014/2015 or 2015/2016 academic years.

The prizes, sponsored by Höganäs AB, will be presented at the World PM2016 Congress & Exhibition, which will take place October 9 - 13, in Hamburg, Germany. The winner of the diploma category will receive a cheque for €750 and the doctorate category winner will receive €1,000. Both winners will also receive free registration to the World PM2016 Congress.

The deadline for submitting entries to the competition is April 29. www.epma.com ●●●

Porvair expands range of sintered steam filters

Porvair Filtration Group, based in Fareham, UK, has launched a new range of steam filters for process and culinary applications. Its Sinterflo® stainless steel filter elements are available in high quality 316L sintered metal fibre, metal mesh and sintered metal powder media.

Porvair's process steam filters are used where clean, dry steam is critical for plant performance and continuous operation, but where there is no direct contact with the manufactured product. The steam

filter elements are stated as having exceptional dirt-holding capacity and are designed to withstand demanding temperature and pressure conditions.

"Quality is at the heart of every stage of our operation and a fundamental part of our culture. Our continuous innovation in steam filtration products enables us to offer new and better solutions to applications - and our widened range for production processes is pivotal to that strategy. It's all in the pursuit of the best possible solutions for our

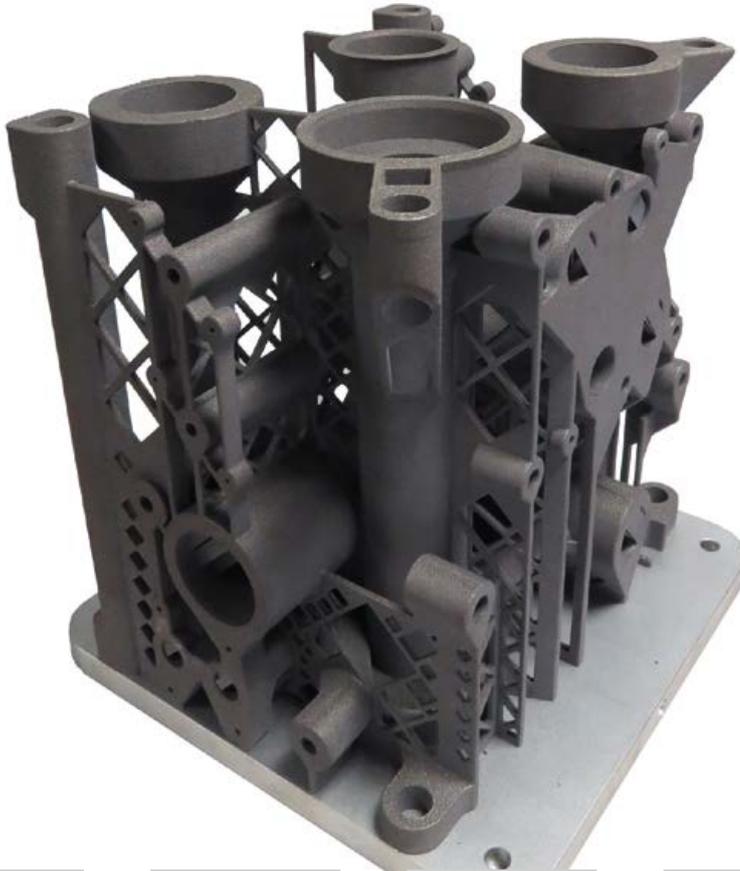


customers," stated Porvair's Market Manager, Andy Fairlie.

Porvair's steam filters are available in a selection of grades for the bespoke requirements across applications such as sterile packaging, pharmaceuticals, brewing, dairy farming, food and beverage and chemical production.

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EPMA announces new Executive Director

The European Powder Metallurgy Association (EPMA) has announced that Dr Lionel Aboussouan is to be appointed as EPMA Executive Director, succeeding Jonathan Wroe who died suddenly late last year following a short illness.



Aboussouan will officially begin the day-to-day running of the EPMA, its staff and projects, following the association's General Assembly on April 8, 2016 in Brussels. In the meantime, Dr Volker Arnhold, former GKN Executive Manager and EPMA Board & Council Member, has been recruited as a temporary Executive Director to assist during Aboussouan's introductory period.

Aboussouan has previously worked at Arcelor Research and the World Steel Association, which represents over 150 steel producers (including nine of the world's ten largest steel companies), national and regional steel industry associations and steel research institutes.

More recently Aboussouan was employed at Arcelor-Mittal as the Head of Health, Safety, Environment and Quality, for one of the company's business units.

"Many of Lionel's skills and working practices that he has gained over his working career will be a real asset to the EPMA moving forward," stated EPMA President Philippe Gundermann. "Lionel will build on the firm foundations left by Jonathan and work with EPMA Members, staff and stakeholders to continue the success of one of Europe's leading trade associations."

www.epma.com ●●●

Carpenter to add titanium furnace equipment to its new superalloy powder facility

Carpenter Technology Corporation, Wyomissing, Pennsylvania, USA, is reported to be spending an additional \$23 million to add titanium furnace equipment to its new superalloy powder facility in Limestone County, Alabama. The purchase will raise Carpenter's investment in the plant to \$61 million.

The new plant's titanium powder product offering will increase Carpenter's reach into aerospace and medical markets and offer growth opportunities in transportation, Tony R. Thene, Carpenter President, CEO and Director told the Decatur Daily. Carpenter is close to completing its second Limestone County plant. The company's first Limestone County plant, a \$518 million superalloy metal plant, began production in early 2014.

www.cartech.com ●●●

ALD Vacuum Technologies expands market presence in North America with acquisition of ALD-Holcroft

AMG Advanced Metallurgical Group N.V. has announced that ALD Vacuum Technologies of Hanau, Germany, has acquired the remaining 50% share of its joint venture company ALD-Holcroft Co. Inc. of Wixom, Michigan, USA from AFC-Holcroft LLC of Wixom, Michigan, USA.

ALD-Holcroft, formed in 2005, acts as the exclusive sales agent for ALD's heat treatment product lines in the NAFTA region. It was stated that the acquisition will enable AMG to streamline its heat treatment and metallurgy furnace marketing operations in North America, Canada and Mexico. AMG produces highly engineered specialty metals and mineral products and provides related vacuum furnace systems and services.

AMG Critical Materials produces aluminium master alloys and powders, titanium alloys and coatings, ferrovanadium, natural graphite, chromium metal, antimony, tantalum, niobium and silicon metal. AMG Engineering designs and produces vacuum furnace equipment and systems used to produce and upgrade specialty metals and alloys for numerous markets.

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SLM Solutions to begin metal powder production

SLM Solutions Group AG, a provider of metal-based additive manufacturing systems based in Luebeck, Germany, has announced it is entering into a cooperation venture with PKM Future Holding GmbH to manufacture metal powders. PKM is the main shareholder of TLS Technik GmbH & Co Spezialpulver KG, a manufacturer of gas atomised metal powders in Bitterfeld, Germany.

"At the time of our IPO we had clearly stated our three-column growth strategy: alongside research and development, as well as distribution and service, the planned expansion of our metallic powder business was to represent a decisive building block," stated SLM Solutions' CFO Uwe Bögershausen "We are pleased to have now found the right partner in PKM, enabling us to offer our customers tailored solutions

in the consumables area. Together with TLS's main shareholder, we will invest a mid-range, single-digit million euro amount to this end."

The development, production and distribution of aluminium alloys for metal-based Additive Manufacturing systems is intended to form the core of the cooperation between PKM Future Holding GmbH and SLM Solutions Group AG, within a joint venture that will be formed. According to the contract, SLM Solutions intends to acquire 51% of the share capital of this planned joint venture.

"We are starting off with aluminium, an important material for us, and we are planning – along with actual production – to also implement refining steps for the powder. This will enable us to adapt consumables even better to customer requirements,"

stated CEO Dr Markus Rechlin.

"We are planning a total production capacity of more than 100 tonnes of aluminium powder per year for Additive Manufacturing purposes. We aim to offer other materials than aluminium at a later point in time."

SLM Solutions intends to bundle the powder business within a separate organisational unit, together with further services for the AM of metal components such as training, consulting and financing, in order to take the particularities of the business into account.

"By generating continuous sales over the course of the year, expanding the powder business should help us offset the strong seasonality of our system business," added Bögershausen. "Over and beyond this, the consumables area is also interesting for us due to the fact that attractive margins can be achieved through developing and marketing metallic powders."

www.slm-solutions.com ●●●



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Hoeganaes Corporation announces AS9100C Certification

Hoeganaes Corporation, based in Cinnaminson, New Jersey, USA, has announced that it has achieved AS9100C Quality Management System certification for its Innovation Center facility located in Cinnaminson. The AS9100C Quality Management System provides the basic quality framework necessary to address both civil and military aviation and aerospace needs.

This enhancement to Hoeganaes's quality systems follows a multimillion-dollar investment in 2015 for the commercialisation of advanced powders for Additive Manufacturing and MIM. The production, design and distribution of its AncorTi™ range of gas atomised titanium powders are now certified under the scope of this rigorous aerospace quality standard. "The attainment of AS9100C certification further demonstrates our long term commitment to delivering high performance powders for AM to world class customers operating in aerospace markets," stated Mike Marucci, Global VP, Advanced Technology. Hoeganaes continues to be certified under the ISO/TS 16949 for automotive quality management, ISO 14001 environmental management and OHSAS 18001 safety management systems.

www.hoeganaes.com ●●●

Titanium Europe 2016 event heads to Paris

The International Titanium Association has announced that its Titanium Europe 2016 conference and exhibition will take place in Paris, France, April 18 – 20. The event will provide a platform to gain insights into the European titanium industry and will serve as a networking venue for business executives and consumers alike.

Presenters at the conference will provide outlooks on world supply and demand, look at developments in the ever-lengthening global supply chain, clarify business trends driving the key commercial aerospace sector and report on the dynamics of the titanium industry in developing new industrial markets and development of innovative products. They will also share insights on the potential for titanium Additive Manufacturing as a novel, game-changing technology.

The event is anticipated to draw a strong number of industry professionals to discuss the dynamics of the European titanium industry. The organiser is also planning a variety of industry related and sightseeing tours for delegates, which includes a visit to Snecma, one of the world's leading manufacturers of aircraft and rocket engines.

www.titanium.org ●●●

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Solid global growth in auto sales and production expected to continue in 2016

2015 was a good year for the global automotive industry. In Western Europe (EU28+EFTA) 2015 showed an increase in new car registrations of 9.2% to 14.2 million units with the smaller Western European car markets such as Netherlands, Sweden, Belgium and Denmark showing particularly good gains. The Russian light vehicle market, however, is still contracting with sales falling by 36% to 1.6 million units, a level last seen during the crisis of 2009.

The US market for new light vehicles sales grew by 6% in 2015 to 17.4 million units whilst light vehicle production in the USA saw a 3.6% increase to 11.77 million units. Overall light vehicle production in North America increased by 3% in 2015 to 17.95 million units with Mexico up 6.1% to 3.39 million units but Canada's production contracted by 4.8% to 2.27 million.

The Chinese passenger car market continues to break records with sales climbing by 7.3% in 2015 to 21.146 million units and production rising by 5.8% to 21.079 million. Sales were particularly strong in the smaller engine cars (up to 1.6 litres) for which tax breaks were introduced in October.

In Japan new car sales slumped by 10% in 2015 to

4.2 million units with the increase in VAT said to be the main reason for the decline. Passenger car production in Japan was down by 5.5% in 2015 to 7.830 million compared with a year earlier. Car production in South Korea increased by 1.2% to 4.58 million, which is just short of the peak of 4.66 million achieved in 2011. Korean car sales increased by 9.1% to 1.81 million.

Other significant car markets in the ASEAN region include Thailand and Indonesia. Thailand reported a 1.76% increase in vehicle production in 2015 to 1.913 million but a 9.4% drop in sales to 799,632 units. Vehicle production in Indonesia dropped by 15.4% in 2015 to 1.098 million.

India has one of the largest vehicle manufacturing industries in the world with annual production of 23.37 million units reported for financial year 2014/2015, an increase of 8.7% over the previous year. Of this total, car production accounted for 3.220 million units, a growth of around 6%. In

Brazil new vehicle registrations dropped by 26% in 2015 to less than 2.5 million as the country continues to battle with a deep recession. Vehicle output in South America was down an estimated 20% for the region as a whole and with Brazil down by 22%. Further declines are expected in South America in 2016.

Forecasts from IHS Automotive, a leading source of market data on the global automotive industry, predict that China, Europe and North America will again do well in 2016. Europe is forecast to grow by around 1.7% with production surpassing 21 million units. China is likely to achieve over 5% growth in output in 2016, whilst Japan is expected to achieve a more modest growth of 2.3%. India's automotive sector is forecast to grow by around 9% in 2016. ●●●

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Bodycote charts the history of metallurgy with interactive timeline

Bodycote, UK, has added an Interactive History of Metallurgy to its website that charts the history of metal processing and heat treatment. Containing over 200 images and numerous videos, the timeline identifies important and fascinating discoveries in the working of metal during more than 10,000 years of history.

Starting in 8700BC with the world's oldest known copper artefacts, through to the metallurgy and engineering processes of today, the resource charts the development of metal working from early mankind through to the scientific and technical breakthroughs of the 20th century.

Bodycote developed the interactive resource to explore the evolution of metallurgy and heat treating and to acknowledge the collective work of scientists and engineers whose hard work and discoveries have enhanced the properties of metals and alloys making them better suited to deliver safer, more durable results in an expanding field of applications.

www.bodycote.com/history-of-metal ●●●



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Anhui Yingliu Group installs Quintus Hot Isostatic Press

Jan Söderström, CEO of Quintus Technologies (formerly Avure Technologies), joined Frank Du, President of China's Yingliu Group, to celebrate the inauguration of a Quintus® Hot Isostatic Press (HIP) at the Anhui Yingliu Group Huoshan Casting Co. Ltd. foundry in Anhui province, China, in early December 2015.

The new HIP is the world's largest in its pressure and temperature class. The new press, QIH 1.6 x 2.5 – 2000 – 1400M URC, brings several advanced capabilities that enable the Huoshan facility to manufacture products meeting mission-critical performance standards in the aerospace and nuclear power environments.

Operating at a pressure of 200 MPA and temperatures up to 1400°C, the Quintus HIP produces complex components with improved fatigue strength and extended service life, ever more important character-



istics that are difficult to achieve in traditional manufacturing technology.

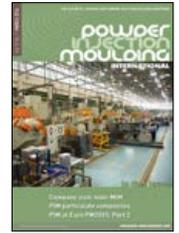
"Quintus HIP systems produce parts with excellent isotropic material properties and offer the highest possible density of all available compaction methods," stated Jan Söderström, CEO of Quintus Technologies.

The event was attended by more than 500 guests, including representatives from prominent Chinese companies in the aviation and nuclear power industries.

quintustechnologies.com ●●●

PIM International out now

The 88 page March 2016 issue of *Powder Injection Moulding International* (Vol. 10 No. 1) has just been published and is now available for free



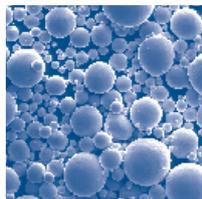
PDF download from the magazine's website. In addition to over 40 pages of industry news, this issue includes the following articles:

- Indo-MIM: A giant in Metal Injection Moulding expands to build on strong international growth
- Opportunities in the PIM of Particulate Composites
- Euro PM2015: Innovative materials offer growth opportunities for PIM
- High Pressure Capillary Rheometer, a simple way to measure the viscosity of MIM feedstocks?

www.pim-international.com ●●●

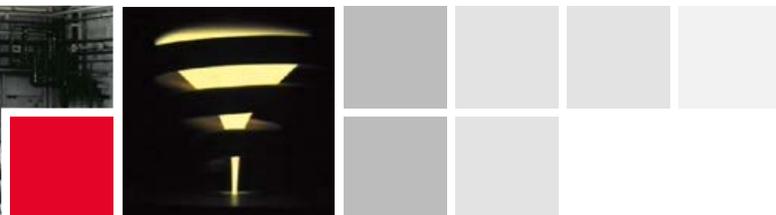
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Hardide Coatings opens new US facility

Hardide Coatings, headquartered in Bicester, Oxfordshire, UK, has announced the opening of a new \$7 million production facility in Virginia, USA. The expansion has been driven by increased demand from North American customers, with sales to the US and Canada more than doubling during 2015. The new factory is expected to create up to 29 jobs over the next three years.

The site in Martinsville-Henry County will service existing and new customers for the company's patented range of hard wearing tungsten carbide coatings in the oil and gas and flow control markets. In addition, the company also plans to expand in the aerospace and advanced engineering sectors and develop applications for its newly-patented coating for diamonds.

Philip Kirkham, CEO of Hardide plc stated, "Having a local production facility in North America will

support the increased demand from existing customers and significantly boost opportunities to expand provision of our coatings throughout the region. We have installed two large capacity chemical vapour deposition (CVD) coating reactors and work is already progressing well on some very exciting customer trials. I would like to thank all in Martinsville-Henry County and Virginia Economic Development departments for their help and assistance and in particular Governor McAuliffe and Secretary Jones for their personal support in helping to get this project underway in Martinsville."

The first two senior employees at the facility, Jamey Ewing, Coatings Supervisor, and Barry Farmer, Pre-treatment Supervisor, spent 12 weeks during the summer in the UK at the company's head office and main production site in Bicester. The pair were trained on the Hardide



Jamey Ewing (left) and Barry Farmer of Hardide Coatings, Inc

coating production processes and techniques and returned to Virginia in September 2015 to assist with the installation and commissioning of the process, production and quality control equipment.

"Production for North American customers, currently being carried out in the UK, will be gradually transferred to Virginia on a case-by-case and phased basis, taking load and capacity of both sites into consideration," added Kirkham.

www.hardide.com ●●●



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Fall in metal prices continued in 2015

Last year has seen a fall in the value of a number of metals. Copper prices have more than halved since their peak in 2011, and dropped from \$6300/mt at the beginning of 2015 to around \$4500/mt at end of January 2016. Nickel has fared even worse falling to \$8500 from \$15,500 a year earlier, cobalt fell to \$22,000/mt from \$31,000, and molybdenum from \$20,000 to \$11,900/mt. Steel billet fell by more than 50% from \$490/mt to \$220/mt.

Over the course of 2015 tungsten (-40%), niobium (-21%) and tantalum (-37%) all experienced substantial downturns in both pricing and consumption and there is likely to be a period of restructuring and consolidation of supply in the year ahead. Tungsten APT prices continued their downward trend in the middle of 2015 to fall to \$160-\$165 mtu in January 2016 from \$320-\$350 mtu a year earlier. The tungsten

market was in oversupply leading to mine production of 87,000 mt exceeding consumption in 2015. In late 2015 the sole tungsten mine in Canada suspended operations because of low W prices and was placed on care and maintenance status. Eight large Chinese tungsten producers are reported to be planning to reduce output of W concentrates.

Bucking this negative trend, however, a new tungsten mine began production in Zimbabwe in 2015; a large new mine in Vietnam has ramped up production for APT and tungsten oxides, the Drakelands tungsten mine in Devon, UK, is scheduled to start production in August 2016 and new ferrotungsten plants also began production in Russia and the Republic of Korea. Drakelands is operated by Wolf Minerals and said to have one of the Western World's largest reserves of tungsten at 37.5 million tonnes. Wolf aims to generate 5,000 tonnes of tungsten concentrate per year over 10 to 15 years. ●●●

Sandvik appoints new Executive VP and CFO

Sandvik has announced that Tomas Eliasson has been appointed Executive Vice President and CFO of Sandvik and member of the Group Executive Management, effective no later than July 2016.

Eliasson is currently CFO for Electrolux, a position he has held since 2012. Previously, he was CFO for ASSA ABLOY during 2006-2012 and Seco Tools between 2002-2006. His professional career started at ABB in 1987.

