

POWDER METALLURGY REVIEW

VOL. 2 NO. 1
SPRING 2013



POWDER METALLURGY IN JAPAN
DEVELOPMENTS IN FERROUS PM MATERIALS
PROFILE: GKN POWDER METALLURGY



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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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POWDER METALLURGY REVIEW

Yokohama highlights global opportunities for PM

Welcome to the second issue of *Powder Metallurgy Review*. Following the extremely positive feedback received for our launch issue (Autumn 2012) at the Euro PM2012 Congress, Switzerland, and the PM2012 World Congress, Japan, we are very pleased to present this much expanded 72 page issue.

As well as being distributed in print format, *Powder Metallurgy Review* is also available as a free PDF download via our website, www.ipmd.net. Well over 2000 digital copies of our launch issue were downloaded, reflecting the strong interest in this new magazine for the global PM industry.

A highlight of 2012 for the PM industry was of course the PM2012 World Congress, organised by the JPMA and JSMP and held in Yokohama from October 14-18. *Powder Metallurgy Review* was there, and in this issue we not only report on a plenary session that featured presentations by the JPMA, MPIF and EPMA covering the state of the global PM industry (page 43), but we also review a number of key papers presented at the congress that highlight some of the latest advances in ferrous PM materials (page 49).

Keeping with a Japanese theme, we present an exclusive review by Dr Yoshinobu Takeda, Höganäs Japan KK, of the current state of Japan's PM industry. Dr Takeda explores how a lack of growth in domestic demand has seen the country's PM companies establish overseas subsidiaries that are able to thrive in the booming Asian automotive market (page 27).

We also report on the Euro PM2012 Conference held in Basel, Switzerland, 17-19 September 2012. This focussed event was of particular interest to the hardmetals community and we report on a number of papers that addressed both hardmetal processing and the characterisation of hard materials for applications in the rock drilling sector (page 65).

The world's largest manufacturer of sintered components, GKN Powder Metallurgy, continues to go from strength to strength and *Powder Metallurgy Review* offers a unique insight to the views of the division's recently appointed CEO, Peter Oberparleiter (page 39).

We look forward to receiving your comments on the contents and direction of this new magazine and, in addition, we welcome the contribution of news and articles that you may wish to submit for publication in future issues.

Paul Whittaker
Editor, *Powder Metallurgy Review*



Cover image

Powder Metallurgy manual transmission gears developed by Höganäs AB, Sweden (Photo courtesy Höganäs AB)



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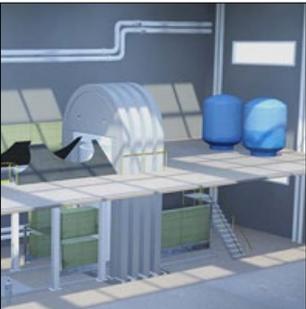


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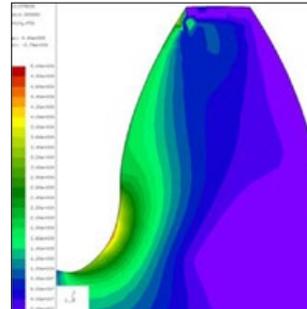
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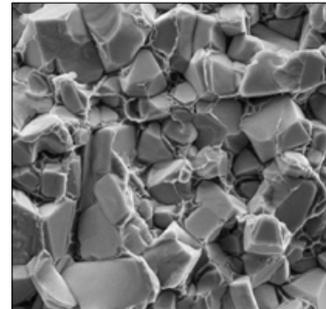
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27 Japan's Powder Metallurgy industry: Overview and current status

Despite current challenging economic conditions in Japan, the country's PM industry continues to benefit from the growth of the Asian automotive market. As a result, many Japanese PM companies have followed auto makers overseas and established lower cost manufacturing subsidiaries. Japan's PM industry is also actively developing new materials, improving processes and looking to novel applications including those outside the automotive sector for growth. Dr Yoshinobu Takeda, Hōganās Japan KK, reviews the current state of Japan's PM industry.

39 Changes at GKN as Peter Oberparleiter becomes new CEO of the PM division

GKN PLC appointed Peter Oberparleiter as the new CEO of its PM division in the autumn of 2012. The appointment followed the retirement of the division's former President and CEO Manfred Weber. *Powder Metallurgy Review* reports on recent developments at the company.

43 PM2012 World Congress: An overview of the global Powder Metallurgy industry

The highly successful PM2012 Powder Metallurgy World Congress, Yokohama, Japan, October 14-18, attracted over 700 delegates and almost 7000 exhibition visitors. *Powder Metallurgy Review* reports on the plenary session that featured presentations from the JPMA, MPIF and EPMA highlighting the current state of the PM industry in Asia, North America and Europe.

49 Developments in ferrous PM materials at PM2012 Yokohama

A number of papers at the PM2012 PM World Congress presented some of the latest advances in ferrous PM materials. Dr David Whittaker reviews some innovative approaches that offer advanced materials with improved mechanical and magnetic properties, enhanced machinability and lower costs.

61 JFE Steel broadens iron powder range for high performance Powder Metallurgy parts

JFE Steel is today one of Japan's leading producers of both reduced (from mill scale) and water atomised iron and steel powders under the brand name of 'JIP®'. We report on recent technical breakthroughs announced by JFE at its exhibit at the PM2012 World Congress.

65 Innovations in hardmetals processing and characterisation at Euro PM2012

The Euro PM2012 Congress, Basel, Switzerland, 17-19 September, offered the hardmetals community a focused technical programme that covered the latest innovations in hardmetals production. Dr Leo Prakash reviews a selection of papers that addressed both the processing of hardmetals and the characterisation of hard materials for applications in the rock drilling sector.

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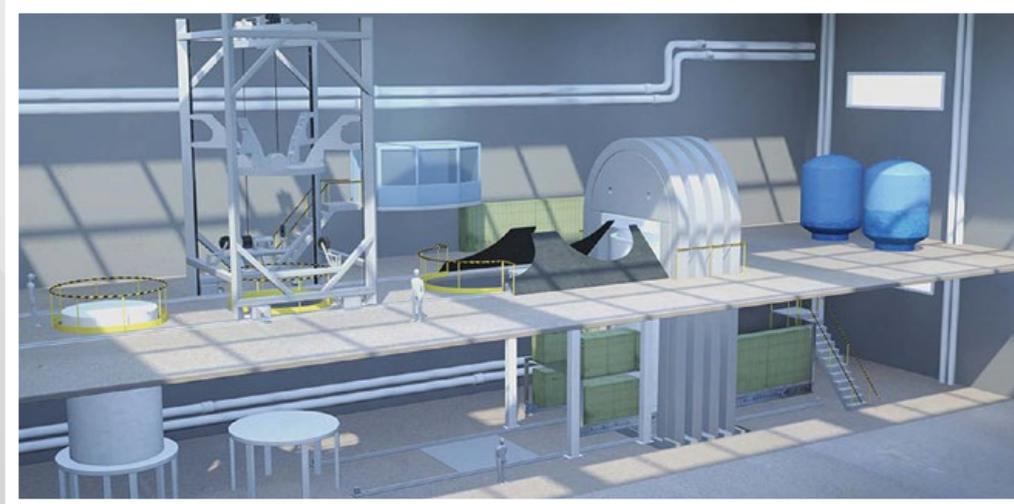
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industry news

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

Carlyle sells Metaldyne to American Securities

Global alternative asset manager The Carlyle Group announced on December 19, 2012, that it had completed the sale of Metaldyne LLC to an affiliate of American Securities LLC. Financial terms of the transaction were not disclosed.

Carlyle Strategic Partners II, a \$1.35 billion distressed investment fund, led a group of creditors in the purchase of Metaldyne in October 2009 and partnered with Metaldyne's management on the company's successful recovery. Since Carlyle's acquisition, Metaldyne has grown revenue by approximately 70% and

employment by approximately 30%.

Michael Stewart, Carlyle Managing Director and Co-Head of Carlyle Strategic Partners, stated, "We teamed with Metaldyne at the height of the Great Recession and the North American automotive industry crisis, believing we could grow the company. Carlyle led the infusion of cash to stabilise Metaldyne's financial situation and allow a great business to emerge from underneath an unsustainable balance sheet. With a deep management team and a committed workforce able to focus on its business, the new Metaldyne is positioned for continued growth

and success as a global automotive manufacturing supplier."

Shary Moalemzadeh, Carlyle Managing Director, added, "Metaldyne has been a highly successful investment for our fund investors. We exceeded our investment goals for Metaldyne, and we are gratified that the company is well positioned for the future. Metaldyne's talented management team and employees should be proud of our collective accomplishments."

Metaldyne, headquartered in Michigan, USA, has more than \$1 billion in revenue and employs 4,000 people at 25 facilities in 13 countries throughout North America, Europe, Latin America and Asia.
www.metaldyne.com ●●●

Hitachi Powdered Metals invests \$38m to expand US production

Hitachi Powdered Metals (USA) Inc., a subsidiary of Japan's Hitachi Powdered Metals Co. Ltd., has announced plans to invest \$38.4 million to construct and equip a second manufacturing facility on its site in Greensburg, IN, USA.

Expected to be operational by August 2013, the expansion will see a new 128,000 square-foot plant housing compacting presses, sintering furnaces, heat treating equipment and

a machining centre. The company, which currently employs 156, states that a further 60 new jobs will be created at the site by 2014.

Established in 1987, Hitachi Powdered Metals (USA), Inc. manufactures precision-made valve guides, gears, sprockets and pulleys for automotive companies including General Motors, Ford, Honda, Toyota and Nissan. Its Greensburg location

is the company's only PM operation in the US.

"Hitachi Powdered Metals (USA), Inc. continues to be a leader in powdered metal technology as we expand our reach into the North American automotive market," stated Greg Owens, Vice President of Hitachi Powdered Metals (USA), Inc.

Parent company, Hitachi Powdered Metals Co. Ltd, headquartered in Japan, also has production bases in Japan, Singapore, China and Thailand, as well as the US site.

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Gasbarre Products, Inc. acquires Major Gauge & Tool

Gasbarre Products, Inc., has announced the acquisition of Major Gauge & Tool, formerly Major Powered Metal Technologies, Livonia, MI, USA.

Through the acquisition, Major Gauge & Tool joins McKee Carbide Tool, located in Olanta, Pennsylvania, to form the Gasbarre Tool Group under the leadership of its President Randy Allenbaugh.

Major Gauge & Tool has supplied the global Powder Metallurgy Industry with innovative tool design for more than 60 years. They design and manufacture tooling for all conventional and multi-level presses used in the PM process including mould, coin, size, warm-forming and hot forge applications.

Major Gauge & Tool manufactures tooling for presses up to 1650 tons. Major's strong tool design capability and high tonnage tooling capacity, combined with their expertise in helical gears and warm form tooling, is key to their core business.

Gasbarre Products Inc. started in 1973 and was driven to design, manufacture and service a complete line of powder compaction and sizing presses for the powdered metal and particulate materials industries. Since then, Gasbarre Products, Inc. has diversified its product lines for start-to-finish manufacturing through its Tooling, Press, and Furnace groups.

The acquisition of Major Gauge & Tool is an important strategic move to create the Gasbarre Tool Group as the leading tool design and manufacturing source for the PM industry.

www.gasbarre.com ●●●

Kennametal to invest in tungsten-cobalt blended powder operations in the US and China

Kennametal Inc. has commenced plans for a new carbide recycling facility in the United States and announced the expansion of its tungsten-cobalt powder operations in Tianjin, China.

The company is starting preliminary work to establish an advanced carbide recycling facility in the US where it will reclaim material from scrap and consumed products such as metal-cutting inserts, and reuse it for new production.

"We're talking about a high-tech operation where we'll process used materials to develop new compounds essential to our industrial technology," stated Kennametal Chairman, President and CEO Carlos Cardoso.

"This is an exciting first for our company, demonstrating our commitment to invest in sustainability and advanced technology strengthening our leadership in America, and our service to customers around the world," continued Cardoso.

By adding tungsten-cobalt blended powder capacity in Tianjin, close to China's source mines, the company expects to streamline customer service in that region and reduce export delays and duties on the material.

www.kennametal.com ●●●

Carpenter and Sandvik end joint venture but agree new supply deal

Carpenter Technology Corporation and Sandvik Materials Technology have announced that they will dissolve their two-year old joint ventures - Powdermet AB in Surahammar, Sweden and Carpenter Powder Products AB in Torshälla, Sweden.

The two companies have agreed that the growth of their respective powder metal businesses would be better served in the form of a supply agreement, by which Carpenter will supply Sandvik. Joint development activities within near-net shape (NNS) will continue within the new set-up of cooperation.

In October 2010, Carpenter acquired a 40% interest in Sandvik Powdermet AB, while Sandvik AB acquired a 40% interest in Sweden-based Carpenter Powder Products (CPP) AB.

The two joint ventures will be fully dissolved by the end of the calendar year.

Carpenter Technology, based in Wyomissing, PA, USA, produces and distributes specialty alloys, including stainless steels, titanium alloys and superalloys, and various engineered products.

Sandvik Materials Technology is a world-leading developer and manufacturer of products in advanced stainless steels and special alloys for the most demanding environments, as well as products and systems for industrial heating.

www.cartech.com

www.sandvik.com ●●●

Stackpole set to implement growth strategy

Canadian Powder Metallurgy producer Stackpole International, based in Ancaster, Ontario, reported in October 2012 that it had successfully completed the refinancing of its outstanding debt by raising \$165 million of senior financing from a syndicate of banks. The proceeds of the refinancing were used to repay existing outstanding debt resulting in

a reduction of Stackpole's annual debt interest costs by more than 50%. The refinancing also provides additional flexibility for Stackpole to continue to implement its growth strategy.

Stackpole was purchased by the Sterling Group in conjunction with Current Capital LLC, a private equity investment and portfolio management firm, from Gates Canada, a subsidiary

of Tomkins, in August 2011 and under Sterling's ownership the company has experienced considerable growth by expanding both its customer base and geographic end markets.

Stackpole manufactures engine and transmission pumps and powder metal components for the global automotive industry. The company currently has 12 manufacturing facilities and technical centres in North America, Europe, China and Korea, employing over 2,000 people globally.

www.stackpole.com ●●●

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Sandvik group implements further restructuring

Sandvik AB has announced in December 2012 further restructuring of the group in several of its key business areas. The company also announced a number of measures to adjust costs due to the weaker market demand experienced during the third quarter and that has persisted thus far into the fourth quarter 2012.

In addition to the ongoing improvement efforts at Sandvik Mining, a reduction of 650 employees globally has been deemed necessary, including the closure of the units in North Bay, Canada, and Rocklea, Australia. Third-party contracts with more than 350 individuals will be terminated.

At Sandvik Machining Solutions, opportunities to generate economies of scale have been identified, states the company. The distribution centre in Kentucky, USA, will incorporate Seco Tools products. Consequently, the Seco Tools US distribution centre in Troy will be closed. Combined with other initiatives across the business area, including a headcount reduction in Fagersta, Sweden, this is expected to

result in a structural reduction in costs of 150 million SEK.

As part of the ongoing review of the wire business, Sandvik Materials Technology will restructure the wire operations at Sandvik Española in Barcelona, Spain. Parts of the product program will be transferred to other units. The work to simplify the organisation will continue to support the ongoing strategic shift of the product mix toward more advanced products. In total, the changes will lead to a further structural redundancy of approximately 220 positions globally.

Sandvik Construction has implemented further actions aimed at optimising the overall cost structure at the business area and addressing the continued subdued market activity. The number of employees is being reduced by 80, in addition to a further 180 employed by third parties.

On the announced adjustments, targeted cost savings will amount to more than 1 billion SEK by the end of 2013. Charges of a nonrecurring nature amounting to approximately

1,300 million SEK are estimated to impact earnings, of which 900 million SEK will be recognised in the fourth quarter 2012.

"A year has soon passed since we began the implementation of the new strategy. A great deal of hard work has been done and much has been achieved. In our drive to continuously improve our company, we have identified several additional opportunities. Consequently, decisions have been taken on a number of actions to adjust costs and capacity. None of these measures affect our ability to grow our business in the long term," stated Olof Faxander, President and CEO of Sandvik.

In 2011 the Sandvik Group had 50,000 employees with annual sales of more than 94,000 MSEK.

The Group conducts operations in five business areas, Sandvik Mining, Sandvik Machining Solutions, Sandvik Materials Technology, Sandvik Construction and Sandvik Venture. Worldwide business activities are conducted through representation in more than 130 countries.

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Metalysis process creates rare earth metals

Metalysis has announced that it has successfully demonstrated the production of rare earth metals using the company's transformational metal production technology. The UK based company states that it has produced the rare earth metals neodymium, terbium, and a terbium-nickel based alloy for the first time.

When compared to existing methods for rare earth production, the Metalysis process is an energy efficient and lower cost process because it produces the metals directly from oxides in a single step. Producing these metals at reduced cost and with a lower impact on the environment will widen access to these metals, and the resulting magnets, which offer crucial functionality in a vast array of technologies.

The main demand for rare earth production comes from their use as magnets in hard drives and motors, as well as catalysts and they are increasingly being used in clean energy technology such as wind turbines and electric cars. The rare earths are used

to make the essential magnets used in all of these components.

Rare earths are usually refined into highly pure oxides once they are recovered in mines, which then have to be processed into their metal form or alloyed with other metals for use as magnets in electronic components. Existing processes are highly energy intensive as they react the metal oxide or chloride either at high temperatures or use extremely toxic chemicals.

The Metalysis process is also capable of making alloys in one step, and the company added that it will now work on producing magnetic alloys in larger quantities, neodymium-iron-boron being a specific example of this. Currently, these alloys are created by mixing all the individual elements together before melting them to yield ingots of the desired alloy, these then have to be processed further to produce powders. This involves numerous steps to obtain a homogeneous product, therefore by adopting the Metalysis process to manufacture the alloyed powder directly, the overall



The Metalysis site in Rotherham, South Yorkshire, houses the R&D facilities as well as the production plant

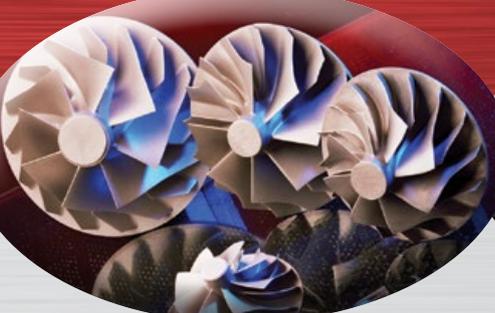
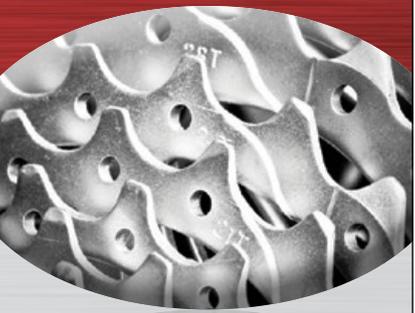
number of stages, and hence energy requirement, is significantly reduced.

Guppy Dhariwal, CEO at Metalysis stated, "Using the Metalysis process to successfully create rare earth metals means we can replicate the success we have achieved in the development of a process for high value metals such as titanium and tantalum. The Metalysis process will help develop the new sources of rare earths from countries outside of China by processing them using our new, environmentally benign, lower cost production process."

www.metalysis.com ●●●



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Avure Technologies launches its new TeraPi Hot Isostatic Press

Avure Technologies of Västerås, Sweden, announced at the PM2012 Powder Metallurgy World Congress and Exhibition held in Yokohama, October 14-18, 2012, that it has developed the next generation of large Hot Isostatic Press (HIP) systems.

The first model of the Avure Tera-HIP (code named TeraPi) system has a work zone diameter exceeding 3 m and stands 5 m in height, representing a major leap forward from the previous world's largest 'Giga-HIP' system produced by Avure and installed in Japan in 2010, which has a work zone of 2.05 m and is 4.2 m tall.

Avure's Dr Anders Eklund stated that whilst HIP is already used in a wide range of applications, there is considered to be huge scope for new markets for HIP using both the existing small to medium size HIP systems as well as the very large systems such as Tera-HIP. This is said to be particularly the case for the production of PM high alloy steel components and near-net-shape (NSS) PM steels and PM super-alloys, plus post densification of PM, MIM and cast parts.

Dr Eklund stated that powder consolidation already made up around 50% of HIP throughput, and the economics of scale using the new Tera-HIP system will make HIP even more attractive as a production process. A 3 m diameter Tera-HIP system will minimise running costs to less than SEK2.5/kg, stated Dr Eklund.

The major producers of gas atomised, high alloy steel powders will be adding some 25,000 tonnes/year of

production capacity by 2013 to meet the expected demand for HIPed PM components and other applications, added Dr. Eklund.

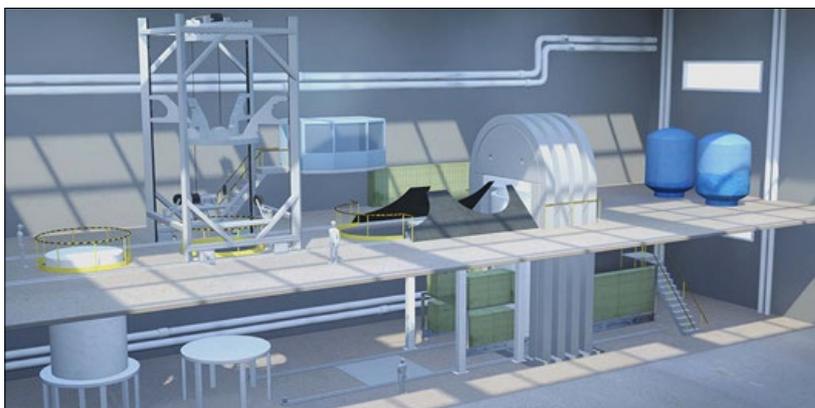
There is additional potential to convert around 10% of the 1.5 million tonnes of water atomised ferrous powders to HIP processing, he said.

Avure reported that its TeraPi Hot Isostatic Press will be modular in design for easy manufacture and quicker installation. The new HIP system comprises a frame constructed from multiple (four) frames, which are wire wound with a total length of 5100 km of high strength steel wire, and a forged steel pressure vessel weighing in excess of 250 tonnes.

The image below shows a visualisation of a typical TeraPi (Tera-HIP) installation with the upper floor used for the press operation and the lower floor for maintenance operations. The system will be capable of processing load weights of around 75 tonnes with a cycle time of about 16 hours.

The furnace used in the system is also of a new design and will be capable of handling large volumes of hot gas with a maximum temperature deviation of just +/- 10°C. It will incorporate Avure's 'Uniform Rapid Cooling' (URC) which means interrupting the insulating capacity of the furnace in a controlled manner in order to shorten cycle time, or to incorporate heat treatment into the HIP cycle. During URC vast amounts of energy are transferred out of the HIP vessel in a short period of time with cooling rates up to 100°C/min achievable.

www.avure.com ●●●



Schematic diagram of the new Avure TeraPi Hot Isostatic Pressing system

NTN develops new double-moulding method for oil-impregnated sintered bearings

NTN Corporation has announced the development of a new manufacturing method for the production of high strength, wear-resistant sintered bearings.

The newly developed "Multi Layer BEARPHITE" is an oil-impregnated sintered bearing that features the internal layers of the bearing made of a material with a high-strength and outstanding wear-resistance, and the outer layers made of a high-strength structural material.

NTN claims this is the world's first 'double-moulding method' - a process that uses two different materials to form a single object. The use of high-strength structural material for the outer layers of the bearing eliminates the need for special heat treatment. The pressing allows for greater dimensional precision with the sizing process, eliminating the need for conventional cutting processes.

The 'double-moulding' method, which is used to form two dissimilar materials into a single object, has been used for high-strength and outstanding wear-resistance

In addition to oil-impregnated sintered bearings, the company states that the 'double-moulding' technology will also be applied to gears and other sintered machinery parts, offering a greater level of use in industrial machinery and automotive markets.

www.ntn.co.jp ●●●



The "Multi Layer BEARPHITE" is an oil impregnated sintered bearing

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Successful partnership proves the concept of Powder Metallurgy transmission gears

Swedish rally driver Ramona Karlsson contacted Höganäs AB in 2010 with the aim of finding a partner for her upcoming rally season. Some three years on, Karlsson and Höganäs reflect on the successful collaboration that proved the concept of PM transmission gears and became the first ever team to race with PM gears in the World Rally Championship

Together with SwePart Transmission AB, Höganäs played an important role in Karlsson's strive for rally success. The team successfully replaced the 4th gear pair during the 2011 season and the remaining gear pairs the following year. As a result, Karlsson and her co-driver become the first Swedish women ever to compete in the World Rally Championship and the first team to ever compete with PM gears.

"Thanks to the confidence and backing by Höganäs we have been able to reach and exceed our competitive goals and on a personal level I was able to reach a very important milestone in my career. To be the first rally driver ever to compete with PM gears – and to show that they really stand the heavy loads they are exposed to – that has been really amazing," stated Karlsson.

The success raised the attention among not only automotive industry members, but also Karlsson's colleagues and followers. Many were

interested in the gear concept and some even asked her how they could get a hand on a similar gear box to replace their own broken-down ones. Anders Flodin, Gear Expert at Höganäs, also experienced this positive feedback.

"When I visited the other teams at the South Swedish rally I was introduced as the 'powder genius who creates gear boxes that won't break'. That was very flattering and a sign that people were talking about our project," stated Flodin.

For Höganäs, the main objective was to prove that PM transmission gears can withstand extreme loads. While Flodin is happy to say that many sceptic transmission engineers have been convinced, he feels that more similar projects are required to completely convince the automotive industry. The passenger car industry deals with other kinds of challenges and it is now up to Höganäs and its collaboration partners to prove that PM gears provide a really interesting proposition.

"I think we do need to present something similar within two years as you typically need to convince the automotive industry more than once. We are already working on another gear project for a passenger car and we have received inquiries from companies within different kinds of motor sports," added Flodin.



Rally driver Ramona Karlsson became the first person to use PM gears in a WRC car

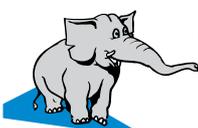
The project ended at a gear conference in Berlin, the International CTI Symposium and Exhibition. While Karlsson admits ending the project feels a bit sad, she feels optimistic about the future and hopes that she will be able to continue her career within motor sports until retirement.

"I've gained so much experienced over the last few years which will be valuable for my remaining career. One of the highlights of this project was when the speakers announced the 'Power of Powder Rally Team' in front of over 100,000 spectators at the World Championship premiere in Mexico. I'm also very proud of the fact that we were able to prove that women can compete on equal terms at the highest level of motor sports. These achievements are something I feel will help me in the future," added Karlsson.

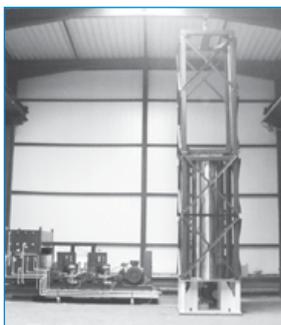
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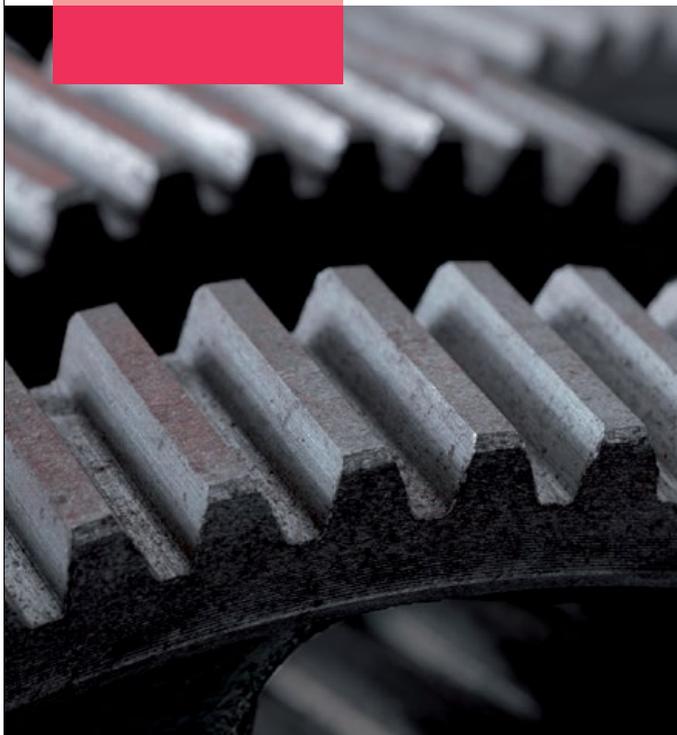


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China to host APMA's second international conference and 2018 PM World Congress

It was announced during the PM2012 World Congress in Yokohama, Japan, that the Chinese Strategic Alliance for Technological Innovation in Powder Metallurgy (SATI-PM), together with the Taiwan Powder Metallurgy Association, will be organising the Asian Powder Metallurgy Association's (APMA) second International Conference on Powder Metallurgy.

APMA 2013 will take place at the International Conference & Exhibition Centre in Xiamen, China, November 3-6, 2013. This new bi-annual series of PM conferences in Asia will cover all aspects of PM technology and there will be an accompanying exhibition.

It was also learned during the PM2012 week in Yokohama that China has been nominated to host the PM World Congress & Exhibition in 2018. Further details as to location will be issued in due course.

www.apma2013.org ●●●

Titanium PM conference to be held in New Zealand

New Zealand's Titanium Industry Development Association (TiDA) has announced that it is hosting the 2013 International Titanium Powder Processing, Consolidation and Metallurgy Conference, to be held 2-4 December 2013.

This conference follows on from the success of the inaugural Ti Powder Conference held at the University of Queensland in 2011. The Conference, to be held at the University of Waikato, will attract leaders in the titanium industry, including academics, manufacturers and international delegates.

The conference will promote Ti powder and processing, consolidation processes, alloy development and applications, and is already attracting delegates who will use this forum to network at this specialised event.

The conference is supported by the Japan Society of Powder and Powder Metallurgy (JSPM), Chinese Society for Metals (CSM), University of Queensland, CSIRO, IRL and the University of Waikato, plus leading Ti manufacturers.

For more information please contact: info@tida.co.nz ●●●

EPMA Sintering Short Course to take place in Austria

The European Powder Metallurgy Association (EPMA) has announced that next year's Sintering Short Course will take place from 24-26 March 2013 in Vienna, Austria.