"Tomas Eliasson has extensive experience from relevant industries and companies. He will be a strong contributor to Sandvik in the finance areas and he will also take a leading role in driving the further progress of the Sandvik Group in general," stated Björn Rosengren, President and CEO of Sandvik.

www.sandvik.com ●●●



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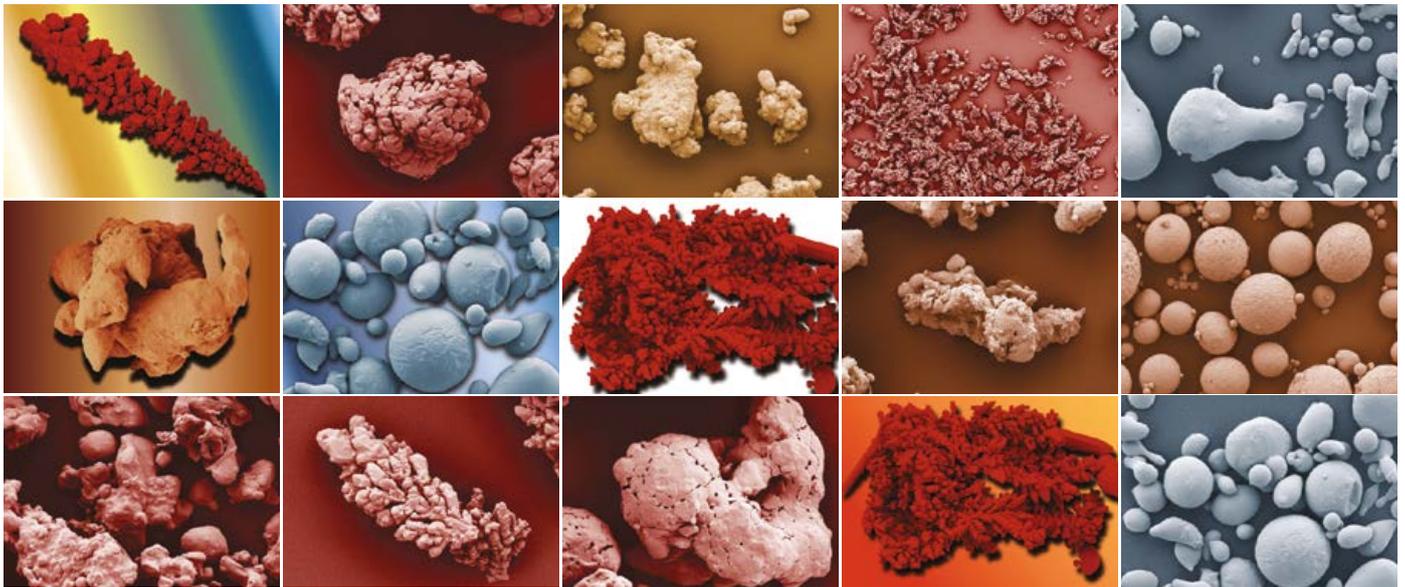




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Carpenter Technology relocating corporate headquarters to Philadelphia

Carpenter Technology Corporation, a producer and distributor of premium alloys, including special alloys, titanium alloys and powder metals, has announced plans to relocate its corporate headquarters to Philadelphia from Wyomissing, a suburb of Reading, Pennsylvania, USA. It was stated that the new headquarters location will allow the company to deepen its customer relationships and play a more integral role in the development of its customers' products.

Carpenter anticipates that the new Philadelphia location will ultimately be home to around 100 positions, while nearly 2,300 Carpenter personnel will remain in Reading. The company added that no planned job reductions are part of the relocation and the relocation is not expected to have any material increase in overall expenses.

"Carpenter is positioning itself for continued growth," stated Tony

R Thene, Carpenter's President and Chief Executive Officer. "As we have expanded our manufacturing footprint and sales presence over the past decade, it has become more important to raise our visibility, broaden our talent pool and improve access to our customers and partners. The Reading manufacturing location remains crucial to the current operating plan and the stated strategy going forward. We're proud of our 125 plus years in Reading, and we remain committed to Reading and to the state of Pennsylvania, where Carpenter today employs more than 3,300 personnel."

Carpenter is in the process of reviewing office locations in Philadelphia appropriate to its needs and growth objectives, with the goal of completing the move in late 2016.

www.cartech.com ●●●

Metalysis receives £20 million investment

The Australian mining company, Iluka Resources Ltd, has announced that it will invest a further £6 million in UK metal powder producer Metalysis Ltd, with an undertaking to commit an additional £4 million before 15 July 2016. The £10 million in total is expected to take Iluka's stake in the company from 20.8% to 28.8%.

Iluka's additional investment, together with an investment of £10 million from UK based Woodford Patient Capital Trust will support Metalysis' commercialisation process as it seeks to further develop its single stage process for a low cost, low environmental impact, transformation of various metals into powder form.

David Robb, Iluka's Managing Director stated, "If Metalysis can commercially produce titanium metal powder direct from rutile and synthetic rutile, at materially lower cost than current technologies, then a dramatic expansion in demand for titanium metal and titanium alloys could be expected. The application of titanium powder in 3D printing also presents potentially significant opportunities in a rapidly expanding market. Such developments would be positive for high grade titanium dioxide feedstock demand."

Iluka's support for Metalysis has been both financial and technical, with an example of the latter aspect being test work involving the addition of other elements to synthetic rutile which allow customised titanium metal alloys to be produced.

"Iluka is encouraged by the progress made by Metalysis towards commercialisation of its solid state metal powder technology. The company is also pleased at the increased focus on titanium as the core element of the Metalysis strategic plan, with a goal to accelerate commercialisation and licensing of its technology," added Robb.

www.iluka.com

www.metalysis.com ●●●

Kennametal appoints DeFeo as President and Chief Executive Officer

The board of directors of Kennametal Inc. has announced the appointment of Ronald M DeFeo as the company's new President and Chief Executive Officer (CEO). DeFeo replaces Donald Nolan, who has left the company to pursue other interests after serving as President and CEO since November 2014.

"We have determined a change in leadership is necessary and are pleased that Ron will step into this role," stated Kennametal Chairman of the Board of Directors Lawrence W Stranghoener. "Ron is a highly experienced CEO who will bring much wisdom, experience and passion for Kennametal. He will sharpen our focus, prioritise our results, and motivate, engage and empower our people to produce the financial results that are expected of an industry leader like Kennametal. We

appreciate Don Nolan's service. He was a necessary change agent through a period of significant turmoil and uncertainty."

A Kennametal board member since 2001, DeFeo served as the Chairman of the Board and Chief Executive Officer of Terex Corporation, a global manufacturer of machinery and industrial products, from March 1998 and March 1995, respectively, until his retirement from the company at the end of 2015. He joined Terex in 1992.

"As a 14-year member of the Kennametal board, I know what the company and its people are capable of achieving," DeFeo stated.

www.kennametal.com ●●●





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Herbert Danninger and Alberto Molinari receive honorary doctorates from Spain's UC3M

Spain's Universidad Carlos III de Madrid (UC3M) has awarded honorary doctorates to Professor Herbert Danninger, TU Wien, Austria, and Professor Alberto Molinari, University of Trento, Italy.



Shown left to right: Alberto Molinari, Mónica Campos and Herbert Danninger during the presentation

The award is the university's highest

academic distinction and is given to an individual for their academic, scientific or artistic endeavours.

Both Danninger and Molinari are international experts in the field of materials science and engineering. "They are two exemplary figures in their field of knowledge," stated Professor Mónica Campos during the ceremony. Campos is a professor in the UC3M Department of Materials Science and Engineering and Chemical Engineering. This department and the Álvaro Alonso Barba Technological Institute of Chemistry and Materials promoted the investiture of the new doctors' honoris causa.

In his acceptance speech, Danninger stated that it was a great honour to receive this degree from a university he has collaborated with for many years as a result of a shared interest in Powder Metallurgy. Professor Molinari, who also participated in joint research projects and teaching under the auspices of the Höganäs Chair, was deeply moved by the new honorary doctorate award. In his speech, he defended teaching and research as complementary and basic paths at university. In addition, both mentioned the collaboration with UC3M Full Professor José Manuel Torralba, who was also attending the event as the regional government's head of the Directorate General for Universities and Research.

Both academics are linked to the prestigious Höganäs Chair in Powder Metallurgy, in which the UC3M participates. They have made many contributions through this association, such as participating in doctoral courses and other educational sessions, the exchange of doctoral students, the creation of joint science publications, etc.

With more than 400 scientific publications in renowned journals, Danninger and Molinari have taught for more than a quarter of a century and held important posts at their universities. "Both have known how to maintain continuous relations with companies from the sector, allowing and facilitating an effective transmission of knowledge to companies," added Campos.

www.uc3m.es ●●●

Inductive components from SMP for medical technology applications

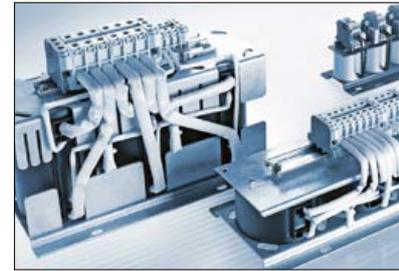
SMP Sintermetalle Prometheus GmbH & Co KG, the German manufacturer of soft-magnetic materials and inductive components based in Graben-Neudorf near Karlsruhe, has announced the development of components for use in Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) systems. Designed as filter or mains chokes, they claim to offer compact, low-loss and energy efficient components that are exceptionally quiet in operation, essential qualities for these demanding medical technology applications.

In MRI scanners the components are installed in the gradient amplifiers which supply output voltages and currents and control the gradient coils that encode the resonance signals for subsequent image reconstruction. The filter and mains chokes are designed to ensure a

clean sinusoidal waveform and low-loss feedback of the unused energy.

Special magnetostriction-free materials, which SMP develops and produces according to individual customer specifications, ensure that components run very quietly. The powder composite materials feature low eddy current and magnetic reversal losses. The components are noted for their low loss balances and optimal EMC properties. They are also maintenance-free.

The three-dimensional isotropy of the materials enables compact, lightweight structures, because the magnetic circuits are minimised. This also lowers the magnetic field strength and the quantity of winding material used can be significantly reduced. The materials have a high saturation induction, up to 2 Tesla, and the oscillation behaviour of the choke can be adjusted specifically by



Components from SMP are installed in the gradient amplifiers which supply output voltages and currents

using certain materials or appropriate, magnetically coupled designs with multiple coils.

Besides medical technology, SMP's inductive components are used in industrial applications in power electronics, automation and signal processing, in drive engineering applications including railway technology, electromobility and maritime engineering, for renewable energies as well as conventional energies, and in the aerospace industry.

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Finding the way forward for nuclear Powder Metallurgy applications

Powder Metallurgy manufacturing methods are yet to be embraced or approved by the civil nuclear industry, but some of Europe's major nuclear organisations are now assessing this potential, reports Mark D'Souza-Mathew, Metallurgist at the UK's Nuclear Advanced Manufacturing Research Centre in Rotherham, South Yorkshire.

As part of continuing efforts to improve the safety of future designs of nuclear power plants, reactor developers are exploring alternative methods for fabricating reactor pressure vessels. Powder Metallurgy offers several advantages over conventional methods by removing weak spots such as welds through near-net shape manufacture. PM parts also have reduced compositional segregation and a finer, more consistent grain structure, which is especially advantageous for bulk non-destructive evaluation techniques such as ultrasonic examination. While studies have shown that PM parts can meet and often exceed the performance of wrought parts under test conditions, there are areas for improvement such as high porosity, oxygen levels, inclusions and epitaxial effects.

A consortium of reactor developers, manufacturers and research institutions are now exploring how PM can be developed for the nuclear

industry. The PowderWay project is funded by the European Commission through Nugenia, the European association for R&D in nuclear fission technologies, and is led by the UK's Nuclear Advanced Manufacturing Research Centre. Project partners include reactor developer Areva, utility group EDF, French nuclear suppliers association PNB, French energy commission CEA and Swedish materials research group Swerea.

The consortium has identified a number of candidate components for PM manufacture and is now consulting with end users to better understand the benefits of PM over conventional manufacturing methods, the acceptance criteria for standardisation and the current state of the art. Crucially, the research will also reveal any obstacles preventing uptake of PM methods. The results will be used to construct a development roadmap which will guide themes for future research funding.

This roadmap will benefit the wider PM industry by targeting research funding towards improving resistance to harsh environmental conditions, enhancing performance and reducing ageing in PM parts. It will also disseminate information about PM through the supply chain and promote the technology to other sectors.

The PowderWay project strategy

is fairly straightforward, states D'Souza-Mathew. It is defining part requirements through consultation with the end users – this includes typical dimensions of candidate reactor pressure vessel parts, as well as thermal, mechanical, fatigue, corrosion resistance and microstructural characteristics.

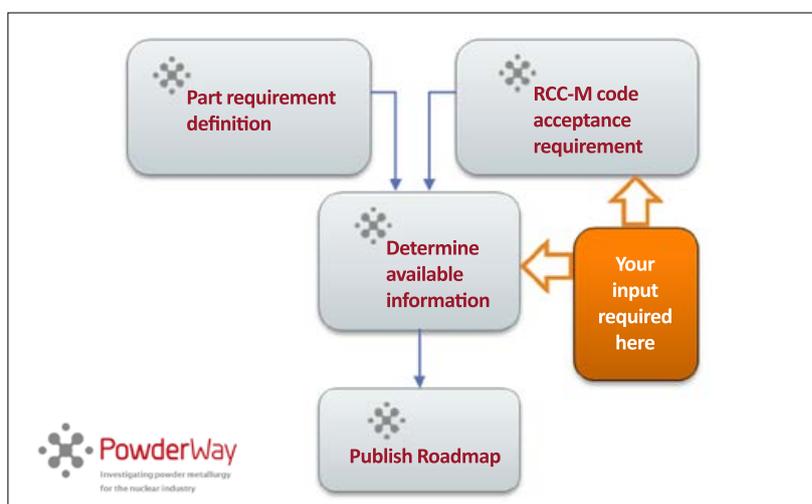
At the same time, the PowderWay project is identifying the requirements and methodology for code acceptance, to determine the information required by the standardisation body so it can present a robust code case. Before PM methods can be deployed in the European nuclear industry, they must be accepted by the standardisation body AFCEN. The consortium is exploring a route for code acceptance within the RCC-M standards for mechanical component fabrication. Code requirements will guide the search for available information in an attempt to qualify the materials, manufacturing processes, benefits, limitations, testing methods and comparative data. Gaps between current technology and potential uptake will be prioritised and recommended in the roadmap.

The consortium has evaluated a range of PM techniques on their maturity and potential for application and is now focusing on three processes: Hot Isostatic Pressing, Additive Manufacturing and Spark Plasma Sintering. Current materials of interest are austenitic stainless steels, nickel-based superalloys and ferritic steel. The intention is to evaluate parts made from these materials in monolithic and dissimilar weld joint configurations. To achieve this, novel and proven non-destructive testing techniques, which are sensitive to PM-specific defects, are also under investigation.

The consortium is keen to talk to established members of the PM industry in order to help it focus on high priority areas and avoid recommending R&D that is already being carried out elsewhere.

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Email: mark.mathew@namrc.co.uk
Tel: +44 (0) 7710 655002

www.namrc.co.uk ●●●



Freeman Technology to launch new powder tester at Powtech 2016

Freeman Technology has announced it will launch the Uniaxial Powder Tester (UPT) at Powtech 2016, April 19 - 21, Nüremberg, Germany. The new powder tester provides an accurate and repeatable measure of the unconfined yield strength (UYS) of a powder to assess and rank flowability.

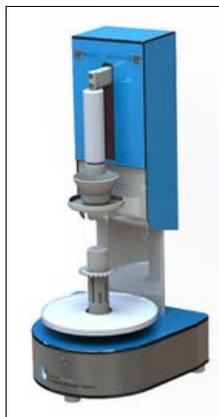
The tester is claimed to be quick, reliable and easy to use, delivering value to scientists, process engineers and QC analysts working in a diverse range of bulk solids handling industries. It is available in manual and advanced versions and is reported as providing a low cost powder testing solution.

Alongside the UPT, the company continues to provide a comprehensive powder characterisation solution in the FT4 Powder Rheometer®, a unique universal powder tester,

which uses patented dynamic methodology, automated shear cells and bulk property tests to quantify the flow properties of powders.

Both instruments can be seen on stand #4-547, where representatives from Freeman Technology will be on hand throughout the event to discuss all aspects of material characterisation. There will also be an opportunity to hear about the company's latest research during Partec, the conference running alongside Powtech.

www.freemantech.co.uk ●●●



POWDERMET2016 programme now available

The Conference Programme for the POWDERMET2016 International Conference on Powder Metallurgy and Particulate Materials is available now on the event's website. The popular conference, which this year takes place in Boston, Massachusetts, USA, June 5 - 8, 2016, is organised by the Metal Powder Industries Federation (MPIF) and will also feature a major PM trade exhibition.

POWDERMET2016 is being held in conjunction with the AMPM2016 Additive Manufacturing with Powder Metallurgy conference. All of the technical sessions, special events and exhibition will be shared and open to delegates of both events.

www.powdermet2016.org
www.ampm2016.org ●●●

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Metal powders may offer alternative to fossil fuels

The use of metal powders to power external combustion engines could offer a viable alternative to the use of fossil fuels, according to researchers at Canada's McGill University in Montréal, Québec. In a study published in the journal *Applied Energy*, the energy and power densities of the proposed metal fuelled zero carbon heat engines are predicted to be close to current fossil fuelled internal combustion engines, making them an attractive technology for a future low carbon society.

"Technologies to generate clean electricity – primarily solar and wind power – are being developed rapidly; but we can't use that electricity for many of the things that oil and gas are used for today, such as transportation and global energy trade," states the lead author of the study, Professor Jeffrey Bergthorson, a mechanical engineering professor and Associate Director of the Trotter Institute for Sustainability in Engineering and Design at McGill University.

When burned, metal powders react with air to form stable, nontoxic solid-oxide products that can be collected relatively easily for recycling, unlike the CO₂ emissions from burning fossil fuels that escape into the atmosphere, state the researchers. Iron powder could be the primary candidate for this purpose, according to the study, as it is readily recyclable with well-established technologies and some novel techniques can avoid the carbon dioxide emissions associated with traditional iron production using coal.



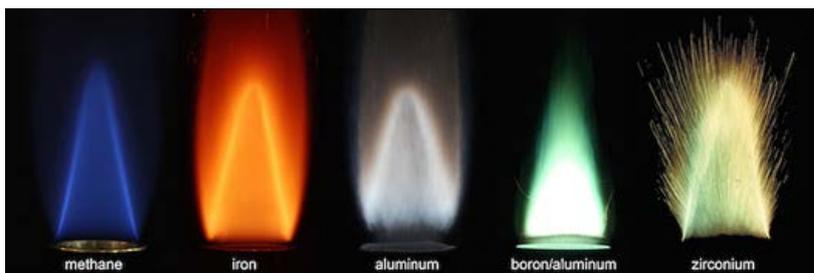
Mechanical Engineering Professor Jeff Bergthorson

"Biofuels can be part of the solution, but won't be able to satisfy all the demand; hydrogen requires big, heavy fuel tanks and is explosive and batteries are too bulky and don't store enough energy for many applications," stated Bergthorson. "Using metal powders as recyclable fuels that store clean primary energy for later use is a very promising alternative solution."

Unlike the internal-combustion engines used in gasoline-powered cars, external-combustion engines use heat from an outside source to drive an engine. External-combustion engines, modern versions of coal fired steam locomotives, are widely used to generate power from nuclear, coal or biomass fuels in power stations.

While laboratory work at McGill and elsewhere has shown that the use of metal fuels with heat engines is technically feasible, no one has yet demonstrated the idea in practice. The next step toward turning the laboratory findings into usable technology, therefore, will be "to build a prototype burner and couple it to a heat engine," added Bergthorson.

www.mcgill.ca ●●●



When burned, metal powders react with air to form stable, nontoxic solid-oxide products that can be collected relatively easily for recycling

Wolfson Centre announces short courses aimed at powder handling industries

The Wolfson Centre for Bulk Solids Handling Technology, part of the School of Engineering at the University of Greenwich, UK, is running a programme of short courses throughout 2016 designed to attract engineers from industry working in the area of bulk solids handling or the flow of powders.

Courses are aimed at engineers, managers, skilled operatives, maintenance crew or anyone involved in using powders or particulates and include:

- Electrostatics in Powder Handling
- Powder and Dust Containment in the Process Industry
- Network Security of Industrial Control Systems in the Process Industry
- Dust Explosions – How to Demonstrate DSEAR/ATEX Compliance
- Caking and Lump Formation in Powders and Bulk Solids
- Undesired De-blending and Separation in Processes and Equipment
- Introduction to Processing of Dry Solid Materials; An overview of core processing methods for powders and granules
- Measurement of the Properties and Bulk Behaviour of Powders and Particulate Materials

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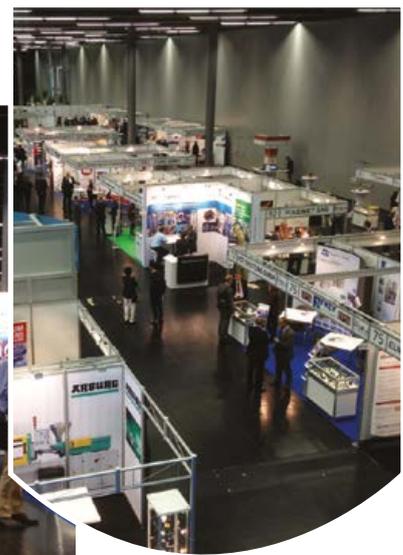
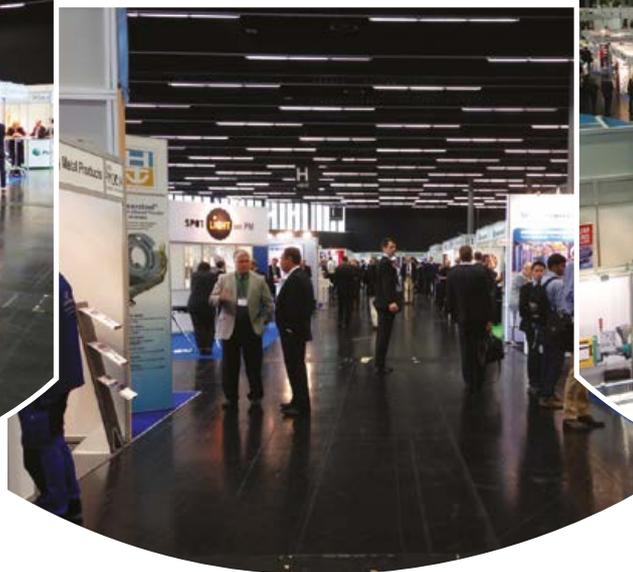
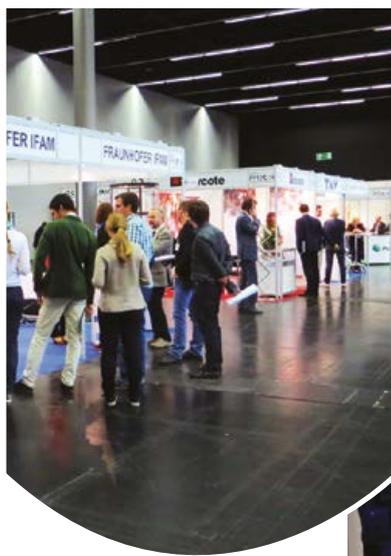
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INDIA FOCUS

The challenges and outlook for India's Powder Metallurgy industry

During a visit to India on behalf of *Powder Metallurgy Review*, Dr Georg Schlieper took the opportunity to meet with Narasimhan Gopinath, President of Powder Metallurgy Association of India (PMAI). During the meeting, Gopinath answered questions regarding the current state of India's PM industry and provided his unique perspective on the opportunities for growth in the country

India is a significant producer and consumer of Powder Metallurgy components, as well as being an important member of the international PM community. The country has numerous PM parts makers as well as a full supply chain including equipment manufacturers and powder suppliers. There is much research and development undertaken at India's academic institutions and research laboratories, evident by the high number of technical presentations made both nationally and internationally by representatives of these organisations.

It is estimated that total production of iron-base PM components in India reached 30,500 tons in 2015, with copper base parts reaching 9,800 tons. Around 76% of the PM components produced in the region are destined for the automotive sector [1].

The automotive industry in India produced a total of 23,366,246 vehicles including passenger vehicles, commercial vehicles, three and two

wheelers from April 2014 to March 2015 as against 21,500,165 from April 2013 to March 2014, registering a growth of 8.68% over the same period. The country exported some 3,573,806 vehicles from April 2014 to March 2015 and recorded domestic sales of 19,752,580 for passenger vehicles, commercial vehicles, three and two wheelers in the period [2].

The Powder Metallurgy Association of India (PMAI) was founded in 1973 and members included scientists employed in government owned defence research laboratories, factories and the department of atomic energy, as well as academics and representatives from India's fledgling Powder Metallurgy industry. Today, members are predominantly from the PM industry and the PMAI serves as an effective trade association in terms of government liaison and trade promotion. It organises workshops and a popular annual conference as well as publishing peer reviewed articles in the bi-annual PMAI Transactions.

In the following interview, the President of PMAI and owner of India's largest manufacturer of PM furnaces, Narasimhan Gopinath (Fig. 1), shares his knowledge of India's PM industry and provides his views on the future growth potential for the region.

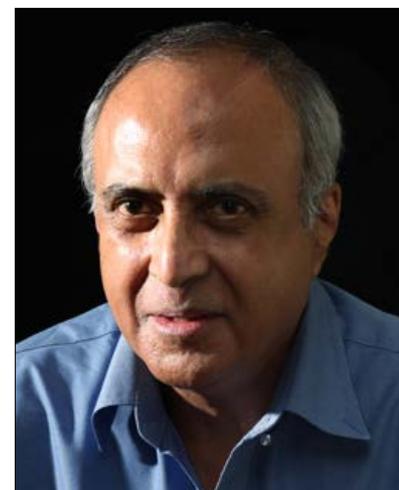


Fig. 1 Narasimhan Gopinath, President of the PMAI, presents his view of India's PM industry



Fig. 2 GKN Sinter Metals, formerly known as Mahindra Sintered Products near Pune, is India's largest PM component manufacturer (Courtesy GKN)

India's Powder Metallurgy parts industry

What are the major structural PM parts companies in India and where are they located?

Gopinath: The development of the Powder Metallurgy industry in India is, as elsewhere, strongly linked to the growth of the automotive sector. The major automobile centres in the country are located in the regions of Chennai, Pune, Delhi and more recently the region of Gujarat, therefore the majority of PM companies can also be found in these regions in order to supply this sector.

The largest PM company in the country is without question GKN Sinter Metals (Fig. 2), which was formerly Mahindra Sintered Products and is located in Pune. Following GKN in this list is Sundram Fasteners, located in Hosur, near Bangalore. Between them they supply over half the market share of automotive PM.

About 10% of India's automobile PM parts consumption is imported from Japan, Europe and the United States, with the remainder manufactured in India by other PM companies such as Speciality Sintered Products, Federal-Mogul, Hitachi, Sintercom, Tenneco, Motherson, Star Sintered Products, NPR and a few others. A new entrant is

Porite who recently broke ground in Pune. It is also likely that PMG will set up shop soon.

There is a relatively strong industry in India producing household appliances. These have a high demand for sintered bearings which is supplied by around 24 smaller PM companies producing mainly bushes and a few structural parts. Of course, there is a wide variety of other applications outside the automobile sector such as machine building, machine tools, conveyors, agricultural appliances and now, in an increasing quantity, power tools.

Are there manufacturers of porous sintered products in India?

Gopinath: Among several manufacturers of bronze filters in India are Vora, Kulkarni, Star Sintered Products and six others. The main application is for silencers on pneumatic cylinders, flame arrestors and pressure regulator parts. Stainless steel filters are not produced in India.

Is there an industry for PM light metals such as aluminium and titanium?

Gopinath: Lightweight components made by aluminium PM, especially composites and titanium are being manufactured by a variety of routes for defence and aerospace applications. However, there is presently no

Indian manufacturer of aluminium PM parts for the automobile industry.

Is there an opportunity to introduce innovative technologies in India?

Gopinath: In the past it was not easy for Indian PM manufacturers to implement innovative technologies. If, for example, an Indian company wanted to convert a shock absorber piston to sintered aluminium, they need a buyer who was invariably located outside India, who would probably prefer a part maker and R&D institution who are located more conveniently to them.

This situation is now changing with the rise of Indian automobile manufacturers, especially Tata Motors and Mahindra, as well as the large R&D centres set up by overseas auto makers in India.

Are there any companies applying Hot or Cold Isostatic Pressing in India?

Gopinath: Hot Isostatic Presses are currently only installed in research laboratories. They are mainly used for technological development and only occasionally for industrial jobs. There are several Cold Isostatic Pressing facilities producing filter candles from bronze.

Magnetic components

What about the ferrite industry in India?

Gopinath: Low cost imports from China almost wiped out the Indian ferrite industry. Today however, perhaps due in part to increasingly stringent quality requirements and the increased prices of Chinese imports, there is a resurgence in India's ferrite industry. Cosmo is the largest manufacturer, with about 500 tons per year, followed by Mahindra CIE with 300 tons per year, then Delta and SSP each with some 200 tons per year. There are also about six other smaller manufacturers totalling a further 100 tons per year.

Metal Injection Moulding and Additive Manufacturing

How do you assess the situation of the Indian Metal Injection Moulding industry?

Gopinath: The Metal Injection Moulding industry in India is dominated by a single company, Indo-US MIM (Fig. 3), who supplies MIM parts worldwide. Four other MIM manufacturers in India, with less installed capacity, have recently been established, with the largest of these being MIM Components (Bangalore) Ltd.

The reason why MIM has not yet developed on a wider scale is that most products where MIM parts are used, for example computers, mobile phones, firearms, medical devices and consumer products, are not produced in India in large quantities. If there existed a larger domestic market for MIM parts, the country would clearly have more MIM companies.

This situation is, however, likely to change following a tentative foray into MIM by the Pune based Indian multinational Bharat Forge, the world's largest forging company and the country's largest manufacturer and exporter of automotive components. There are also a number of MIM incubation centres being set up to help promote the technology.

Are there activities in metal Additive Manufacturing?

Gopinath: At present there are a relatively small number of Additive Manufacturing machines installed in India. However, I expect that progress in AM will not be as slow as it was for MIM in India.

Additive Manufacturing machines, mainly from EOS, are being imported in increasing numbers and there are already three manufacturers of 3D printers (for ABS) in Mumbai and Bangalore. I think a major impetus for AM will come from the jewellery sector as gold is extremely popular in India. A number of designs for AM rings and bracelets were displayed at the PMAI's recent PM16 conference held in Pune.

Diamond tools, hard materials and heavy metals

What is the situation of the Indian diamond tool industry?

Gopinath: The Indian diamond tool industry (beads and segments) mainly focused on cutting granite stones, is thriving. The traditional manufacturing method of hot pressing is being replaced gradually with 'free sintering' which becomes mandatory for small beads used in multi strand cutting machines. The major suppliers are StaySharp, Optima, SD Tools and Diabu who supply over half the market. The remainder is supplied by over fifty other small manufacturers, some of whom such as Sanwa and Korgavkar make high quality and exotic beads. The concrete cutting sector is served by Hilti, Wendt as well as several others.

And how are the hardmetals and heavy metal industries fairing?

Gopinath: The tungsten carbide industry is also doing well. Indian and international companies servicing India's industry included Sandvik (Fig. 4), Electronica, Rapicut, Seco, Kennametal, TaeguTec, Sumitomo and Seco Tools. There are also at least half a dozen smaller companies supplying specialised or niche products, where they can compete against the larger players by offering smaller batches for example.

The fact that tungsten and cobalt are not mined in India is not an impediment given the capacity of local recycling plants and imports by Indian owned overseas mines. Heavy metal, mainly tungsten, parts are made in bulk by the Indian Ordnance Factory as well as to a smaller extent by Innomet, who is also a manufacturer of nickel, stainless and HSS powder.



Fig. 3 MIM components made by Indo-US MIM Tec Pvt. Ltd, have earned international awards. These parts received the 2014 MPIF Grand Prize in the Automotive - Engine Category (Courtesy MPIF, USA)



Fig. 4 In 1956 the Government of India invited Sandvik in Sweden to set up a cemented-carbide manufacturing factory in India (Courtesy Sandvik)



Fig. 5 Electropneumatics & Hydraulics (I) Pvt Ltd, Pune, designs and manufactures standard and customised metal forming equipment. The pictured press is the company's 500T CNC Hydraulic Powder Compacting Press

Powder and equipment suppliers

What metal powder production is there in India?

Gopinath: There are several production plants for iron powder. Höganäs has a factory atomising approximately 20,000 tons per year. Sundram Fasteners has its own iron powder atomising facility with a capacity of approximately 9,000 tons. Smaller manufacturers sell around 6000 tons per year of atomised and mill scale sponge iron powder. Most of their powder goes to smaller PM part makers as well as for welding electrodes.

Industrial Metal Powders Ltd., located in Pune, is one of the world's largest manufacturers of high quality electrolytic iron powder.

Rio Tinto has announced plans to invest in an iron powder annealing and blending plant in Gujarat with an annual output of 60,000 tons.

Many Indian powder manufacturers have been concerned about imports from China following the removal of export duty on iron powder exports from the country. However, these fears have not yet been realised on account of concurrent removal of export benefits and due to the fact that Indian iron powder is now competitively priced. Moreover, it is not easy to change the iron powder supplier for existing products as the dimensional changes are often different and a change of the iron powder may require new tooling.

Copper powder production is remarkably strong in India with about 13,800 tons per year being

produced mainly by Kandoi, PP Patel and Star Sintered. Of course, bronze bearings are a big market for copper powder, but there are other consumers of copper powder outside of PM. Several producers of bimetal bearings have their own in-house production of copper powder. Copper powder is used extensively by manufacturers of diamond tools, catalysts and electrical contacts.

MEPCO in the temple city of Madurai is one of Asia's largest manufacturers of aluminium powder with a capacity of 30,000 tons per year, however the main use for this powder is in India's large fireworks and paint industries. They have about half of the Indian market with Arasan, Sun Ark and two others sharing the remaining.

Let us talk about equipment suppliers. Are powder presses built in India?

Gopinath: There are a number of manufacturers of mechanical compacting and sizing presses suited to Powder Metallurgy. The leading supplier is Newmet who has an installed base of over 500 presses, mainly for the manufacture of bearing bushes and diamond tools. Hydraulic presses are available from Electropneumatic (Fig. 5) as well as Yugantak and Glassnost. However most of these presses are imported from Europe (200 from Dorst alone) and of late from China. The Chinese presses are said to be reasonably good and of course much cheaper than similar European presses. Therefore a large number have been installed in Indian PM companies.

As the owner and Managing Director of Fluidtherm you have an intimate insight into the Indian manufacturers of sintering furnaces

Gopinath: It seems almost all established Indian furnace manufacturers have supplied at least one sintering furnace to one or other segment of the Indian PM industry. Fluidtherm however is a specialised manufacturer of furnaces for Powder Metallurgy with several furnaces shipped to OEM furnace makers in Germany.

Apart from installing furnaces at most major Indian PM part makers we also sell directly to part makers in South Korea and China. In addition to Fluidtherm there are four other PM furnace manufacturers who serve the Indian market, the largest among them being Malhotra Engineers.

Cremer, Sinterite and CM Furnaces have all supplied continuous furnaces to India PM companies. Ipsen, GM Furnaces and Elnik have supplied MIM furnaces.

Research and academic institutions

How many academic institutions or research organisations are concerned with Powder Metallurgy?

Gopinath: At our annual PMAI conferences approximately 200 papers are submitted every year by more than 25 academic institutions and research laboratories, of which we select about 75 for presentation. Main contributors are from research laboratories from the nuclear and defence establishment, seven of the eleven Indian Institutes of Technology and several other institutions.

Governmental research institutions are often defence oriented and work at the front fields of science, but they also sell their technologies as a spin-off to the private sector. There is also a non-military research organisation with many laboratories located all over India.

Last year the PMAI began presenting an award for the best paper at its annual PM conference. Entry is open to students and young professionals who are not supported by a company. The award winner receives a fully paid trip to an international PM conference and the winner last year (Fig. 5) was sent to POWDERMET2015 in San Diego, USA. The winner of the recent PM16 conference, a student from a Spanish University will attend the PM World Congress in Hamburg, Germany.

Challenges to the growth of India's PM sector

What challenges does India face to the growth of its PM industry?

Gopinath: Improvements to the country's infrastructure are a prime requirement for industrial growth, a job that is perhaps easier to achieve in a country which is not a multi-cultural, multi-religious, vibrant democracy such as India. In many regions there is a shortage of good roads and the cities are already crowded, meaning that it might be difficult to build more roads or factories. It is not possible to tear down

"In my opinion the Indian economy is very strong because of the nature of its people"

historic structures to build roads. Furthermore, regional bureaucracy can also slow down the process.

The region of Gujarat, however, is a good example of how improvements to infrastructure can lead to growth. During his time as Chief Minister of Gujarat, Narendra Modi, now India's Prime Minister, worked hard to attract the automobile industry to the region. Gujarat's infrastructure was improved with new transport links, along with offering tax breaks to encourage auto makers to establish factories in the area. The policy proved successful, with Tata Motors, the largest Indian owned automobile company, setting up a plant there to build the world's cheapest car, the Nano. They are not alone, other auto makers such as Suzuki, Ford, Mahindra's, Fiat and the light commercial vehicles specialist, Force Motors have followed suit.

Today other states compete against each other and try to attract as much investment as possible, often at the cost of other regions.

In my opinion the Indian economy is very strong because of the nature of its people. However, with a population of over one billion, there are challenges in getting the economic gains of industrialisation to the disadvantaged section of the population.

What are your expectations for the future of PM in India?

Gopinath: With the increasing number of research organisations in the country there is a possibility that the Indian PM industry can become more innovative and gradually close the technological gap between India and the Western industries.

We have a middle class in society that is expected to grow to several times the size it is now. This will help create an increasing demand for vehicles and luxury goods.

One major resource is that we have millions of children and young people today who will soon grow to

make up a massive workforce.

Over the next five years we expect a growth in car sales of around 5% annually. The growth of automobile parts manufacturers will be higher, probably between 15 and 20% annually due to increasing export opportunities. By 2050 we expect to be the second or third largest vehicle manufacturer in the world.

Even with the challenges of improving India's infrastructure I am confident that the Indian PM industry will remain in a good position.

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Fluidtherm Technology: India's innovative furnace manufacturer looks forward to continued growth

Fluidtherm Technology Pvt Ltd is India's largest manufacturer of furnaces for the Powder Metallurgy industry. The company is one of the industry's leading innovators, regularly presenting its technological developments at international conferences and exhibitions. Dr Georg Schlieper recently visited Fluidtherm and met with the company's founder and CEO, Narasimhan Gopinath. In this exclusive report for *Powder Metallurgy Review*, we review the growth of Fluidtherm and reasons for its continued success

Fluidtherm manufactures a wide range of furnaces for heat treatment, chemical processing and Powder Metallurgy (PM) at its site in Chennai, India, where the company also operates an in-house R&D and thermal process prototyping and optimisation facility. The history of Fluidtherm is closely linked to the biography of its founder and CEO, Narasimhan Gopinath. Soon after his graduation from Delhi University, Gopinath established a sales agency selling capital goods such as cranes, conveyors, presses and heat treatment furnaces in his hometown, Chennai. He also employed a small team of engineers to provide installation and after-sales services.

"This business, which lasted from 1975 to 1982, was enjoyable and stress free but I felt we were not realising our full potential" commented Gopinath. "It was the 7th of September 1982, I still remember the

date well, when I gave notice to all my principals and we got into manufacturing. Had I an inkling of what this would entail I would have opened a laundry instead!" However ignorance is bliss and so with modest financial

resources, enough to buy a couple of welding machines and tools, and together with his committed team, he began to produce spare parts for heat treatment furnaces such as mesh baskets, muffles, fans, etc. "After



Fig. 1 One of two sinter hardening mesh belt furnace installed at one of Fluidtherm's customers, Daekwang Sintermetal, in South Korea

seven years as a salesman, getting orders was not a problem although the market was very weak at that time with just two car makers, two truck makers and five two wheeler manufacturers, all of whose capacity was limited by licences issued by the then socialist government," stated Gopinath.

to meet the then leading manufacturer for technology licensing. However, their installed base was modest but their licence fee was not." Gopinath therefore decided to develop this on his own. "Lessons were learnt from early failures and in a short time we set up a successful demonstration plant."