The popular short course will cover individual aspects of the process, starting from sintering concepts through to practical considerations, mainly for batch scale materials and applications. The course will also feature lectures on the sintering atmospheres, process variation and new developments in furnace technology.

For more information contact Joan Hallward: jh@epma.com
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Additive Manufacturing for the watch and jewellery industries

EOS, a technology and e-manufacturing solutions provider for Additive Manufacturing (AM), showcased precious metal parts made of 18 ct yellow gold at EuroMold in Frankfurt, Germany, 3-6 December 2012. The parts were manufactured on a new, small prototype metal laser-sintering system PRECIOUS M 080.

The compact and affordable laser-sintering system offers a manufacturing solution designed for the particular needs of the jewellery and watch industries.

For the system development EOS joined forces with Cookson Precious Metals (CPM), worldwide established supplier for the precious metal industry. Based on a strategic development partnership both companies plan to introduce and further develop precious metal-based applications to the jewellery and watch industry. Under this partnership, EOS is the technology provider, whilst Cookson will cover sales for named industries.

The product and services offerings will range from consulting, Direct Metal Laser-Sintering (DMLS)-based design processes, the production of precious metal parts and the development and production of special precious metal alloys for the additive manufacturing process. They also plan to develop a bespoke solution chain for high volume jewellery production. To begin with, CPM offers AM capacities

enabling the production of designs made of 18 ct yellow gold (3N colour).

Stella Layton, CEO of Cookson Precious Metals states, "With this technology, 3D bespoke jewellery and watch components can be created from CAD files. This takes us on an exciting journey permitting the creation of highly complex and intricate designs that weren't thinkable before. The particular beauty of Additive Manufacturing is that it can be used to produce both one-off pieces as well as large scale production eliminating many process steps and tooling costs that we see today."

Dr. Adrian Keppler, EVP Strategy and Business Development at EOS stated, "With CPM we found a perfect partner to introduce our innovative technology to the luxury goods industry, thus shifting paradigms in manufacturing. We truly believe that our AM process offers a huge potential for these industries. Compared to conventional manufacturing techniques it paves the way for a completely new approach towards design and manufacturing. This is what we call 'design-driven manufacturing'. The technology offers a freedom of design the industry has long been searching for. The most demanding jewellery brands can now create entirely new products and geometries that still meet their high quality requirements. The technology



The 18 ct yellow gold ring (top) and cuff links (bottom) were manufactured on a new, small prototype metal laser-sintering system PRECIOUS M 080

challenges designer's imagination and pushes it to the next level."

Both EOS and CPM envision customised e-manufacturing solutions that will change the economics of making jewellery or watches. The technology enables time savings, thus lowering the general costs of entry into the business of making quality jewellery and watch parts in precious metal. As such, e-manufacturing with DMLS enables designers to produce pieces that do not have to deal with the boundaries of conventional production techniques.

www.eos.info ●●●

Fraunhofer ILT and Concept Laser develop Additive Manufacturing for the automotive industry

Additive manufacturing with metals is becoming increasingly important in the automotive industry, states the Fraunhofer Institute for Laser Technology ILT, in Aachen, Germany. Time and cost reductions in production are making this technology increasingly attractive to the carmakers.

Daimler AG has been working with Fraunhofer ILT and Concept Laser to apply the technology to applications involving vehicle and engine technology. Together they have developed a new high-performance Laser-

CUSING® machine 'X line 1000R', whose build chamber size surpasses anything that was previously available.

The project partners formed as part of the 'Alu generative research and development project', organised by the German Ministry of Education and Research. Together with different partners from industry, including Daimler AG, Fraunhofer ILT examined the laser fusing technology for production applications involving aluminium components.

The new X line 1000R machine was

specifically configured to cater for Daimler AG's special requirements for automobile applications. The aim of Daimler AG was to replace costly sand-casting and die-casting applications in early phases of development. In addition, the LaserCUSING process will in future offer the possibility of generating lightweight structures with a high level of rigidity which will permit weight-optimised geometries with almost no restrictions on the design.

The centrepiece of the X line 1000R consists of a high-power laser in the kilowatt range which enables a ten fold increase in productivity compared with standard laser fusing machines available on the market.

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Plansee furnace parts now available to purchase online

Plansee has announced that its online shop, 'Plansee- Express', is now offering finished parts for high-temperature furnaces. In addition to plate, rod, wire and welding electrodes, molybdenum, TZM and tungsten threaded rods, pins, tube, rivets, washers and nuts are now available to purchase online for high-temperature furnace applications.



Plansee offers a wide range of products for high temperature processes

These materials are used in applications where conventional metals reach their limits and are no longer an option. With their durability and dimensional stability, they maintain their reliability under extreme high-heat conditions and also when frequent cycling occurs.

Ceramic insulators and tubes can also be ordered from Plansee Express. These products are available directly from stock and with rapid delivery, states the company.

The Plansee Express shop offers a world-wide service and is constantly adding new product groups and materials to its online catalogue.

The company also develops and manufactures tailored components for high temperature furnaces such as metallic hot zones and heating elements, radiation shields, furnace fixtures, hearth components, crucibles, as well as annealing and sintering boats.

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Jayesh Industries to expand fine powder production

Jayesh Industries Ltd., based in Mumbai, India, is an established manufacturer and exporter of ferro alloy powders. Now, as part of a major expansion programme, the company is starting fine powder manufacturing at a unit in Navi, Mumbai. The company is commencing with the production of cobalt, nickel, tungsten, tungsten carbide & prealloyed powders.

Jayesh Industries' Ashok K Gosavi told *Powder Metallurgy Review*, "The new metal powder products will be introduced to the domestic and international markets from January 2013. The project is at the last stage of its completion. Our metal powder manufacturing unit is well equipped with all advanced production technology and quality systems. Our intention is to supply our metal powder products to the hardmetal, diamond tools, PM and MIM sectors."

www.jayeshgroup.com

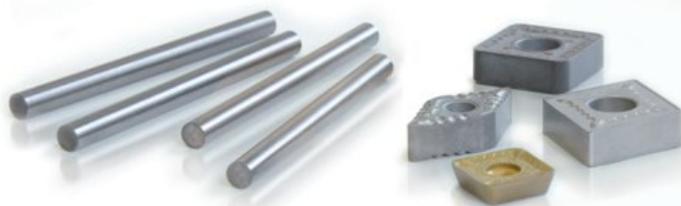


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Potential for PM aluminium components in new Wankel rotary engine

Automotive manufacturers are under pressure to meet the continuing demands for vehicles with improved fuel efficiency and toughened emissions standards, especially for vehicles used in urban areas. Dr Johann Blaha and his colleagues at AVL List GmbH, in Graz, Austria, together with researchers from Mepurapulvergesellschaft and LKR Leichtmetallkompetenzzentrum in Ranshofen, Austria, have been investigating the use of PM aluminium components in a prototype Wankel rotary engine for an extended-range electric vehicle (EREV) developed by Audi. They presented their results to date at the Euro PM2012 Conference held in Basel, Switzerland, September 16-19, 2012.

AVL List GmbH is one of the world's leading innovators of powertrain systems for the automotive industry, and the company has developed a prototype Wankel rotary engine for use as a range extender in the Audi A1 e-tron electric car, which was first introduced as a concept car at the 2010 Geneva Auto Salon. A1 e-tron (Fig. 1) was designed for zero emission city traffic using a robust electric motor with a peak power of 75kW (102 PS) driving the front wheels and giving a range of 30 miles on a fully charged battery.

AVL collaborated with Audi to find the ideal internal combustion engine (ICE) to extend the e-tron's battery range, and came up with the single-rotor Wankel rotary engine concept (Fig. 2). The low weight engine is extremely compact and is small enough to sit below the boot

(cargo) floor of the e-tron. The single rotor 254cc Wankel engine provides the power to generate up to 15 kW of electrical energy, stretching the total range of the e-tron car from 30 to 155 miles using one tank (3.2 gallons/13.6 lt) of petrol.

AVL used its Design for Manufacturing approach to investigate the use of PM aluminium alloys for the rotary engine housing and the single rotary piston in order to reduce mass (weight) of these components compared with the heavier conventional quench and tempered steel. Reducing the weight of these components would in turn reduce the amount of necessary counterweight, and therefore reduce acceleration losses. CO₂ reduction is optimised by using an innovative coating technique for the engine housing in order to reduce friction of sliding surfaces in the engine, and by increasing the thermo-dynamic efficiency by thermal insulation. Fig. 3 shows a schematic of the engine housing and the temperature distribution of the PM aluminium rotary piston used in the small Wankel engine.

Dr Blaha stated in his presentation that two air atomised aluminium alloy powders having irregular particle shape have been investigated for the housing and piston applications. The two aluminium alloy powders produced by Mepura for this research included alloy Al2618 (AlCu2Mg1,5Ni) and alloy Al4041 (AlSi12Cu). The extruded, heat-resistant PM alloy Al2618 has excellent mechanical properties up to 300°C and is already established for turbines and engines. The extruded PM Al4041

(AlSi12Cu) provides very good high temperature strength and good wear resistance. Powder extrusion billets with particle sizes lower than 400 micron were said to provide the best results.

Selecting the optimum extrusion process

Mepura currently uses two routes for the extrusion of PM Al alloy powders – the classic route via direct hot extrusion and also a 'Continuous Rotary Extrusion' (CRE or Conform as it is otherwise known) (Fig. 4). In the direct extrusion process the powders are first cold isostatically pressed (CIP) to produce billets having green densities of 70 to 80%. These billets have sufficient green strength for handling during the extrusion process. In the CRE process the powder is directly consolidated in one step which reduces costs; however, the mechanical properties are not as good as in the hot extruded product due to the lower pressures used and the lower degree of deformation. The focus, therefore, remained with the direct hot extrusion process.

In the process used to produce the aluminium rotary pistons, CIPed extrusion billets with a diameter of 305 mm and a billet length of ~750 mm were pre-heated to a temperature of 450°C for 12 hours and extruded with a direct extrusion press with a press force of 40 MN. The extrusion behaviour of both PM aluminium alloys showed differences in flow characteristics and friction behaviour. These effects were further investigated on a small scale extrusion press at LKR (Leichtmetallkompetenzzentrum Ranshofen), the third partner in the Austrian Research Promotion Agency (FFG) funded devel-

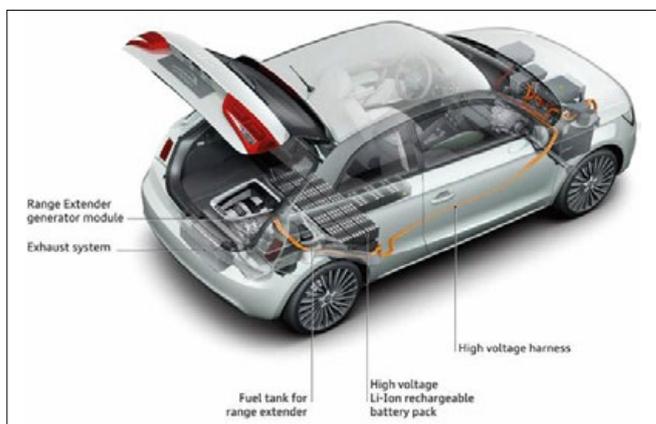


Fig. 1 Audi A1 e-tron with Wankel rotary engine Range Extender (Courtesy EPMA)

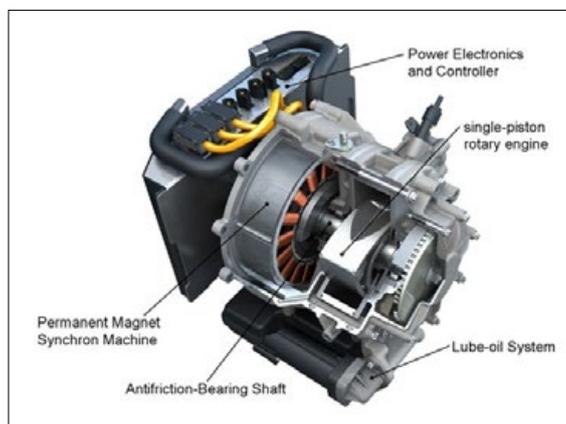


Fig. 2 Schematic of the single-rotor Wankel rotary engine used in the Audi A1 e-tron (Courtesy Audi AG)

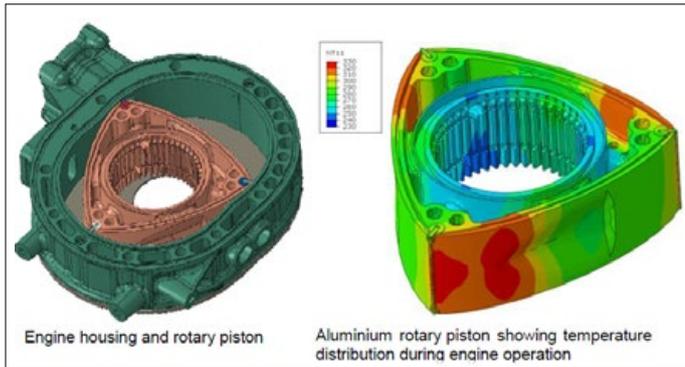


Fig. 3 Schematic of Wankel engine housing and rotary piston (left) and aluminium piston showing temperature distribution during engine operation (right) (Courtesy EPMA)

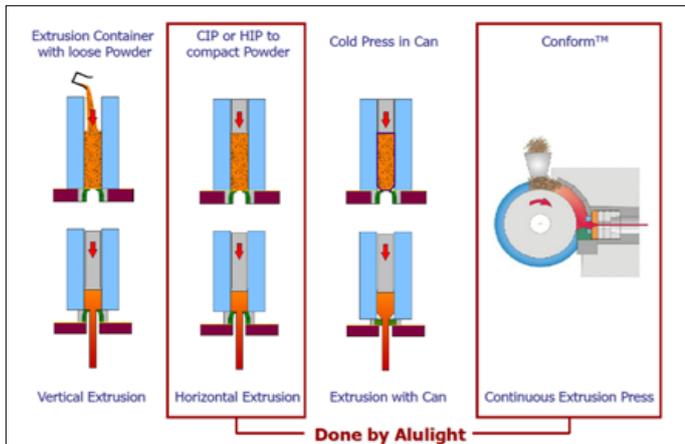


Fig. 4 Extrusion processes used to produce PM aluminium extruded bars for Wankel engine components (Courtesy EPMA)

opment project, in order to transfer optimised process parameters to the industrial extrusion press. The extrusion ratio was ~1:9. To reduce the amount of machining after the extrusion of the rotary piston tight manufacturing tolerances were implemented.

Dr Blaha stated that the main benefits of PM and extrusion processes are the high thermal stability of the PM aluminium alloys, the reduced production time per component, and the greater flexibility in length of the manufactured components. Also due to the high solidification rates during atomisation, extruded PM aluminium alloys provide very fine grain sizes (40 to 150µm) compared with cast alloys. The tensile properties of both PM alloys were investigated from room temperature up to 240°C based on tests performed according to DIN 50125 on a Zwick universal testing machine. Both PM-aluminium alloys showed similar temperature dependent behaviour. Yield strength reduced from 175 MPa to ~115 MPa at 240°C test temperature. Contrary to Al2618, which showed constantly increasing ductility, for Al4041 the elongation at fracture stabilised above 200°C at a value of ~23%.

Further investigations are to be carried out on the use of surface coating for thermal insulation of the rotary piston and to improve tribological performance. Results from engine test bed data for the new prototype Wankel rotary engine are expected to be available by the end of 2012. The success of the project would see Wankel rotary engines produced commercially again in Europe, for the first time since the 1960s when NSU first used a single rotor unit developing 50 HP for the 2-seat NSU Spider in 1964. NSU was absorbed by Audi, which in turn became part of the Volkswagen group of companies. Only Mazda in Japan has pursued the Wankel rotary engine using it in some of its cars such as RX-8, the earlier RX-7, and other models. ●●●

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DensiForm® helical Powder Metallurgy gears for automotive transmissions

The Powder Metallurgy industry has been striving for over 20 years to achieve greater penetration of the market for gears used in automotive transmissions, but with limited success to date. Automotive transmission gears are competitively produced by machining wrought steels, and the PM industry still has to convince the automotive OEMs that it can match the performance and dimensional accuracy of machined gears.

This is especially the case for helical gears with a helix angle above 30 degrees. Additionally, although PM technology offers lower cost still



Fig. 1 Development helical gear produced by the DensiForm® process [1]

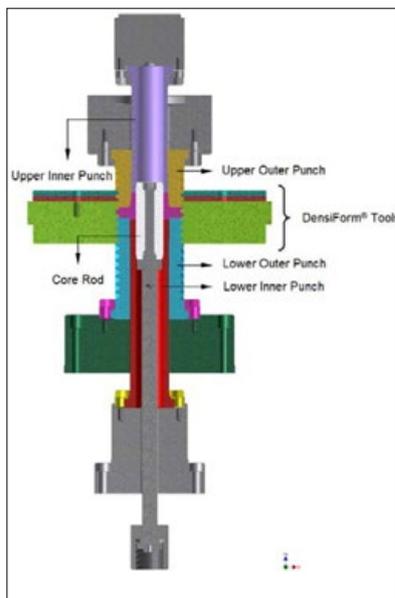


Fig. 2 Tool layout for the DensiForm® process [1]

some limitations in static and fatigue properties of sintered steel materials which preclude the use of conventionally produced PM parts for these applications.

A major step forward in automotive helical gear production by PM was outlined in the paper 'DensiForm® Helical Powder Metal Gears for Automotive Transmissions' by Dr Salvator Nigarura, Director of Research and Development at PMG Corporation and colleagues in Columbus, USA, presented at PM2012 World Congress in Yokohama, Japan, October 15-18, 2012.

Dr Nigarura presented information on a new and powder metal compatible surface densification technology called DensiForm®, which he stated has been adapted to produce complex, highly loaded helical transmission gears having superior dimensional accuracy and uniform surface densification of the gear teeth from the root to the active flank surfaces. Dr Nigarura stated that the DensiForm® process has the added benefit of substantially increasing the core density of the sintered helical gears whilst performing sizing and surface densification, bringing the levels of mechanical and fatigue properties in the gears up to the level required for high torque transmission applications.

A development manual transmission helical gear (Fig. 1) having 39 teeth and a helix angle of 33 degrees was

produced by compacting a Mo prealloyed steel powder (0.85 wt% Mo) mixed with 0.2 wt% graphite and pressing lubricant. The gears were compacted to a green density of 7.2 g/cm³, followed by sintering at conventional temperature (1150°C/2100°F) on a belt furnace. Dr Nigarura stated that the DensiForm® process is performed in the same Powder Metallurgy press used for powder compaction with the added benefit of substantially increasing the core density to 7.35 g/cm³ whilst performing sizing and surface densification. This new process is significantly different from the surface rolling process for PM gears which is performed in a separate circular die force controlled rolling machine.

Fig. 2 shows the layout of tools used for the surface densification of the development helical gear shown in Fig. 1. Given the helical nature of the external form of the part, the upper (outer and inner) and lower outer punches follow a helical motion that is in keeping with the geometry of the gear (the punches rotate together as they advance axially). The lower inner punch remains stationary, as do the DensiForm® tools and die. This action is different from that seen at powder compaction where the die floats.

Dr Nigarura said that simulation of the DensiForm® process, especially for helical gears, is capable of predicting with a high level of precision the amount of densification and the uniformity of the densified layer. The important benefit of simulation is the design of DensiForm® tools and of the blank geometry to achieve the level of

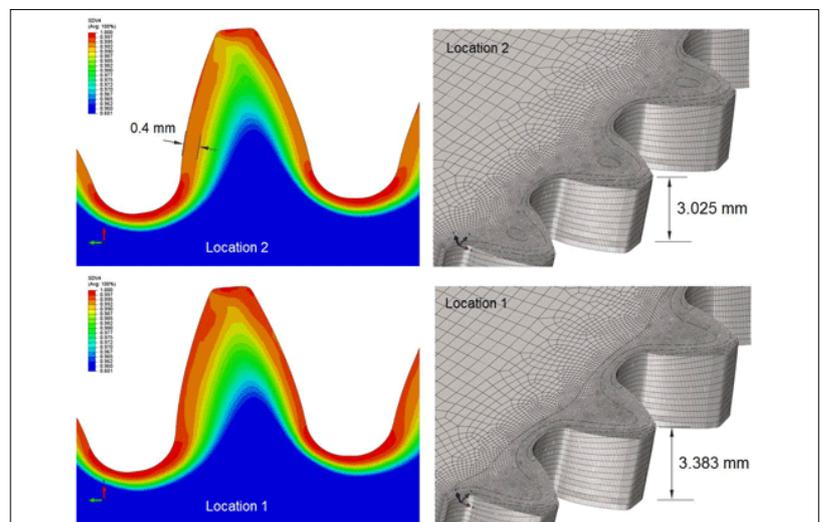
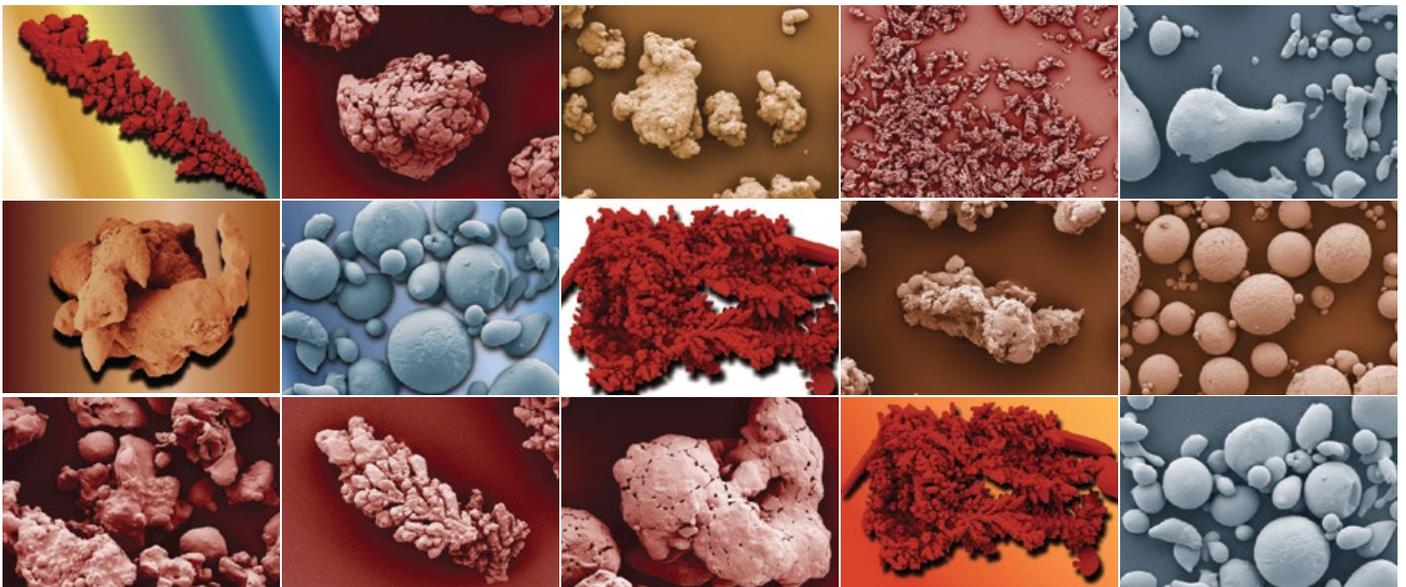


Fig. 3 Relative density distribution after DensiForm® [1]



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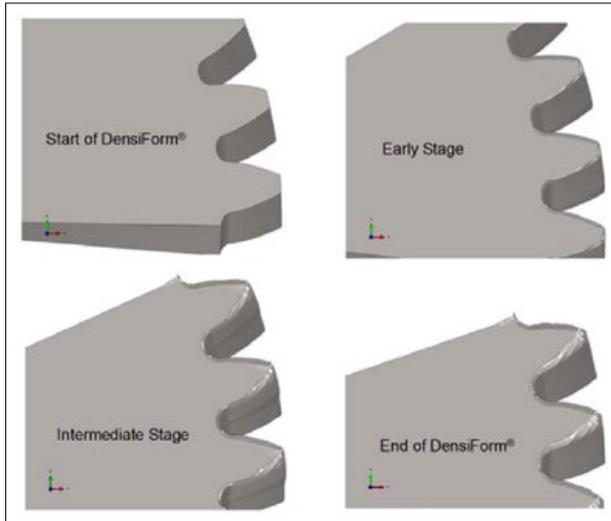


Fig. 4 Evolution of deformation/densification during DensiForm® [1]

densification needed. Furthermore, simulation of the DensiForm® process allows for accurate predictions of final part geometry and dimensions as well as density levels following surface densification.

The results of the simulation analysis given by Dr Nigarura are presented in Figs. 3 and 4. Planar sections at two axial locations are shown in Fig. 3 with accompanying density maps at those locations. The extent of densification is shown in terms of relative density, which is the ratio of the current density to the theoretical density of fully dense steel. A density

of 7.83 g/cm^3 (with corresponding relative density of 0.996) is seen at a depth of 0.4 mm from the surface at location 1. Similarly, at location 2, a density of 7.8 g/cm^3 is reported at a depth of 0.4 mm on the left flank. Adequate depths of densification are seen to be achieved on the gear flanks, while substantial densification depths are achieved in the root area.

The surface and core densified gears were subsequently heat treated in two groups. The first group was atmospheric carburised using endothermic gas and then quenched in oil. The second group was vacuum carburised using low pressure acetylene (less than 20 mbar) and then quenched using high pressure helium gas (20 bar) to minimise distortions.

Dr Nigarura found that whilst heat treatment introduces distortion, vacuum carburisation with high pressure gas quenching reduces significantly the level of distortions. A high gear quality, AGMA A-4 for profile error and A-6 for helix error is obtained after high pressure gas quenching. In terms of properties Dr Nigarura reported a Young's Modulus of 150,000 MPa and Poisson's Ratio of 0.27 at the sintered core density $>7.35 \text{ g/cm}^3$. Further work is being done to characterise DensiForm® produced sintered steel gears in a real transmission and results will be presented in a future paper. ●●●

[1] S Nigarura, R Parameswaran, M Bird, M Scott, G Rau, 'DensiForm® Helical Gears for Automotive Transmissions' Presented at the PM2012 World PM Congress, Yokohama, JPMA/JSPM



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Japan's Powder Metallurgy industry: Overview and current status

Despite current challenging economic conditions in Japan, the country's PM industry continues to benefit from the growth of the Asian automotive market. As a result, many Japanese PM companies have followed auto makers overseas and established lower cost manufacturing subsidiaries. Japan's PM industry is also actively developing new materials, improving processes and looking to novel applications including those outside the automotive sector for growth. In this exclusive report for *Powder Metallurgy Review*, Dr Yoshinobu Takeda, Höganäs Japan KK, reviews the current state of Japan's PM industry.

It has been a difficult few years for industry in Japan. For many, the problems began in 2008 with the Lehman Brothers collapse which affected Japan's banks and insurers. This was followed by the global recession in 2009 and the devastating earthquake and tsunami and resulting Fukushima nuclear disaster in March 2011. In October 2011 the region was also affected by the serious flooding in Thailand, and the ongoing political dispute between Japan and China which began in 2012. In addition to these factors, the Japanese currency exchange rate decreased from ¥110/\$ in 2008 to <¥80/\$ in 2011, and from ¥160/€ in 2008 to ¥100/€ in 2012 (Fig. 2).

With more than 90% of structural PM parts produced in Japan used in automotive applications, and over 60% of PM bearings also destined for this industry, it is clear to see how fluctuations in the automotive sector directly affect the PM industry (Fig. 3). There can be no question that the recent difficulties have had a huge impact on Japan's automotive industry and, as a result, its PM industry.

However, the recent economic growth seen in some parts of Asia

has had a positive impact on the expansion of the region's PM markets. For example, overseas production of Japanese cars in Asia grew from 4.9 million in 2008 to 7.5 million in 2011 (Fig. 4). Consequently, Japanese PM companies have expanded in Asia too, setting up a number of overseas operations. Customers of these new facilities are not only the Japanese automotive subsidiaries, but also local industries and other global companies.

This has allowed Japanese companies to enjoy global competitiveness in performance, quality, delivery and price.

Japan's production of PM components in 2011 was reported to be some 101,797 metric tonnes, with the value of these stated at ¥160,154 million. The vast majority of this production consisted of structural parts, accounting for 91.6% of the total tonnage, or 71.9% of the total value.