"We got into PM seriously when we installed sintering furnaces at the Federal Mogul (then Brico) valve seat and valve guide plant in India"

After a few years the Indian economy began to grow and the company began to prosper. With a bank loan in 1984, Gopinath established Magnatherm Alloys, a foundry for in-house manufacture of previously out sourced heat resisting steel castings such as furnace jigs, pusher trays, etc, used in heat treatment furnaces. In due course there came a desire to upgrade from making parts of furnaces to whole furnaces. At that time environmental authorities were legislating against the large number of cyanide salt bath heat treatment furnaces across India, so an environmentally friendlier alternative was required.

"I had heard of the concept of fluidised bed heat treatment, an environmental friendly alternative to salt baths so I travelled to the USA

Fluidtherm Technology Pvt. Ltd. was incorporated in 1985 and moved into its present location in 1989 for the manufacture of fluidised bed furnaces and operation of a process prototyping facility and laboratory. The company received many orders thanks to increased environmental awareness and a total of around 400 fluidised bed furnaces were built and delivered in the first ten years, and some 534 to date. "This achievement got us the prestigious 'National Award for Technology Development' from the Government of India, the closest thing to a Nobel prize that Indian industry can expect for technological achievement," added Gopinath. Fluidtherm became well-known and highly regarded among engineers in the Indian metalworking industry as a

supplier of high quality heat treatment furnaces.

As time passed Fluidtherm started manufacturing continuous hardening and tempering furnaces as well as annealing, brazing and sintering furnaces for Indian auto part makers. In the late 1990s a close cooperation developed with a German annealing furnace maker and for many years Fluidtherm supplied parts of, and whole furnaces to, them and to two other German furnace makers.

"We got into PM seriously when we installed sintering furnaces at the Federal Mogul (then Brico) valve seat and valve guide plant in India. In the early 2000s we were invited to visit a prominent German firm, with strong PM credentials, for discussions and finalisation of a strategic partnership," says Gopinath. The agreement, which kept Fluidtherm out of Europe and USA, lasted for about ten years until the ownership of this firm changed hands. "While we already had creativity, a scientific temper and a fundamental knowledge of metallurgy and engineering, we remain grateful to all our German OEM customers for introducing us to European standards, their best practices and their manufacturing systems," stated Gopinath.

During this period there was a steady increase in the number of Fluidtherm installations in India. OEMs and PM part makers from Europe and North America, who had



Fig. 2 Today Fluidtherm manufactures furnaces suited to a wide range of applications. Shown here is a continuous nitrocarburising (heat treatment) furnace

established joint ventures in India where Fluidtherm furnaces were used, found that the parts sintered or heat treated in these furnaces were of high quality. This led to exports to their manufacturing facilities in South-East Asia, specifically in South Korea and China. Later furnaces were supplied to non-affiliated locally owned PM part makers in these regions.

Fluidtherm has an annual production rate of around 25 furnaces which are manufactured by a permanent workforce of 42 at its 4050 m² site. At least two apprenticeship positions are offered each year.

In-house R&D that is unique in this sector

Research at Fluidtherm began in the late 1980s with the establishment of an in-house R&D laboratory and thermal process prototyping facility. This was one of the first investments by the company as the design of their furnaces, made without help from any licensor, required much fundamental development work.

"The difference between a licensor and a licensee is not intellectual capability, it is the mistakes made previously from which the licensor has learnt before the licensee came along. We needed this facility in which to make our mistakes, so that our customers got equipment and processes that worked without trouble," commented Gopinath.

The research carried out at the Fluidtherm facility is not only related to furnace design, but also to the development of innovative heat treatment processes. The most recent of over 40 development projects are the novel Pownite[®] and CCGQ (continuous carburising gas quenching) processes.

Pownite[®] gas alloying process

The Pownite[®] process, for which Fluidtherm has applied for patents, is a process for strengthening the matrix of a sintered part by gas alloying. The process is carried out between 590°C and 700°C in an

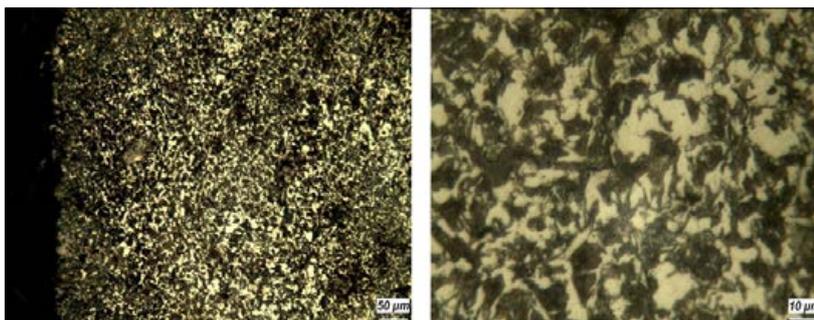


Fig. 3 Microstructure of Pownite[®] heat treatment, surface (left) and core

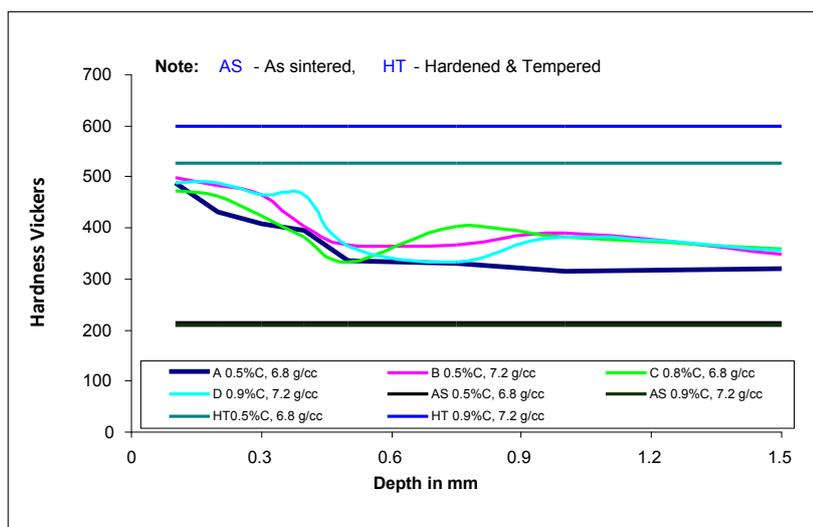


Fig. 4 Hardness profile of Pownite[®] processed 2%Cu + 0.5% C sintered bushes

atmosphere containing precisely controlled amounts of ammonia.

Nascent nitrogen (from the breakdown of ammonia) diffuses into the surface of the parts, but the purpose is not to form a surface layer of iron nitride as is the case of the nitriding processes. Instead, nitrogen is diffused through the section thickness of the part due to interconnected porosity and austenite is formed by this nitrogen diffusion at a temperature above the eutectoid point in Fe-N-C ternary system. This austenite can optionally be converted to bainite and hard transformation product by ageing the parts between 250°C and 550°C.

Variations of the process allow diffusion of a fairly uniform extent of nitrogen throughout the part or, if desired for wear applications, in a concentration near the surface akin to case hardening.

Pownite[®] is applied to plain

Fe-Cu-C steels containing 0.5 - 0.8% C as well as low alloy steels with resulting improvement in hardness and mechanical properties. As the process does not require oil quenching, the parts are free from impregnated oil after hardening and exhibit less distortion than oil quenched parts.

Fig. 3 shows the microstructure of a Fe-2%Cu-0.5%C sintered steel after Pownite[®] processing. At the surface there is hard bainite (dark) and some ferrite (white) but no nitrides are visible. The microstructure in the core contains more ferrite (white) and also some bainite (dark).

Hardness profiles of Fe-2%Cu PM steels with varying density and carbon content after Pownite[®] processing are shown in Fig. 4. All samples exhibited microhardness at the surface of roughly 500 HV and the core hardness was between 300 and 400 HV.



Fig. 5 Gear tooth test fixture (left) and clean break shown after testing (right)



Fig. 6 Macrostructure of the gear tooth

The CCGQ process

The CCGQ process (also patent applied) is under production scale development to provide a defined carburised case in Powder Metallurgy parts typically made in powder grades similar to Astaloy 85Mo.

This process is an alternative to traditional atmosphere case hardening and oil quenching which usually results in the entire section of the part being hardened and thus

becoming brittle. The defined case with a sharp drop in hardness after a given depth, is made possible by reducing the quenching intensity by the use of atmospheric pressure gas quenching.

Parts will typically be carburised in a continuous mesh belt furnace very much like a sintering furnace and then quenched in what is essentially a sinter hardening module. Reduction in distortion and

bright parts would be a bonus. The similarity with a mesh belt sintering furnace should make it user friendly to the PM industry.

Fig. 5 shows the clean break of a gear tooth after testing. Fig. 6 shows the macrostructure of a martensitic case of a gear tooth in Astaloy 85Mo which was carburised and gas quenched as described above.

Furnace type	Mesh belt	Walking beam	Pusher tray	Bell / elevator	Steel strip conveyor	Graphite tube	Continuous hardening mesh belt	Fluidised bed	Retort	Laboratory
Sintering	•	•	•	•		•				•
High Temperature Sintering		•	•			•				•
Sinter Hardening	•	•	•							•
Steam Treatment	•		•					•	•	
Aluminium Sintering	•		•							•
Heat Treatment	•						•	•		•
Powder Annealing, Reduction, Carburising	•	•	•		•			•		•
Hardmetals			•	•		•				•
MIM		•	•							•
Ceramics	•	•	•	•						•
Diamond Tools	•		•							•
Friction Materials	•		•	•						•

Table 1 Furnaces for Powder Metallurgy available from Fluidtherm



Fig. 7 Mesh belt sintering furnace

Full range of furnaces for Powder Metallurgy and heat treatment applications

Fluidtherm offers a full range of furnaces for the PM industry, including powder annealing furnaces as well as mesh belt, walking beam and pusher furnaces for the sintering, steam treatment and heat treatment of PM parts (Table 1).

Apart from general engineering software, Fluidtherm makes extensive use of CFD packages such as ANSYS and FLUENT for structural stress analyses of furnace components, modelling convection ducts and transient thermal analyses. Below are a number of highlights and special features that demonstrate the high technical competence of Fluidtherm's engineering.

Mesh belt furnaces

The industry standard mesh belt furnace (Fig. 7) has today reached a high level of sophistication, with near zero downtime other than for belt changing. Total automation is achieved that includes supervised loading, discharging and entering an idling mode without operator intervention when production is interrupted. State-of-the-art software for safe and efficient furnace operation is completely developed in-house. Mesh belt furnaces, where gradual debinding is performed in a muffle



Fig. 8 Sinter hardening furnace

under a $N_2 + H_2$ sintering atmosphere, are offered in addition to furnaces with rapid debinding in a well proven direct gas fired chamber (RBO). When used along with an endogas atmosphere from either an internal or external gas generator, this allows significant cost savings especially in locations where gas is cheap.

Sinter hardening

The main advantages of sinter hardening, done by gas quenching sintered parts as they emerge from the sintering section of the furnace (in an integrated module), is a reduction in manufacturing cost

compared to the traditional practice of reheating and oil quenching. Additional advantages include lower distortion due to the absence of a vapour blanket, bright parts, elimination of oil contamination of the parts and washing (thus less pollution). The cooling rate can be adjusted within limits and quench cracks are eliminated.

The Fluidtherm sinter hardening furnace (Fig. 8) was developed with the help of modelling from the FLUENT software and the help of the nearby Indian Institute of Technology. It applies convection cooling by turbulent flow caused by a nozzle field through which the same

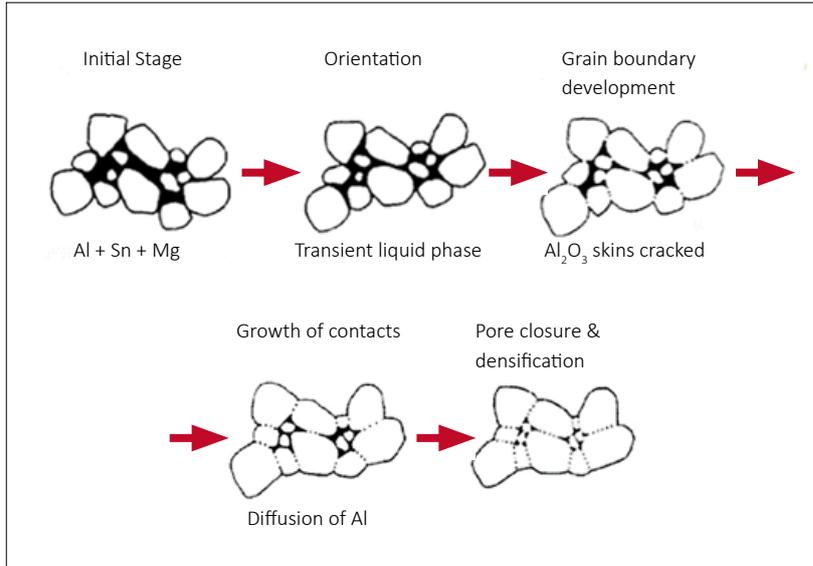


Fig. 9 The five stages of aluminium sintering: powder compaction, particle orientation, grain boundary development, contact growth and densification

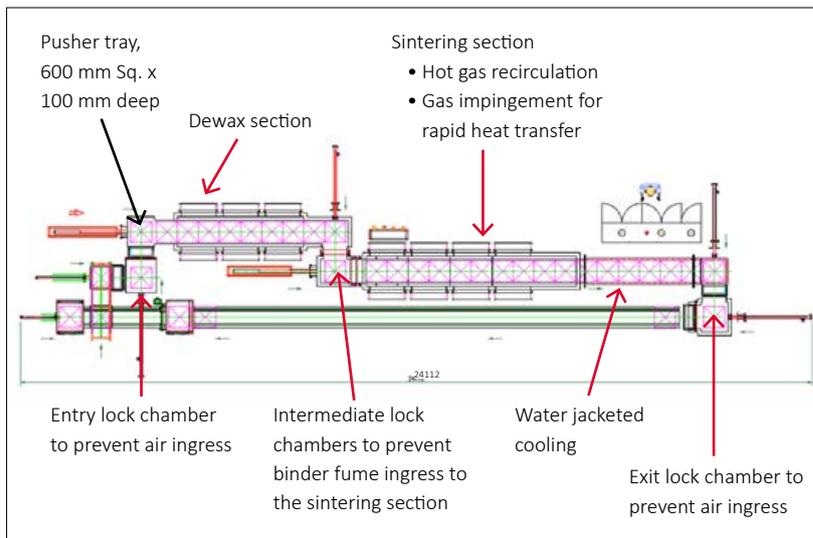


Fig. 10 Schematic layout of an aluminium sintering furnace

furnace atmosphere gas, nothing extra needed, is re-circulated by a blower across a heat exchanger. The cooling rate depends on component geometry, belt loading, blower speed and belt speed. The maximum cooling rate recorded in production conditions is 8.6°C/second.

In an effort to make sinter hardening applicable to low alloy PM parts, Fluidtherm is working on a continuous sintering plant with pressure gas quenching.

Continuous aluminium sintering furnace

Sintering of aluminium powder compacts poses special challenges to the furnace design due to the adherent skin of alumina on the powder. Critical conditions for high quality sintering are a very high degree of temperature uniformity ($\pm 3^\circ\text{C}$), 100% nitrogen atmosphere with very low contamination (max 3 ppm oxygen and - 70°C dew point) and the elimination of debinding atmosphere ingress into the sintering section.

The five sintering stages are shown schematically in Fig. 9. After delubrication, and shortly before the sintering temperature is reached, a liquid phase forms and allows the aluminium powder particles to change their orientation. The formation of spinel (MgAl_2O_4) absorbs most of the oxygen contained on the particle surfaces so that the diffusion barriers are removed. Neck



Fig. 11 Aluminium sintering furnace

formation occurs followed by pore closure and densification.

The aluminium sintering furnaces designed by Fluidtherm are characterised by an all metal hot zone that allows maintenance of atmosphere integrity lower than 2 ppm oxygen and -70°C dew point throughout the sintering section. A special baffle system is employed to insulate the heater radiation from the workload. Uniform heat transfer is effected by jet impingement so $\pm 2^{\circ}\text{C}$ is maintained in the sintering and delubrication sections. Atmosphere lock chambers are placed at the entry, exit and between the delubrication and the sintering sections in order to prevent the exchange of gas, see Fig. 10 and Fig. 11.

Continuous steam treatment furnaces

Steam treatment is an exposure of PM parts to steam at approximately 540°C , so a firmly adherent surface layer of iron oxide Fe_3O_4 is formed not only on the outer surface, but also inside the pores. The process is generally applied to PM parts used in automotive brakes and compressors to improve the hardness, wear resistance and corrosion resistance. The continuous steam treatment furnace developed by Fluidtherm has a pusher type transport mechanism instead of the otherwise common mesh belt mechanism (Fig. 12). This furnace utilises humidified nitrogen in place of steam.

Conventional mesh belt steam treatment furnaces are necessarily open at both ends. Over 90% of the steam consumed is needed to keep air out of the furnace and the remainder meets the thermodynamic requirement of the process. The Fluidtherm furnace keeps air out of the furnace with the use of atmosphere lock doors at both ends. This reduces the gas consumption dramatically and, in addition, enables processing under pressure. This makes the use of humidified nitrogen, the generation of which needs much less energy than steam, possible.



Fig. 12 Continuous pusher steam treatment furnace



Fig. 13 High temperature sintering furnace

High temperature sintering furnaces

Fluidtherm has installed several high temperature pusher furnaces designed for operation at 1350°C to 1450°C for sintering iron and stainless steel parts and 1700°C for hardmetal, tungsten and uranium oxide sintering (Fig. 13). A sophisticated programmable pusher system ensures negligible vibration during transport and a consequent increase in the length and production capacity of the furnaces. This is further increased by the use of a split

furnace design where binder removal is done in a parallel track. Encapsulated fans for enhancing the cooling rate reduce the overall size of the equipment.

Internal muffles eliminate hot spots and this not only improves the temperature uniformity, it also improves the purity of atmosphere the parts are exposed to. The increasing use of high sintering temperatures for automobile structural parts requires the use of large capacity furnaces, typically with a tray size of $500\text{ mm} \times 460\text{ mm}$, twenty

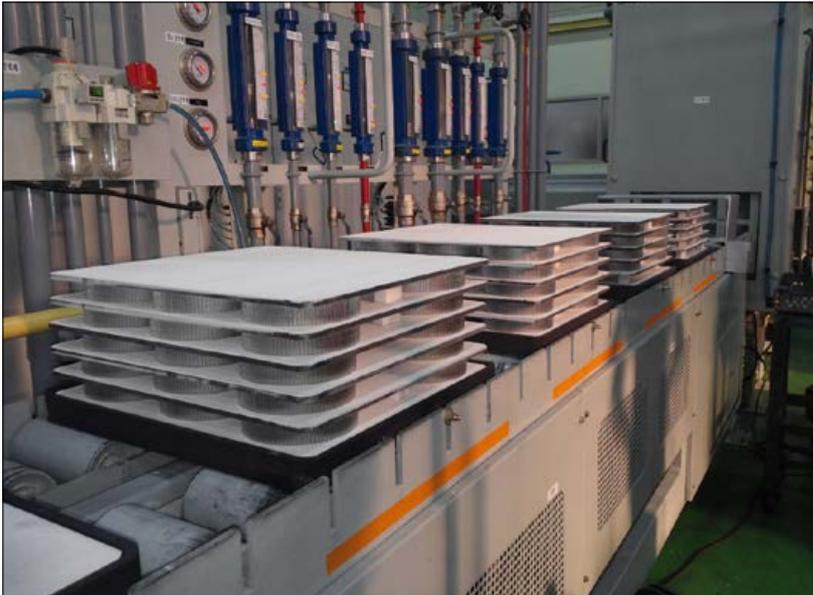


Fig. 14 Gears in stacked trays emerging from a high temperature sintering furnace with a capacity of 420 Kg/hr

trays per hour and a net production capacity of over 500 kg/hr (Fig. 14).