Fig. 1 Over 90% of structural PM parts are used in automotive applications in Japan. This award winning part from Hitachi Chemical Co., Ltd., is a reduced weight sinter diffusion bonded carrier for a high torque transfer mechanism used in a 4WD transmission (Courtesy JPMA)

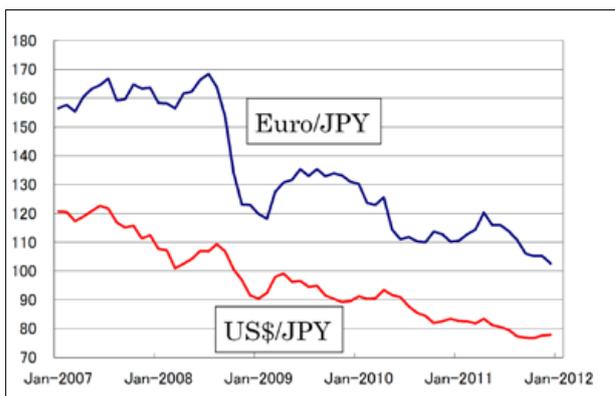


Fig. 2 History of Japan's exchange rate fluctuations from 2007 to 2011

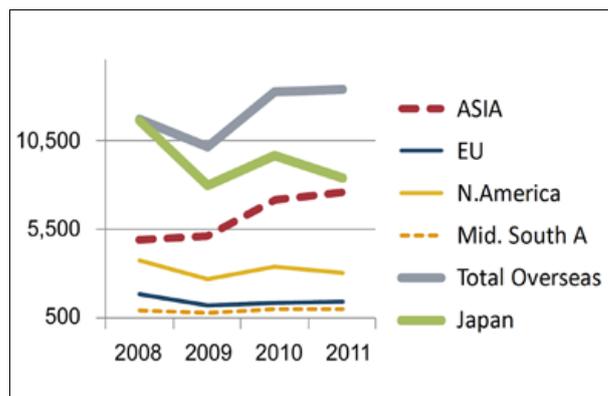


Fig. 4 Trends in overseas and domestic production of Japanese vehicles

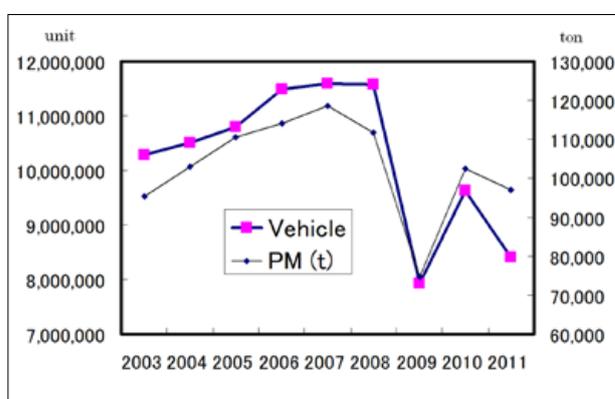


Fig. 3 Comparison of Japan's vehicle production and PM automotive part production

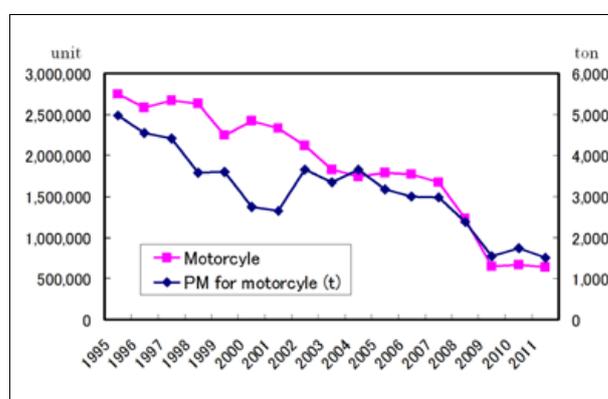


Fig. 5 Comparison between motorcycle production volumes and PM parts for motorcycle applications

PM bearings accounted for 6.3% by weight and 8.4% by value, while other applications account for 2.2% of the total tonnage but 19.7% of the value (Table 1).

PM applications in the automotive market

The Japanese automotive market has a number of differences to that of either the US or Europe, namely:

- Diesel engine use in passenger cars is less than 5%, and is primarily for export
- Over 90% of gasoline engines are equipped with variable valve timing control systems (called VVT, VTEC, and NVCS etc.)
- Hybrid electric vehicles (HEV) are becoming increasingly popular, with sales of 255,000 HEV's among the 1,246,000 small passenger car market in Japan. Toyota's Prius has been the bestselling car for more than three years
- The mini car (less than 660 cc) category, including trucks, has

about a 20% share in production volume and 37% of domestic sales in 2012

- Continuously variable transmissions (CVT) are very popular with over 75% of the market. The remainder are almost all automatic transmissions (AT), with

manual transmissions limited to niche segments such as sports models or for export

- Composite PM camshafts are not popular in Japan
- Most hydraulic power steering systems have been replaced by electric power steering (EPS).

	2011	Ton	%	Million ¥ JPY	%	Automotive (t)	Non-automotive (t)		
Machine Parts		93,245	91.6%	115,174	71.9%	85,349	91.5%	7,893	6.9%
Bearing		6,370	6.3%	13,376	8.4%	3,876	60.8%	2,493	39.1%
Others		2,182	2.1%	31,604	19.7%				
Total		101,797		160,154					

Table 1 Breakdown of PM part production in Japan in 2011 (Data courtesy JPMA statistics)

	2005	2006	2007	2008	2009	2010	2011	2012	Total
VVT	0	0	2	3	1	3	2	1	12
Bearing	2	2	2	2	3	2	3	2	18
MT	1	1	0	0	0	1	0	0	3
Carrier	0	0	0	1	0	0	1	0	2
CVT	0	0	0	0	1	2	0	1	4
Others	9	10	6	7	9	3	8	7	7

Table 2 Summary of JPMA Awarded components by category over the last eight years



Fig. 6 These sintered components are used in a high response VVT system manufactured by Sumitomo Electric Industries Ltd. The PM parts comprise three sprockets, three housing-sprockets, three inner-plates, two housings and rotor [Courtesy JPMA]



Fig. 8 Light weight PM automotive bearing caps produced by Sumitomo Electric Industries Ltd, reduce the need for costly machining [Courtesy JPMA]



Fig. 7 Three sintered parts for use in an electric VVT control system, manufactured by Diamet Corp. [Courtesy JPMA]



Fig. 9 Governor part for a motorbike starter clutch, manufactured by Hitachi Chemical Co., Ltd. [Courtesy JPMA]

Based upon these features, the type of PM components found in Japanese cars are different from those manufactured in Europe or the US. Table 2 shows a summary of JPMA award winning components in the last eight years. The main focus of these is on bearing and VVT applications, which is a reflection of the main markets for Japan's PM industry.

Variable Valve Timing (VVT)

One of the most significant developments over the last decade has been the manufacture of VVT components, playing an important role in production for both the domestic and overseas markets. Advanced VVT systems incorporating electric cam phasing, hydraulic cam profile switching and electric lost motion for valve lift, etc., have opened up additional opportunities for PM due to their complex mechanisms (Fig. 6). However, there are pros and cons for this business as the manufacturing of VVT components requires heavy investment, large CNC compaction presses and an expensive machining line along with the standard PM line.

Although many components are manufactured using ordinary Fe-Cu-C materials and processes, some new technologies have been developed, or processes improved, to enable more

Powder Forged conrods

Powder Forged (PF) conrods and main bearing caps are recognised as important PM components in North America, as the volume there is huge. However, only two in-house plants produce PF conrods in Japan. Toyota produces it exclusively for its V type engine and Mazda for a 4-cylinder engine designed by Ford. There have been no reports of any new applications in Japan.

Main bearing caps

Powder Metallurgy main bearing caps are not as popular in Japan as in the USA, but technical developments to increase competitiveness against

cast alternatives have made another step forward by eliminating the costly finishing processes and allowing further weight reduction. Sumitomo Electric Industries developed the main bearing cap shown in Fig. 8, which provides a 14% weight saving over traditional cast main bearing caps.

Continuously Variable Transmissions (CVT)

Continuously Variable Transmissions are simpler than manual or automatic transmissions, and use fewer PM components. However, some of the new CVT systems such as Nissan's Xtronic CVT and Subaru's Lineartronic

“One of the most significant developments over the last decade has been the manufacture of VVT components”

make use of PM components for additional mechanisms to increase efficiency and the performance of the system. Although manual transmissions are a niche in the domestic market, they are widely used in overseas models and therefore the synchroniser hub is still an important PM component in Japan.

Stop-go technology

The "Idle Stop" system to improve fuel economy has become popular and an additional PM oil pump driven by an electric motor compensates for the drop of oil pressure.

Motorcycles

The domestic motorcycle market in Japan has decreased steadily in recent years, from a high of 2.8 million units in 1995 down to just 690,000 in 2011 (Fig. 5). As such, the amount of PM used in motorcycle applications has also decreased, from 4977 tonnes in 1995, to 1504 tonnes in 2011. The volume of PM used in each motorcycle has, however, increased from 1.8 kg/unit in 1995 to 2.35 kg/unit in 2011.

Non-automotive applications for PM

Non-automotive applications for PM in Japan cover many different industries (Fig. 10). The manufacturing of some of these has decreased in Japan as a result of companies transferring production to their overseas subsidiaries, however some sectors have also seen growth in the domestic production.

Typical non-automotive applications are compressor components. Major Japanese PM companies began production at their overseas subsidiaries in the late 1980s and domestic production continuously decreased from 4000 tonnes in 1995 to less than 1000 tonnes in 2011 (Fig. 11). The economics of foreign subsidiaries allow them to compete with the cheaper, local PM parts available, for these less demanding components (when compared to automotive components, for example).

PM parts for home appliances and business machines have decreased in recent years. Those for power tool applications also decreased from 350

tonnes in 2000 to 200 tonnes in 2011. The reasons for such trends are not only customers' transferring production to overseas manufacturers, but also a change of market or change of materials.

Construction machines

An application area that has shown significant growth in Japan is that for PM components used in construction machines. The Japanese construction machine industry has grown, using some 500 tonnes of PM parts in 1997 to about 1700 tonnes in 2011 (Fig. 12). Exports of construction machines have increased from a value of ¥687 billion in 2003 to a high of ¥1825 billion in 2008 and ¥1635 billion Yen in 2011 (Fig. 13). The industry's growth over this time has come from an increase in exports, with some 51% of the total value from exports in 2003, up to 73.3% in 2011. The most successful product is a hydraulic power shovel (excavator) unit.

PM bearings

The PM bearing sector depends less on automotive applications than structural PM parts, however the

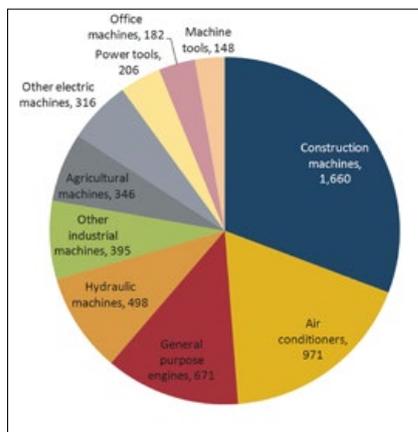


Fig. 10 Breakdown of the non-automotive PM parts market in Japan

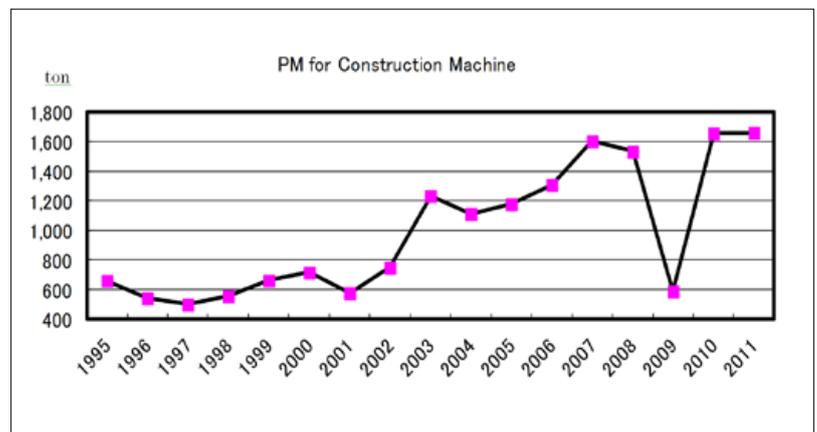


Fig. 12 Tonnage of PM parts produced in Japan for use in construction machines since 1995

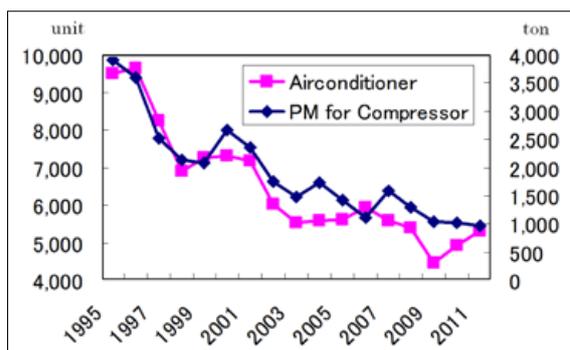


Fig. 11 Production of air conditioner units in Japan and the tonnage of PM parts used in the compressor

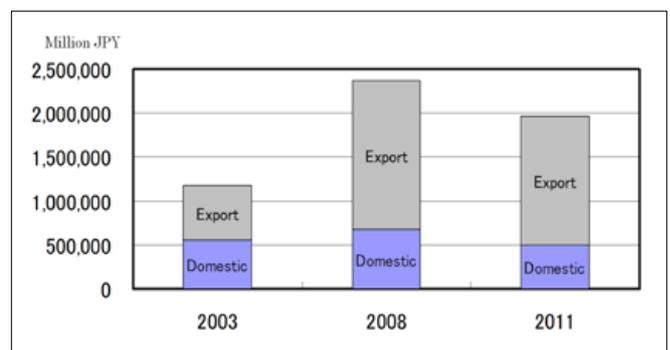


Fig. 13 Value of construction machine production in Japan for domestic and export sales

importance of automotive applications are increasing as the domestic non-automotive market is decreasing (Fig. 14). As a typical functional material, competition against alternative bearing technology might not be as high as for the structural PM part sector. However, PM bearing manufacturers are continuously improving the performance of their products in order to differentiate themselves against competition from cheaper PM bearings produced overseas (Figs. 15 & 16).

Trends in PM materials production and usage

High strength applications

For ordinary structural components, Fe-Cu-C (MPIF FC-XXXX) dominates. For high strength applications there are two groups of material, the traditional Fe-Ni-Mo-Cu diffusion bonded (FD-XXXX) group known as Högånäs Distaloy (Fig. 17), and the new lean alloy group. FD is currently most widely used for demanding applications either with or without heat treatment. In the lean alloy group, JFE launched a homo-hybrid-alloy, 0.40%Mo prealloy powder diffusion bonded with another 0.15% Mo. The Japan Powder Metallurgy Association [JPMA] awarded it as an outstanding new material in 2007. Kobelco prealloy 46F_H series, 46F2H (0.5Ni-0.5Ni), powder has been used widely for some time.

Alloys which do not contain elements having a high affinity to oxygen are preferred by the major PM companies due to the use of endothermic gas for sintering and heat treatment. However, recently the use of Cr steel powder FL-5305 (3Cr-0.5Mo Astaloy CrM) and FL-5208(1.5Cr-0.2Mo Astaloy CrL) began in Japanese companies and their overseas subsidiaries.

In 2010, the JPMA awarded Hitachi for its use of sinter hardened Cr steel. The reasons for choosing a leaner alloy or a Cr alloy are the price volatility of Ni and Mo, and inconsistent supply issue of Ni alloyed powder made by second suppliers of FD grades.

At the PM2012 World Congress in Yokohama, JFE presented another new lean alloy powder, 5CRA (0.5Cr-0.2Mn-0.2Mo) claiming high strength after heat treatment with high-pressure compaction. The secure supply of materials containing Ni, in particular, is of great concern

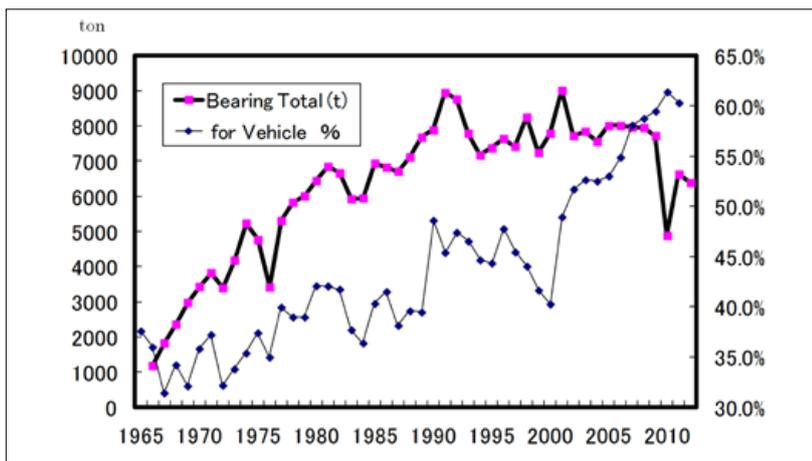


Fig. 14 Production of bearings in Japan and percentage of bearings for vehicle applications



Fig. 15 Corrosion resistant porous bearing material for use in automotive petrol pumps, manufactured by Diamet Corp. (Courtesy JPMA)

to the automotive industry. In that respect, the benefit of using a lean alloy or Cr alloy is clear.

Machining enhancing additives

As mentioned before, machining enhancing additives have been intensively developed by both JFE (JFM3 & 4) and Kobelco (KXS) in order to meet the stringent demands for the final machining of VVT parts etc. The basic idea of such additives is based upon the finding that Gehlenite ($2\text{CaO}-\text{Al}_2\text{O}_3-\text{SiO}_2$) in wrought steel seems to contribute to improved machinability by chip breaking, lubrication and protection of the cutting tool surface with its layer. JFM3 is explained as $\text{SiO}_2-\text{CaO}-\text{MgO}$ and KXS is $\text{Al}_2\text{O}_3-\text{SiO}_2-\text{CaO}$. However, the performance of such machining enhancers depends very much on the machining conditions, cutting tool and materials, therefore traditional MnS is still looked upon as the most robust



Fig. 16 Oil impregnated sintered bearing designed for an ultra-high speed scanner motor used in a laser beam printer, Porite Corp. (Courtesy JPMA)

material. Kobelco has two series of free cutting steel powders not as added mix powder, but alloyed with either S or MnS.

Bonded mix

Bonded mix development is also quite active in Japan. Kobelco and JFE have variations of Segless or Cleanmix for improvement in compressibility, fillability, ejection and green strength, which compete with Högånäs Japan's Starmix. JFE's investigation and report on the mechanism and characteristics of mixed powder based on powder surface chemistry, strengthened such developments. In 2009 the JPMA awarded Högånäs AB for their development and commercialisation of a new bonded mix, which eliminates compaction loss by stabilising AD.

Bearing performance

There are continuous research and material developments to improve

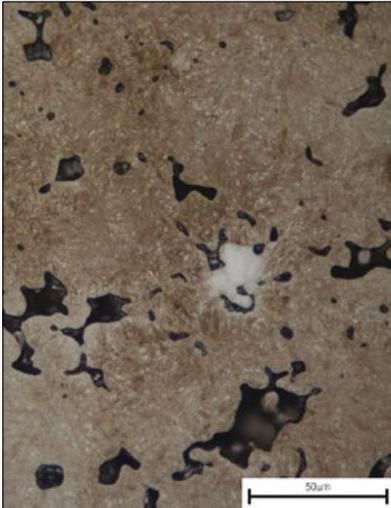


Fig. 17 Micrograph of Distaloy AQ powder produced by Höganäs AB, suitable for high strength applications



Fig. 18 Heat and wear resistance material for high temperature engine parts developed by Hitachi Chemical Co., Ltd. (Courtesy JPMA)

bearing performance in Japan. Bearings with a longer life, higher load carrying capacity, higher heat resistance, replacement of Cu base with Fe base new materials and better high temperature corrosion resistant EGR bearings, corrosion resistant fuel pump bearings etc, have been developed and recognised by the JPMA's industry awards, year after year.

Functional materials

Typical functional materials for automotive engines are Valve Seat Rings (VSR) and Valve Guides (VG). Three piston ring manufacturers and four major PM companies compete to develop new materials to meet the harsher demands of engines with improved economy. As the material design of the VSR is directly linked to the design of the engine, with a different engine giving a different environment for the VSR, there are

many different materials tailored to specific engines. Laser cladding VSR technology was looked upon as a major threat for Powder Metallurgy VSR, because it enabled greater valve-opening diameter and less material use. However, it finally diminished after limited use, perhaps due to the difficulty of process control.

Valve guides are simpler than valve seat rings, and therefore there are only a few materials currently on the market. The balance between wear resistance and machinability is the key for material development.

Examples of other new functional materials in the JPMA awards are the heat and wear resistant 32%Cr-2%Mo alloy for turbochargers by Hitachi Chemical Co., Ltd (Fig. 18) and the vacuum sinter-hardened HSS vane by Sumitomo Electric Industries Ltd.

Japan's major PM producers and materials suppliers

The major PM component producers in Japan are Diamet (a 100% subsidiary of Mitsubishi Material Corp.), Fine Sinter, Hitachi PM (100% subsidiary of Hitachi Chemical Co.,Ltd) and Sumitomo Electric Industries Ltd. Including the in-house production of Toyota, they dominate about 80% of the domestic market. In 2010 there were 111 PM companies (with 10 or more employees) registered, with a total of 11,017 employees.

Diamet, Hitachi and Sumitomo each have two manufacturing plants in Japan, and Fine Sinter has five plants. Among car manufacturers in Japan only Toyota has sizable in-house production. Daihatsu, Mazda, Honda and some of tier one suppliers (Aisin Seiki, Hitachi Automotive Systems, Showa and Yamada) have limited production. Three piston ring manufacturers (Nippon Piston Ring, TPR and Riken) also have specialised PM structural parts production, such as valve seat rings.

Overseas subsidiaries and joint ventures are shown in Table 3. Currently, production at overseas subsidiaries is primarily for automotive components for local supply. Hitachi, which recently started construction of a subsidiary in Indonesia, has also announced the first Japanese PM subsidiary in India. Sumitomo also announced a subsidiary in Indonesia as a joint venture with two local company groups. Diamet, which use to be the partner of PMG, is now returned to a group company of Mitsubishi Material and announced its new subsidiaries in China in 2011 and in Indonesia in 2012.

	Korea	China	Thailand	Malaysia	Indonesia	Singapore	Vietnam	India	USA	Brazil	Europe
Diamet		✓		✓	✓						
Fine Sinter		J/V	✓		J/V				✓		
Hitachi		✓	✓		✓	✓		✓	✓		
Sumitomo	J/V	✓, J/V	✓	✓	J/V				J/V		✓
Toyota											✓
Honda					J/V		✓			✓	
Porite		✓	✓	✓	✓	✓			✓		
NPR	J/V	✓	✓					✓	J/V		
TPR		J/V									

Table3 Locations of major Japanese PM company subsidiaries

Fine Sinter, established in 2000, is the merged company of Tokyo Sintered Metals (since 1950) and Nippon Powder Metallurgy (since 1947). The major shareholders are Toyota (20.8%), Denso (5.0%), KYB (5.0%), Aisin Seiki (3.0%), Sumitomo Electric Industries (2.9%) and JFE Steel (2.1%). In October 2012 it also announced plans for an Indonesian subsidiary. This now means that all four Japanese major PM companies are finally going to have subsidiaries in Indonesia as well as in China.

The rapid growth of the automotive market in Asia provides good opportunity for those companies to grow. Japanese overseas subsidiaries are now estimated to produce almost the same volume of PM parts as in Japan.

The major Japanese iron powder suppliers are JFE (since 1966) and Kobelco (since 1970). Daido Steel and Mitsubishi Steel produce stainless steel powder, as do Fukuda, JX Nippon Mining & Metals. According to JFE's catalogue, the company produces reduced iron powder made from mill scale and ore, with production capacity of 3,300 ton/month following its announcement of a 20%

increase in 2012. JFE also produces water-atomised powder, made of molten steel from a converter in their steel plant, with a capacity of 45,000 ton/year. Kobelco produces water atomised powder exclusively, with a production capacity of 7,500 mt/month (September 2011) including non-PM applications. Along with plain iron

Fukuda, which was established in 1700, produces electrolytic, atomised copper and copper base alloy powders, with a capacity of 14,400 ton/year in Japan. It has a subsidiary in China with production capacity of water-atomised powder of 4,800 ton/year since 2003. JX Nippon Mining & Metals, which was established as a copper mining

“Japanese overseas subsidiaries are now estimated to produce almost the same volume of PM parts as in Japan”

powder grades, both companies have FD (partially alloyed) powder compatible to Höganäs' and FL (prealloyed) powder. In August 2012 JFE announced that it is considering an overseas plant and are currently looking for a local partner in ASEAN, China or India. JFE, Kobelco and Höganäs AB, which started business more than 50 years ago in Japan, dominate the Japanese iron powder market. Other overseas suppliers' activities are very limited according to trade statistics.

company in 1905, has water atomised and electrolytic copper powder, too. Another copper powder supplier, Mitsui Mining and Smelting, used to have both processes, but withdrew its electrolytic copper powder for PM and focused on electronics applications and atomised Cu powder in 2009. Imports of Cu powder increased from 1204 tonnes in 2001 to 3598 tonnes in 2011, according to trade statistics, with China accounting for 70%, Germany 10%, Australia 9%, UK 4% and others 7%.

Advertising information Summer 2013 issue

The summer issue of *Powder Metallurgy Review* will be published in May 2013.

In addition to more than 2,500 anticipated digital downloads and extensive print distribution to PM product manufacturers worldwide, the summer 2013 issue of *Powder Metallurgy Review* will be distributed at:

- **2013 Plansee Seminar**
Plansee, Austria, June 3-7
- **PowderMet 2013 Conference and Exhibition**
Chicago, USA, June 24-27

Exclusive articles scheduled for this issue include “Advances in powder compaction technology” and “The potential for large scale HIP products”.

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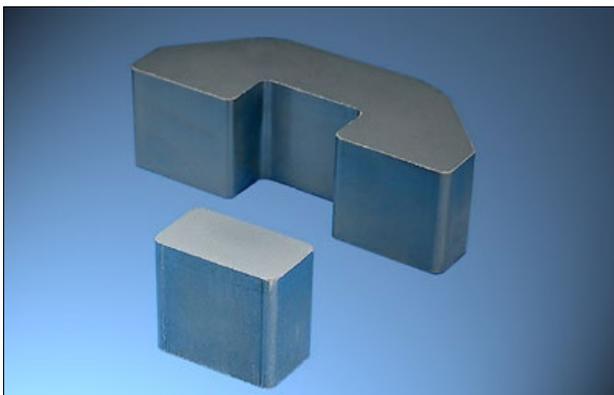


Fig. 19 The magnetic core of a reactor used in the boost converter of a hybrid vehicles, developed by Daido Steel Ltd and Toyota (Courtesy JPMA)



Fig. 22 Parts for an electric vacuum pump designed for an electric vehicle brake assist system, Sumitomo Electric Industries, Ltd. (Courtesy JPMA)



Fig. 20 Porite Corp developed this low noise sintered gear for use in the motor pinion of a multifunction home office printer, copy machine and scanner. (Courtesy JPMA)

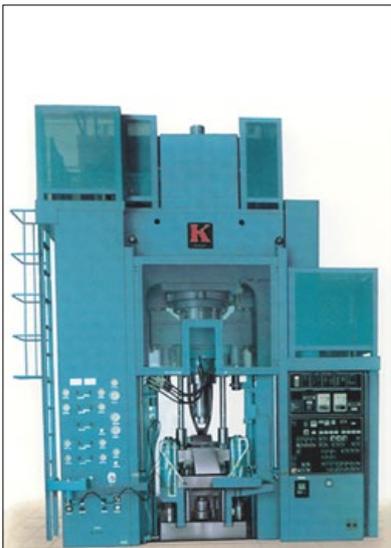


Fig. 21 Kohtaki Precision Machine Co., Ltd. manufacture a range of presses for powder metallurgy applications

Technology and processing innovations in Japan

In the area of ferrous structural PM components there have been many improvements over the last decade, but not many outstanding innovations except for the development of Soft Magnetic Composites (SMC). Major PM companies and powder suppliers have conducted developments on SMC relating to powder, additives, compaction, heat treatment and design. The SMC session in JSPM meetings is always interesting and very well attended.

One of the most outstanding innovations has been the design of a high density and low loss powder magnetic core for a reactor in hybrid vehicles (Fig. 19). Developed through a collaboration between Toyota, Daido and Toyota Central R&D, this was presented at the JPMA Special Seminar of the JSPM conference. According to the presentation this is an excellent example of collaboration between the R&D team, powder supplier, in-house PM production and the design department of the HEV system. It enabled the successful commercialisation of a SMC reactor core made from shape controlled spherical Fe-3%Si atomised powder, coated with high heat resistant insulation, compacted at extremely high pressure of over 1270 MPa using a new die wall lubrication technology and design modification of the assembly. Each of the steps had looked impossible, but the consortium persevered, found solutions and succeeded. The bestselling car in its class in Japan, Toyota's Prius, is equipped with it. Although the growth rate and volume of SMC are smaller than expected, the

progress looks very steady. The torque sensor for power steering (Fine Sinter), the stator core for a DC motor in an ABS system (Aisin), the injector cores for diesel common rail engines (Hitachi and Sumitomo), the claw teeth motor core (Hitachi), a miniature motor core, a reactor core and an ignition core are all in production using Höganäs Somaloy powder.

Improvement of dimensional tolerance is a never-ending issue. Toyota views this challenge as a "Zero-Loss Activity", and one of the technologies developed by them is for optimised filling with their patented 'Aeration' filling shoe. Investigation of powder behaviour during filling was conducted by using visualisation equipment and in-situ measurement of AD with a tailor made electronic sensor. The process eliminates the finish turning of synchroniser hubs, which require +/- 0.05mm tolerance, using a bonded mix powder. It also helped to eliminate green scrap when resuming compaction after pausing compaction.

Distortion caused by heat treatment is another issue for PM components. Although the same issue exists in wrought steel components and there is no 'royal road' to solve it, Sumitomo presented an elaborated achievement at Euro PM2011 (Barcelona, Spain, 9-12 October, 2011) that optimised quenching conditions and enabled the elimination of hard finishing for a high precision transmission component.

Improvement of rolling contact fatigue strength was challenged by Hitachi, with a combination of surface rolling and Carbide Dispersed (CD) CQT. CD CQT was developed for wrought Cr-Mo steel to improve the pitting fatigue strength in the early 2000's. For a component made of Fe-0.5Ni-

0.5Mo-0.3 graphite, this heat treatment is used.

Diamet developed a proprietary Fe-Cu-C-X alloy, which has high strength, comparable to FD grade steel. PM companies prefer robust Fe-Cu-C and very high density Fe-Cu-C made of the highest compressibility powder has become popular.

Higher densities can also be achieved by other methods. A number of medium sized PM companies have successfully commercialised Hōganās Hipaloy, which provides 7.5 g/cc by the 1P1S process for various non-automotive applications. Cold forging of PM is a well-known and established technology. A new challenge, using JFE's patented sintering and cold-forging process, has been reported, involving collaboration between a cold forging company and Hitachi.

Professor Takemasu at Nissei Co. Ltd., a leading rolling machine manufacturer, and researchers at Hōganās have collaborated to investigate the surface rolling of PM gears. A major obstacle for PM companies in using surface rolling technology has been the unpredictable length of time necessary, and trial and error involved, in optimising the rolling tool and preform to reach the target shape of the gear with deep enough densification. The newly developed algorithm and integrated CAD-CAM system for making a rolling tool finally solved it. The investigation also proved that Hipaloy has strength equivalent to typical wrought Cr-Mo steel used for transmission gears in Japan. This achievement is now under commercial development by some PM companies in Asia.