Large furnaces that use 100% hydrogen atmosphere utilise specially engineered vacuum locks which keep the furnace atmosphere pure and at the same time reduce the gas consumption. Gas tight internal doors allow the use of different atmospheres in different sections of the furnace and isolate one section from the gases of others.

Strong exports and further growth

Fluidtherm is a specialist enterprise with all the necessary in-house resources for the development, manufacture and installation of furnaces for a wide range of appli-

cations including heat treatment, chemical processing and Powder Metallurgy. Although the company is now the largest manufacturer of PM furnaces in India, it is not just the Indian PM industry that is responsible for its continued growth. Fluidtherm relies strongly on the international sales of its furnaces and sees many opportunities for further increasing these exports.

"The current low demand for Powder Metallurgy furnaces in India cannot sustain Fluidtherm," stated Gopinath. "In 2015, 83% of our turnover came from exports, mostly to South Korea and China, thanks to our local partners."

"I think we have several good things going for us, not just our technology, but our developmental

mind-set and the vast technological infrastructure here. India has a large, educated and English speaking workforce, with a customer first attitude," added Gopinath.

A new building at Fluidtherm's facility in Chennai is currently under construction to increase production capacity. The company is also actively seeking to expand its network of international agents and partners. "We have an attractive deal for entrepreneurs in 'open' regions and are looking for takers," concluded Gopinath.

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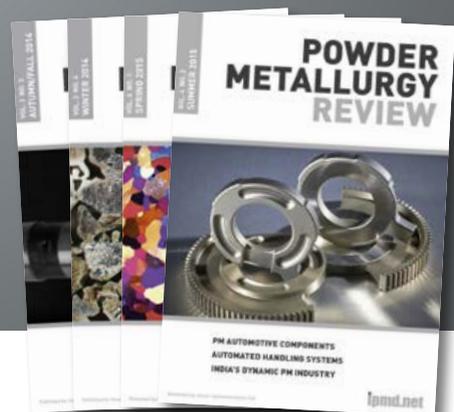
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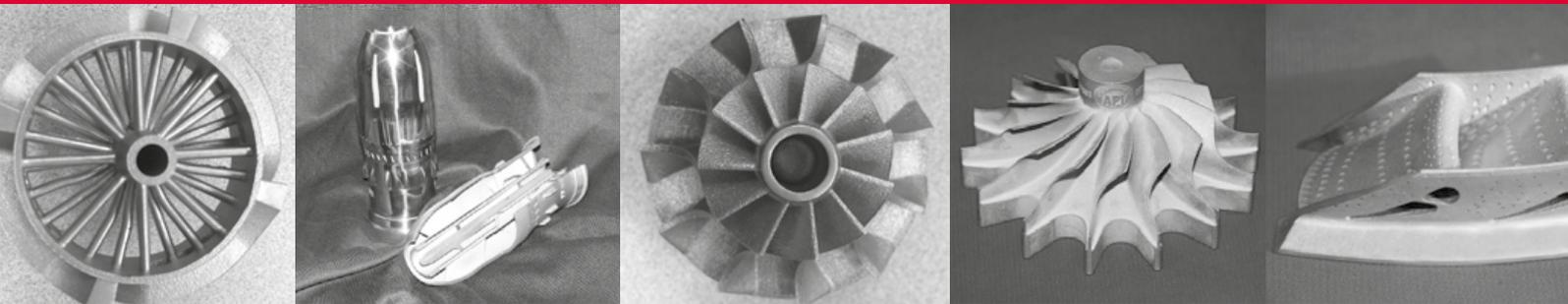
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China's cemented carbide industry: Growth prospects for the world's leading producer

Cemented carbide production has been one of the fastest growing segments of Powder Metallurgy with tonnage estimated at around 65,000 mt globally in 2014. China is the leading global manufacturer of cemented carbides with over 40% market share. In the following report Zhongjian Zhang, President of the Cemented Carbide Branch of the China Tungsten Industry Association, identifies the key players and reports on the current state and outlook for the cemented carbide industry in China.

Cemented carbides, or hardmetals as they are commonly known in Europe, are Powder Metallurgy products based primarily on tungsten carbide bonded with cobalt. Invented in Germany in 1923, the first commercial application was for drawing dies to produce tungsten wire and these were soon followed by cutting tools for the machining of metals. Cemented carbide cutting tools are today among the most widely used products for turning, milling, cutting, grooving, thread cutting, drilling and boring of metals and other materials in sectors such as automotive production, aerospace, railways, energy generation, etc. However, the applications for cemented carbides have also expanded into other areas such as mining tools, construction and civil engineering, oil and gas drilling tools and wear resistant parts for chipless forming (Fig. 1).

Cemented carbide production

Cemented carbide production has been one of the fastest growing segments of Powder Metallurgy with tonnage estimated at around

65,000 mt globally in 2014. Of this total, China accounted for 27,000 mt in 2014 which makes the country the leading global manufacturer of cemented carbides, with over



Fig. 1 Cemented carbide tools are used in many applications including mining, oil exploration and rock drilling [Courtesy Zhuzhou Cemented Carbide Corp]

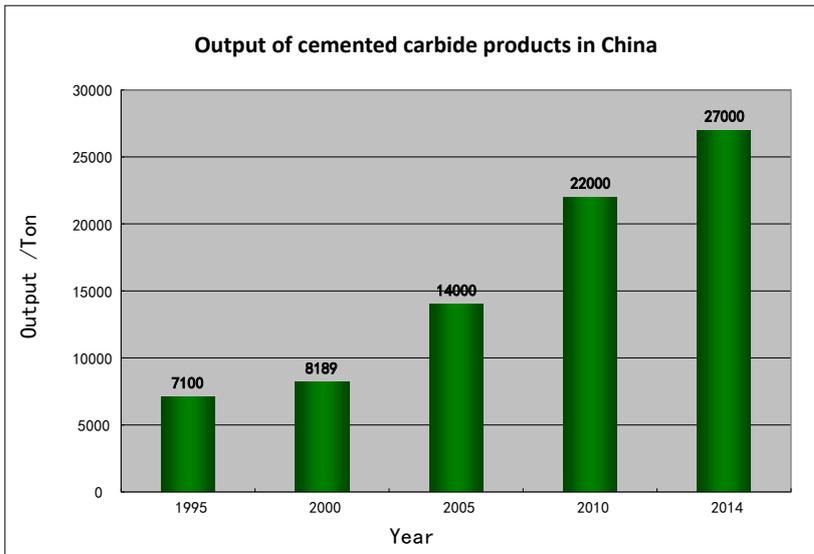


Fig. 2 Output of cemented carbide products in China 1995 – 2014

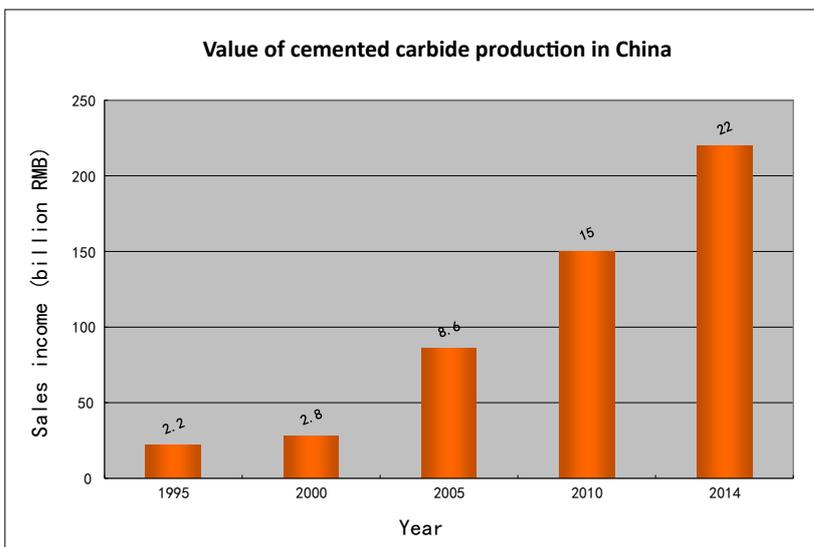


Fig. 3 Sales income of cemented carbide production in China (billion RMB)

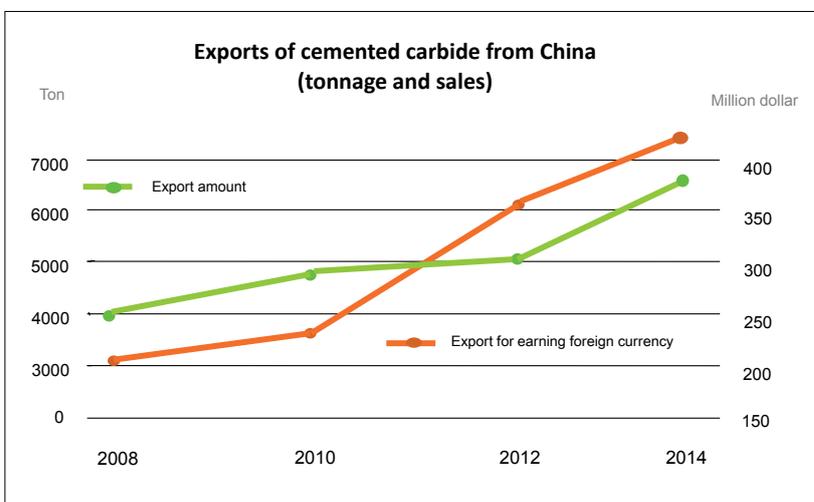


Fig. 4 Exports of cemented carbide from China in tonnage and sales income 2008 – 2014

40% market share (Fig. 2). Sales revenue for cemented carbides produced in China in 2014 stood at RMB 22 billion (Fig. 3). It is, however, no coincidence that China's dominant position in this market is due to the fact that the country holds almost 30% of the world's tungsten ore reserves and that China accounts for around 87% of the world's tungsten output. The country also accounts for 50% of the world's tungsten consumption and 80% of the volume of tungsten traded globally. Exports reached 6,780 mt in 2014, which is around a quarter of total production, with a sales value of around \$500 million (Fig. 4). Imports of cemented carbide products in China reached 1,508 mt in 2014.

Cutting tool production

In 2014 cutting tool production in China was reported at 5,000 mt, with output of cutting inserts for CNC machines reaching 93 million pieces. Cemented carbide tools for mining reached 6,000 mt and wear parts around 10,000 mt, wherein bar material was 4,500 mt and hardfacing material some 1,310 mt. The output of cemented carbide for deep-processing and oil and gas exploration reached 4,850 mt in 2014. At the same time, the output of micro drill components was more than 500 million pieces and the output of solid cemented carbide tools for hole drilling/machining was around 26 million pieces. Fig. 5 compares the market share of the main cemented carbide product groups in 2009 and 2014.

According to the machine tool association, some 7.398 billion cutting tools were produced in China in 2013, representing an annual market worth more than RMB 40 billion. Of this total cemented carbide tools made up around 45% of the market, with high speed steels at 53% and superhard tools at 2% (Fig. 6). Cemented carbide tools accounted for around RMB 20 billion in sales of which CNC indexable carbide inserts made up approximately 50%.

Key players in China's cemented carbide industry

Zhuzhou, in the Hunan Province, is considered to be the home of cemented carbide production in China. Zhuzhou Cemented Carbide Group Corp Ltd (ZCC) was one of China's key projects in the nation's 'First Five-Year Plan' and the company is, after more than fifty years of production, the country's largest producer of cemented carbides and tungsten products with sales of almost RMB 6 billion in 2014. It is also home to significant technology research efforts.

In addition to the long established ZCC, the Zhuzhou region is today estimated to have almost 140 enterprises engaged in the production of cemented carbide and tungsten-base products. Most of these enterprises are classed as small to medium size companies with around 22 having sales of over RMB 100 million. Some of the other cemented carbide producers in the region include Zhuzhou OKE, Zhuzhou Jinggong, Zhuzhou Jinwei, Zhuzhou Kingtal, Zhuzhou Seed, Zhuzhou Tongyi, Zhuzhou Huarui, Zhuzhou Lizhou, Zhuzhou Jinding and many others.

Zhuzhou OKE Cemented Carbide Co., Ltd, produces a range of NC inserts for high precision machining of special materials and also carbide drill bits. In 2014 total output of cemented carbide increased 105% compared with that of 2009. At the same time the sales income increased 241% and the profit increased by a factor of 15.

Seed Cemented Carbide Technology Co., Ltd., manufactures various deep well processing tools, high precision cemented carbide parts, machined cemented carbide parts such as non-standard inserts, tubes, rings and plates, integrated cemented carbide parts and composite parts of cemented carbide and other metal materials. In 2014 exports accounted for over 70% of total income.

Total output of cemented carbides in the Zhuzhou region was some

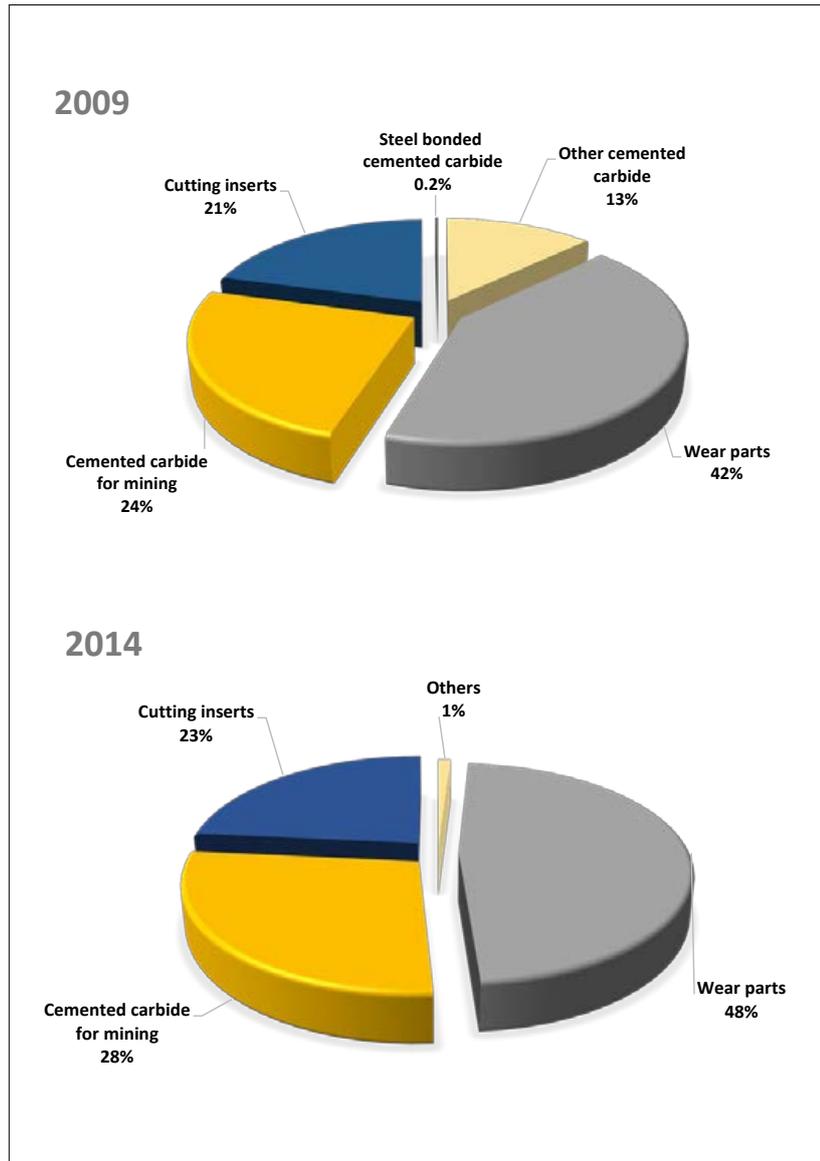


Fig. 5 Comparison of market share of different cemented carbide product groups in 2009 and 2014

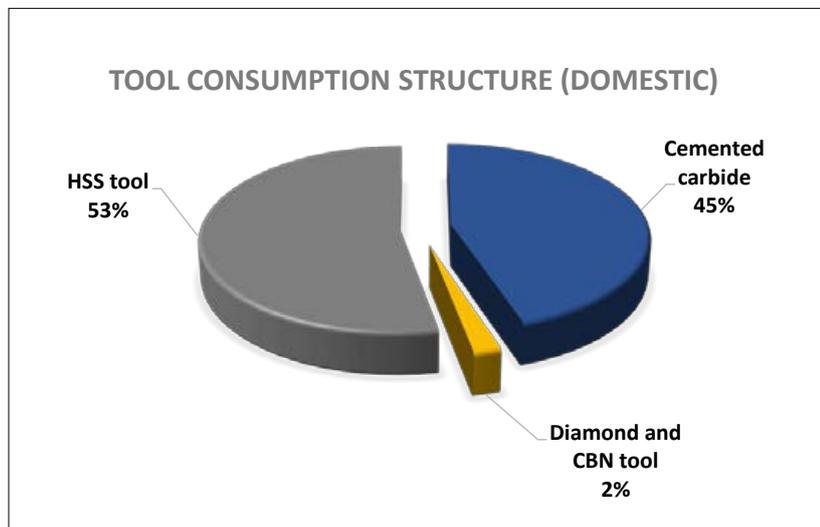


Fig. 6 Breakdown of domestic cutting tool consumption

8,600 mt in 2014, having a sales value reported at RMB 11 billion, or 50% of China's total cemented carbide sales. The reason for the high sales value is that carbide inserts for CNC machining are one of the main products in the Zhuzhou region and in 2014 output represented some 75% of all CNC inserts made in China.

Significant Chinese cemented carbide producers in other regions include: Xiamen Golden Egret Special Alloy Co., Ltd, based in Xiamen, which reported that total output of cemented carbide in 2014 increased 185% compared with that of 2009. CY Carbide MFG. Co., Ltd, founded in 2003 in Jiangsu, manufactures cemented carbide and tools such as saw blade tips, woodworking cutting blades, rods, cold heading dies, cold punching dies and wire-drawing dies. CY Carbide reported that export income accounted for 45% of total income in 2014.

KLT Carbide Co., Ltd., headquartered in Chengdu, manufactures high precision sealing rings, shaft sleeves, nozzles, valve cores, valve seats and drilling bits for oil exploration. In 2014 total output increased 436% compared with that of 2009, with sales income increasing by 187%. Exports increased by 233% and accounted for 64% of total income. Table 1 lists the top ten Chinese cemented carbide producers according to sales income in 2014.

Recycling of cemented carbide and tungsten scrap

Recycling of cemented carbide scrap is today an important element in the availability of tungsten carbide raw materials with the amount of carbide scrap recycled reaching an estimated 30% of total carbide output. There are a number of companies involved in the recycling industry and these include Shandong Linqo Wolong Cemented Carbide Co. Ltd., GEM Jingmen New Material Co. Ltd., Xiamen Golden Egret Special Alloy Co. Ltd., as well as others in Qinghe Hubei, Wenzhou Zhejiang, etc. The total recycling amounts of cemented carbide scrap reported by Linqo Wolong and GEM Jingmen in 2014 added up to over 1,600 mt. The processes used for recycling cemented carbide scrap include the zinc-process, electrolysis, mechanical crushing and high temperature calcination-crushing.

The companies involved in the recycling of tungsten scrap include Hunan Anhua, GEM Jingmen New Material Co. Ltd., Xiamen Golden Egret Special Alloy Co. Ltd. and others. The main process used for recycling tungsten scrap is gas oxidation-ion exchange and the total recycling amount of tungsten scrap reached around 10,000 mt in 2014.

Product areas for China's cemented carbide industry

CNC Indexable inserts

Indexable inserts for CNC cutting tools used in machining metals were first developed in Europe and the United States in the 1970s. After more than 40 years of development and innovation, CNC inserts have become major market products in the field of metal cutting. At present in Europe and the United States and other developed countries, about 80% of inserts for metal cutting use hard alloy coating, diamond or PCBN inserts.

Whilst China was a relative latecomer to the production of cemented carbide tools with production of CNC carbide inserts first starting in the mid-1980s, the country has since made great strides in advancing its materials technology and production know-how in order to compete with the high-end carbide tools product offered by producers in Europe, the United States, Japan and Israel. However, imported high-end cutting tools, especially coated inserts and superhard PCBN inserts, still account for around one-third of cutting tools used in China.