Press technology is an important area for PM. Kohtaki Precision Machine Co., Ltd. has reported the development of a new servo hydraulic press (Fig. 21). The servo hydraulic press offers significant energy saving over traditional presses, as the hydraulic pump is controlled to work only when the pressure is needed and at the exact pressure. Aida Engineering Ltd, a world leading stamping and forging press company, has developed a servo mechanical press. The servo mechanical press enables a flexible press cycle by programming the electronic control of the servomotor. Exploiting this, Aida has proposed a new compaction process to reach close to full density by heating the green form between first and second pressing.

The Japan Powder Metallurgy Association

The Japan Powder Metallurgy Association (JPMA) has around 70 member companies and is actively involved in the promotion of Japan's PM industry.

The 'JPMA Award Special Session' at the Japan Society of Powder and Powder Metallurgy's (JSPM) meeting is held every year. JPMA members invite their customers to the session with the intention of showing state-of-the-art PM technologies in commercial production. This is also a good opportunity for PM companies to have mutual stimulation in technological achievement, and the openness of the session is remarkable. For most PM designers or process engineers the ordinary sessions at the JSPM meeting are of little interest, but this special session is an eye-opening opportunity for them.

The JPMA also organise an annual closed meeting for its members, 'Case Studies of Production Efficiency Improvement'. Major PM companies give presentations related to not only technical matters but also systems to improve business efficiency. Proprietary information is not disclosed, of course, but JPMA members strongly believe friendly rivalry is the key to strengthen the industry against competitive technologies. Powder or equipment suppliers are also invited to give sales promoting presentations in this meeting.

Amongst the ten committees coordinated by the JPMA is the 'Committee for International Standardisations', which is the representative of the Japanese Industrial Standards Committee (JISC) for ISO TC 119 Powder Metallurgy. Under consensus of the JPMA's technical committees for metal powders, sintered parts, MIM etc, this committee dispatches delegation teams to the international committee. This means that the JPMA is fully involved in the standardisation in Japan, except for the hardmetals sector. The JPMA's committee for the environment has worked on setting a new reduction



Mr Kazuyoshi Tsunoda, President of the JPMA



Mr Kazunori Arai, Executive Director of the JPMA

value for its "Voluntary action plan for environment of PM industry". It has presented case studies of "CO₂ emission reduction", "Waste product reduction" and "Cases close to serious pollution"

The JPMA is taking a strong initiative within the Asian PM Association (APMA) which was established in 2008. In October 2009, the first board meeting was held in Japan and the first APMA international conference was held in Jeju, Korea in October 2011. Current members are Korea, India, Taiwan, China and Japan. As the region with the highest growth for the PM industry worldwide, the APMA is expected to play an important role, under close cooperation with the EPMA and MPIF.

www.jpma.gr.jp

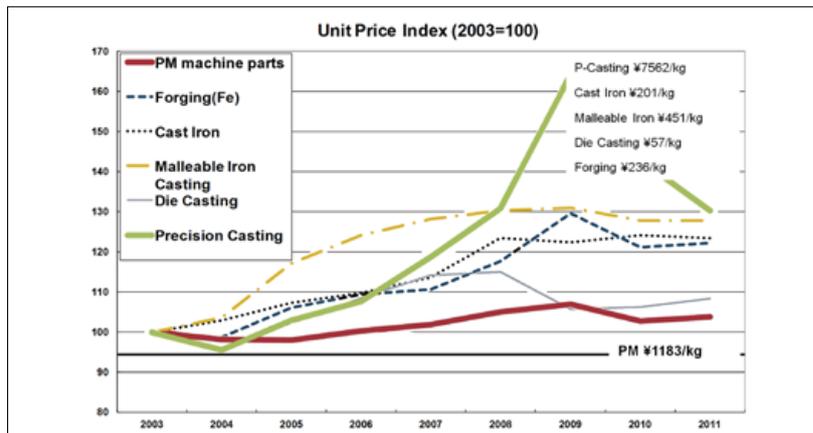


Fig. 23 Price index of the development of competing industries

Challenges for Japan's PM industry

It is anticipated that production of vehicles in Japan will remain at the current level, but overseas levels will grow. In order to supply the overseas facilities of Japan's automotive industry, its PM industry needs globalisation. By 'globalisation' this means not only a need to have overseas subsidiaries using Japanese technologies, but by also offering competitiveness against alternative technologies and foreign PM companies, in respect to performance, quality, cost and flexibility.

Competing technologies in Japan, such as casting, forging and machining, are constantly improving their manufacturing techniques. The cost comparison of competing industries is shown in Fig. 23, which clearly shows that PM has price competitiveness, but it also might mean that PM could have an increased sales price while providing benefit to customers. However, companies using competing technologies with either in-house production, or by affiliated companies or "Keiretsu" companies, could be an obstacle to switching to PM.

Therefore, what is the competitiveness of the Japanese PM Industry? It should not simply depend on the strength of PM component manufacturers. Powder suppliers, press manufacturers and tool manufacturers, machining shops and heat treatment shops and academic support all contribute to it. From this point of view, Japan is a rare country, having reasonably strong industries in all of the areas which support the PM industry. For example, Japanese compaction presses are widely used in Asia for making small to medium size parts thanks to their excellent reliability

and cost performance. At the PM2012 World Congress in Yokohama, Ingo Cremer, EPMA President, stated, "In the European equipment sector, there is strong competition from Chinese and Indian reproductions of European basic models. European manufacturers are responding with more sophisticated machines and cooperation with Asian partners." The Japanese equipment sector has a similar issue, and it was also weakened by the high currency exchange rate. Due to market size limitations, Japanese press manufacturers seem to focus on volume zone presses but not high-end big CNC hydraulic presses.

The strength of Japan's industries also consists of the intangible, such as teamwork spirit, QC mind, contrivance (Kaizen), craftsmanship based on long experience, sincerity and fidelity cultivated by lifetime employment along with creative design capability. Money cannot buy such intangibles, they cannot be copied easily or be made up easily in other countries. Accordingly, it seems to be the real strength of the Japanese PM Industry, but it could also be the biggest issue when they have overseas subsidiaries. Japanese management in these subsidiaries strive to implant and cultivate such a DNA.

A lack of academic support has been a big issue in comparison with Europe, even the JPMA associates with the JSPM to promote academic research relating to PM, by way of the 'Research Promotion Program'. Frankly speaking, it is not successful as the majority of academic studies are rather far from the industry's interest and the funding for it is too small to stimulate academic people to be involved in practical themes. This is not only the problem of the PM industry but also a common problem of Japanese manufacturing

industries, as the ministry of education, science and technology (MEXT) does not have a focus on basic manufacturing technologies and practical material research at all. Professors who are active in relation to PM components or ferrous PM materials are almost bound to diminish. Although major Japanese iron powder suppliers and component manufacturers are highly equipped with modern analytical equipment, deep investment in academia is necessary to make real progress of PM technology and to educate students who will join the PM industry or become users of PM.

Conclusion

In conclusion, two facts from 2011 need to be remembered, namely that the Japanese car industry produced 27% of the world's vehicles and that the Japanese PM industry produced about 200,000 ton of PM components globally. In the growing Asian countries, the Japanese automotive and PM industries play important roles, although the Korean and Chinese industries are increasing their volume significantly.

Looking back over the last five years, both the Japanese automotive and PM industries showed unyielding strength despite various devastating incidents. However, more effort needs to be made to create new markets by championing new technologies. A promising new application in the non-automotive sector, equivalent to the PM transmission gear, has not yet been found.

Acknowledgements

The author appreciates the kind cooperation of the JPMA in providing statistics, reports and permission to use the material.

The report also refers to published statistics from the following: METI Survey of Machinery, Japan Customs, Japan Automotive Manufacturers Association, Japan Electrical Manufacturers' Association, Construction Equipment Manufacturers Association and Toyota Annual Report 2012.

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Changes at GKN as Peter Oberparleiter becomes new CEO of the PM division

GKN, a leading global force in component production and technology for a number of end-user sectors, including the automotive industry, appointed Peter Oberparleiter as the new CEO of its Powder Metallurgy division in the autumn of 2012. The appointment followed the retirement of the division's former President and CEO Manfred Weber, who successfully steered GKN's PM business into its current world leading position. *Powder Metallurgy Review* reports on recent developments at the company.

GKN PLC is a UK listed global engineering group that supplies technologies and products that can be found at the heart of vehicles and aircraft produced by the world's leading manufacturers. The group serves three primary markets, automotive, aerospace and land systems, through four divisions: GKN Driveline, GKN Powder Metallurgy, GKN Aerospace and GKN Land Systems (including agriculture, construction and mining). Approximately 44,000 people work in GKN companies and joint ventures located in more than 35 countries.

GKN's Powder Metallurgy division is the world's largest manufacturer of sintered components, predominantly supplying the automotive sector. Notably, GKN Powder Metallurgy is the only global player in the industry that offers customers a powder-to-part capability, thanks to its Hoeganaes powder production operations.

The new President and CEO of GKN's Powder Metallurgy portfolio, Peter Oberparleiter, assumed leadership on 1 October 2012, succeeding the former President and CEO Manfred Weber.



Fig. 1 The new CEO of GKN's PM division, Peter Oberparleiter

Taking PM to the next level

Oberparleiter's sights are firmly set on taking GKN's PM business to the next level, in part through leveraging market trends and ensuring that more products are specifically designed for the Powder Metallurgy process.

Commenting on future plans, Oberparleiter told *Powder Metallurgy Review*, "The GKN Powder Metallurgy business continues to make good progress, strengthening and consoli-

dating its market leading position on technology and global operational capability to deliver growth. As a division we must now focus on taking the business to the next level. Our challenge is to accelerate our growth and return opportunities on a global scale; leveraging our world leading position and the increasing trend towards design for Powder Metallurgy."

Oberparleiter added, "For us to achieve this we must unlock our full potential in the complete value stream,

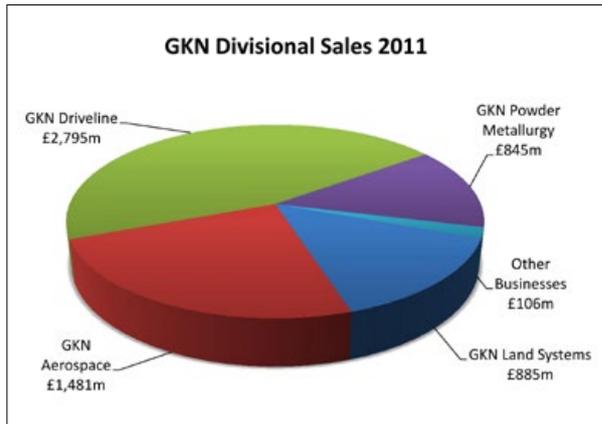


Fig. 2 GKN divisional sales, 2011



Fig. 4 A selection of PM products manufactured by GKN Sinter Metals using various production processes



Fig. 3 The retiring former CEO of GKN Powder Metallurgy, Manfred Weber

starting from raw materials to the finished part.”

Having joined GKN in 1987 and progressed through a range of operational and finance roles in Sinter Metals Europe, Oberparleiter was appointed President of GKN's Sinter Metals European operations in 2007. In 2009, he moved to GKN

Driveline as the Global Director of Finance and IT. GKN told *Powder Metallurgy Review* that, “Peter's broad mix of experience and record of success will enable him to lead the Powder Metallurgy business to the next level of performance.” Commenting on the primary areas of growth for the PM industry, Oberpar-

“GKN Powder Metallurgy continues to benefit from increasing trends in industrial and automotive markets to improve fuel efficiency and reduce emissions”

CASE STUDY 1: MPIF Grand Prize award winning VVT rotor adapter assembly

In the automotive engine category of the 2012 MPIF awards, GKN Sinter Metals received the grand prize for a VVT rotor adapter assembly consisting of a powder metal steel rotor and adapter, used in a Chrysler V-6 engine. Utilising a two-piece design allows for a reduction in machining while minimising the material waste due to the near net shape capabilities. With GKN's ability to form vertical slots for oil feeding, the adapter requires no machining prior to assembly. GKN is able to provide a product with very high density and tensile strength, while reducing manufacturing processes



and therefore costs for the total VVT (Variable Valve Timing) system.

leiter stated, “GKN Powder Metallurgy continues to benefit from increasing trends in industrial and automotive markets to improve fuel efficiency and reduce emissions, which drive demand for components such as variable valve timing in engines, high-performance gear sets in automatic transmissions and differential gears.”

Oberparleiter succeeds Manfred Weber, who started his career at Sintermetallwerk Krebsöge GmbH in 1984 as Powder Forging Manager at the Radevormwald plant in Germany. He joined GKN as part of the Krebsöge acquisition by GKN Sinter Metals in 1998, becoming Vice President Operations and Technology. In 2004 Weber was appointed President Sinter Metals Europe and President of Sinter Metals globally in January 2008. He was President and CEO of GKN Powder Metallurgy from 2010 to 2012.

“With his unique knowledge and experience Manfred is recognised as

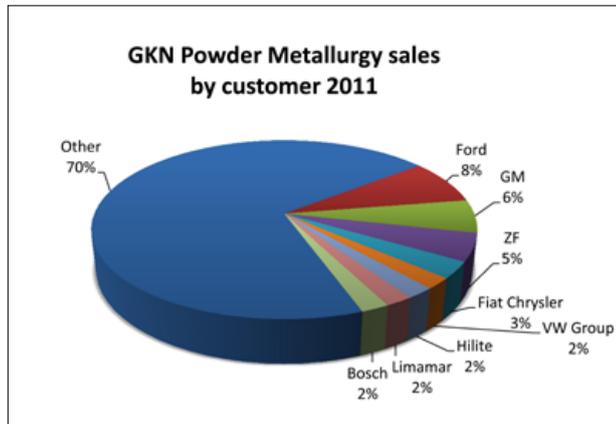


Fig. 5 GKN Powder Metallurgy sales by customer 2011

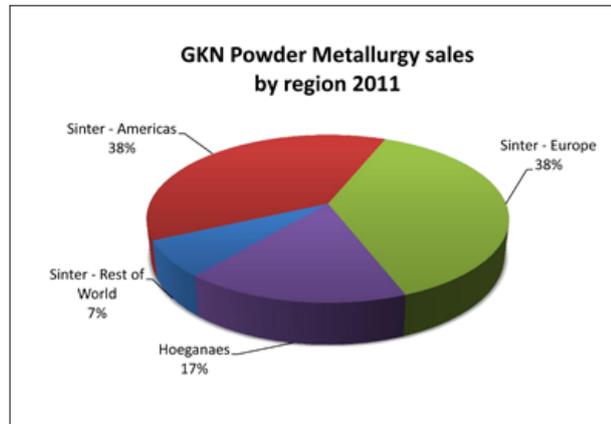


Fig. 6 GKN Powder Metallurgy sales by region, 2011

a leading expert in the field of Powder Metallurgy and is highly respected both internally and externally within the industry. He has brought vision, leadership and passion to GKN Powder Metallurgy and has played an instrumental part in building the business into a world leader," GKN told *Powder Metallurgy Review*.

Leading Powder Metallurgy innovation

GKN Sinter Metals offers its customers a wide range of products, technologies and services, ranging from engineering and design consultation to product development, testing and the manufacture of the most complex components.

Besides the focus on conventional sintering technology, GKN Sinter Metals also offers parts from related processes such as Powder Forging (PF) and Metal Injection Moulding (MIM), as well as being a market and technology leader in the production of Powder Metallurgy filters and bearings.

GKN has won numerous awards for its innovative PM products and in 2012 the company was presented with two Metal Powder Industries Federation (MPIF) "Grand Prize" awards for a VVT rotor adapter assembly (Case Study 1) and a unitised one-way clutch (Case Study 2). The MPIF's Design Excellence Awards recognise PM parts that offer improved net-shape capabilities, innovative precision fabrication methods, production efficiency, sustainability contributions and manufacturing cost reductions.

Expanding global operations

GKN Powder Metallurgy is the world's largest manufacturer of metal powder precision components, supplying more than 3,000 customers globally with around six billion parts per year. The organisation's global production and sales network currently employs approximately 7,000 people in more than 35 production sites in Germany, Italy, South Africa, India, China, Brazil, Argentina, Canada and the USA.

In 2011 GKN Sinter Metals had a global market share of approximately 18%, with the automotive industry accounting for around 75% of the company's business.

In November 2012 GKN announced that its Powder Metallurgy division had commenced on the construction of a new PM manufacturing facility in China. The ground breaking ceremony took place for the new \$26 million plant in Yizheng. The facility, which will cover an area of 30,000 m², will be completed in 2013.

GKN has been active in China since 1988 and now operates from 12 locations, employing more than 5,000 people. GKN's Powder Metallurgy division currently operates from two sites in China, both in Danyang City.

The new plant will produce precision parts for automotive applications in engine, transmission, body and chassis, as well as a range of compo-

CASE STUDY 2: MPIF Grand Prize award winning unitised one-way clutch

GKN Sinter Metals won the grand prize in the automotive transmission category of the 2012 MPIF awards for a unitised one-way clutch (OWC) module made for the Chrysler Group LLC. The module has four powder metal steel parts (powder-forged race and cam, and two pressed-and-sintered retainer plates) as well as 22 additional parts (clips, springs and roller elements). This product is the first self-contained loose-roller OWC module for torque converter stator applications using all powder metal and powder-forged main components. The retainer plate has net shape features that cannot be formed by other manufacturing



processes without major secondary operations. Selecting the powder metal process reduced production costs by 20% and increased the volume rate by 50%. Powder metal's reliability is supported by more than 10 million OWC assemblies in the field with zero warranty claims.



Fig. 7 PM parts entering the dewaxing zone of a sinter belt furnace at GKN



Fig. 8 Bill Michael retired as the Senior Vice President, Sales and Marketing, Hoeganaes Corporation, in 2012



Fig. 9 Jim Shaul, the new Vice President, Sales and Marketing, at Hoeganaes Corporation

nents for power tools, white appliances and other industrial and consumer applications. Production is expected to start by Q4 2013 and upon completion the plant will have the capacity of 100 million components per year.

Commenting at the time of the ground breaking ceremony, Nigel Stein, Chief Executive GKN plc, stated, "China is a key growth market for GKN and integral to our strategy of increasing our global footprint. We already have a strong presence in the country and are delighted to be expanding our powder metallurgy business. The new plant will ensure we are better positioned to serve our Chinese customers, develop close relationships and further strengthen our customer base."

Hoeganaes: At the heart of GKN's "powder-to-part" capability

Hoeganaes Corporation, founded in 1953, is a world leader in the production of atomised steel and iron powders for PM, developing materials that lead to property advancement and PM process efficiency. The company was acquired by GKN plc in 1999 and today Hoeganaes operates on a global basis with facilities in Asia, Europe and the Americas.

As well as producing the metal powder that GKN Sinter Metals requires to manufacture precision components for automotive, industrial and consumer applications, Hoeganaes also serves PM parts makers in the wider PM community

with a broad portfolio of powders and technological expertise.

"This international focus, combined with our own manufacturing facilities in the United States, Europe and Asia, along with marketing representatives around the world, enables Hoeganaes to serve customers effectively on a global basis," stated GKN.

2012 also proved to be a year of change for Hoeganaes, with the announcement that Bill Michael was to retire as Sr. Vice President of Sales and Marketing after 38 years of service. Michael has been the face of Hoeganaes Corporation in the Powder Metallurgy market as well as an eminent leader in the industry. He was part of the original start up team for the Gallatin, Tennessee plant and served as its first General Manager in 1979. Since 1999, he was principally responsible for Hoeganaes' international market development, overseeing the European presence including their Huckswagen market service operation in Germany. He was also a primary participant in the acquisition and integration of Ductil Powders, Buzau, Romania into the organisation. His role also included setting up a sales team and agency network in Asia, eventually resulting in the Hoeganaes Corporation Danyang, China market service operation.

Michael was succeeded by Jim Shaul, who joined GKN Sinter Metals in 2005 as the Sales Director responsible for the GM and Delphi accounts. Shaul then moved on to numerous other positions, with his most recent position as Executive Director, Sales & Marketing, for all the major automotive accounts. In addition to Shaul's sales and engineering experience, he also brings to Hoeganaes a unique outlook on operations, which will provide a more thorough understanding of PM's products and processes, coupled with his years of working with end-user customers. This degree of experience will greatly benefit Hoeganaes' effort to continue to foster the growth and expansion of PM applications".

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PM2012 World Congress: An overview of the global Powder Metallurgy industry

The PM2012 Powder Metallurgy World Congress was held in Yokohama, Japan, October 14-18, and attracted over 700 delegates and almost 7000 exhibition visitors. *Powder Metallurgy Review* reports on the plenary session that featured presentations from the JPMA, MPIF and EPMA highlighting the current state of the Powder Metallurgy industry in Asia, North America and Europe.

The PM2012 Powder Metallurgy World Congress, jointly organised by the Japan Powder Metallurgy Association (JPMA) and Japan Society of Powder & Powder Metallurgy (JSPM) under the auspices of the Asian Powder Metallurgy Asian (APMA), had as its slogan 'Challenges for the next generation' and there was indeed much for the next generation, as well as the current one, to ponder over in the Technical Programme.

There are the challenges not only to broaden the spectrum of materials and applications already covered by PM components, Powder Injection Moulding (PIM), hard materials, magnets and hot isostatic pressing, but there are also opportunities to contribute to the development of a host of new technologies. In particular PM can help improve fuel efficiency and reduce emissions of vehicles, the PM industry's biggest customer.

Some 500 technical presentations were included in the oral and poster sessions and a lively accompanying exhibition featured 95 PM producers, metal powder suppliers and equipment producers from 15 countries. There were also opportunities to participate in a variety of social events that portrayed traditional Japanese music, customs, culture and cuisine.

The Powder Metallurgy industry in Asia

In the Global Powder Metallurgy Review session which followed the opening ceremony, Kazuyoshi Tsunoda, President of the JPMA reported that China and India had become members of the APMA at the association's first conference held in

Jeju, Korea, in November 2011.

Tsunoda stated that China is now the region's largest PM producer with a total of over 143,000 tonnes of ferrous and non-ferrous PM parts produced in 2011, having overtaken Japan in 2009. He further stated that most of the PM industries in the other countries in the region also showed steady gains in 2011 (Table 1).

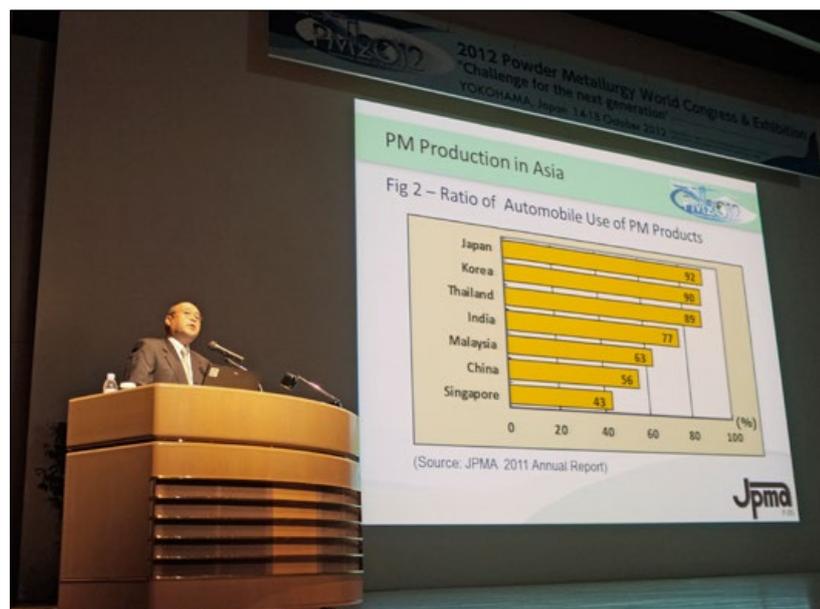


Fig. 1 Kazuyoshi Tsunoda, President of the JPMA, presented an overview of PM activities in Asia

AREA	Iron base	Copper base	Total	11/10(%)
China	134,544	8,884	143,428	104.6
Japan	93,538	3,567	97,105	94.7
Korea	62,543	1,318	63,861	106.2
India	35,400	14,500	49,900	111.1
Taiwan	27,000	1,800	28,800	116.3
Thailand	15,401	145	15,546	101.1
Malaysia	6,009	162	6,171	98.7
Singapore	1,744	674	2,418	108.4
Total	376,179	31,050	407,229	102.5

Table 1 Production of PM parts and bearings in Asia in 2011

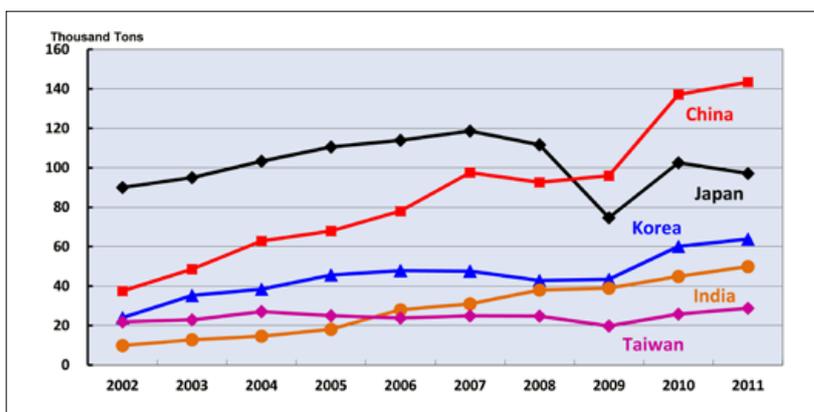


Fig. 2 Production trends in five PM producing countries in Asia 2002-2011

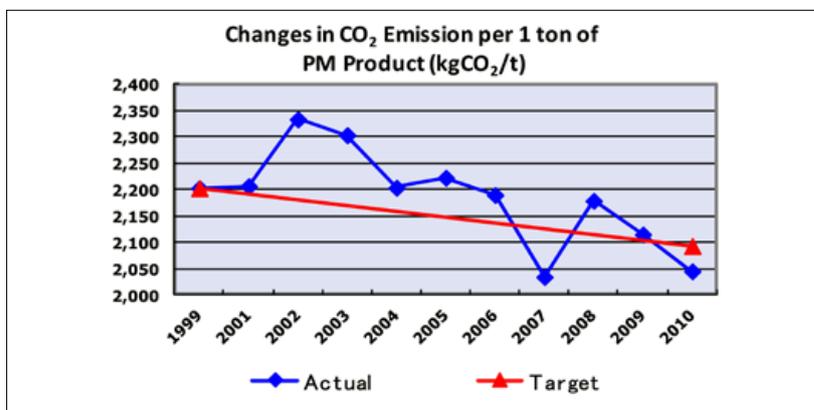


Fig. 3 Voluntary Action plan to reduce CO₂ emission in PM production in Japan 1999-2010

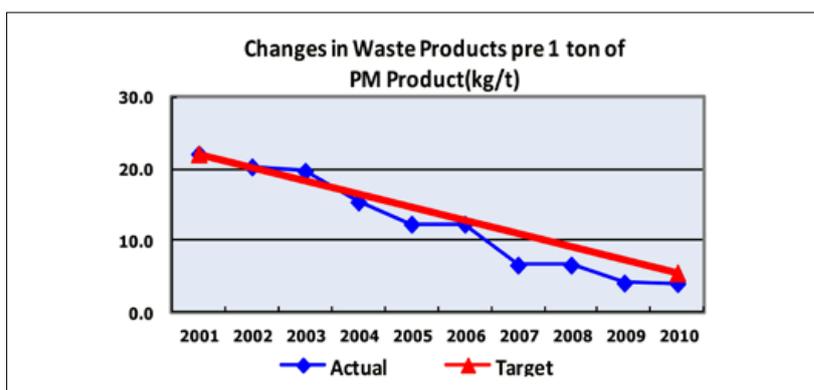


Fig. 4 Voluntary Action plan to cut waste products in PM production in Japan 2001-2010

Fig. 2 shows the steady progression of PM growth in the major industrialised countries of Asia since 2002.

Tsunoda said that the most recent economic crisis saw PM grade iron powder shipments in Japan slump from around 110,000 mt to below 80,000 mt in 2009, but that the recovery in the global economy helped to boost PM iron powder shipments in 2010. However, the earthquake and tsunami in north east Japan in March 2011 had a significant impact on reducing demand for PM products over the remainder of that year.

The need for the automotive industry to make vehicles more fuel efficient has given Japanese PM companies the opportunity to develop new applications, and has helped to increase the average weight of PM parts per car to around 10 kg in Japan, said Tsunoda. There is also a strong trend towards electric vehicles (EVs) and hybrid electric vehicles (HEVs) as was illustrated through the development of high density and low loss powder magnetic cores for reactors in Toyota's Prius.

Tsunoda reported on the Voluntary Action Plan by Japan's PM industry to reduce CO₂ emissions in PM production and also to reduce the amount of landfill waste resulting from PM production. He stated that CO₂ had been reduced from a starting point of 2200 kg CO₂/ton in 1999 to 2015 kg CO₂ in 2010, and that this would be further reduced to 2009 kg CO₂ by 2020 (Fig. 3).

This voluntary action has succeeded in reducing waste in PM production from 20 kg/ton in 2001 to 4.1 kg/ton in 2009, said Tsunoda. A further reduction to 3.1 kg/ton is expected by 2020 (Fig. 4)

Another successful JPMA initiative are the seminars on 'Case Studies on Environment and Energy Saving through Production Efficiency'. There have been 166 presentations by JPMA members since 1980 where companies openly discuss how they have succeeded in developing new products to improve the environment or where savings in energy or production efficiencies have been made. A special JPMA seminar containing case studies in this area was held during the PM2012 World Congress.

State of the North American Powder Metallurgy industry

In the Global Powder Metallurgy Review session Matthew Bulger, President of the Metal Powder Industries Federation (MPIF), focused on recent trends in the North American PM industry (Fig. 5). Bulger stated that iron powder shipments increased by 3% in 2011 to 327,447 mt despite the two month shut down of one of the major powder suppliers.

Iron powder shipments have grown by almost 9% in the first 8 months of 2012 to 239,446 tons, said Bulger, thanks to the continuing revival of vehicle production in the region. With US light vehicle sales expected to exceed 14.8 million over the whole of 2012, many PM parts makers, especially those focusing on the automotive sector, are again experiencing double-digit growth.