Key characteristics of CNC inserts produced in China compared with traditional welded cutting inserts include:

- High efficiency
- High reliability and long service life
- Chip breaking and ease of removal
- High precision of inserts and re-orientation precision
- Mechanical clamping, indexable, rapid replacing
- Good size/dimensions consistency, enabling presetting

These characteristics will be important in the implementation of one of China's national development programmes, "High-end CNC machine and basic manufacturing equipment". The project specifies that by 2020, 80% of CNC machines

Rank	Company	Sales income (thousand RMB)
1	ZCC	5,980,770
2	GESAC	2,623,880
3	ZGCC	2,417,260
4	Zhangyuan Tungsten	2,025,000
5	NCC	758,730
6	Jiangxi Yaosheng	733,100
7	Shanghai Tool Works	653,310
8	Jiangsu Hetian Tech	469,580
9	Jingmen Dewei-GEM	317,950
10	Zhuzhou OKE	297,190

Table 1 Top ten cemented carbide producers in China according to sales income in 2014



Fig. 7 CNC cemented carbide inserts and cutting tools made in China



Fig. 8 Examples of diamond coated, PCBN and cermet superhard tools made in China

used for manufacturing in the aerospace, automotive, ship and power generation sectors must be produced domestically. From now until 2020 it is estimated that production of CNC machines in China will increase by over 15% annually.

It is estimated that there are at present twelve enterprises in China producing indexable inserts from carbide and superhard materials according to International Standards materials types P, K, M and S, the latter for aerospace applications. These companies include Zhuzhou Diamond Cutting, Xiamen Golden Egret Special Alloy, Ganzhou Achteck, Zhuzhou OKE, Chengdu Bangpu, Zhuzhou Huarui and Jiangxi Jiangwu. Sales volume in 2014 was estimated to be 93 million pieces and three newly built production lines, with annual capacity of over 10 million pieces, began production in 2013. Total annual production capacity of CNC inserts is said to be around 146 million pieces (Fig. 7).

It is expected that by 2020 the annual production capacity of China's cemented carbide CNC inserts will reach more than 300 million pieces, which can meet 50% of the demand of the domestic market, up from the present third.

Superhard materials

In recent decades tools made from superhard materials such as natural and synthetic diamond, polycrystalline diamond (PCD) and polycrystalline cubic boron nitride (PCBN) (Fig. 8) have been added to the cutting tool mix and currently make up around 2% of total sales in China. Superhard tools have

problems of difficult-to-machine materials. It is expected that over 15 million superhard tool pieces will be produced in China by 2020.

PCB micro drill bit production

The global market for printed circuit board (PCB) carbide micro drill bits used in the electronics industry was around 1.2 billion pieces in 2013 with

“Production of PCB drill bits is expected to reach 1.6 billion pieces by 2020 and China is expecting its market share to exceed 50%”

become indispensable for some machining applications such as green machining, turning replacing grinding, milling replacing grinding, machining of hard materials, high speed cutting and dry cutting.

Superhard material tools have also been widely applied in machining of hardened steel, high temperature alloys, die steels, all kinds of non-ferrous alloys, advanced composite materials and wood processing. The main advantages of superhard tools are the good dimensional precision after machining, greatly improved service life of the tools and overcoming the

China having around 40% market share. Production of PCB drill bits is expected to reach 1.6 billion pieces by 2020 and China is expecting its market share to exceed 50%. The main foreign PCB micro drill bit producers are Union Tool, Topoint Technology, Kemmer Prazision and HP Tec GmbH. The largest production enterprise in China is Shenzhen Jinzhou Seiko Technology with 0.23 billion pieces output in 2014.

The main development trends in cemented carbide PCB micro drill bits are that of decreasing drill bit diameters to around 0.1 mm and below, as well as the production of



Fig. 9 PCB carbide micro drill bits and milling cutters

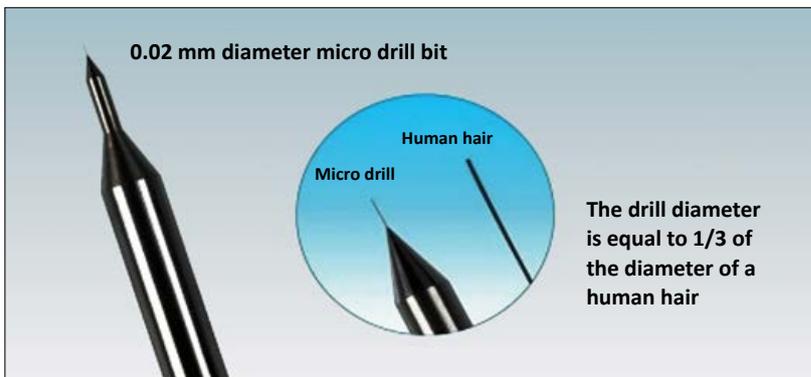


Fig. 10 PCB carbide micro drill bit having 0.02 mm diameter



Fig. 11 PDC bits for oil drilling (left), hole boring (centre) and rock coring (right)



Fig. 12 Different types of new hobbing tools (TBM hob, overbreak hob, internal pressurized hob) and inserted cutter ring produced by Zhuzhou Cemented Carbide

coated micro drill bits. Examples of PCB micro drill bits are shown in Figs. 9 and 10.

Carbide tools for engineering resources, mining and down hole drilling

Both down hole drilling for oil and gas exploration and also mining/quarrying depend greatly on cemented carbide and superhard roller bits, etc. Carbide bits are also extensively used for civil engineering, tunnel construction, highway construction and maintenance and for the construction of railway infrastructure. Examples are given in Figs. 11 and 12.

Developing and drilling of oil and gas fields requires a substantial number of cemented carbide and diamond composite buttons, PDC bits, roller bit tools and precision wear parts such as mechanical seals, bearings, bushings, nozzles, valve core seats, high-pressure plungers, electric submersible pump shaft sleeves and chasers for pipeline processing. At present the production output of cemented carbide buttons and compact alloy in China is over 3,500 mt. The main enterprises include Zhuzhou Cemented Carbide, Zigong Cemented Carbide, Xiamen Golden Egret, Suzhou Shreate, Chongyi Zhangyuan, Zhuzhou Kingtal, Hunan Century New Material and Zhuzhou JWE. The main enterprises for producing tools include Chengdu Deep, Kingdream, Changsha Heijin-gang, LHS Rock Tools and Tianjin LILIN.

Companies producing mining shield tools mainly include Zhuzhou Diamond Drilling, Liaocheng Tian-gong and Luoyang Jiujiu. Annual production capacities surpass 30,000 pieces. Enterprises producing road plane milling tools mainly include Xuzhou Kennametal and Zigong Cemented Carbide.

It is estimated that ongoing exploration work for oil and gas will see an increase in demand for cemented carbide drill tools and precision carbide wear parts with sales to this sector in China forecast to exceed



Fig. 13 Solid cemented carbide milling cutters

RMB 10 billion by 2020 with about one-third for exports. It is also estimated that domestic production of PDC bits will exceed 60,000 pieces by 2020. The market for carbide tools for mining shield tools is forecast to exceed RMB 2 billion by 2020 and carbide tools used in road building and construction will be around RMB 0.8 billion by the same year.

Solid carbide drill bits

Another market sector which has seen sustained growth for cemented carbides tools is the production of solid cemented carbide drill bits, milling cutter bodies and removable drill bits with a growing choice of removable work pieces and also CVD and PVD coated drill bits (Figs. 13 and 14). Major Chinese enterprises involved in this sector include Zhuzhou Diamond Cutting, Shanghai Tool Work, Xiamen Golden Egret Special, Harbin Tool Works and Jiangsu Changzhou Xixiashu.

In addition to steel materials for the workpiece holder, special bits for hard-to-machine materials such as titanium alloy, high temperature alloys and composite materials for aerospace have also been developed. Advances in removable cemented carbide bits have resulted in a reduction in the time to change the cutter body, resulting in reduced tool management costs. The amount of hard alloy materials used in the

cutter body has also been reduced and removable bits now offer longer tool life whilst eliminating the need for re-sharpening. It is estimated that sales of solid cemented carbide drill bits in China will exceed 40 million pieces in 2020.

Technology innovation for further growth

China's cemented carbide industry acknowledges that although great strides have been made in recent decades at research centres such as the Key State Laboratory of Cemented Carbide, the Key State Laboratory of Powder Metallurgy and the National Tungsten Materials Engineering Technology

Centre, more work needs to be done urgently to meet the increasing demand for improved efficiency cemented carbide products. This will particularly be the case for 'high-end' CNC carbide tools needed for advanced CNC machining equipment in sectors such as automotive, aerospace, rail transportation, ship building, oil and gas and minerals



Fig. 14 Solid cemented carbide twist drill bits

exploration, minerals, etc.

This will require research into: advanced hard materials and tools, forming of complex cemented carbide composite parts, densification and sintering, multilayer nano composite coating and grain orientation control, gradient composite material, in-service behaviour and performance characterisation. There will also be the need to develop process technology for hard materials having high purity, ultrafine and nanostructures, super coarse and complete crystallisation structure, gradient structure, inhomogeneous composite structure, cemented carbide and diamond composite.

Hard wear and corrosion resistant materials should be developed as well as steel matrix composites,

polycrystalline material composites, high hardness and high toughness functional structures and hard material finishing as well as surface spraying. High-end indexable insert designs, structural designs and the wider application of tools should be promoted which include CNC tool inserts, superhard tools, precision wear-resistant sealing parts, high

"It is estimated that sales of solid cemented carbide drill bits in China will exceed 40 million pieces in 2020"



Fig. 15 Key growth is expected in China's aerospace sector, helped by the introduction of domestically manufactured aircraft such as the ARJ21 developed by state owned COMAC and set to enter service in Spring 2016

speed wire rolls and composite rolls, structural parts for nuclear shielding, excavating drills, coal mining tools and road plane milling tools.

These ambitions are supported by China's 'Made in China 2025' initiative, a policy similar to Germany's Industry 4.0 plan for intelligent manufacturing. The aim for China is that future production should be innovation-driven in order to transform the country from a 'large' manufacturing state into a 'great power' manufacturing state.

The focus of Made in China 2025 will be on a number of areas such as novel information technology, numerical control machines and robots, equipment for aeronautics and astronautics, equipment for ocean engineering, high tech watercraft, advanced equipment for rail traffic, energy-saving and new energy vehicles, electric power equipment, new materials, biomedical and medical devices, agricultural machinery and equipment. The policy includes five modules when applied to equipment manufacturing. These include materials, process and equipment, works, transportation and selling. These are independent modules with each having a software system, communication system, sensor system, automatic detection and control system.

There will also be a need over the next five years to undertake deep industry reforms and to upgrade industry including the cemented carbide sector. Sales of the state-owned enterprises currently account

for around 50% of total income, but the joint-stock and private enterprises have proved themselves to be more productive and profitable. State-owned enterprises for cemented carbide production must, therefore, carry out reforms which will greatly change the capital structure and operational mechanisms of the enterprises concerned and which will lead to the mergers and acquisitions of numerous joint-stock enterprises and private enterprises. The cemented carbide industry in China will also benefit from new and innovative business start-ups.

Future growth in the cemented carbide and superhard materials sectors will of course ultimately depend on the growth of the Chinese economy. The country aims to achieve an annual economic growth rate of around 7% in the period up to 2020. In 2014 a total of almost 24 million vehicles were produced in China, accounting for a quarter of the world total. This number is expected to rise to over 25 million in 2015, an increase of 7% and by 2020 total vehicle production is estimated to reach 30 million, maintaining the country's position as the world's largest vehicle producer. The annual demand for CNC inserts and cutting tools just for the automotive sector alone is expected to exceed 300 million pieces by 2020.

Another key growth sector is China's aeronautical industry. The country has started mass producing commercial aircraft and series production of large passenger aircraft.

It will also be producing in large quantities military fighter jets and helicopter gunships. It is estimated that the global aerospace sector accounts for around 12% of the cutting tool market.

Outlook for China's cemented carbide industry in 2020

It is estimated that in 2020 production output of China's cemented carbide industry will be 33,000 mt with sales income around RMB 50 billion.

Export of cemented carbides is expected to exceed 10,000 mt, with foreign exchange earning these exports in excess of US \$1 billion. High-end carbide NC inserts will exceed 300 million pieces. Solid cemented carbide tools will exceed 40 million pieces. PCB drill bits will be close to 800 million pieces. Operating income of carbide bits and structural parts for oil and gas exploration and mining, transportation infrastructure, precision wear parts and cemented carbide drilling tools will exceed RMB 1.5 billion. It is estimated that more than thirty cemented carbide enterprises will be listed on the stock exchange. If estimates are correct, China can look forward to maintaining a powerful cemented carbide industry.

Author

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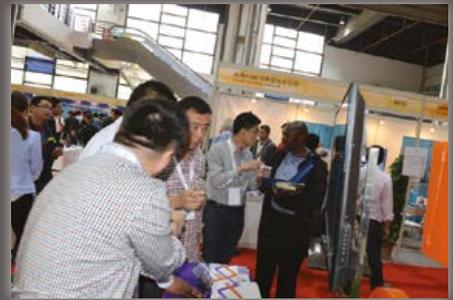
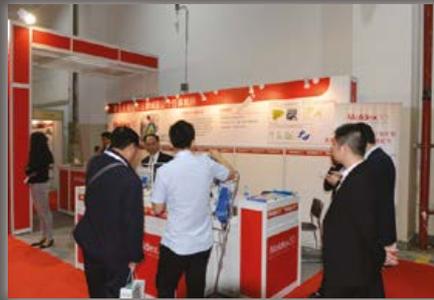
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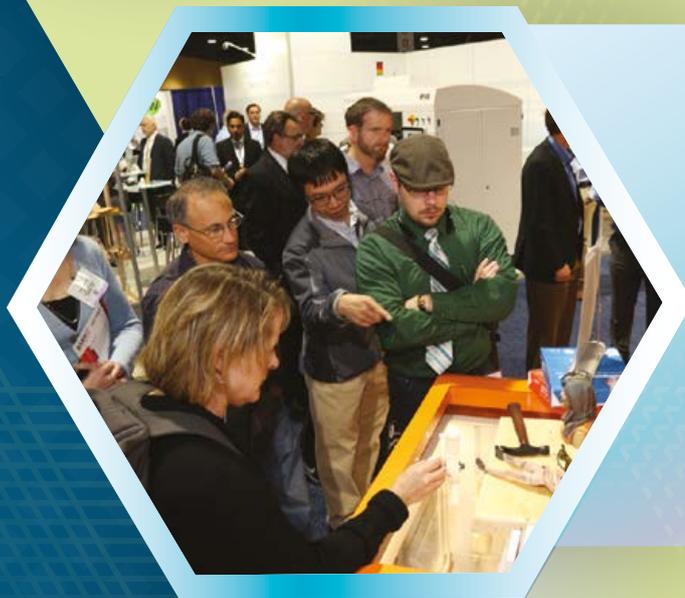
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Hagen 2015: Advances in metal powder technologies at Germany's annual PM symposium

The 34th Hagen Symposium, organised by Germany's Fachverband Pulvermetallurgie, was held in Hagen, Germany, on November 26-27, 2015. The annual meeting for the German-speaking PM community attracted more than 200 delegates and the accompanying exhibition included some 62 exhibitors. Dr Georg Schlieper reports on a number of presentations focused on the hardmetal industry as well as a presentation that looks at the potential of thermoelectric materials. A novel sintered soft magnetic composite material, that combines the advantages of SMC with the strength of sintered PM materials, is also discussed.

Historical development of hardmetals and trend towards finer hardmetal grades

As is the tradition at the Hagen Symposium, the meeting opened with a presentation by the winner of the Fachverband Pulvermetallurgie's prestigious Skaupy Prize. This year's recipient was Professor Wolf-Dieter Schubert, Technische Universität Wien, Austria, (Fig. 1) who was introduced in a laudatory speech by Burghard Zeiler, Secretary General of the International Tungsten Industry Association. Schubert began his Skaupy Lecture with a review of the history of hardmetal materials, then discussed the trend towards finer hardmetal grades due to the growing demand for harder materials with higher strength and toughness.

Hardmetal, also known as cemented carbide, is a composite

material consisting of hard and wear resistant tungsten carbide (WC) embedded in a metallic binder phase, usually cobalt (Co). The availability of high quality tungsten carbide powders has always been a

key requirement for the production of high-performance hardmetal tools for cutting metal, wood or rock, wear parts and metal forming tools.

The current world market for hardmetal products is estimated



Fig. 1 Wolf-Dieter Schubert (centre right) receives the Skaupy Prize from Burghard Zeiler (left), Hans Kolaska (centre left) and Herbert Danninger (right)

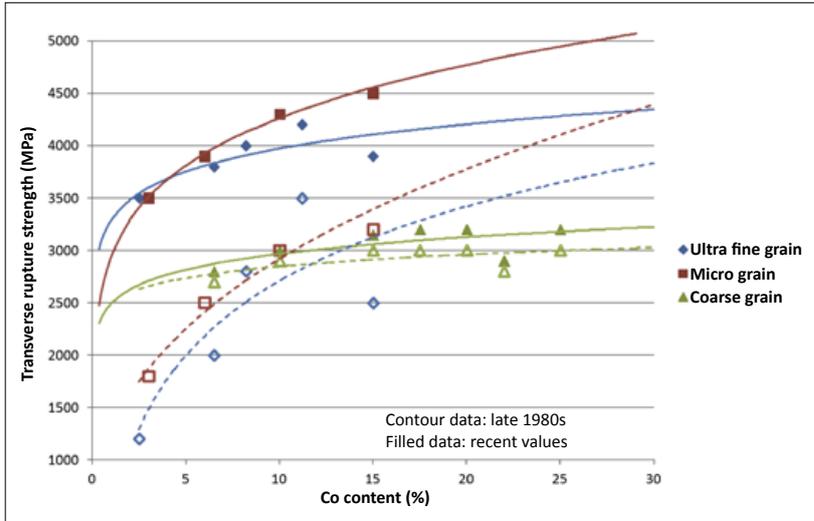


Fig. 2 Strength of hardmetal grades (Courtesy H. Westermann) [1]

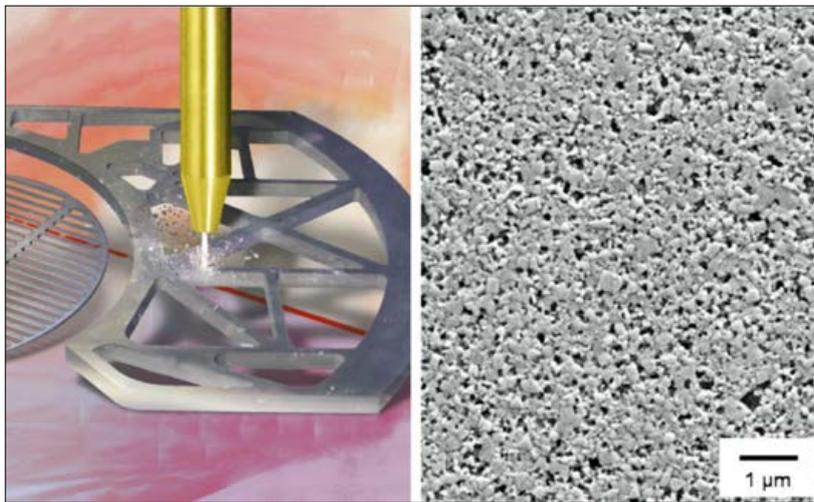


Fig. 3 Water jet cutter (left) and the nanocrystalline microstructure of 'binderless' hardmetal (Courtesy Ceratizit) [1]

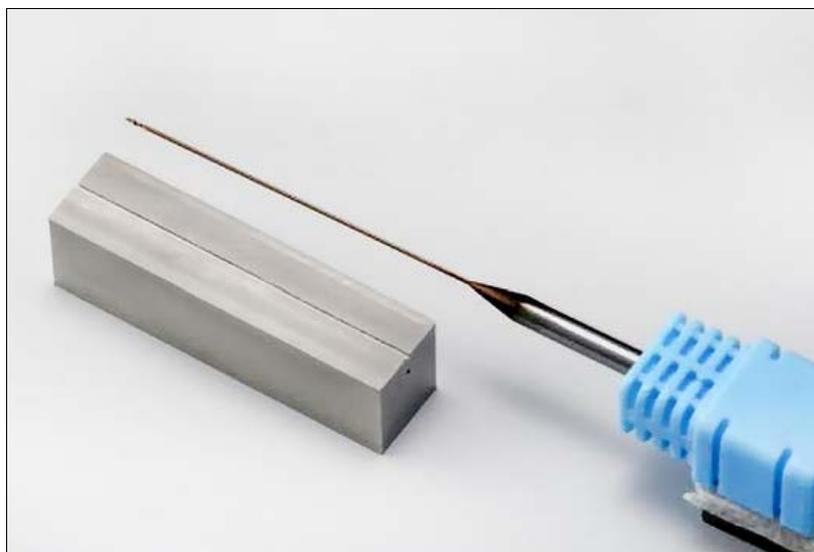


Fig. 4 Deep drill for printed circuit boards (Courtesy MMC Hitachi Tool) [1]

at 75,000 tons per annum. Besides the impressive growth in size, the structure of the hardmetal market has also undergone fundamental changes. From standard WC powders with particle sizes of 1-5 µm in the past there has been a clear trend towards finer powders and today submicron powders are predominant, with a market share of approximately 55%. Coarser WC grades (> 5 µm) contribute roughly 12 % of the world market. The submicron powders are further divided into micro grain (average particle size 0.5 – 1 µm, 85% share), ultra-fine grain (0.2 – 0.5 µm, 15%) and nanocrystalline powders (< 0.2 µm, < 1%).