The MPIF estimates that the average PM parts content per typical vehicle is set to increase to 19.8 kg in 2012, which is double that of Japan or Europe. This is said to give PM parts a 30% share of all engine parts and includes powder forged connecting rods, bearing caps, valve seat inserts, VVT parts, etc. Bulger said that potential growth for PM in the automotive sector appears more likely in transfer case and transmission applications.

However, Bulger warned that the upsurge in North American vehicle production will pose a serious capacity issue for the PM industry, which saw plant closures, the scrapping of older equipment and staff cuts of 20 to 30% during the depth of the last recession in 2009. Many PM parts producers supplying the automotive sector are already straining to meet growing demand, and compacting press capacity in the larger compacting press size range, especially above 700 tons, is a serious constraint.

In 2011, 15 compacting presses were shipped to the North American PM industry, up from only 9 presses shipped in 2010. Bulger said it could take around 12 months to build a high-end powder press and put it into production. Another serious constraint is said to be a shortage of skilled employees after the deep cut backs three years ago. "Playing catch up now is painful and PM executives are experiencing the same difficulty

with employee skills facing the entire auto-supply sector", stated Bulger.

Bulger added that the other sectors of PM such as metal injection moulding (MIM), and hot isostatic pressing (HIP), were also doing well. MIM production, which is less reliant on the automotive sector than conventional PM parts, grew by nearly 40% in 2011, whilst the HIP sector experienced robust growth due to the general surge in demand from the oil-and-gas, tool steel, and aerospace markets. PM HIP now accounts for around 30% of the HIP market with the remainder being the HIPing of castings.

The growing demand for light-weight materials is encouraging new attention aimed at PM aluminium, titanium, and magnesium structural applications, stated Bulger. Just one example is the recent qualification by Boeing of PM titanium alloy products for commercial aircraft use as an alternative to machining parts from bar, plate, castings, forgings, or extruded products.

Bulger reported that an updated



Fig. 5 Matthew Bulger, President of the MPIF, outlines developments in the North American PM industry

'PM Industry Roadmap', a project of the MPIF's Technical Board, Industry Development Board, and numerous additional industry experts, was released earlier this year. Based on the first Roadmap completed in 2001, the update shows that the industry has made steady progress in high-

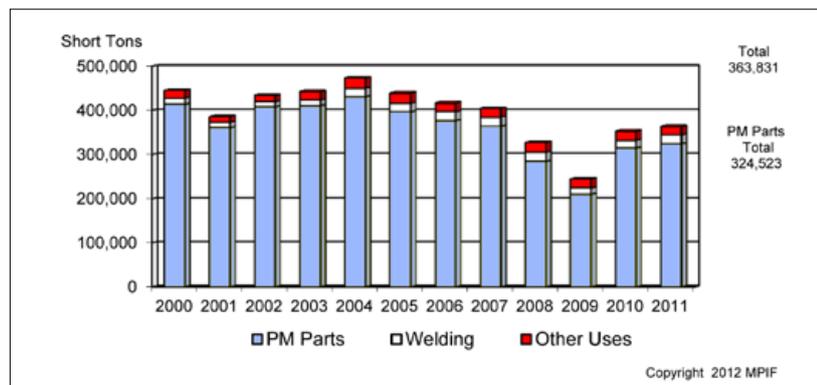


Fig. 6 North American Iron powder shipments (Courtesy MPIF)

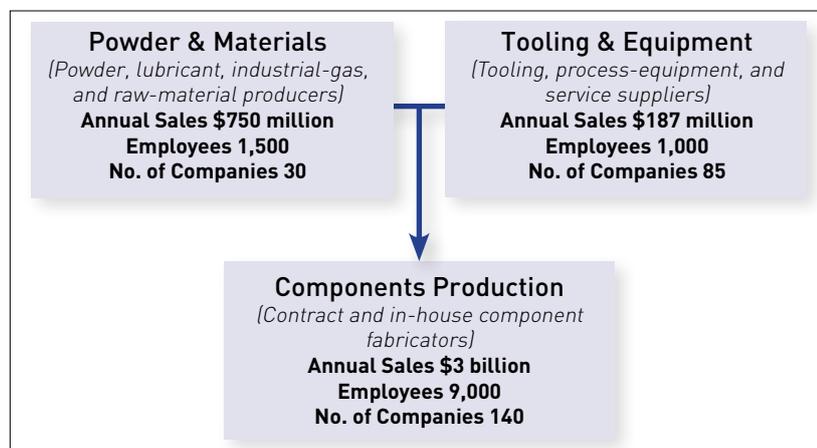


Fig. 7 Structural component Segment of the North American Conventional PM Industry (Courtesy MPIF)

density processing, new materials, 3-D additive manufacturing systems, modelling, and advanced manufacturing methods.

Looking ahead, the new Roadmap identifies three main topics that will impact the industry's growth: high-density PM components, processing of lightweight materials, and electrical and electromagnetic applications. While the current PM industry is driven by automotive applications, growth in the next decade must be found in other markets. The overall need for alternative energy sources should open new markets and applications for PM.

The MPIF has, in conjunction with the publication of the new Roadmap, also produced a brief video that describes the technical barriers, challenges, opportunities, and priorities that are expected to drive the PM industry's continued growth over the next ten years.

The European Powder Metallurgy market

Ingo Cremer, President of the European Powder Metallurgy Association (EPMA), reviewed current production trends in the various sectors of the European PM industry (Fig. 8).

Cremer began with the impact of the ongoing turbulence in the Eurozone countries and how this is affecting consumer demand, particularly for automobiles. The automotive sector and its suppliers performed better than expected in 2011, but this was in the main due to strong exports of luxury cars, he said.

Cremer stated that despite the threat of price-competition from low-cost economies, Europe's PM industry still had a bright future. However, he warned against the relocation of PM manufacturing facilities outside of the European continent. "We must not make the mistake to give all our production capacities to low cost countries, because once we no longer have our production capacity, we have no chance to earn with industrial applications."

PM operates in a strongly competitive market, said Cremer, with profit margins positive but under pressure, particularly from the automotive sector, the PM industry's biggest customer. Nevertheless, PM has managed to increase the average weight of PM

parts in vehicles by 37% over the past ten years to 10 kg. Fuel price increases and new technologies such as DSG and VVT will help PM to find additional applications in cars, he said.

Data presented by Cremer indicated that all sectors of PM in Europe have enjoyed solid growth since the low point of 2009, with European iron powder shipments for PM applications showing modest growth in 2011 compared with 2010. Iron powder shipments in the first half of 2012 have shown similar trends to 2011.

The European MIM industry has shown strong growth in recent years, as has the European HIP sector, with the production of HIPed PM high speed steels and tool steels exceeding 6,000 metric tonnes in 2011. Hard materials production in Europe has almost regained its pre-financial crisis level reaching an estimated production level of around 22,000 tonnes in 2011 (Fig. 10).

Cremer reported on the efforts by the EPMA to lobby the European Commission over an Energy Tax Directive (ETD) COM (201) 169, which the



Fig. 8 Ingo Cremer, President of the EPMA, reviewed trends in the European PM industry

EPMA believes will negatively impact the competitiveness of Europe's PM industry. He said that a Position Paper by the EPMA has been circulated to the European President and The European Commission in order to raise awareness of the negative impact of the ETD on the PM sector.

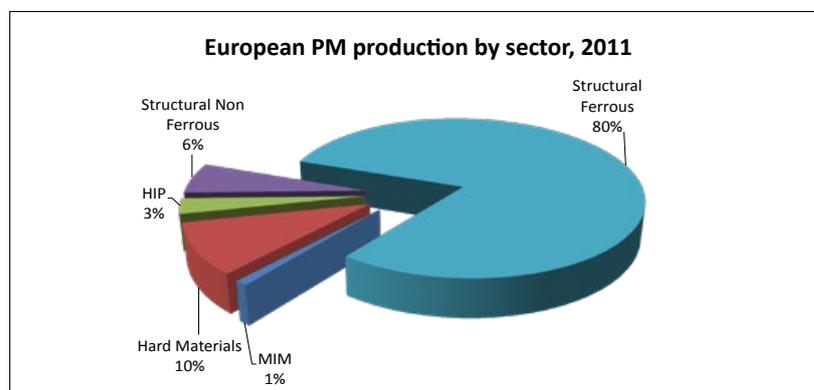


Fig. 9 Estimated European PM industry production totalled 220,000 tonnes in 2011

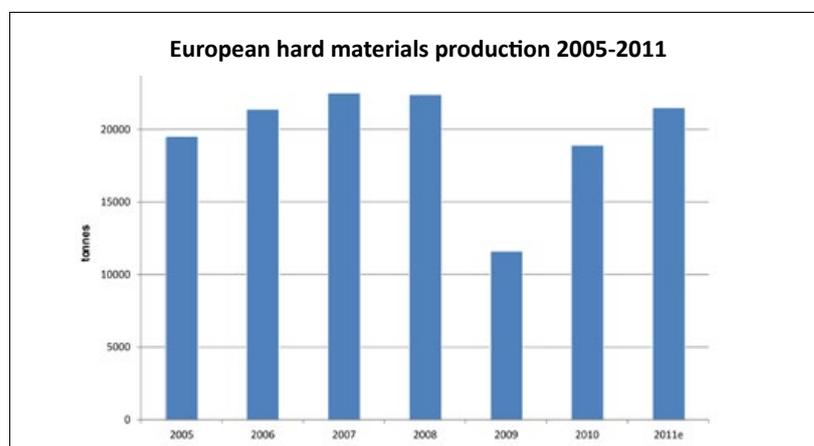


Fig. 10 Estimated hard materials production in Europe 2005-2011 (Source Kennametal/HC Starck).

PM2012 World Congress Gallery



Traditional Japanese music at the PM2012 opening ceremony



The Kobelco stand in the PM2012 World Congress exhibition



The JFE stand in the PM2012 World Congress exhibition



A powder compacting press displayed on the Iwatani stand



Dancers at the PM2012 World Congress farewell party



The PM2012 World Congress farewell party



Delegate participation during the farewell party



Mr Kazuyoshi Tsunoda, President of JPMA, thanked participants

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Developments in ferrous Powder Metallurgy materials at PM2012 Yokohama

A number of papers at the PM2012 Powder Metallurgy World Congress, Yokohama, Japan, October 14-18, 2012 presented some of the latest advances in ferrous PM materials. Dr David Whittaker reviews some innovative approaches that offer advanced materials with improved mechanical and magnetic properties, enhanced machinability, and lower costs. All are aimed at potentially broadening the application of ferrous powder metallurgy technology.

Malleable iron powders: A route to high performance PM parts

A novel approach to high performance ferrous PM material development was discussed in a group of three papers, presented by Rio Tinto Metal Powders. The described approach mimics the concept of malleabilisation of cast irons.

In cast iron metallurgy, a white cast iron is subjected to a malleabilisation heat treatment after casting to convert the original cementite phases into graphite nodules. In the PM approach revealed, the graphite is precipitated within and around the surfaces of the raw material powder particles during the annealing heat treatment stage of the powder production process. Also, a powder composition is selected, which is capable of creating close to full density on sintering at conventional ferrous PM sintering temperatures, through supersolidus liquid phase sintering (SLPS).

Development of a new malleable iron powder grade

In the first generation development of this concept, discussed in a paper by F Chagnon and C Coscia, the powder composition selected to achieve these

objectives was Fe-2%C-1%Si, with the precise compositional details and physical properties being given in Table 1.

to 1166°C. The influence of sintering temperature on achievable density is shown in Fig. 2 and this figure also shows the high level of linear dimen-

“graphite is precipitated within and around the surfaces of the raw material powder particles during the annealing heat treatment stage of the powder production process”

The compressibility of this powder was fairly modest as can be seen in Fig. 1, with the samples used in the test programme compacted at 650 MPa to achieve a green density around 6.6 g/cm³.

However, by appropriate control over the sintering cycle, it was found that sintered densities of 7.54 to 7.56 g/cm³ (i.e. 99% of full density or higher) could be attained within a sintering temperature window of 1158

sional change (around 3.7%) generated by the SLPS treatment within the optimum temperature window.

Fig. 3 illustrates the impact of both the green and sintered density on dimensional size change variation and emphasises the need for close control over green density to minimise the variation in the final dimensions of parts made from this powder type. This issue will be returned to later in this report.

C %	O %	Si %	S %	+60 mesh %	-60/+100 mesh %	-100/+325 Mesh %	-325 mesh %	Apparent density g/cm ³	Flow s/50g
1.97	0.10	1.05	0.001	Trace	17	63	20	2.85	30

Table 1 Chemical and physical properties of MIP [1]

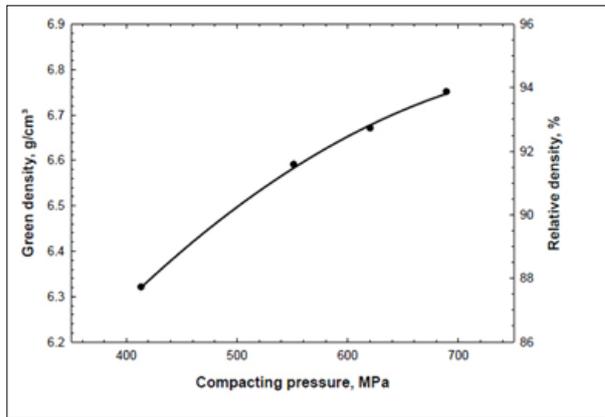


Fig. 1 Compressibility of MIP material mix with 0.5% wax [1]

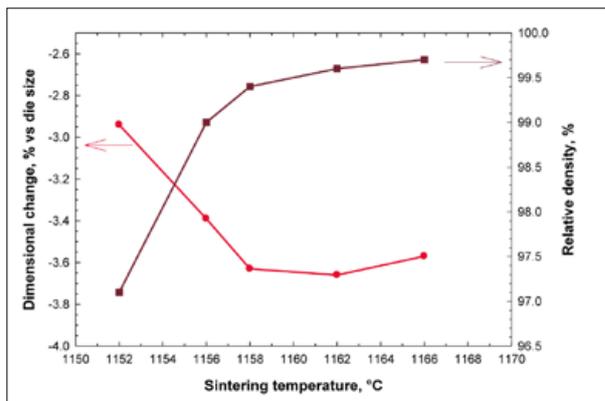


Fig. 2 Effect of sintering temperature on dimensional change and density [1]

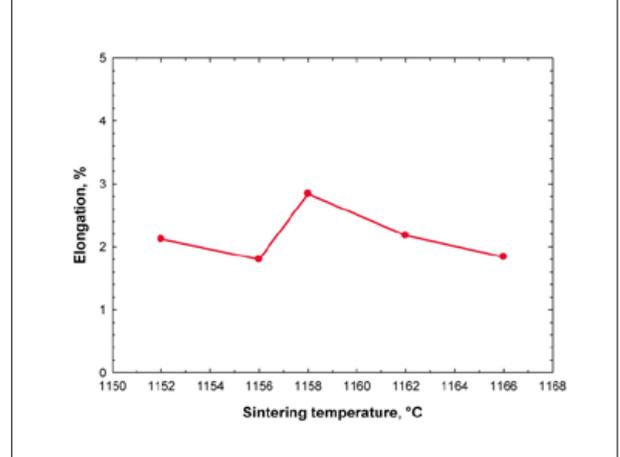
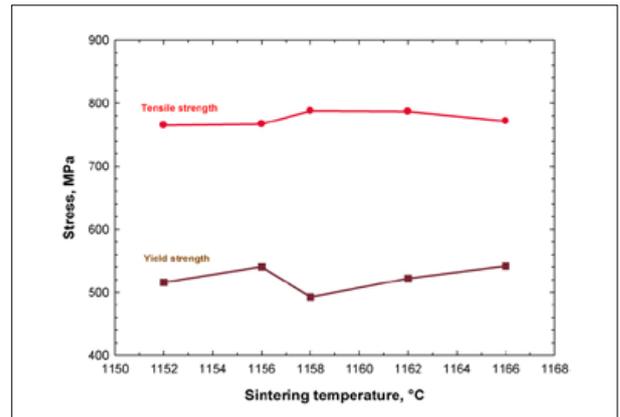


Fig. 4 Tensile properties of specimens made with MIP vs sintering temperature [1]

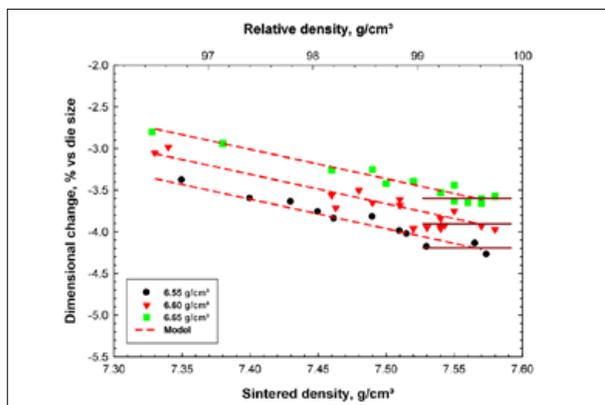


Fig. 3 Variation of dimensional change with green and sintered density of specimens pressed with MIP [1]

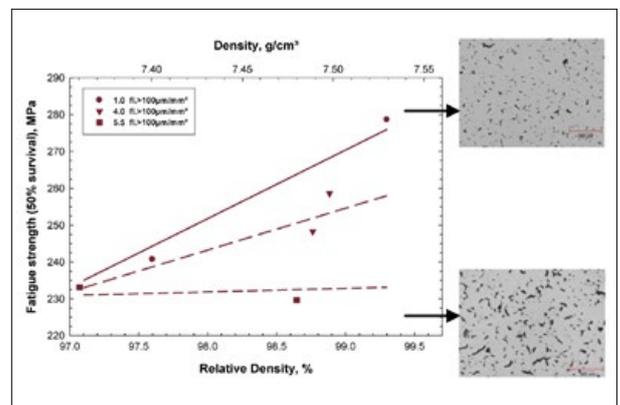


Fig. 5 Effect of density and number of graphite flakes/mm² >100 µm on axial fatigue strength at R = -1 of specimens made with MIP [1]

The evolution of tensile properties with sintering temperature is shown in Fig. 4 and this figure demonstrates that the effects of variations in sintering temperature are quite modest. Within the optimum sintering temperature range, tensile strengths of 776 +/- 11 MPa, yield strengths of 523 +/- 20 MPa and elongations of 2.2 +/- 0.4% can be achieved. These values are comparable to the pearlitic malleable cast

iron class 80002 and the ductile iron grade 100-70-03.

Fig. 5 shows that axial fatigue strength is very sensitive to both sintered density level and the number of graphite flakes/mm² having a dimension greater than 100 µm.

The issues of the influence of graphite particle shape on fatigue strength and of the control of sintering dimensional change were taken up in the other two papers in this group.

It was recognised that the graphite produced at powder particle surfaces in the initial development was of a flake morphology and that, if graphite morphology could be modified to a nodular form, this could have a positive influence on a range of mechanical and, particularly, fatigue properties.

Effect of graphite particle shape on static and dynamic properties of malleable iron powder materials

In a second generation development, revealed in a paper by F Chagnon, M Moravej and J Campbell-Tremblay, an addition of 0.2% P in the form of admixed ferrophosphorus was made in order to suppress the SLPS sintering temperature window (Fig. 6) and retain nodular graphite in the core of the powder particles.

In this study, the composition and physical properties of the base powder (referred to as MIP-A) were as stated in Table 1. As indicated in Table 2, MIP-A also had a 0.5% lubricant addition while MIP-B had additions of both 0.5% lubricant and 0.2% P.

It can be seen from Fig. 7 that, with MIP-A, sintered densities in the range 7.54 to 7.56 g/cm³ can be achieved in the temperature range of 1158 to 1166°C, while, with MIP-B, sintered densities of 7.51 to 7.53 g/cm³ can be achieved at only 1118 to 1124°C. Fig. 8 shows that linear dimensional changes were around -3.9% for MIP-B and -4.1 to -4.2% for MIP-A. This lowering of sintering temperature had the desired

influence on graphite morphology and the consequent influence on sintered properties at either end of the optimum temperature window for each of the compositional variants can be seen in Table 3.

The improvement in axial fatigue strength with MIP-B was particularly marked, but there were also useful improvements in tensile strength, yield strength and elongation. The only property that appeared to be inferior with MIP-B was impact energy.

The stated requirement for very precise control over green density levels in order to achieve acceptable control over sintered dimensions after the significant shrinkage occurring during SLPS can lead to the conclusion that the ability to achieve this without post-sintering processing would only be possible within certain product geometry constraints.

	P %	Lub. %
MIP-A	0	0.5
MIP-B	0.2	0.5

Table 2 Mix composition [2]

	MIP-A		MIP-B	
Temperature °C	1158	1166	1118	1124
Sintered density g/cm ³	7.53	7.56	7.51	7.53
Tensile strength MPa	780	795	884	868
Yield strength MPa	552	572	586	592
Elongation %	1.82	1.78	2.6	2.5
Hardness HRC	28	29	28	29
Axial fatigue strength, MPa (R= -1; 50% surv.)	241	279	312	333
Temperature °C	1162		1121	
Sintered density g/cm ³	7.56		7.52	
Impact energy J	33		22	

Table 3 Sintered properties of specimens pressed from MIP-A sintered at either 1158 or 1166°C and MIP-B sintered at either 1118 or 1124°C [2]

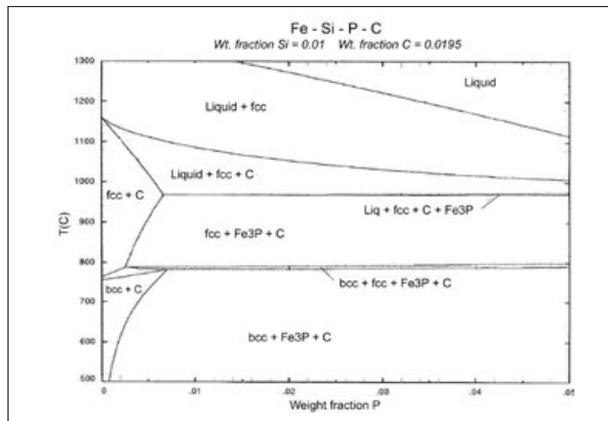


Fig. 6 Equilibrium phase diagram for the ternary Fe-C-Si-P system at 1120°C [2]

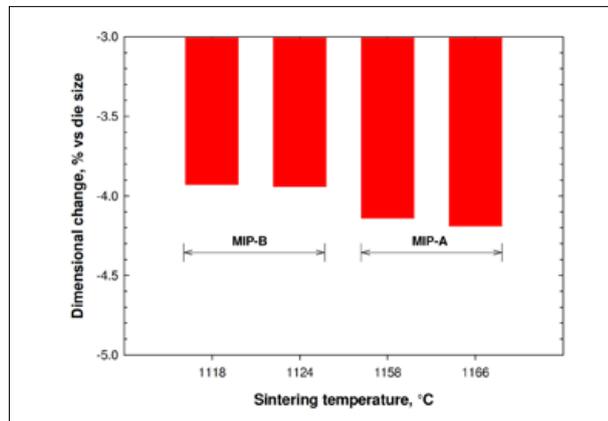


Fig. 8 Dimensional change values measured within the sintering windows of MIP-B and MIP-A materials [2]

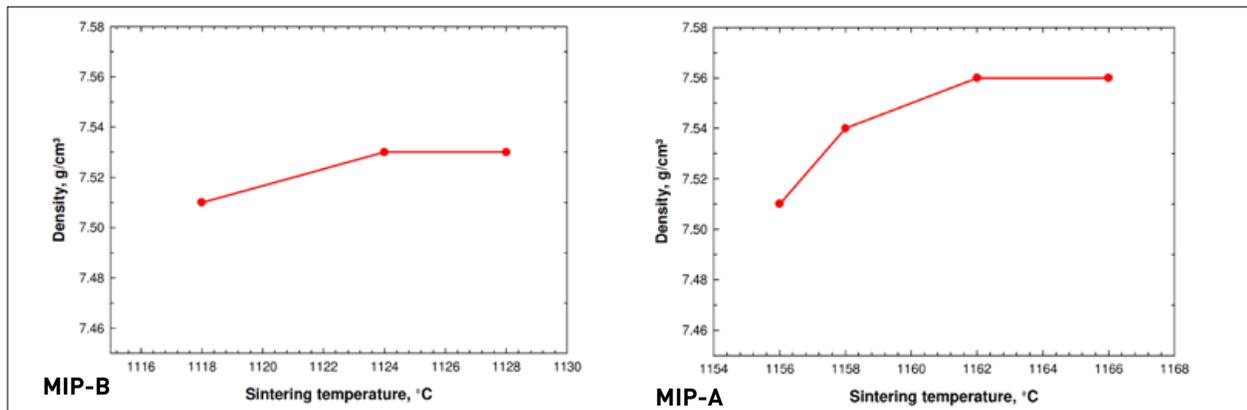


Fig. 7 Densification curves of specimens pressed with MIP-B and MIP-A [2]

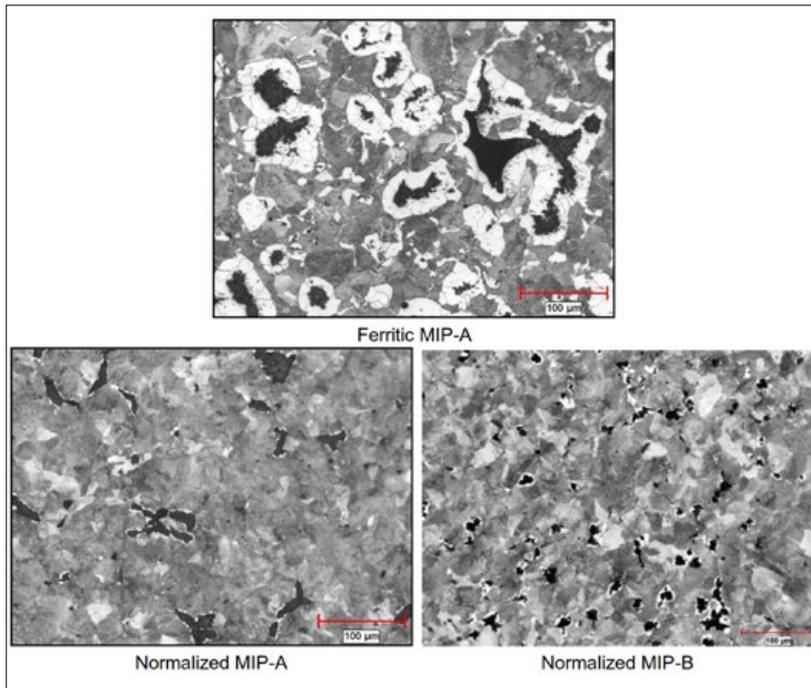


Fig. 9 Etched microstructures of MIP materials [3]

Machinability of malleable iron powder materials versus ductile iron and powder forged FC-0205 materials

The final paper in this group, presented by M Moravej, J Campbell-Tremblay and C Labrecque, therefore focussed on the issue of finish machining of the new malleable iron grades.

The machinabilities of the developed malleable iron grades were compared, through face turning tests, with those of a powder forged FC-0205 grade with 0.3% MnS and a ductile cast iron, DI-65-45-12.

The MIP-A grade was assessed in the as-sintered condition, which had a pearlitic matrix with a volume fraction of around 20% ferrite surrounding the graphite particles (this microstructure was termed “ferritic” by the authors). Both MIP-A and MIP-B were also assessed in a normalised condition after sintering and the normalisation

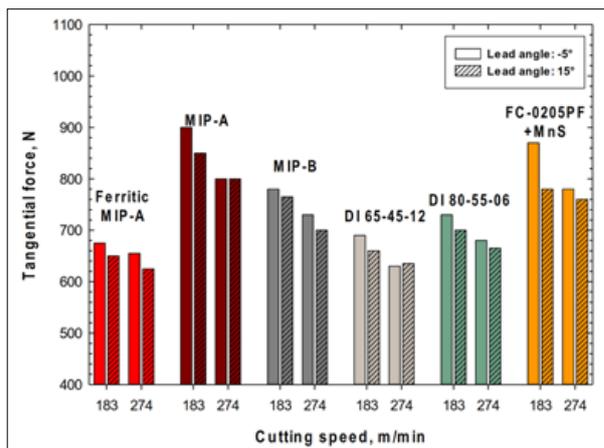


Fig. 10 Tangential force versus cutting speed of MIP materials compared to ductile iron castings and FC-0205 PF+MnS at two different lead angles; semi-roughing operation [3]

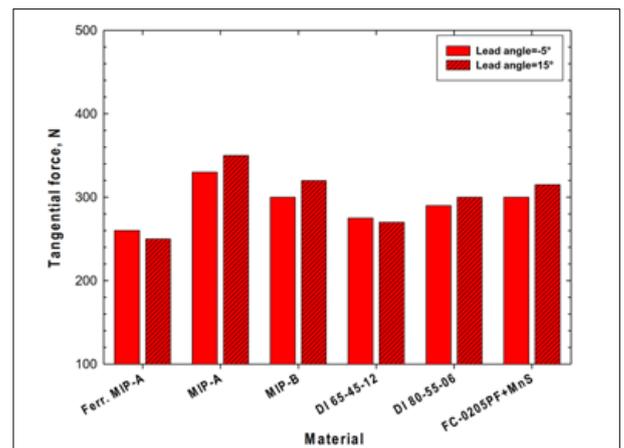


Fig. 12 Tangential force of MIP-A and MIP-B compared to ductile iron castings and FC-0205 PF+MnS at two different lead angles; finishing operation [3]

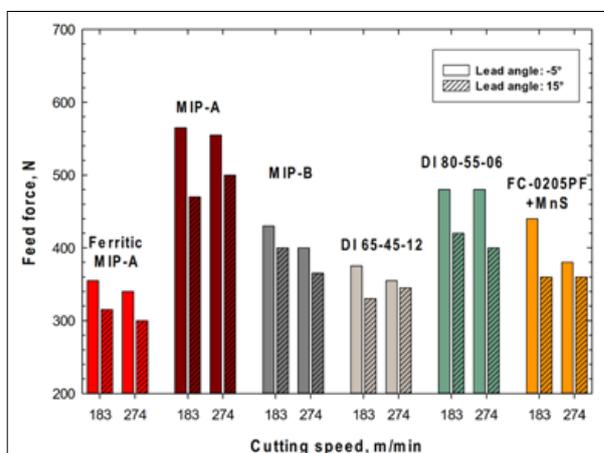


Fig. 11 Feed force versus cutting speed of MIP materials compared to ductile iron castings and FC-0205 PF+MnS at two different lead angles; semi-roughing operation [3]

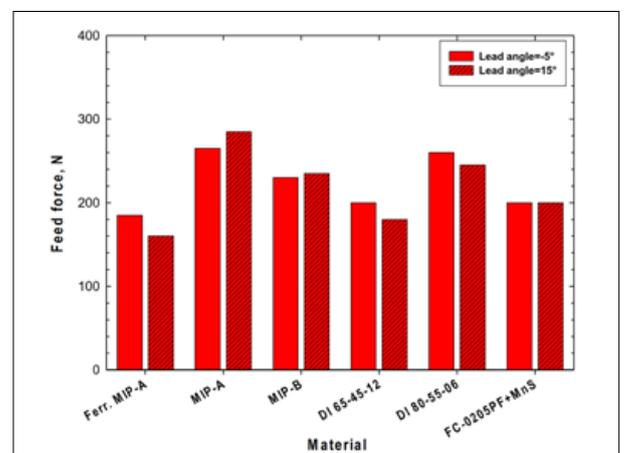


Fig. 13 Feed force of MIP-A and MIP-B compared to ductile iron castings and FC-0205 PF+MnS at two different lead angles; finishing operation [3]

treatment had the effect of significantly reducing the volume fraction of ferrite in the microstructure; consequently, this condition was referred to by the authors as "pearlitic". The microstructures of these various MIP compositions/conditions are shown in Fig. 9.

Two regimes of cutting operation were simulated in the face turning tests: a semi-roughing operation at two different cutting speeds (183 and 274 m/min) and a finishing operation at one cutting speed (137 m/min). In both categories of test, two different lead angles (15 and -5°) were studied.

The results of the semi-roughing tests are shown in Figs. 10 and 11, while those of the finishing tests are shown in Figs. 12 and 13.

Overall, the authors have concluded that the ferritic malleable iron powder parts had similar machinability to the ductile iron DI-65-45-12 and the pearlitic malleable iron parts had similar machinability to DI-65-45-12 and the powder forged FC-0205 grade with 0.3% MnS.

Lean alloy developments deliver cost-effective ferrous PM materials

Many of the standard ferrous PM materials have been relatively high in alloy content and were developed at a time when alloying elements such as nickel, copper and molybdenum were relatively inexpensive.

In recent years price increases and price fluctuations for alloy additions have stimulated developments of ferrous PM grades with significantly lower overall alloy contents.

steels (FC-0205 and FC-0208) have been, and still remain, the major "workhorses" of the PM structural parts industry. Copper increases the strength of the ferrite in a ferrite/pearlite as-sintered microstructure, through solid solution strengthening. Copper steels can deliver yield strengths at 7.0 g/cm³ density in the range 330-420 N/mm² and remain the cost-effective option in this strength range.

For higher strength parts used in the as-sintered condition, diffusion-alloyed and hybrid-alloyed materials,

"In recent years price increases and price fluctuations for alloy additions have stimulated developments of ferrous PM grades with significantly lower overall alloy contents."

A review of the lean alloy grades introduced by Hoeganaes Corporation, USA, was presented in a paper by W Brian James, Bruce Lindsley and K S Narasimhan.

Lean ferrous PM alloys provide lower cost solutions for PM parts

This paper reviewed the lean alloy concepts introduced by Hoeganaes Corporation for PM parts used in each of three different conditions – as-sintered, quench-hardened and tempered and sinter-hardened and tempered.

For as-sintered materials, copper

with copper, nickel and molybdenum as alloying elements, have often been selected. At equivalent alloying element levels, it has been demonstrated that hybrid alloys have higher hardenability than their diffusion-alloyed counterparts (Fig. 14) and this results in higher fractions of bainite and martensite in the microstructure. In view of this enhanced hardenability, hybrid alloys with lower molybdenum contents have been shown to match the performance of standard diffusion alloyed grades.

More recently, hybrid PM manganese steels, based on pre-alloyed

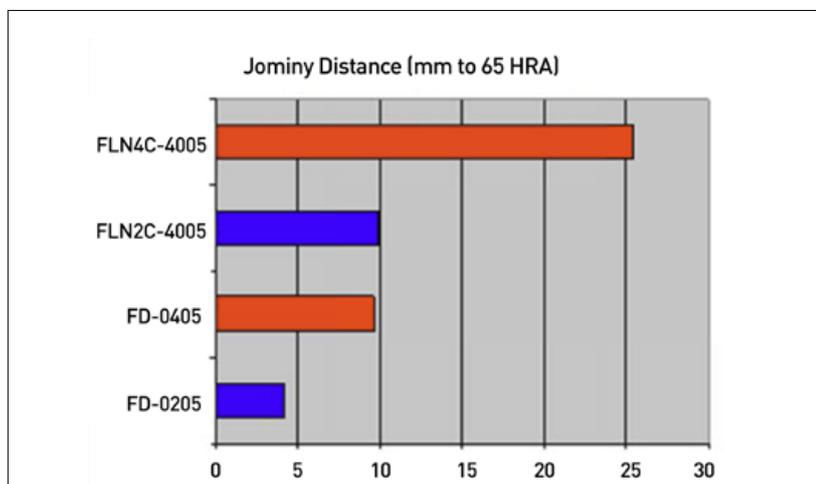
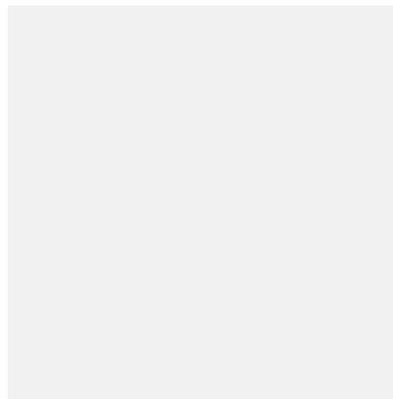


Fig. 14 Jominy hardenability comparison between hybrid alloys based on a prealloyed (0.5% Mo) powder (FLN2C-4005 and FLN4C-4005) and diffusion alloys based on an iron powder (FD-0205 and FD-0405) [4]

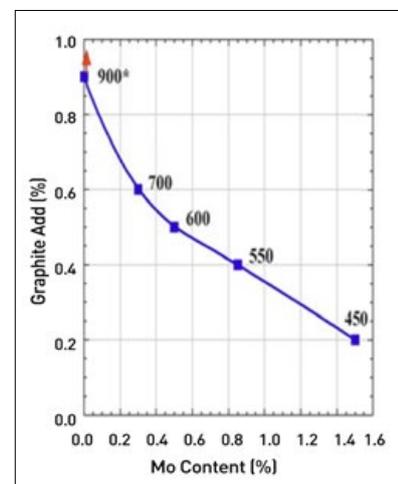


Fig. 15 Minimum graphite contents required for through hardening oil quenched cylindrical compacts of 25 mm diameter [4]

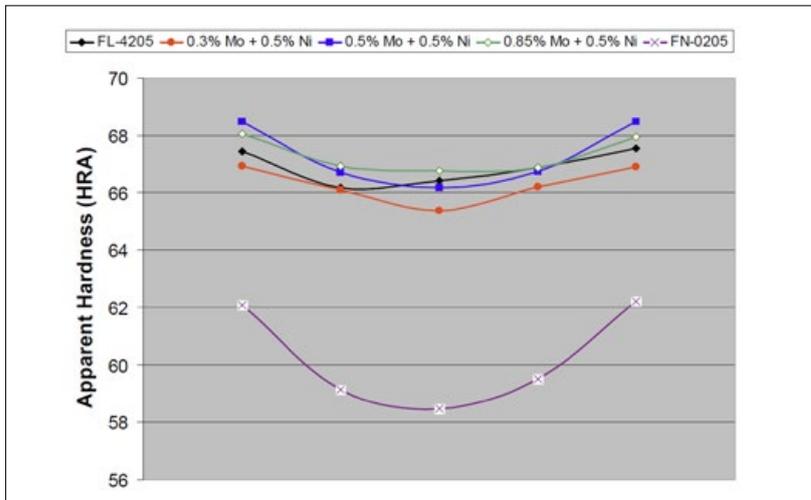


Fig. 16 Apparent hardness vs. distance across a 13 mm diameter oil-quenched cylindrical compact [4]

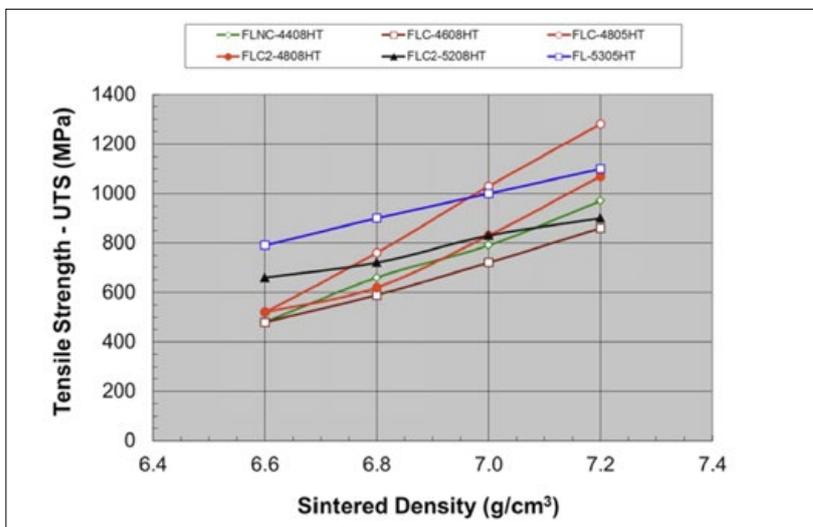


Fig. 17 Ultimate tensile strength of various standardised sinter-hardened PM materials [4]

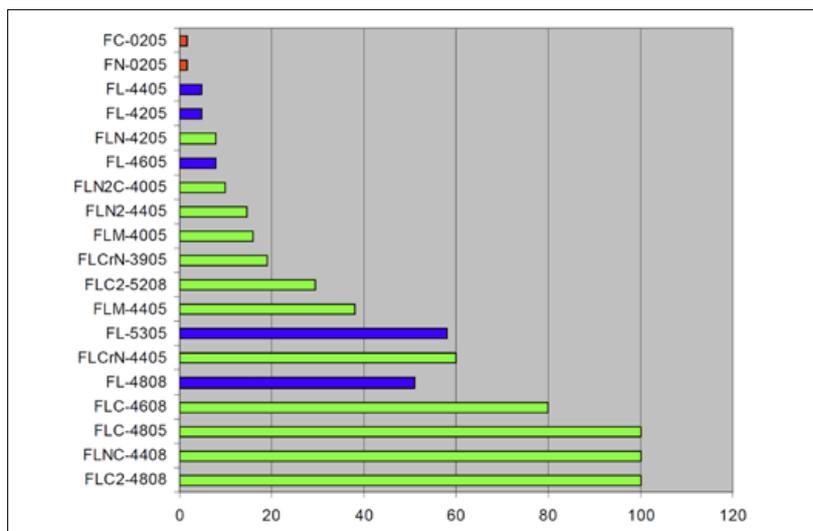


Fig. 18 Jominy distance (mm) to an apparent hardness of 65 HRA at a density of 7.0 g/cm³ for various ferrous PM materials. (red = admixed; blue = prealloyed; green = hybrid alloy). The following are not currently MPMF standard grades – FLM-4405; FLCrN-3905; FLCrN-4405 [4]

powders with 0.5% or 0.85% Mo, have been introduced that match the strength of diffusion-alloyed grades in the as-sintered condition. These materials contain no Ni or Cu additions and therefore have a much reduced total alloy content and can be sintered at 1120°C in a 90N₂:10H₂ atmosphere.

Higher performance lean alloy grades are also available. These include PM chromium steels that are hybrid alloys, based on 0.3 and 0.85% Mo prealloyed powders. These materials, even when cooled at standard sintering furnace cooling rates (<1°C/sec) form significant amounts of martensite, leading to high strength after a tempering treatment. These materials can again be sintered at 1120°C, but need a full 30 minutes at this temperature to induce the required degree of diffusion from the master-alloy addition used and, therefore, are generally viewed as being more suitable for high temperature sintering (1250°C).

For parts that are to be (oil) quench-hardened and tempered, a prealloyed powder with admixed graphite would generally be the initial material considered. The prealloyed material selected would be the leanest one with the necessary hardenability to create through hardening in the size of part being processed.

Prealloyed Ni-Mo steels were introduced in the 1970s and had good hardenability but reduced compressibility. Prealloyed powders with Mo as the principal alloy addition were introduced from 1990. Molybdenum alone has no significant effect on compressibility at levels up to 0.85% and, indeed, powders with 1.5% Mo are as compressible as some water atomised iron powders.

As Mo content is increased, the graphite addition required to through harden compacts 25 mm diameter x 25 mm height is reduced (Fig. 15). The average microindentation hardness level for each molybdenum/graphite combination is also quoted in Fig. 15.

Although diffusion-alloyed grades are often specified for quench-hardened and tempered applications, they are not as suitable for heat treatment because of their relatively lower hardenability compared with their hybrid alloy counterparts (see Fig. 14).

Recent work has shown that a hybrid alloy, based on a 0.3% Mo prealloyed powder and with 0.5% admixed Ni, can

through harden in a compact of 13 mm diameter x 25 mm height, matching the performance of higher Mo content hybrid alloys and the FL-4205 prealloyed material (Fig. 16).

Significantly higher hardenability is needed for PM materials that are to be sinter-hardened and tempered, as the cooling rates are much lower than for oil-quenching (1 to 3°C/sec compared with >100°C/sec).

Most ferrous PM materials used for sinter hardening are hybrid alloys containing admixed copper to enhance hardenability, although there are some hybrid or prealloyed PM chromium steels that do not need a copper addition. The challenge when developing sinter hardening grades is to attain the required hardenability while retaining adequate compressibility.

Furnaces with convective cooling systems allow larger parts to be sinter hardened and also permit leaner alloys to be used for small to medium sized parts.

The original sinter hardening grade was FLC-4608. More recently, new grades have been developed and have become standardised materials (FLC-4805, FLC2-4808 and FL-5305). Fig. 17 shows the sinter hardened tensile strength of these standardised grades.

Other new materials have been introduced commercially but have not yet become standardised.

Fig. 18 demonstrated the relatively low hardenability of prealloyed and hybrid-alloy powders that are used for oil quenching compared with the much higher hardenability of powders developed for sinter hardening. Some of the intermediate hardenability materials (e.g. FLM-4005, FLM-4405 and FLCrN-3905) sinter harden at the cooling rates available with convective cooling systems.

The authors' overall conclusion was that the next generation of ferrous PM materials will use alloy additions in a more effective way and will include alloying elements, such as Cr, Si and Mn, which have not traditionally been associated with PM.

Automotive transmission gears: Enhancing design for the PM process

Past efforts to introduce Powder Metallurgy gears into automotive transmissions have often been based

of the hub flutes, gear rotation and the geometry of the tip of the hub.

PM manufacture, on the other hand, offers much greater freedom in designing tooth roots to reduce bending stresses.

In this study, the following root

“PM manufacture offers much greater freedom in designing tooth roots to reduce bending stresses.”

on a like-for-like substitution for machined steel gear forms.

Two papers presented by Höganas AB made the point that this approach seriously undersells the capabilities of PM in targeting such product applications and described important initiatives that the company is pursuing in this context.

Tooth root optimisation of Powder Metal gears – reducing stress from bending and transient loads

A paper presented by Anders Flodin and Michael Andersson examined the concept of redesign of the tooth root geometry of PM gears to reduce bending stresses.

In conventional gear cutting using a hob, there are significant restrictions on the range of tooth root radii that can be generated with the root being a function of the trochoid movements

geometries, as depicted in Fig. 19, were compared:

- Original 1.99 mm (as given by a hob tip radius = 0.8 mm)
- Full radius

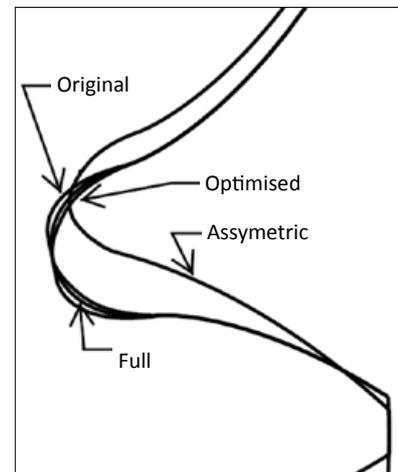


Fig. 19 Root geometries compared [5]

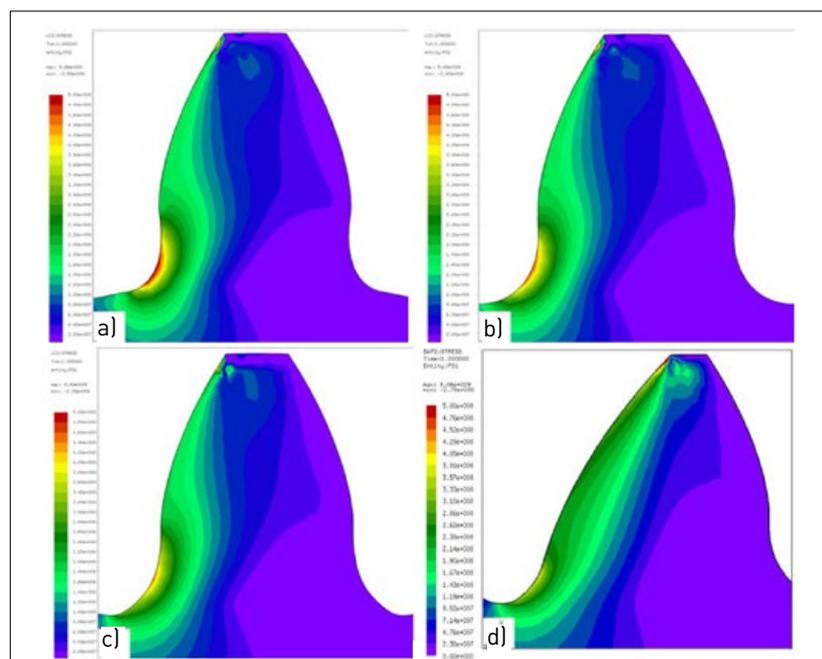


Fig. 20 Tooth root stresses, static analysis, a) original, b) max radius, c) optimised and d) asymmetric. Note, same stress scale for all geometries [5]

Geometry	Static stress [MPa]	Difference	Dynamic stress [MPa]	Difference	Dynamic amplification
Original	500	-	1010	-	2.02
Max radius	434	-13%	865	-14%	1.99
Optimised	408	-18%	792	-22%	1.94
Asymmetric	405	-19%	719	-29%	1.78

Table 4 Peak stress in tooth root [5]

Material	Elastic modulus (GPa)	Poisson's ratio	Thermal expansion (°C ⁻¹)	Fatigue limit, surface (MPa)	Fatigue limit root (MPa)
Powder metal	160	0.28	12.5·10 ⁻⁶	1100@5·10 ⁷ Cycles	650@10 ⁷ Cycles

Table 5 Material data for PM [6]

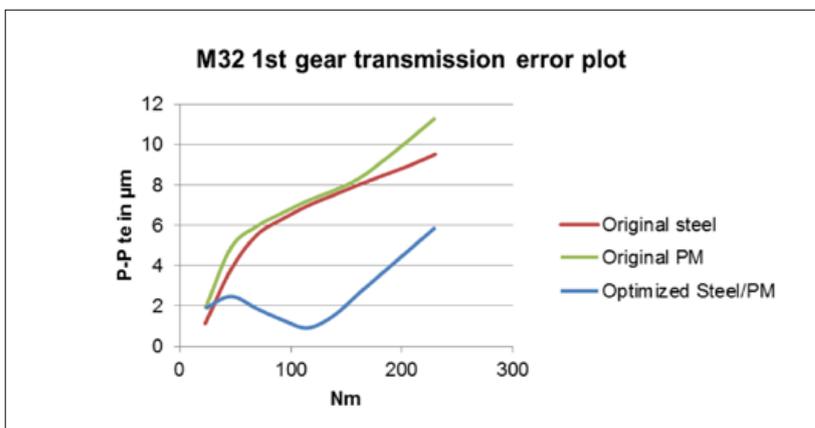


Fig. 21 Transmission error for first gear in the investigated M32 transmission [5]

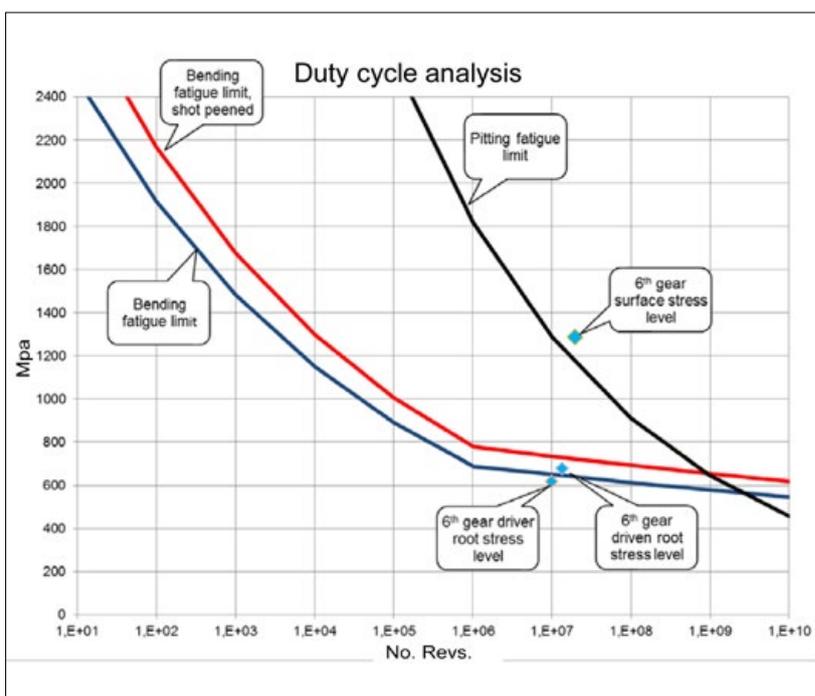


Fig. 22 Loads on 6th gear pair with correlating S-n curves for case hardened Astaloy85Mo PM gears with ISO 7 or better tolerances [6]

- Optimised curve shape
- Asymmetric gear tooth

Finite element modelling has compared these root geometries in terms of peak stresses in the root (see Fig. 20 and Table 4).

It has been demonstrated that it is possible to reduce root stress in a gear tooth by replacing the cut trochoid root shape with a curve shape defined by a spline that is designed, iteratively, to reduce root stress. It is also possible to manufacture a gear with this root shape in mass production using PM manufacturing technology.

Where contact stress cannot be kept within the allowable stress levels, asymmetric gearing can also be introduced, with the challenge here being to balance stresses and NVH (noise, vibration and harshness) when driving on the coast side of the gear.

Automotive transmission design using full potential of Powder Metal

A second paper, by Anders Flodin (Höganäs AB) and Peter Karlsson (Vicura AB), described a particularly ambitious programme, in which the design of a specific automotive transmission is being assessed in detail and the viability of incorporation of gears, manufactured by PM, in this transmission without sacrificing performance is being evaluated.

The transmission, chosen for this programme, was a 6-speed manual gearbox, used by GM in the Opel Insignia model, with a 4-cylinder turbocharged 2-litre engine delivering 220 hp / 320 Nm, and in other GM vehicles.

The 1st, 2nd and reverse drive gears are machined directly into the shaft of the gearbox and therefore could not be considered as candidates for replacement by PM. All other gears in the transmission – the reverse idler, the 1st and 2nd driven gears and both drive and driven members for 3rd, 4th, 5th and 6th gear – were, however, evaluated as potential PM targets.

The methodology adopted in this programme began with a system analysis. This comprised disassembly of the gearbox, while recording pull-off forces for gears and bearings and measuring axial play in the system.

The housing was scanned and imported into FE software. Shafts and gears were measured, modelled and assembled into the housing.

An essential part of a system

Inertia M32 Steel vs Sinter							
	Inertia Steel	Inertia Sinter			Mass (kg)		
	M32	Copied PM	Optimised PM	Diff	Steel M32	Sinter	Diff
1	2154	1769	1670	22%	1.097	0.896	18%
2	1285	1114	1090	15%	0.953	0.819	14%
3	1991	1605	1532	23%	1.159	0.93	20%
4	983	860	848	14%	0.831	0.73	12%
5	244	224	224	8%	0.323	0.297	8%
6	213	196	196	8%	0.387	0.355	8%
R	1336	1140	1109	17%	0.946	0.791	16%

Table 6 Weight and inertia reduction for the redesigned transmission [6]

analysis is the bearing stiffness. The bearing representation in this system model was reduced to define the stiffness between two nodes, representing the inner ring and the outer ring, due to the fact that this bearing stiffness is strongly nonlinear and depends on both bearing design and load direction/magnitude.

Simplified modelling techniques, in order to save calculation time, were used for bolts, roller bearing contact between gears and shaft as well as gear to gear contacts in the system analysis where the focus is on deformation of housing, shafts and bearings.

The output from the system analysis was gear misalignment and transmission deflections, which were used as input to the gear analysis where the micro geometry was adjusted to provide the best working behaviour of the gears, considering the misalignment and bending from shafts and bearings.

The influence of these micro geometry adjustments on peak to peak transmissions error (TE), a parameter that describes the quality of the mesh cycle of two gear flanks, is shown in Fig. 21. It is desirable to keep TE as low as possible. The green curve is for the "copied" PM gear with the steel flank design. This curve is higher than the original machined steel gear (red curve) for all torques, because of the lower stiffness of the PM material compared with the solid steel. The result from the design iterations to improve TE for the "optimised" PM gear is shown in the blue curve, where TE is lower for every torque level and is likely to perform significantly better

than the PM gear with the copied design.

A "typical European consumer usage" duty cycle was used to evaluate gear life.

Misalignment data was taken from the system analysis and was accounted for in the micro geometry of the tooth flanks. Abuse load was 6500 Nm on the differential cage, based on measured vehicle data.

The working behaviour of the gears in the system were modelled for 50%, 100%, 150% and 200% load and a range of temperatures, in order to assure the functionality under different conditions.

Initially, all PM gears were modelled as being sintered and case hardened Astaloy85Mo products at a density level of 7.25 g/cm³, using the material data shown in Table 5.

For this particular transmission, it has been demonstrated that the reverse idler gear and the 3rd and 4th gear pairs can be made with the shortest possible manufacturing route that gives 7.25 g/cm³ density.

For the 5th and 6th gear pairs, it was identified that a double press/double sinter process to increase density to 7.4 g/cm³ or the application of post-sintering operations, such as shot peening or super-finishing, would be necessary to increase performance.

The durability of the 6th gear pair, manufactured using Astaloy85Mo at 7.25 g/cm³, is presented in Fig. 22. It can be seen from this figure that tooth root bending fatigue was within acceptable limits but that contact stress on the gear flank was a little too high. These gears, therefore, would require an increase in performance

to qualify; hence, the need for the processing variants proposed above.

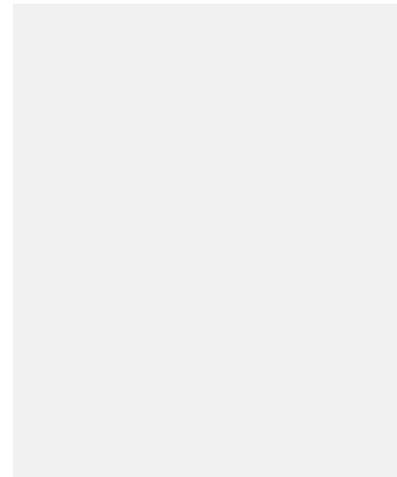
The first and second driven gears would need either the application of surface densification or more radical redesign.

The gear redesign in the GM transmission has taken both micro- and macro-geometry into account in order to reduce weight and inertia. Table 6 summarises the weight and inertia reduction benefits achievable for the driven gears in the transmission using "copied PM" and "optimised PM" concepts. Optimised redesign can remove 1.1 kg of mass.

The next step in this on-going initiative will be to redesign the first and second gear pairs using the more advanced design philosophies such as non-involute gearing and asymmetric gear teeth to be able to prototype the gear box without using any performance enhancing technologies such as Hot Isostatic Pressing (HIP) or other densification technologies.

There are a few unknown factors when moving away from the traditional involute curve shape. It is quite possible to reduce the contact and bending stress, but the difficulty lies when the transmission error has to be kept low for both drive and coast sides in order to avoid noise problems. This will be modelled to achieve good mesh properties before gear manufacture.

A few transmissions will then be built according to the optimised design but employing different PM technologies and will be installed in a car for everyday driving as a proof of concept. The transmissions will also be put into test rigs to test durability, noise and efficiency according to specified drive cycles.



Process developments enhance performance of PM soft magnetic materials

Two papers presented by Kobe Steel addressed process developments aimed at enhancing two separate aspects of the performance of PM soft magnetic materials; firstly, minimising core loss for high frequency applications and secondly, increasing the mechanical strength of soft magnetic iron cores.

Influence of particle size on core loss in dust cores, for high frequency application

A paper from Tomotsuna Kamijo, Hirofumi Hojo, Hiroyuki Mitani and Shinya Arima reported on a study of the influence of particle size on core losses in soft magnetic composite dust cores.

In an initial set of experiments, an atomised high purity iron powder

300NH was sieved into particle size fractions with mean particle size ranging from 30 μm to 85 μm . Powder samples from each of these fractions were then processed into soft magnetic composite cores with a density of 7.0 g/cm³ and core losses

particles sizes are seen to be effective in reducing eddy current losses.

In earlier reported studies with higher magnetisation conditions (1.3T), coarser powder sizes were observed to reduce coercive force and hence reduce hysteresis losses

“at higher frequencies, finer mean particle sizes are effective in driving down losses”

were then measured, over a range of frequencies, at 0.1T magnetic flux density.

As shown in Fig. 23, total core loss was almost independent of powder particle size at 1 and 5 kHz frequencies, but, at higher frequencies, finer mean particle sizes are effective in driving down losses.

The total core losses are subdivided between eddy current losses and hysteresis losses in Figs. 24 and 25 respectively. Again, finer mean

and, therefore, there was an optimum particle size for minimum total core losses. At the lower magnetisation conditions (0.1T) reported here, however, the movement distance of a magnetic domain wall is estimated to be much shorter and therefore particle size has minimal influence on hysteresis losses.