The reason for the trend towards finer hardmetal grades is the growing demand for harder materials with higher strength and toughness. This was achieved by a substantial reduction of the number of defects in the hardmetal such as residual porosity, local grain growth and precipitations.

The transverse rupture strength of various hardmetal grades in the late 1980s and today is depicted in Fig. 2. A comparison shows that, in the past, the fine grained grades particularly exhibited clearly lower strengths than the coarse grained hardmetals. Even after eliminating the residual porosity by Hot Isostatic Pressing (HIP) there was still local grain growth that could not be avoided. The high strength micro grain and ultra-fine grades are based on an improved powder production technology and the use of grain growth inhibitors such as vanadium carbide (VC).

Beginning in the 1990s, advanced Physical Vapour Deposition (PVD) coating technologies provided an additional significant contribution to the success of hardmetal tools for cutting applications. The combination of micro grain hardmetal with high strength and PVD coating under compressive stress has proven to be a reliable and efficient concept for the cutting tool industry. Optimised geometries and reduced surface roughness at the cutting edge led to substantial improvements of cutting tools with adaptation to the applica-

tion. According to Schubert, further significant progress can be expected in this sector.

In his comprehensive review, Wolf-Dieter Schubert outlined the most important applications of micro grain hardmetals and the progress made since the 1980s. About 60% of these grades are used for metal cutting tools, usually with a PVD coating of 1 – 5 µm thickness consisting of TiAlN, AlCrN or DLC (diamond-like carbon). Between 1985 and 2009 the cutting performance of a hardmetal roughing cutter as expressed by the volume of material removed per time unit has been increased by a factor of 15 due to improved hardmetal quality, coating and cutting edge geometry.

Wear parts requiring high strength are increasingly made from micro grain and ultra-fine hardmetal. With approximately 18% share they sit in second place. Applications are extremely diverse and include classical wear parts such as wire drawing dies, cutting blades, sealing rings, milling cutters (coated) and many more. So-called 'binderless' hardmetals, which, with a hardness of 2800 HV10, have the highest hardness of hardmetals, are used for water jet cutting (Fig. 3).

Tools for the electronics industry are another important sector with a share of roughly 10% of the total market for submicron hardmetals. Drills and milling cutters for printed circuit boards are produced in huge quantities. Drills can have diameters down to 20 µm, deep drills down to 50 µm and the depth-to-diameter ratio can be up to 100 (Fig. 4).

Indexable inserts for metal cutting applications represent roughly 8% of the submicron market. This market continues to grow as submicron powders with improved compacting and sintering properties are available. Indexable inserts made from micro grain hardmetal grades with PVD coatings are used for drilling, milling and partly even for turning. All-purpose tools enable a broad range of applications for many metal alloys and there is a clear trend to reduce the size of the inserts in

order to save raw material. Innovative compaction techniques are used to produce cutting edge geometries that were previously impossible to realise.

Current trends in cutting tools and material developments

Another contribution on the subject of cutting tools was presented by Professor Dirk Biermann, Technical University Dortmund, Germany. He stressed the point that technically advanced solutions in the cutting tool sector should not only consider the cutting tool material, coating

water jet treatment with an abrasive medium for the modification of the cutting edge micro geometry. This process is flexible and can be used either to generate complex cutting edge shapes or to improve coated cutting edges. The rounding of the cutting edge is achieved in a system where the required movements are performed by an industrial robot (Fig. 5). The tool is manipulated freely under a fixed nozzle and the edge preparation aims at eliminating microscopic defects in the cutting edge that originate from the grinding process. In addition, the cutting edge profile is optimised for the respective machining process. This concept

“This concept enables the modification of even limited areas of a cutting edge in the desired way and creates complex cutting edge shapes”

and cutting edge geometry, but also the material properties of the work piece and the processing parameters such as cutting speed, feed rate, cutting depth, mechanical and thermal stresses, lubricating and cooling media. Not only are the individual aspects relevant, but also the interaction of many of these parameters should be considered.

Biermann discussed the benefit of

enables the modification of even limited areas of a cutting edge in the desired way and creates complex cutting edge shapes.

Besides newly manufactured tools, re-sharpened machining tools are also improved by the water jet treatment. When twist drills are re-sharpened, new main cutting edges and a new cross-cutting edge are generated. As microscopic



Fig. 5 Robotic arm with twist drill in a water jet spray unit (Courtesy D Biermann) [2]

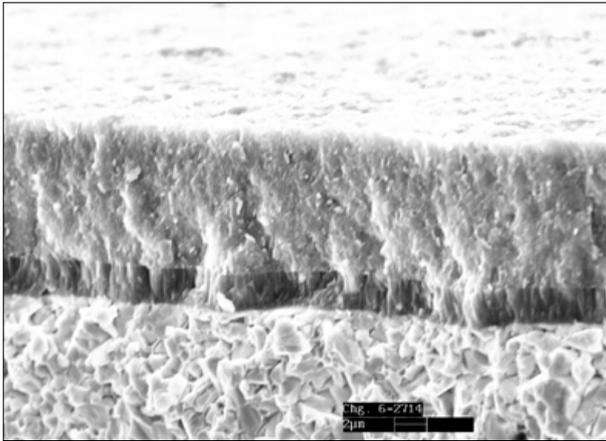


Fig. 6 SEM image of TiN/TiCN/AlTiN coating [courtesy R Pitonak] [3]

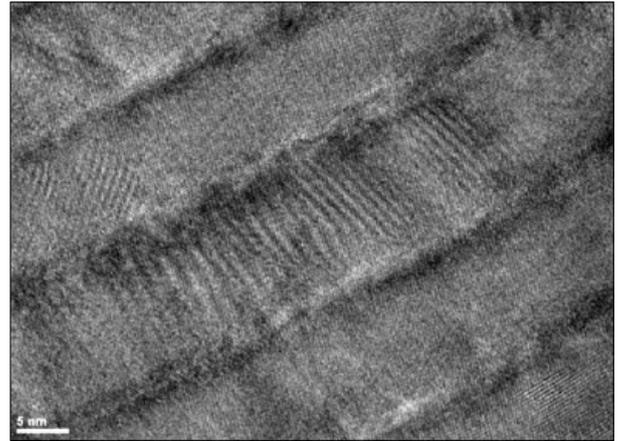


Fig. 7 HR-TEM image of nano layers in HR-CVD AlTiN [courtesy R Pitonak] [3]

defects are again introduced into the region of the cutting edge by regrinding and the shape of the cutting edge after regrinding is not adapted to the cutting process, a rounding of the cutting edge is also required here. Usually regrinding affects only the flank of the cutting tool and the original coating is still present on the rake face.

Reinhard Pitonak of Boehlerit GmbH, Austria, reported on innovative multilayer coatings for cutting tools deposited by Highly Reactive Chemical Vapour Deposition (HR-CVD). When these coatings were investigated with optical and electron microscopes, they exhibited a rather common structure with columnar crystal growth (Fig. 6). A more detailed analysis using high resolu-

tion SEM and TEM, however, revealed that the entire coating was composed of micro crystals (~100 nm) that themselves exhibited a unique lamellar substructure (Fig. 7).

Lamellae occurred at different positions in the coating and their respective orientation was uncorrelated. In addition, the TEM analyses showed that with minimal tipping new surfaces with periodic nano layers appeared and the previously observed structures disappeared. This suggests that the entire coating consists of highly organised lamellar substructures that can be clearly distinguished from one another. This nano layered structure has previously been described for PVD coatings, but according to Pitonak it is entirely new for CVD coatings.

Ultrasonic fatigue testing of hardmetals

Herbert Danninger, Professor at the Technische Universität Wien, Austria, and Chairman of Fachverband Pulvermetallurgie, presented results of a joint research project sponsored by major players in the European hardmetal industry. The project title "Ultrasonic Fatigue Testing of Hardmetals (UFTH)" indicates that the objective was to study the fatigue behaviour of hardmetal under high frequency loading. The high frequency allows the extension of the fatigue tests, which for practical reasons are usually limited to 10 megacycles, into the gigacycle range.

According to Danninger, testing in the gigacycle range offers the chance to work out the mechanisms of fatigue and crack initiation in particular clarity. Generally, one can differentiate between various types of material failure, especially in fatigue. There is 'structure controlled' and 'defect controlled' crack initiation (and for real components, geometric effects such as notches, scratches etc. should be considered as a third type of crack initiation). Structure controlled crack initiation starts at one or more structural features which are abundant in the material. An example is the relatively coarse carbide size in chromium alloyed cold working steel of type 1.2379 (AISI D2). The probability of a crack being initiated at such a carbide is very high

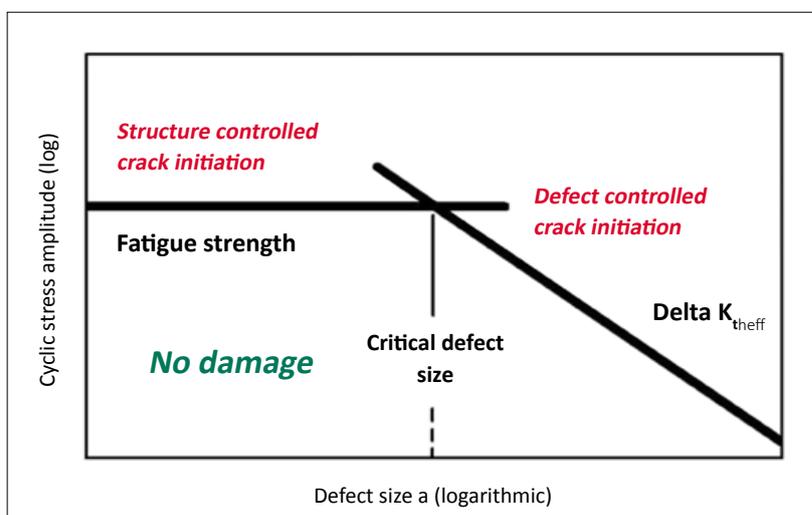


Fig. 8 Kitagawa-Takahashi diagram (after H Danninger) [4]

and consequently the scattering of individual values is small.

The alternative is defect controlled crack initiation. In this case the crack starts from structural defects which are very rare; typical examples are oxide, carbide or nitride inclusions in high purity steel grades such as roller bearing or spring steels, or slag inclusions in powder metallurgy tool steels. This type of material failure is comparable to that of high-performance ceramics in static tests where generally the largest existing defect in the loaded volume determines the strength. Danninger concludes that even metallic materials in gigacycle fatigue may show 'ceramic behaviour'.

The microstructure versus defect controlled fracture behaviour is evaluated, for example, with a Kitagawa-Takahashi diagram (Fig. 8). The fatigue strength is plotted against the defect size in a double logarithmic diagram. Up to a certain size of defects, these are irrelevant for the failure; the strength is defined by the structure. At a certain critical defect radius, the crack starts from the largest defect in the loaded volume. The fatigue strength of the material is then lower, the larger the defect is. The characteristics required for this plot are the fatigue strength of the defect-free material (or a material with subcritical defects) and the 'effective threshold stress intensity factor' $\Delta K_{th,eff}$ which is a material characteristic for the crack propagation. Thus, the Kitagawa-Takahashi diagram requires only fatigue-related data.

The test rig used for fatigue testing is schematically shown in Fig. 9. The load is introduced by a 20 kHz electrical signal which is converted to a symmetrical tension-compression loading ($R = -1$) and amplified by an acoustic horn. The load amplitude is indirectly measured by a strain gauge on the adapter piece and the heat generated by the high test frequency is removed by a cooling circuit.

As common in fatigue testing, several tests were run at a certain stress level and the failure

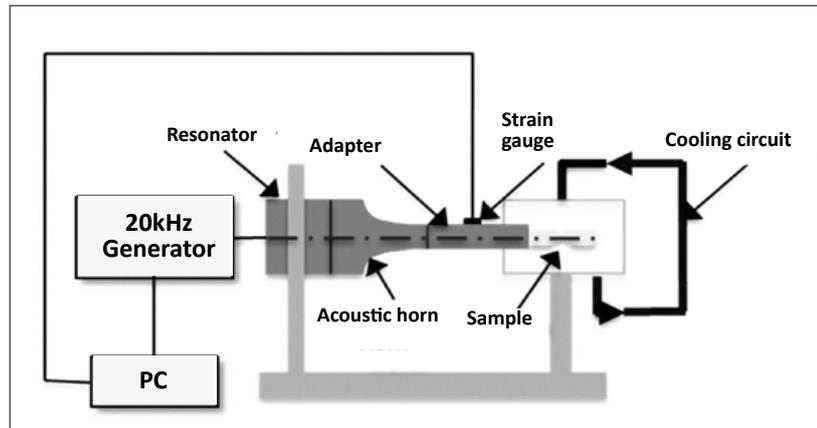


Fig. 9 Test rig for gigacycle fatigue testing (Courtesy H Danninger) [4]

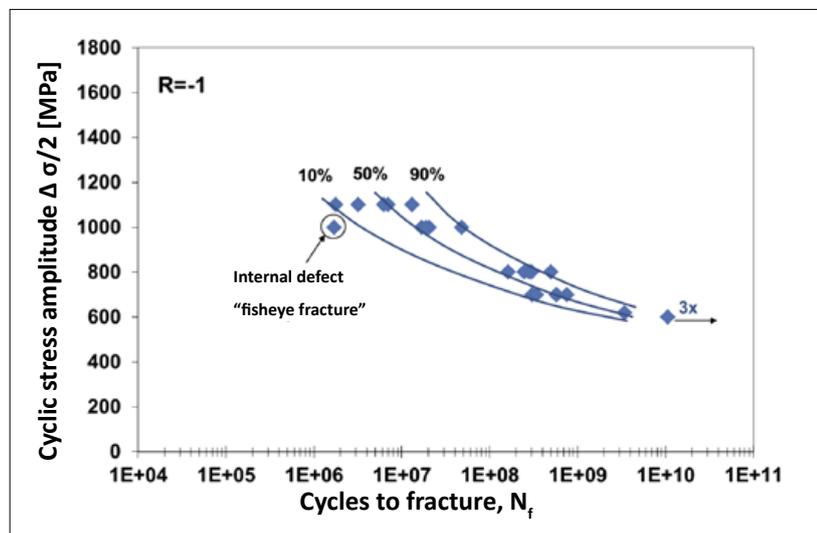


Fig. 10 Typical SN curve for hardmetal (courtesy H Danninger) [4]

probabilities were calculated from the results. Fig. 10 shows a typical SN curve. As can be seen, the dispersion of the individual values is small, which is surprising given the low toughness of cemented carbides. This can be interpreted as an indication of a structure controlled failure and a defect-free microstructure, writes Danninger.

Also apparent is the fact that, at least up to the maximum applied load and up to a number of $10E+10$ cycles, no real fatigue limit exists. The curves continue to decline at higher N values in a slightly concave curve. This behaviour is consistent with the results found for other materials in the gigacycle range, such as high-alloy steels or sintered steels. In contrast to the traditional conception for steels having a body-centred

cubic lattice, no real fatigue limit could be found for PM steels.

The potential of thermoelectric materials

Thomas Weissgärber of the Fraunhofer Institute IFAM in Dresden, Germany, reported on the present status and potential of thermoelectric materials. The distribution of charge carriers in a material is affected by temperature gradients in such a way that an electrical voltage arises between regions of different temperature.

This phenomenon, first described in 1821, is referred to after its discoverer as the Seebeck Effect. Mobile charge carriers in warm areas have a higher kinetic energy and diffuse faster than the charge carriers in

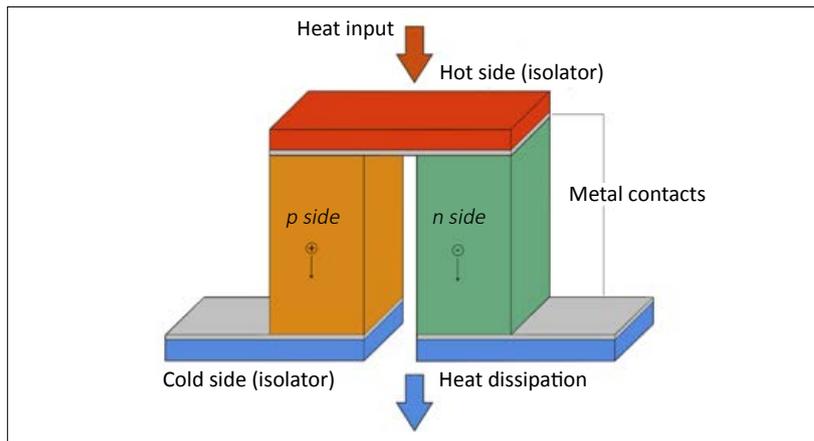


Fig. 11 Basic unit of a thermoelectric module [Courtesy T Weissgärber] [5]

cold areas, so more charge carriers move from warm areas to cold areas than vice versa. As a result, charge carriers accumulate in the cold areas and an electrical potential difference between the areas is obtained which is proportional to the temperature difference. The electrostatic repulsion of equal charges, however, drives the charge carriers back against the temperature gradient in the direction of the warm area. After reaching the steady state between these effects there is no forward current of charge carriers in the material.

In metals the mobility of charge carriers is so high that the Seebeck Effect cannot be exploited technically, but certain semiconducting materials exhibit a more pronounced Seebeck Effect. Negative charge carriers are electrons and positive charge carriers are missing electrons, i.e.

voids. Depending on the type of charge carrier that accumulates at the cold side, either a positive charge, i.e. voids, or a negative charge, i.e. electrons, researchers distinguish between *p*-type and *n*-type thermoelectric materials. Materials researchers at IFAM are developing technical solutions with the objective of using the waste heat of technical processes or motor vehicles for the generation of electrical power.

The basic design of a thermoelectric module is shown in Fig. 11. It consists of a *n*-type and a *p*-type material. The two pieces are electrically connected with each other on one side. The temperature gradient between the hot and cold sides leads to the formation of an electrical voltage in both materials. If an electrical load is connected to the two legs to form a closed circuit,

a flow of electricity is generated. A thermoelectric module contains many of these basic units which are electrically connected in series and thermally in parallel. For a continuous flow of electricity the temperature gradient must be maintained, that is, on the hot side, heat must be supplied and, on the cold side, heat must be dissipated. The module does not contain any moving parts and is free from wear.

The efficiency of thermoelectric materials for transforming heat to electrical energy is defined by the efficiency coefficient zT . A selection of *p*-type and *n*-type thermoelectric materials and their efficiency coefficients is given in Fig. 12 as a function of the temperature. Many of these materials are intermetallic compounds of tellurium and another metal. High temperature materials with efficiency coefficients between 1 and 1.5 are available, but efficiency coefficients above 1.5 are still very rare. Modules having sufficient performance and reliability are under development. In order to be competitive in the field of waste heat utilisation, Weissgärber says, better thermoelectric materials with efficiency coefficients between 1.5 and 3 have to be developed. Besides the thermoelectric efficiency, the toxicity, availability and cost must also be considered.