In terms of magnetic properties, therefore, it would be concluded that the finer the particle size, the better.

However, particle size choice is

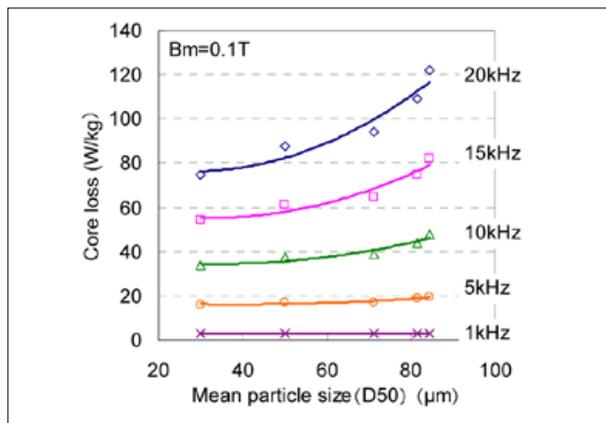


Fig. 23 Relationship between mean particle size and core loss [7]

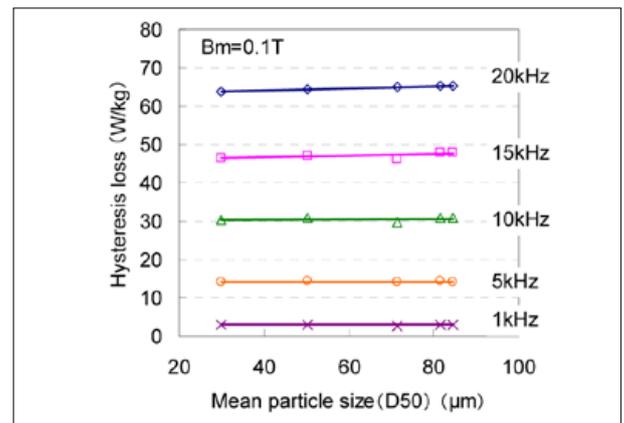


Fig. 25 Relationship between mean particle size and hysteresis loss [7]

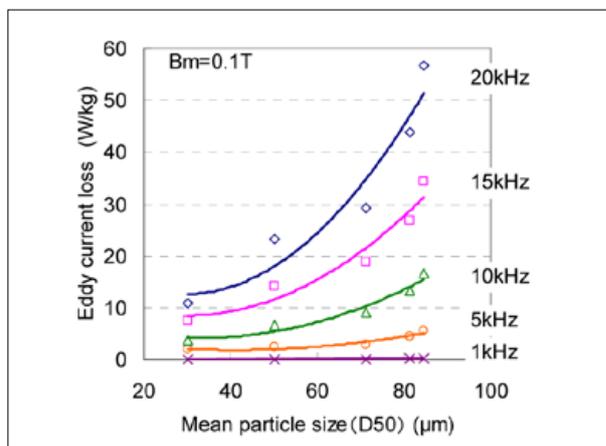


Fig. 24 Relationship between mean particle size and eddy current loss [7]

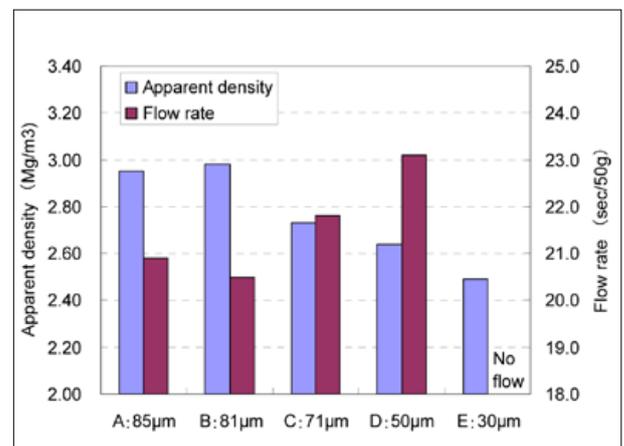


Fig. 26 Apparent densities and flow rates of powders with different particle sizes [7]

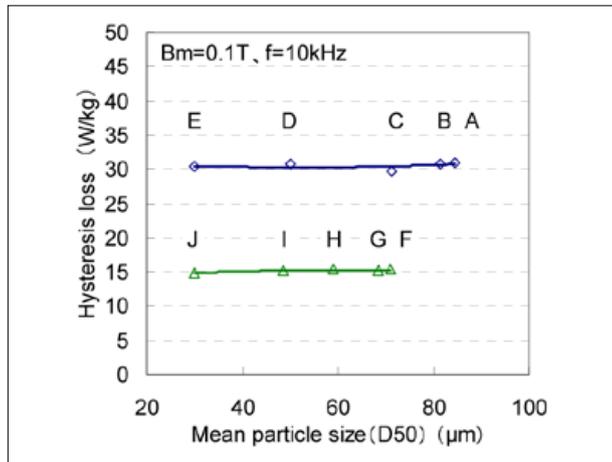


Fig. 27 Relationship between mean particle size and hysteresis loss [7]

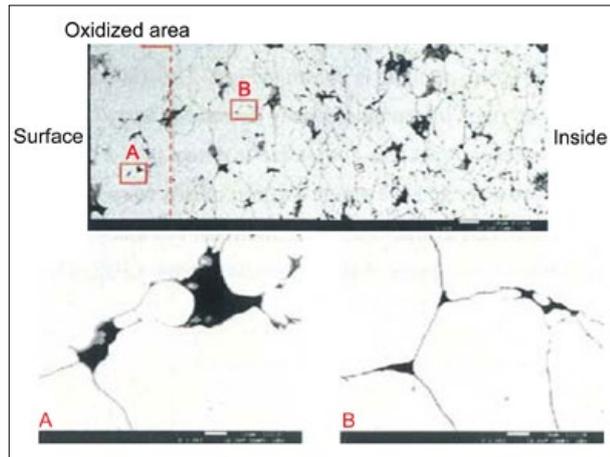


Fig. 29 FE-SEM image [8]

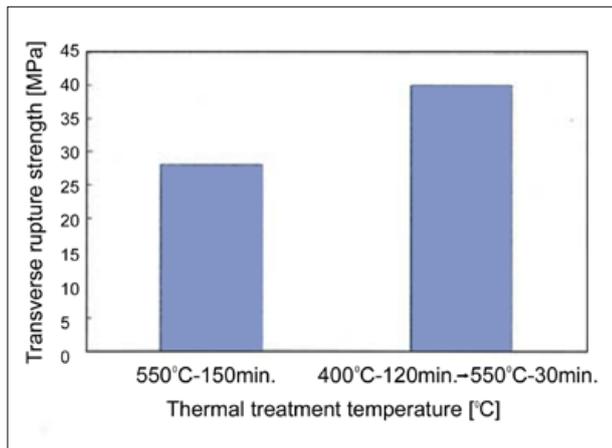


Fig. 28 Relationship between thermal treatment temperature and transverse rupture strength [8]

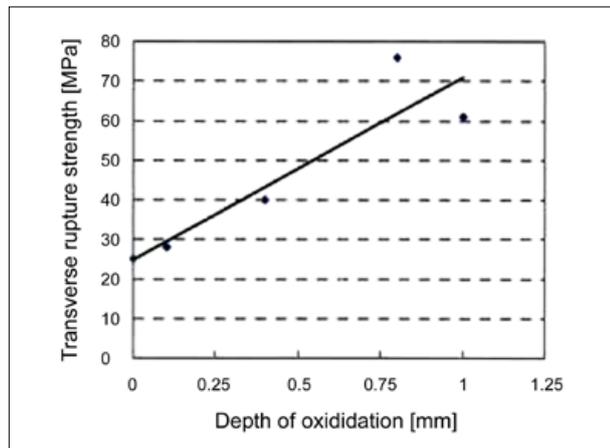


Fig. 30 Relationship between the depth of oxidation and transverse rupture strength [8]

also influenced by other considerations, such as compressibility, apparent density and flow rate, all of which deteriorate at finer particle sizes (Fig. 26). The authors have therefore concluded that a mean particle size of around 50 μm probably represents the optimum compromise between low core loss and acceptable processibility.

It can be seen from Figs. 24 and 25 that generally hysteresis loss accounts for more than 80% of total core loss. A need to find means of reducing hysteresis loss was therefore identified.

To achieve this objective, a second batch of powder samples was processed into soft magnetic composite cores and assessed, in terms of magnetic properties, in a similar manner to the initial batch.

For these samples, the 300NH powder was annealed three times at 970°C for 1.5 hours and was then sieved into fractions with mean

particle sizes ranging from 30 μm to 71 μm. These samples were then processed, using a combination of warm compaction and die wall lubrication, to achieve a density level of around 7.4g/cm³.

This processing route was found to reduce hysteresis loss by around 50%, compared with the initial powder batches (Fig. 27). The two sets of powder batches were observed to deliver almost identical results in terms of the relationship between eddy current loss and mean particle size.

Overall, the authors have therefore concluded that the triple annealed powder with around 50 μm mean particle size processed into a 7.4g/cm³ soft magnetic composite is the most appropriate magnetic powder product and that the development of this outstanding low core loss product is expected to stimulate an expansion of the market penetration for SMCs.

Influence of oxidation depth on strength of soft magnetic iron core for electric motors

A second paper, from Mamoru Hosakawa, Mikako Takeda and Watanu Urushihara, turned attention to another issue that can limit the use of PM soft magnetic cores – the mechanical strength of the iron core, which, if not adequate, can lead to damage or breakage during the production of complex shaped cores.

It has been observed that, during the process of forming the insulating layers between individual powder particles during the production of an iron core, voids and other defects can be created that can act as trigger points for fracture initiation. Therefore finding means of reducing these voids, while maintaining insulation between powder particles, has been deemed critical to increasing mechanical strength of the core.

The authors have investigated the development of a thermal process

route to form iron oxide layers to fill the voids between powder particles and therefore enhance transverse rupture strength of the core.

An effective thermal treatment, in this context, was found to comprise lubricant decomposition at 400°C for 2 hours followed by a treatment at 550°C for 30 minutes (Fig. 28). A cross-sectional SEM image of a sample, subjected to this thermal treatment, is shown in Fig. 29. The sample was oxidised to a depth of 0.4 mm from the surface. The decomposition of the lubricant was effective in promoting oxidation to a greater depth within the sample, resulting in increased strength.

However, oxidation was only observed in the region of the sample surface and it was surmised that strength could be further improved if oxidation depth could be increased. The use of an oxygen release additive agent combined with the lubricant decomposition during the thermal process was therefore investigated. Mannitol or lithium peroxide was added at a level of 0.1 wt% and an improvement of transverse rupture strength to 61-76 MPa was observed. The relationship between oxidation depth and transverse rupture strength is shown in Fig. 30.

Following these studies, the authors are proposing to develop the strengthening technology for consolidated soft magnetic PM products.

Author

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References

- [1] 'Development of a New Malleable Iron Powder Grade' by, Rio Tinto Metal Powders, Quebec, Canada. Presented at the PM2012 World PM Congress, Yokohama, October 15-18 2012.
- [2] 'Effect of Graphite Particle Shape on Static and Dynamic Properties of Malleable Iron Powder Materials' by F. Chagnon, M. Moravej, J. Campbell-Tremblay, Rio Tinto Metal Powders, Quebec, Canada. Presented at the PM2012 World PM Congress, Yokohama, October 15-18 2012.
- [3] 'Machinability of Malleable Iron Powder Materials vs Ductile Iron and Powder Forged FC-0205 Materials' by M. Moravej, J. Campbell-Tremblay, C Labrecque, Rio Tinto Metal Powders, Quebec, Canada. Presented at the PM2012 World PM Congress, Yokohama, October 15-18 2012.
- [4] 'Lean Ferrous PM Alloys Provide Lower Cost Solutions for PM Parts', W Brian James, Bruce Lindsley and K S Narasimhan, Hoeganaes Corporation, USA. Presented at the PM2012 World PM Congress, Yokohama, October 15-18 2012.
- [5] 'Tooth root optimization of Powder

Metal gears – Reducing stress from bending and transient loads', Dr. Anders Flodin, Dr. Michael Andersson, Höganäs AB, Sweden. Presented at the PM2012 World PM Congress, Yokohama, October 15-18 2012.

[6] "Automotive transmission design using full potential of powder metal", Dr. Anders Flodin, Höganäs AB, Sweden, Peter Karlsson, Vicura AB, Sweden. Presented at the PM2012 World PM Congress, Yokohama, October 15-18 2012.

[7] 'Influence of particle size on core loss in dust cores, for high frequency application', Tomotsuna Kamijo, Hirofumi Hojo, Hiroyuki Mitani, Shinya Arima, Kobe Steel, Ltd., Japan. Presented at the PM2012 World PM Congress, Yokohama, October 15-18 2012.

[8] 'Influence of oxidation depth on strength of soft magnetic iron core for electric motors', Mamoru Hosakawa, Mikako Takeda and Watanu Urushihara, Kobe Steel, Ltd., Japan. Presented at the PM2012 World PM Congress, Yokohama, October 15-18 2012.

Acknowledgments

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JFE Steel broadens iron powder range for high performance Powder Metallurgy parts

JFE Steel (formerly Kawasaki Steel Ltd) started the production of iron powders at its East Japan Works in Chiba in 1966 and is today one of Japan's leading producers of both reduced (from mill scale) and water atomised iron and steel powders under the brand name of 'JIP®'. Bernard Williams reports on recent technical breakthroughs announced by JFE at its exhibit at the PM2012 World Congress held in Yokohama, Japan, October 14-18 2012.

JFE Steel has in recent years been broadening its range of steel powders to meet the demands for high density, high performance, low cost Powder Metallurgy (PM) components having high fatigue strength, as well as powders for PM parts having enhanced green density, and machinability.

Some of these developments were discussed with *Powder Metallurgy Review* during the recent PM2012 Powder Metallurgy World Congress held in Yokohama, Japan.

New Ni-free PM steel powder grades

In the past, diffusion-bonded Ni steel powder was widely used in PM components to achieve tensile strengths up to 1000 MPa. However, because of the sharp rise in the cost of Ni and volatility of supply, JFE Steel, along with most of the other major powder producers around the world, developed lower cost Ni-free steel powders. In the case of JFE, these Ni-free steel powders were first

introduced in 2009 with the trade name JIP® FM Series. The new FM Series are pre-mixed powders based on a low Mo content (0.45%) prealloyed powder mixed with Cu, graphite and lubricant, which can be compacted to high density and sintered in a mesh belt furnace to achieve as-sintered tensile strength of 600 MPa; in the heat treated carburised condition tensile strength reaches up to 1000 MPa, the equivalent of conventional, higher cost diffusion-bonded PM 4% Ni steels. An additional benefit of the FM Series is

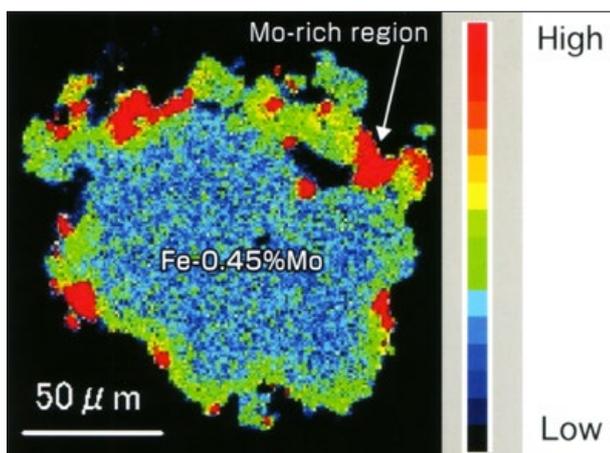


Fig. 1 Diffusion bonding of Mo to a 0.45%Mo prealloyed steel powder produces a Mo-rich region for enhanced sinterability

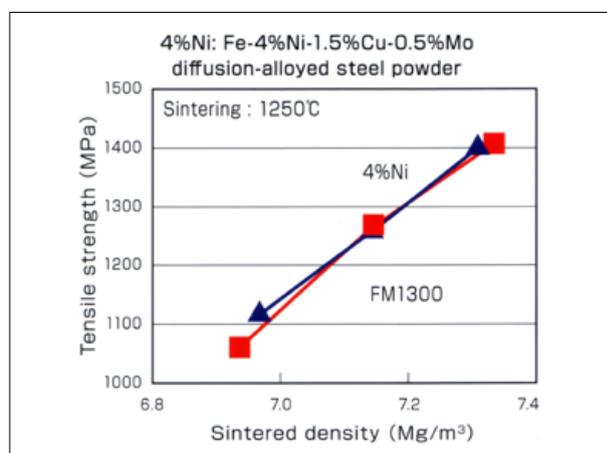


Fig. 2 Tensile strength of sintered and case hardened FM1300 PM steel

its excellent machinability.

At PM2012 in Yokohama, JFE Steel introduced the latest in its JIP® FM Series of high strength PM steels, with the development of FM1300 and FM 1500 grades. FM1300 is a hybrid-alloyed steel powder, designated JIP AH4515, based on 0.45% Mo to which 0.15% Mo is diffusion bonded [Fig. 1]. This is said to lead to enhanced sintering and strengthening of the sintering necks due to the Mo-rich region (α -Fe phase). JFE reports that FM1300 achieves the equivalent tensile strength of conventional PM 4%Ni sintered material but at lower cost when sintered at 1250°C to >7.3 g/cm³ density [Fig. 2]. Fatigue strength is also higher for the FM1300 material as is shown in Fig. 3.

The second new development aimed at reduced cost, high performance PM steels is JIP FM1500. This powder has been designated as JIP® 5CRA and is based on a lean prealloyed steel with the composition Fe-0.5%Cr-0.2%Mn-0.2%Mo. When sintered to a density of 7.25 g/cm³ at

1200°C the bright-quenched material has a tensile strength in excess of 1500 MPa [Fig. 4]. The rotating bending fatigue strength of sintered and gas carburised JIP® 5CRA steel shown in Fig. 5 is higher than that of the conventional 4%Ni PM steel.

Improved lubrication system for high green density

In 2009 JFE began marketing its JIP® Clean Mix HDX lubricant to allow the compaction of parts to high green densities at room temperature whilst maintaining superior powder flow characteristics compared to conventional pressing lubricants such as wax or zinc stearate. Now the company has added its Zn-free JDX-CMX lubricant system to its Clean Mix range which allows the reduction in the amount of pressing lubricant required to reach the desired green density. The company states that even a small amount of the new lubricant provides

the intended density under lower compacting pressure (see Fig. 6), which allows a lower tonnage powder press to be used to produce larger, high density compacts.

Improved machinability PM steels

There is an increasing demand for more complex shaped PM structural parts having higher dimensional accuracy, and many PM parts are today machined after sintering to meet these demands. This has required effort on the part of the powder manufacturers to develop free machining additions for PM steels such as MnS to improve machinability; however these can cause problems such as the contamination of the sintering furnace. In order to solve this JFE Steel developed its JIP® Clean Mix JFM Series which has the 0.2% addition of a silica containing composite oxide powder to promote shear deformation of chips during machining. Additionally, the

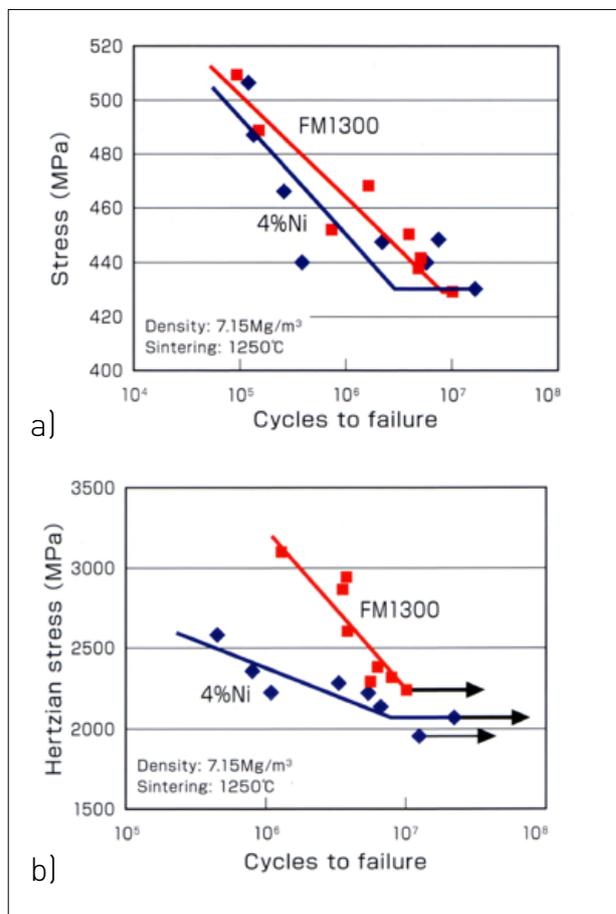


Fig. 3 Comparison of rotating bending fatigue strength (a) and contact fatigue strength (b) of sintered FM1300 grade and 4%Ni PM steel

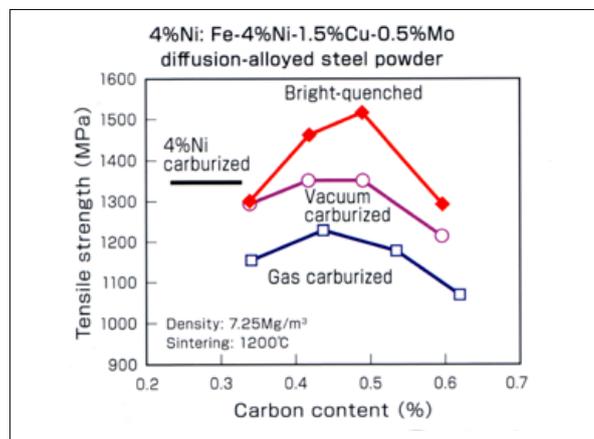


Fig. 4 Tensile strength of sintered and heat treated JIP® 5CRA (red)

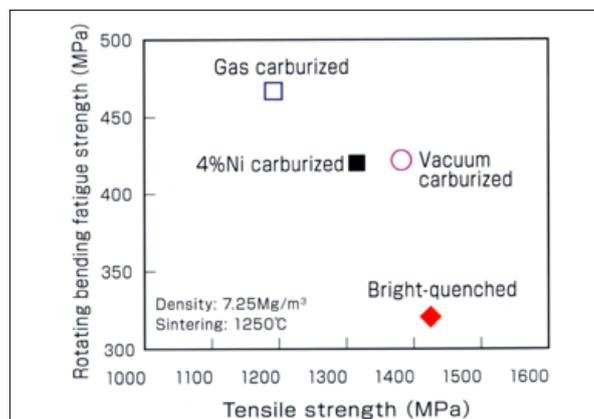


Fig. 5 Rotating bending fatigue strength of sintered and heat treated PM steels (JIP® 5CRA in red)

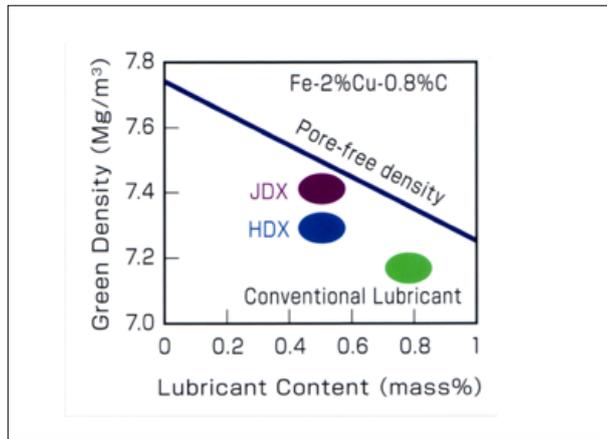


Fig. 6 Green density vs. lubricant content for the new JIP@ JDX-CMX lubricant system

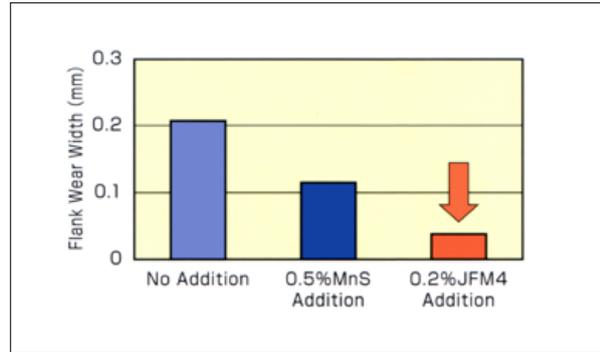


Fig. 8 Reduced flank wear with the 0.2% JFM4 machining addition after 550m turning. (Workpiece: Sintered Fe-2Cu-0.8C; cutting speed: 200m/min, cutting depth: 0.5mm, feed rate: 0.1mm/rev.)

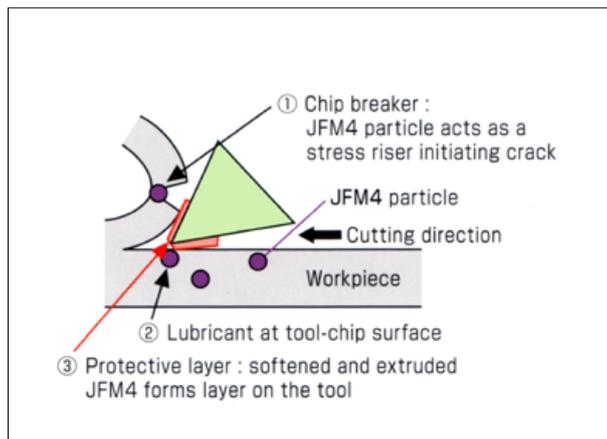


Fig. 7 Function of JFM4 particles dispersed in the sintered workpiece as chip breaker and lubricant at the tool-chip surface

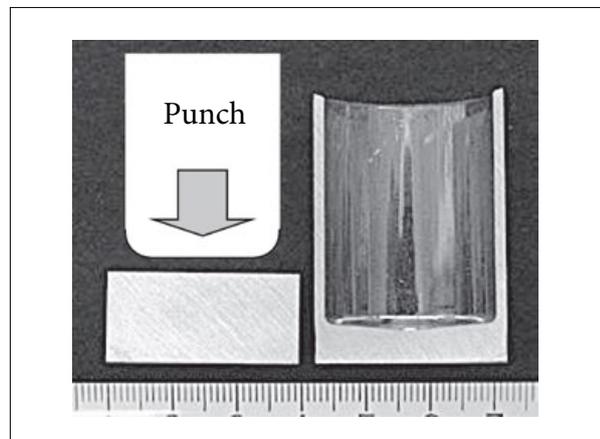


Fig. 9 Sintered preform (left) and crack-free backward cold extruded PM material (right). (From: 'JIP@ Iron powder Products and Technology Trends in Powder Metallurgy' published in JFE Technical Report, No.16, 2011)

composite oxide powder forms a protective film on the tool during machining thereby reducing tool wear. The mechanism of machinability enhancement using JFM4 is shown in Fig. 7. Fig. 8 shows that flank wear is significantly reduced after 550m turning of the JFM4 sintered material compared with 0.5% addition of MnS and PM Fe-2%Cu-0.8%C with no machining additive. There is said to be little difference in the mechanical properties and dimensional change in the newly developed material compared with additive-free PM grades. Toshio Maetani and his colleagues from JFE Steel Corp. Research Laboratories presented a paper on this development at PM2012.

Cold Forging to produce fully dense PM parts

JFE also told *Powder Metallurgy Review* that it had recently developed a new process to produce full density, high performance PM steel parts having complex geometries by combining sintering and cold forging. The process involves compacting and pre-sintering a low alloy Mo steel powder to produce a preform which has sufficient transformability to withstand cold forging (or backward extrusion) with a reduction in area of 85% possible of the pre-sintered material. Fig. 9 shows the sintered preform (left) with the crack-free cold forged material (right). The fully dense cold

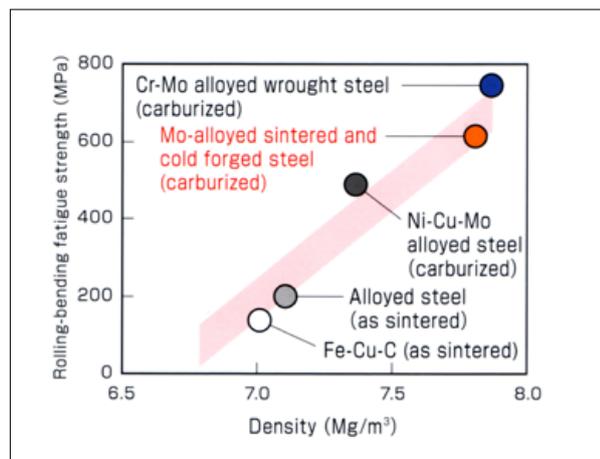


Fig.10 Fatigue strength vs density of Mo-alloyed sintered and cold forged carburised steel.

forged material is re-sintered and heat treated (carburised) to achieve a rotating bending fatigue strength of 600 MPa, and hardness of 60 HRC, which is comparable to the hardness of Cr-Mo alloyed wrought steel. JFE states that automotive transmission gears are just one area of potential applications.



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Innovations in hardmetals processing and characterisation at Euro PM2012

The Euro PM2012 Congress held in Basel, Switzerland, 17-19 September 2012, offered the hardmetals community a highly focused technical programme that covered the latest innovations in hardmetals processing and characterisation. Dr Leo Prakash reviews a selection of papers for *Powder Metallurgy Review* that addressed both the processing of hardmetals and the characterisation of hard materials for applications in the rock drilling sector.

Sintering behaviour of binderless tungsten carbide

Interesting sintering studies on the WC grain growth characteristics of binderless WC compacts with different grain growth inhibitors (GGI) such as Cr_3C_2 and VC, and WC grain sizes from 100 to 600 nm milled under different conditions were presented by Johannes Pötschke from the Fraunhofer Institute for Ceramic Technologies and Systems, Dresden.

The influence of the GGIs on sintering behaviour is evident from Fig. 1. Even though the start of

sintering between 800 and 1400°C is not influenced by the GGIs, the authors data point out that GGIs shift the sintering temperature to a higher temperature for full densification in the following order:

$$\text{Without GGI} < Cr_3C_2 < Cr_3C_2 + VC < VC$$

The effect of milling conditions on the sintering rate is seen in Fig. 2. High intensity milling (not defined) reduces the final required sintering temperature by more than 150°C according to the authors. They

correlate this with the change in surface area on milling, using the same starting WC powder.