According to Weissgärber, tellurides are usually manufactured by casting, but Powder Metallurgy can

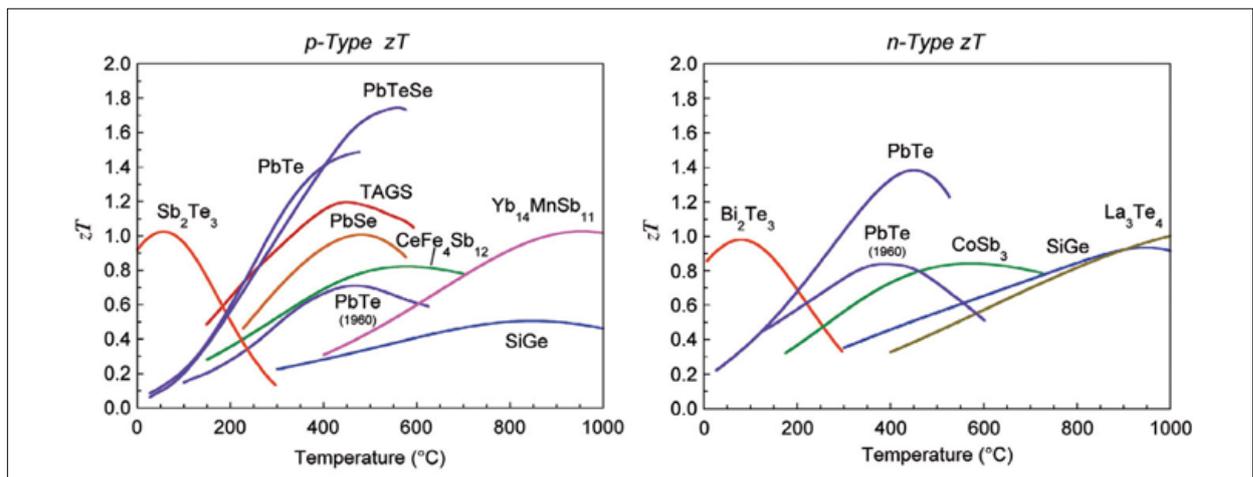


Fig. 12 Thermoelectric materials and their efficiency coefficients (as published in paper by LaLonde, A D et al. Lead telluride alloy thermoelectrics. *Materials Today*, 14, 2011, 526-536) [5]

be applied to improve the mechanical properties with equal thermoelectric properties. In general, PM offers high quality and homogeneous materials as well as materials which can only be prepared by PM (silicides are one example). The PM process described by Weissgärber for the most widely used thermoelectric material bismuth telluride Bi_2Te_3 involves atomising a melt of the desired composition, high energy milling and hot pressing or spark plasma sintering SPS to consolidate the powder. Melt spinning and SPS can be used to produce nano structured materials.

The utilisation of waste heat by means of thermoelectric modules is an interesting technology for the automotive industry that can be utilised to meet the demanding CO_2 limits in the future. The potential to improve the energy efficiency of industrial processes is also of great interest. Progress has been made in recent years in the development of thermoelectric materials for applications at higher temperatures, but further research is necessary before this technology can be exploited commercially.

Sintered soft magnetic composites combine the advantages of SMC with the strength of sintered PM materials

An innovative concept for soft magnetic PM materials was presented by Jens Burghaus of Robert Bosch GmbH, Stuttgart. Currently, soft magnetic PM materials are either composites made up of iron powder and a polymeric binder or sintered alloys. Soft Magnetic Composites (SMC) are characterised by low eddy current losses, which is advantageous for applications in alternating magnetic fields, but the mechanical strength is limited. Sintered soft magnetic materials have a higher strength, but also high eddy current losses. This is why the requirements for many soft magnetic applications are not yet met by PM materials.

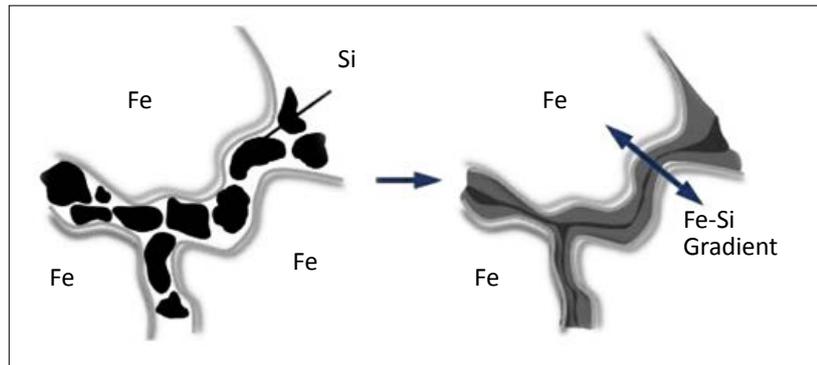


Fig. 13 Schematic concept for SSC material [Courtesy J Burghaus] [6]

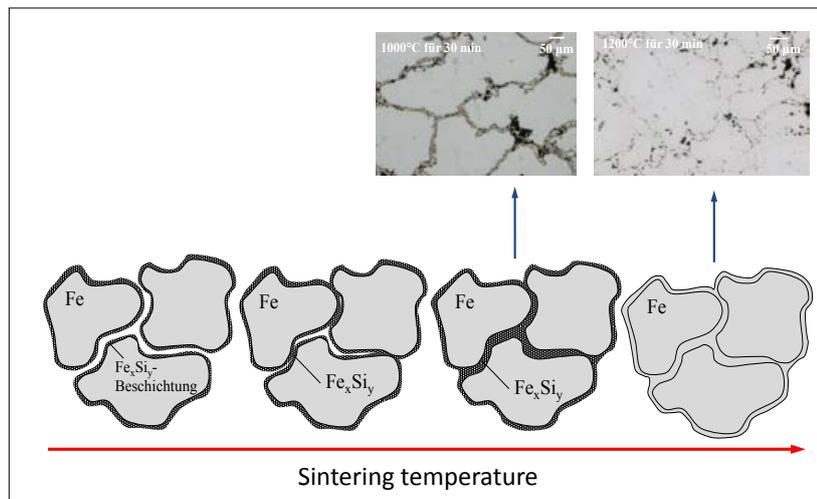


Fig. 14 Sintering of Si coated iron powder [Courtesy J Burghaus] [6]

A new material concept was presented called sintered soft magnetic composites (SSC) because it combines the advantages of SMC with the strength of sintered PM materials. The basis for the new material concept is the conventional soft magnetic iron-silicon alloy. In sintered iron-silicon alloys, iron is used due to its favourable soft magnetic properties: high saturation of approx. 2.15 T, high maximum permeability and coercive force.

In contrast to the traditional, homogeneous sintered material the new concept aims at a defined, inhomogeneous microstructure which is composed of a high-resistance iron-silicon phase that completely envelops the soft magnetic iron particles. The interdiffusion between silicon and iron during sintering

should be limited so that an iron silicide phase Fe_3Si is formed at the particle boundaries (Fig. 13). In the boundary phase, a bulk electrical resistivity of up to $2 \mu\Omega\text{m}$ can be achieved. Such a high resistivity is not realised in a homogenous iron-silicon alloy. In addition, iron silicide exhibits a ferromagnetic atomic order which means a reduced air gap as compared to conventional systems. Researchers aimed at a high density and a sound sintered structure that provides sufficient mechanical strength and good magnetic properties.

Attempts with a mix of iron powder, an iron-silicon master alloy for a total silicon content of 3% Si and lubricant, then compacted at 800 MPa and sintered at temperatures between 1050°C and 1200°C, failed because the formation of sinter contacts required a temperature of 1200°C and the diffusion of silicon

Material	Sintered powder mix	Coated powder sintered	Höganäs 1P Somaloy 500
Heat treatment	1100°C, 30 min [N ₂]	1000°C, 30 min [N ₂]	Robert Bosch GmbH, CR/ARM3
Density [g/cm ³]	6.56 / 6.83*	6.88	7.48
Resistivity [μΩm]	0.76 / 0.75*	1.38	58
Induction @ 50 kA/m [T]	1.40 / 1.55*	1.56	1.92
Max permeability	271 / 451*	433	504
Coercive force [A/m]	255 / 243*	265	310
Bending strength [MPa]	61 / 80*	119	42

Values marked with an asterisk () are for repressed samples.*

Table 1 Comparison of different soft magnetic PM materials [6]

in iron at this temperature was so fast that a homogeneous alloy was formed. In the next step, 1% copper was added with the intention of forming a transient liquid phase with a low melting copper-silicon eutectic during sintering that would enhance the sintering process. A compromise between magnetic properties and strength, although not fully satisfactory, was achieved at a sintering temperature of 1100°C, but the electrical resistivity was too low for AC applications.

Finally the iron powder particles were coated with a thin iron-silicon phase by a treatment in a fluid bed reactor with a reactive silane gas SiH₄. The coated powder was mixed with lubricant and compacted, then sintered at temperatures between 1000°C and 1200°C. The microstructure after sintering at 1000°C showed that the powder particles had been completely coated with an iron-

silicon phase of 2 μm thickness and the coating was still intact, at 1200°C it has been completely dissolved in the matrix (Fig. 14). The total silicon content was 2%.

A comparison of the two newly developed SSC materials with a commercial SMC is given in Table 1. The concept of silicon-rich particle boundaries appears feasible, but further improvement is still required before this concept can be commercialised. Above all, the density must be increased in order to further enhance both the mechanical and magnetic properties.

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Safety in the PM industry: Steps in reducing the risk of fire and explosion with metal powder dusts

A session on combustible dusts at POWDERMET2015, held in San Diego, USA, May 17-20, 2015, included two papers which assessed the potential risks with metal dusts and, perhaps more importantly, provided guidance on mitigation strategies to avoid these risks. Dr David Whittaker reports for *Powder Metallurgy Review* on the papers from this session.



The potential for creating pyrophoric fires or even explosions with finely divided dusts of highly combustible materials, such as in flour milling or sugar refining, is widely recognised. However, a number of incidents over the years have concentrated the minds of both powder makers and PM parts manufacturers on the possibility of encountering similar problems with metal powders. Consequently, the conference programme at POWDERMET2015, included a session entitled "Combustible Dusts" that included two papers on the subject.

Preventing fire and explosion of metal dust

The first of these papers was by Alfonso Ibarreta and Timothy Myers of Exponent, USA. The paper provided an overview of combustible metal dust hazards and mitigation strate-

gies prescribed in the USA by the National Fire Protection Association's NFPA 484 Standard for Combustible Metals and related standards [1].

The popular perception is that metals do not burn, but, according to NFPA 484, "any metal in a fine enough form can be combustible and/or explosible". It is the small particle size or large surface area to

volume ratio of a combustible dust that differentiates it from a bulk combustible solid. The combustion rate of bulk solids is limited by the surface area of the solid in contact with the oxidiser (air) and so, as the particle size of a material decreases, the specific surface area increases and combustion rate per mass of material increases.

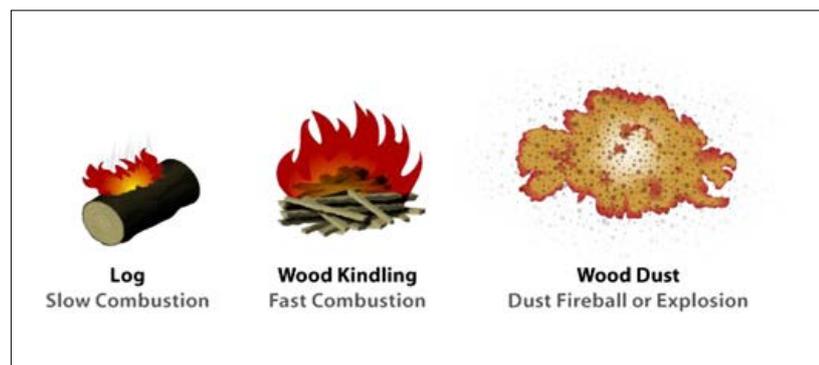


Fig. 1 Analogy of how the rate of combustion of wood increases as the particle size decreases (after Eckhoff) [1]

NFPA areas of guidance:	
Hazard Analysis	Particle size separation
Building construction	Mixers and blenders
Building explosion venting	Dryers
Equipment explosion protection	Dust collection equipment
Equipment isolation	Fire protection
Bulk storage	Housekeeping
Material transfer systems	Management of change
Size reduction operations	Control of ignition sources
Segregation, separation, or detachment of dust handling and processing areas	Employee training, inspection, and maintenance

Table 1 NFPA combustible dust standards, including NFPA 484, cover a wide range of subjects

This concept is illustrated through the analogy shown in Fig. 1. In this scenario a log of wood is difficult to ignite and burns relatively slowly; however, if the log is chopped into kindling it is easier to ignite and burns more rapidly. In the extreme, if the log is ground up into a fine dust

handling processes, unintentional releases from equipment or from accumulations in a facility.

The first four elements are sufficient to create a flash fire, but, for an explosion, some degree of confinement is also needed. Confinement can be caused by the outer shell of

“The first four elements are sufficient to create a flash fire, but, for an explosion, some degree of confinement is also needed”

and dispersed in air, it is much easier to ignite and burns very rapidly. A flame propagating through a cloud of fine wood dust dispersed in air is, in some ways, similar to a flame propagating through a mixture of a flammable gas or vapour and air.

The authors identified five elements needed to create a dust explosion: combustible dust, an oxidiser, an ignition source, a dispersion of the dust and confinement. Oxygen in the air is the most common oxidiser, although other gases can act as oxidisers, with some metals reacting with halogens or carbon dioxide. Ignition sources include static electricity, sparks from electrical equipment, hot surfaces, frictional heating and open flames. Dispersion of dust may occur from

equipment, the walls of a building or by the presence of a heavily congested area.

Combustible metal dusts can present unique challenges compared to more traditional organic dusts and the paper listed these hazards as:

- Some combustible metal dusts can burn at very high temperatures (up to 8,000°F).
- Some combustible metals can produce very rapid pressure rises during a deflagration. Aluminium and magnesium powders, for instance, have very high values of the deflagration index, K_{st} .
- The standardisation of fire suppression systems for metal dusts is challenging, because a number of metals are not

compatible with traditional suppression agents. For instance, many combustible metals react with water and so water sprinkler automatic fire suppression is not effective.

- Even extinguishing agents designed for combustible metals can be dangerous to deploy because of risks related to further dust dispersion.
- Explosion suppression and isolation system design is complicated because of the high combustion temperatures and K_{st} values.
- Combustible metal dusts can create an exothermic thermite reaction with oxides of other metals and so they should not be processed or conveyed in equipment used for other metals.
- Combustible metal dusts are electrically conductive and therefore the presence of even small quantities of dust can cause shorts in electrical equipment.

The NFPA 484 Standard describes explosion and fire prevention and mitigation methods and states requirements to prevent the occurrence of ignitable dust clouds in the presence of ignition sources. The areas of guidance in the standard (Table 1) are very wide-ranging and so the authors chose to restrict themselves to identifying examples of methods used by facilities to deal with common hazards.

Requirements in the standard focus on keeping combustible dusts and powders inside process equipment and minimising dust clouds and accumulations. These issues can be addressed by multiple methods: designing and maintaining equipment to be dust tight, operating equipment at negative pressure, using dust collection at points of dust generation and frequent housekeeping to limit accumulations. A variety of requirements address the control of the following ignition sources: sparks (friction, electrical, static electrical), grounding and

bonding, hot surfaces, hot work, open flames, heating systems, slipping belts, bearings and electrical equipment.

Explosion protection of equipment can be broken down into two sub-sets, explosion prevention and explosion mitigation. Explosion prevention methods include oxidant concentration reduction (inerting), reduction of combustible dust concentration and dilution with a non-combustible dust. Explosion mitigation methods include explosion venting, explosion pressure containment, explosion suppression and explosion isolation.

Protective measures against fire and explosion of metal dusts

The second paper in the session was from Gerd P Mayer, Eric Finley and Helen Sztarkman of Rembe Inc., USA, and addressed protective measures against fire and explosion of metal dusts and the "peculiarities" of their applicability [2]. In a general introduction, the authors spelled out the three major considerations in explosion protection.

The first consideration was defined as explosion prevention. Explosion prevention strategies comprise suspending of highly combustible process media in oil to avoid any possible reaction with oxygen, conditioning (transferring a combustible substance into a non-combustible one) or blanketing with an inert gas. While it is an attractive strategy in an ideal world, the authors counselled that, in real processes, the applicability of explosion prevention methods is limited.

The second consideration was therefore the avoidance of ignition sources. A similar range of potential sources to that identified in the previous paper was discussed, but it was concluded that preventing ignition sources with 100% certainty is difficult and costly and is made even more difficult because of the uncontrollable human factor.



Fig. 2 The Rembe Q-Rohr-3-6T-AL [2]



Fig. 3 Flame length of an explosion with aluminium dust [2]



Fig. 4 Explosion of aluminium dust with the Rembe Q-Rohr-3-6T-AL installed (compare with Fig. 3) [2]

Hence, there is a need for the third consideration, mitigation of the effects of an explosion. Various NFPA standards were quoted as defining proper mitigation techniques for processes that have combustible dust risks. For example, enclosures are commonly fitted with properly sized explosion panels if the enclosures are outside or close to an external wall.

If an enclosure is inside the building, flameless indoor venting systems represent an option or chemical suppression might be used.

In addition to the venting, interconnected enclosures must be equipped with devices designed to isolate an explosion so that it does not propagate. Passive flap valves and active quench valve devices are



Fig 5 Dust collector equipped with Q-Rohr indoor venting system [2]

commonly used for this purpose and chemical isolation is also an option.

These mitigation techniques are now available for metal dust processes, but with additional considerations that need to be taken into account. Metal dusts are different because, even though many metal powders do not have a high K_{st} value compared with organic materials (except for Al and Mg that can exceed 500 bar.m/sec), the risk

temperatures of 1650-2200°C, whereas metal powders can easily exceed 2750°C.

With metal powder dusts, dust collectors are prone to explosions by their nature due to the dust that may be stored in them and the high potential for ignition sources. NFPA 484 covers the use of wet-type and dry-type dust collectors and states that they "shall be located outside buildings". Nevertheless, in practice,

"Explosion venting and isolation are very feasible options in many metal dust applications"

of fire and explosions is increased because, in processes generating metal powders, the probability of self-ignition is increased. In addition, metals and metal powders have much higher energy contents than organic materials. This leads to very long burning times, an issue compounded by the fact that normal extinguishing agents, such as water or sodium bicarbonate, cannot be used. After an explosion, organic materials can reach burning

many dry dust collectors are installed indoors and this is permitted if a process hazard analysis ensures that the risk to personnel and operations is properly minimised for new and existing systems. There are other mandatory conditions for indoor usage: the minimum ignition energy must be greater than 100 MJ, the maximum explosion pressure must be below 8 bar and the K_{st} value must be less than 150 bar.m/sec.

Explosion venting and isolation

are very feasible options in many metal dust applications. However, recirculation of air is strictly prohibited. Where dust collectors are installed outdoors, explosion panels are an excellent option for venting an explosion, but care must be taken that the vent is directing the potential explosion away from people, buildings etc.

Once an explosion starts in an enclosure equipped with an indoor venting system, the pressure build-up will not exceed the design strength, upon which the vent area calculation was based. The explosion heat is dissipated in the venting system so no dangerous flames are released.

Rembe themselves have had such a system, the Q-Rohr (Fig. 2), approved in 2014 for metal dust applications. The benefits of the Q-Rohr in containing aluminium dust explosions can be judged by comparing Fig. 3 and Fig. 4. Explosions with a high content of aluminium dust create very hot and long fireballs, but it can be seen that even with an outdoor dust collector, the Q-Rohr could be used to limit safely the effects of an explosion.

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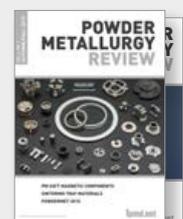
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