In Table 1, the authors document the influence of WC grain size, milling conditions and GGI additions on the properties of binderless sintered WC compacts. Excellent mechanical properties with a hardness up to 2600 HV10 and fracture toughness up to 6.5 $MPa\sqrt{m}$ were achieved.

In conclusion, it is pointed out that the correct choice of milling parameters to enhance sinterability could lead to binderless WC compacts

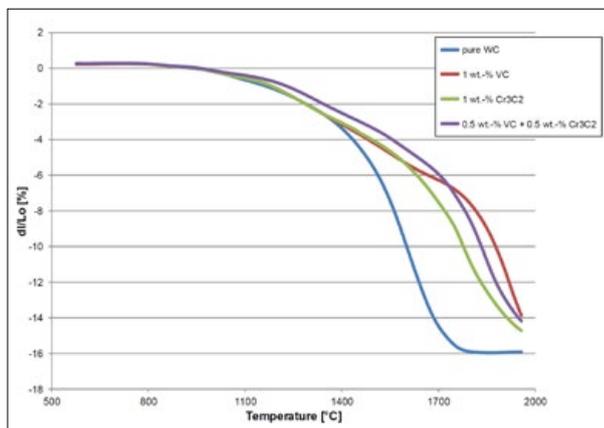


Fig. 1 Influence of added grain growth inhibitors on the sintering behaviour of the P115 starting powder [1]

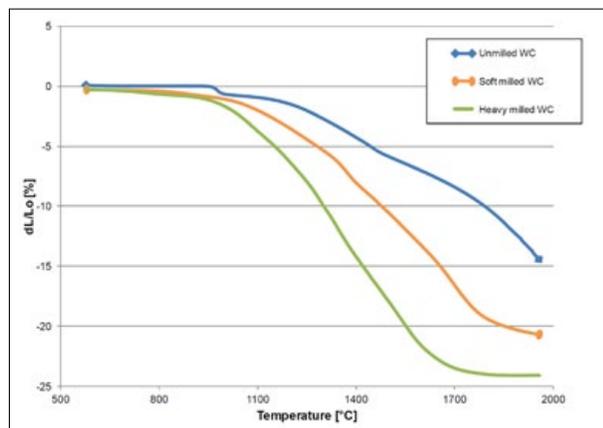


Fig. 2 Influence of milling conditions on the sintering behaviour of the P115 starting powder [1]

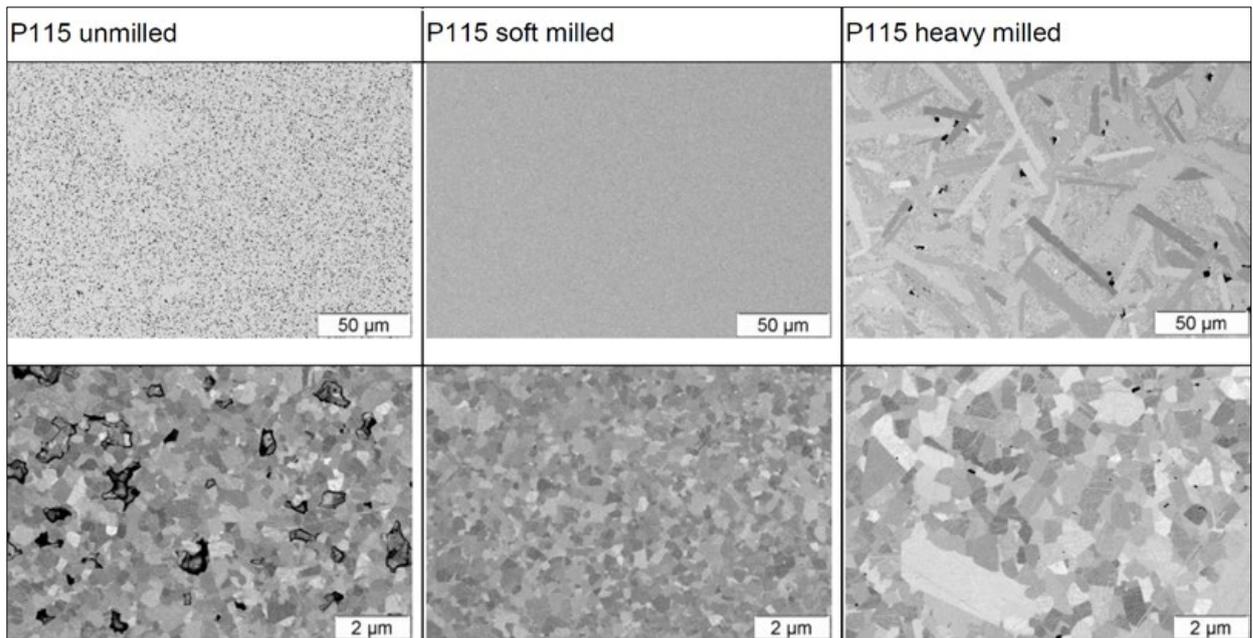


Fig. 3 Microstructure development of WC P115 with different milling conditions, top: SE2-Images at 500x magnification; below: AsB-Images at 10000x magnification [1]

WC Powder	Milling condition	Grain refiner	Content wt-%	Density %	Hardness HV10	Fracture Toughness MPa√m
P200	soft+long	none	0.0	98.7	2520	6.5
P200	soft+long	VC	0.9	99.9	2410	6.2
P200	soft+long	Cr3C2	1.2	98.2	2580	5.8
P200	soft+long	VC+Cr3C2	1.0	98.7	2580	6.5
P115	heavy+short	none	0.0	99.8	1370	5.6
P115	heavy+short	VC	1.0	99.9	2340	6.8
P115	heavy+short	Cr3C2	1.0	99.9	2410	6.7
P115	heavy+short	VC+Cr3C2	1.0	99.8	2450	6.7
P115	soft+long	none	0.0	99.9	2540	6.6
P115	heavy+long	none	0.0	99.0	1600	5.0
P100	soft+long	Cr3C2	1.0	99.3	2710	7.2

Table 1 Mechanical properties of sintered binderless WC with and without grain growth inhibitors [1]

Powder	N content [wt%]	a [Å]	σ_a [Å]	c [Å]	σ_c [Å]	Atmosphere
WCN-0	0.02	2.9065	<0.0001	2.8384	0.0001	Flowing N ₂
WCN-1	0.68	2.9030	<0.0001	2.8312	0.0001	Pressurised N ₂
WCN-2	0.43	2.9047	0.0001	2.8362	0.0002	Pressurised N ₂

Table 2 Nitrogen content and lattice parameters (together with standard deviation δ) of WC synthesised under nitrogen atmosphere [1]

with good mechanical properties, even without GGIs. Examples of the influence of milling on microstructure are presented in Fig. 3. In all cases pickup of cobalt by milling was in the 10's of ppm range, i.e. almost negligible pickup.

Interaction of nitrogen with WC and nitrogen-assisted sintering of hardmetals

The influence of nitrogen on the properties and microstructure of TiCN cermet and WC-Co hardmetals with mixed carbides has been studied in depth by the Vienna University of Technology over the past decades. An interesting piece of work on the influence of nitrogen on WC grain size during sintering was presented by Prof. Dr. Walter Lengauer in his inimitable fashion.

Nitrogen was incorporated into tungsten carbide by two methods:

- During synthesis of WC powder by mixing tungsten and graphite powder in graphite boats with a heat treatment under a pressure of up to 40 Bar Nitrogen at temperatures up to 1600°C.
- By nitridation of commercial WC powders at 60 to 150 Bars in the temperature range 1100 – 1700°C for up to 5 hours.

Needless to say that during synthesis, the nitrogen content of the W(CN) powders is dependent upon

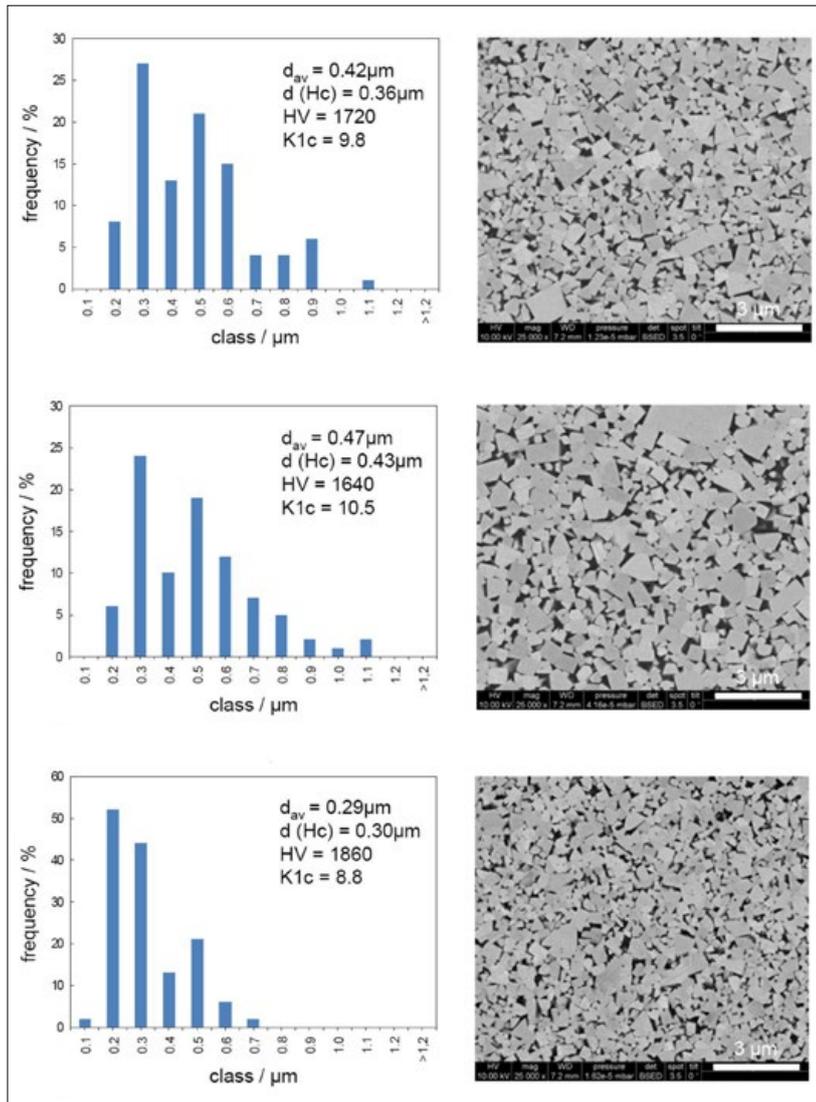


Fig. 4 Right: Microstructure of hardmetals with original WC and nitrided WC (WC/10%Co). Top: original WC, middle: WC nitrided at 1700°, bottom: WC nitrided at 1100°C. Left: corresponding linear intercept evaluation of WC grain size (from 3 images). The data given in the graphs are average values by vacuum and SinterHIP cycles. All hardmetal formulations contained conventional grain-growth inhibitors VC + Cr₃C₂. SEM/BSE 25,000x [2]

pressure, as has also been published by Japanese researchers. In this work, more than 10% nitrogen could be incorporated into WC, whereas the nitrogen partially replaced the carbon atoms in the tungsten lattice to yield stoichiometric ratios very close to 1 for the [C+N]/W ratio.

As can be seen in Table 2, the replacement of carbon by nitrogen leads to a decrease in both the lattice parameters a and c of the hexagonal unit cell of WC.

The nitridation experiments clearly brought out the fact that the diffusivity of nitrogen in WC is very low. In this case only surface nitridation could be detected and this was more for finer WC

grains compared to coarser WC grains. The authors go on to demonstrate that nitrogen reduces grain growth, especially below temperatures of 1400°C in the case of the powders studied here.

The second part of this paper presents results on sintering of these two types of nitride powders with 10Wt% cobalt and grain growth inhibitors. The synthesised WCN powders show outgassing of nitrogen in three or four steps in accordance with the different types of bonding of N in the WCN crystals. The earliest outgassing temperature is around 1187°C at which temperature a two phase liquid equilibria (confirmed by DTA results) exists.

The results presented could lead to the conclusion that WCN powders need to be consolidated under different pressing parameters and that degassing leads to large pores at high nitrogen contents. The authors also note that WC grain refinement could be observed at a nitrogen content of 0.02%, without any porosity if sintered under Nitrogen. This confirms results from the dawn of Hardmetals technology that the sinterability of WC-Co mixtures is dependent on the atmosphere. Whereas hydrogen is followed by vacuum in terms of densification rate, nitrogen and argon atmospheres show lower sinterability and lower grain growth of WC.

The data presented by the authors in Fig. 4 is interpreted that low temperature nitriding of WC, i.e. below 1300°C leads to decreased grain growth of WC in the WC-Co alloys by the inhibition of solid state grain growth of WC particles, probably at temperatures below 1130°C. The authors suggest that nitriding WC powder with a nitride rim is beneficial for retarding WC grain growth.

Materials characterisation of hardmetals for rock drilling applications

The world's growing requirements for raw materials was also reflected in the Hard Materials sessions at Euro PM2012. Three papers dealing with rock drilling applications, and with a focus on materials characterisation, were presented by three groups of authors.

Rock drilling is essential for modern society in the mining and construction drilling industries, for example in ore and mineral mining, infrastructure projects and oil and gas drilling. Rock drilling can be performed by different drilling techniques, with the most common drilling technique applied in hard rock applications being percussive drilling. In this, the drill crown (bit) rotates and percussively impacts into the rock, the rock is crushed in the impacts and the bit is rotated to a new position before the next impact. The bit is equipped with buttons of WC-Co cemented carbide and, depending on the application, different button geometries and cemented carbide grades are used to optimise drilling performance.

Wear of the cemented carbide

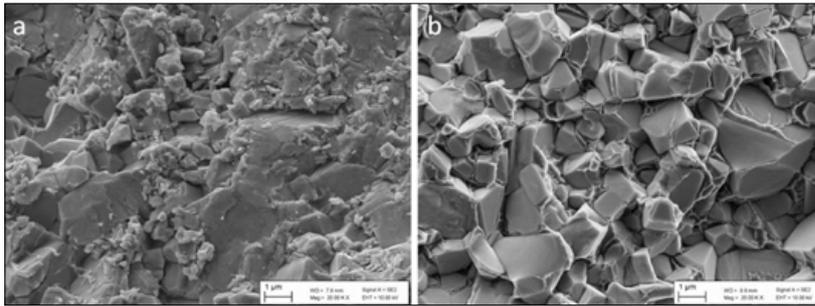


Fig. 5 SEM images of worn cemented carbide samples 1 and 2 fractured under a compressive [a] and a tensile [b] stress state, respectively. Note the severe damage of the fracture surface in [a] [3]

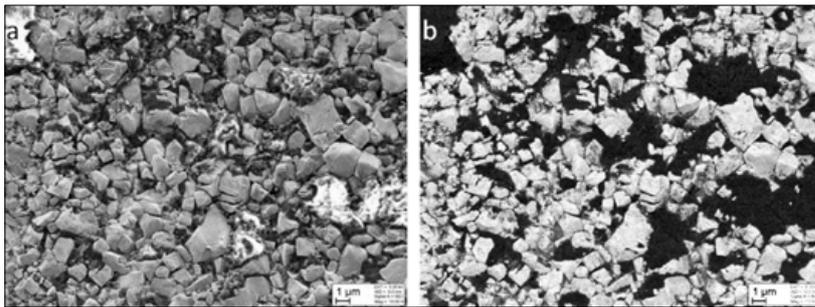


Fig. 6 Surface morphology of worn hardmetal drill button (untilted view). Exactly the same area is imaged using the SEI [a] and BEI [b] detector, respectively. With the BEI detector areas with adhered rock material (dark due to a lower mean atomic number) are easily revealed [3]

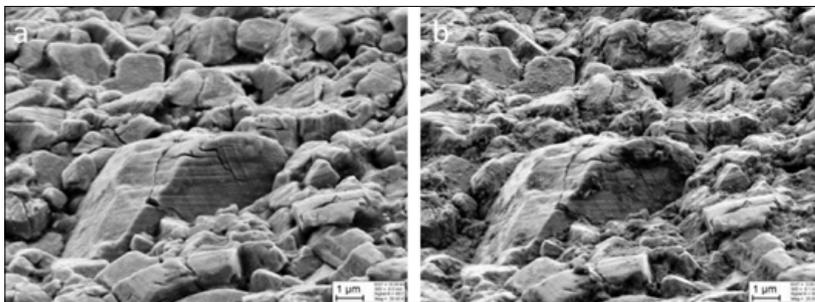


Fig. 7 Surface morphology of worn hardmetal drill button (70° tilted view). Exactly the same area is imaged using 10 keV [a] and 3 keV [b] electrons (SEI mode). With the lower acceleration voltage it becomes clear that the WC grains are covered by thin layers of rock material [3]

buttons is normally one of the lifetime-limiting factors for rock drill bits. To increase the lifetime of the buttons in rock drilling it is essential to investigate and understand the active wear mechanisms. Investigation of worn cemented carbide buttons from rock drilling includes not only the characterisation of the worn surface but also characterisation of the affected sub-surface layer in cross-section. Laboratory testing and modelling of wear is essential to develop better mining tools for improved performance, as is an understanding of the fracture toughness of hardmetals.

On the understanding of Cemented Carbide degradation in rock drilling: The importance of metallographic sample preparation

The research group from Atlas Copco [S Olovsjö, R Johanson] and colleagues at Dalarna University (U Bexell, M Olsson) clearly brought out the importance of specimen preparation for interpretation of wear evaluation of cemented carbides, not only on the wear surface but also in sub-surface layers. Fracture cross-sectioning of worn mining bits under tensile stresses is mandatory to reveal surface and subsurface degradation of the hardmetal structure. Fig. 5 shows

the fracture surface of bits cross-sectioned and fractured in compression and tension. Compression cross sectioning induces additional severe damage.

Besides the sample preparation technique used, also the microscopy characterisation performed has a strong impact on the results achieved. The combination of high lateral resolution and high depth of focus makes scanning electron microscopy in combination with energy dispersive X-ray spectroscopy a powerful technique when it comes to characterising the degradation and wear mechanisms of the hardmetal drill buttons. However, to take full advantage of the possibilities of SEM the microscope settings should be optimised depending on the microstructural features to be studied. Setting parameters of interest are;

- Type of detector (SE-, BE-, SE/BE in-lens detector), which will affect the topographical/elemental information in the SEM image (see Fig. 6).
- Primary electron energy (acceleration voltage), which will affect the electron-surface material interaction depth and thus the depth of sight and resolution (see Fig. 7).
- Tilt angle, which will affect the topographical information (3D feeling) [Figs. 6 and 7].
- Working distance, which will affect the depth of field/resolution.
- Aperture size, which will affect the depth of field/resolution.

Test methods for high rate impact loading of hardmetals

The paper presented by the NPL research group [H G Jones, K P Mingard, J Zunega, M G Gee and B Roebuck] reports on the results of ongoing laboratory impact tests with two different loading mechanisms (electrodynamic and pneumatic) on a WC-6Co sample, relating the results to a microstructural investigation of the mechanisms of damage during testing. The electrodynamic jig generated a maximum test load between 550 and 600 N with impact times of about 3 ms in a single 40 ms cycle. Tests upto 22 million cycles, both interrupted and uninterrupted using an impact target of hardmetal with a hardness of HV 2000 were performed. In the case of

the pneumatic testing, the impact load was 2000 N for one and ten million cycles respectively at 50 Hz.

In the tests carried out so far, the carbide grains are fractured and crushed on the surface during impact and a layer forming where impact had taken place. EDX shows that this layer is oxygen rich and deficient in cobalt suggesting it is tungsten oxide. The oxide layer becomes fractured and in places lifts from the surface forming voids or further layers beneath it. Below the surface, there is some intergranular fracture between carbide grains and the cobalt binder but there is no significant fracture as observed by Beste *et al.* The two methods described so far show similar progression of the oxide formation, but the higher load pneumatic testing created a compacted impacted region in the middle of the crater.

Fig. 8 shows a sampling of the topography of the impact region after pneumatic testing, whereas the electrodynamic testing shows similar artefacts in the impact area.

Fracture toughness of rock bit cemented carbides

The aim of the research work presented by an international group of authors (Y Torres, E Tarrés, B Roebuck, P Chan, M James, B Liang, M Tillman, R K Viswanadham, K P Mingard, A Mestra and L Llanes) [5] was to document and analyse fracture toughness and corresponding crack – microstructure interactions for mining and rock bit cemented carbides. The characteristics of the hardmetals studied are shown in Table 3.

Fracture toughness was determined using single edge notched bend (SENB) specimens of dimensions 10 x 5 x 45 mm, with a notch length-to-specimen width ratio, a/W, of 0.4. Notches were induced in the material by electrical discharge machining, followed by notch tip sharpening using a razor blade impregnated with diamond paste. The resulting notch tip curvature was between 10–20 µm. A pre-crack was introduced through application of cyclic compressive loads under reverse cyclic bending.

Stable crack growth was observed during cyclic compression, cracks becoming arrested after extension between 80 and 100 µm from the notch tip. Based on previous experience on residual stresses induced during

pre-cracking, these pre-cracks were further propagated under far-field cyclic tensile loads. Crack extension behavior under constant applied load ranges was monitored in situ using a high resolution telescope.

Generated cracks were extremely fine and sharp, following transgranular paths through either the binder phase, although close to the carbide–binder interface, or the carbides. However, the coarse aspect of the microstructure points out the prevalence of a crack–microstructure interaction relatively uncommon in fine–carbide hardmetals, i.e. crack deflection (Fig. 9).

Such phenomenon may be described as pronounced in terms of both effective crack path perturbation and event occurrence frequency. Hence, it should be considered as another relevant toughening mechanism, besides the one associated with plastic stretching of ductile ligaments, for these hardmetal grades.

Finally, fracture toughness was determined by testing the pre-cracked SENB samples to failure under constant loading rate values, between 200 and 400 N/s. Stress intensity factors given in the literature were used in the fracture mechanics evaluation. Fracture toughness values for each hardmetal grade, determined from at least three tests per set, are included in Table 3.

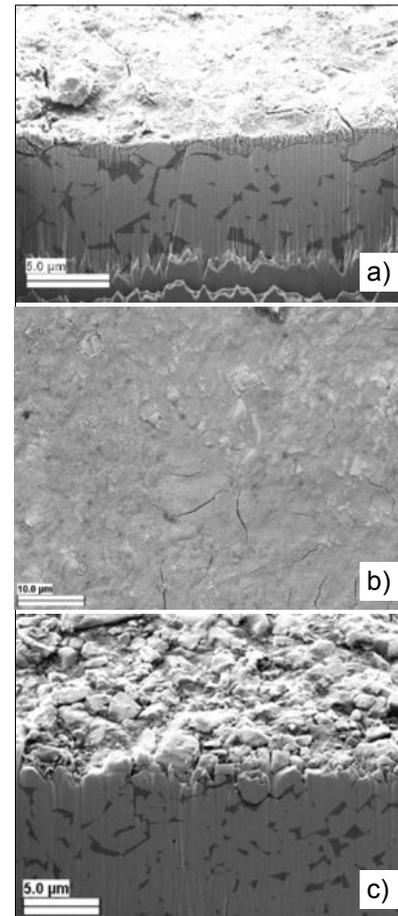


Fig. 8 SEM images taken at 5 kV of a) FIB section in the middle of the impact region, b) centre of impact region, and c) FIB section through edge of impact crater [4]

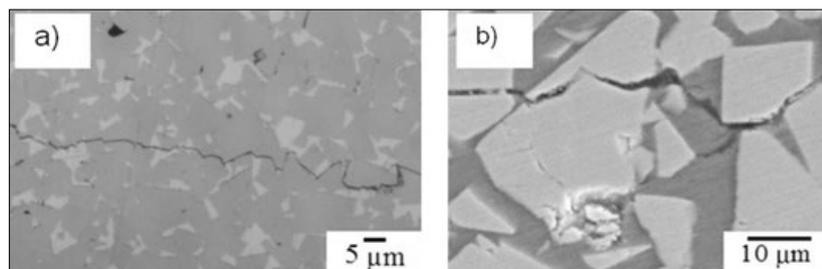


Fig. 9 a) Optical micrograph showing the magnitude and frequency of crack deflection phenomena during stable crack propagation; b) SEM micrograph detailing crack deflection mechanisms, both within a coarse carbide and through the subsequent binder ligament, during stable crack propagation [5]

Grade	% _{wt} Co	d _{wc} (µm)	λ _{co} (µm)	C _{wc}	HV30 (GPa)	K _{1c} (MPa√m)
A	10.0	2.15	0.89	0.61	11.3 ± 0.6	17.9 + 0.8
B	14.0	2.02	1.09	0.56	10.6 ± 0.7	17.7 + 0.6
C	9.5	2.44	1.24	0.70	11.2 ± 0.6	17.1 + 0.8
D	12.0	4.15	2.00	0.50	9.6 ± 0.6	20.4 + 0.5

Table 3 Microstructural and mechanical (hardness and toughness) characteristics for the materials investigated [5]

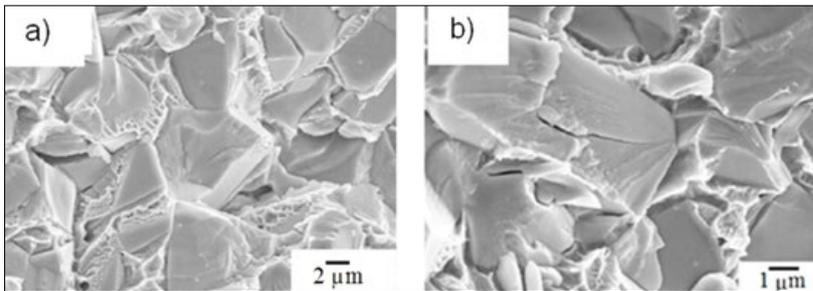


Fig. 10 a) SEM micrograph showing fractographic aspects associated with unstable failure in SENB specimens tested to rupture; b) SEM micrograph showing details on the transgranular fracture of carbide particles [5]

Relevant differences are only observed for the hardmetal grade D, this material exhibiting the highest fracture toughness value. The fracture surfaces show, dimple ductile rupture in the metallic binder interspersed with cleavage and intergranular fracture of the carbides as the relevant fractographic features discerned in all the cases (Fig. 10a). Particularly, crack–microstructure interactions involving large carbides mostly exhibited a transgranular character, as clearly discerned from the river pattern features observed on them (Fig. 10b).

The most relevant toughening mechanism for WC-Co is, according to literature, crack shielding due to ductile cobalt ligament bridging behind the crack tip. The effective saturation toughness may be estimated from literature:

$$K_k = \sqrt{K_I^2 + \frac{C^* E \sigma_y A_f \left(\frac{\lambda_{Co}}{2}\right)}{(1-\nu^2)}}$$

where K_I is the critical crack-tip stress intensity factor required for crack initiation; E is the Young's modulus and ν is the Poisson's ratio of the composite; σ_y is the binder flow strength determined from a Hall–Petch type relation ($\sigma_y = \sigma_0 + k_y [\lambda_{Co}]^{-1/2}$, with $\sigma_0 \sim 480$ MPa and $k_y = 7.7$); A_f is the area fraction (intersected by the crack plane) of the ductile binder; and C^* is a "work of rupture" function that depends on constraint (and thus on the strength of the binder–carbide interface) and constitutive properties of the binder.

Based on the analysis of the experimental findings on fracture toughness assessment and analysis for four different rock bit cemented carbides, the authors draw the following conclusions:

- Rock bit cemented carbides exhibit relatively high fracture toughness values (between 17 and 20 MPa√m) in direct association with their specific microstructural characteristics, i.e. large carbide grain size and relatively high cobalt content.
- The influence of microstructure on the measured fracture toughness may be accounted by considering the complementary and effective operation of ductile ligament bridging and crack deflection as the prominent toughening mechanisms.

They do point out that additional results and analysis is necessary to strengthen their postulate that crack deflection was an operative toughening mechanism intrinsic to coarser carbides as well as from the expected higher effective ductility of the binder in the materials studied here.

The renewed interest in understanding the strengthening and wear mechanisms in rock drilling hardmetal applications will also facilitate the development of hardmetals in other applications.

Author

Dr. Leo J Prakash holds a Ph.D. in Cemented Carbides and has over three decades of experience in the field of cutting tools for wood and metals as well as wear parts.
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References

[1] 'Sintering Behaviour of Binderless Tungsten Carbide', Johannes Poetschke, Volkmar Richter, Tim Gestrich, Fraunhofer Institute for Ceramic Technologies and Systems, Germany. Presented at Euro PM2012, Basel,

September 16–19, 2012, and published in the Conference Proceedings by EPMA

[2] 'Interaction of Nitrogen with WC and Nitrogen-Assisted Sintering of Hardmetals' Marius Wetzel, Sabine Wawrzik, Christoph Buchegger, Christian Gierl, Walter Lengauer, Vienna University of Technology, Austria. Presented at Euro PM2012, Basel, September 16–19, 2012, and published in the Conference Proceedings by EPMA

[3] 'On The Understanding Of Cemented Carbide Degradation In Rock Drilling – The Importance Of Metallographic Sample Preparation', Stefan Olovsjö¹, Richard Johanson¹, Ulf Bexell², Mikael Olsson², ¹Atlas Copco Secoroc AB, Sweden, ²Dalarna University, Sweden. Presented at Euro PM2012, Basel, September 16–19, 2012, and published in the Conference Proceedings by EPMA

[4] 'Test Methods For High Rate Impact Loading Of Hardmetals', H.G. Jones, K. P. Mingard, J. Zunega, M. G. Gee and B. Roebuck, National Physical Laboratory, UK. Presented at Euro PM2012, Basel, September 16–19, 2012, and published in the Conference Proceedings by EPMA

[5] 'Fracture toughness of rock bit cemented carbides', Y. Torres¹, E. Tarrés^{1,3}, B. Roebuck², P. Chan³, M. James³, B. Liang⁴, M. Tillman³, R. K. Viswanadham⁵, K. P. Mingard², A. Mestra¹ and L. Llanes¹, ¹CIEFMA - Universitat Politècnica de Catalunya, Spain, ²NPL, UK ³Sandvik Hard Materials, UK ⁴Smith International Inc., USA ⁵Sandvik Rotary Tools, USA. Presented at Euro PM2012, Basel, September 16–19, 2012, and published in the Conference Proceedings by EPMA

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