Vision 2025
Future Developments for the European PM Industry
The European PM Industry Roadmap
January 2015

www.epma.com
Contents

The European PM Industry Roadmap 2
Executive Summary 3
Recommendation 3

Vision 2025
1.1 - Future Developments for the European PM Industry 4
1.2 - Definition of PM 4
1.3 - Roadmap Recommendations 5

Powder Metallurgy
2.0 - The Scope, the technology and the products 6
2.1 - The Importance of PM to European Manufacturing “PM Inside” 6
2.2 - Toolbox of Processes and Materials 8
2.3 - Generic Advantage offered by the PM route and its products 9

A Market Overview
3.1 - The Commercial and Industrial Marketplace 10
   Structural PM Components 10
   Hardmetals and Diamond Tools 11
   Hot Isostatic Pressing 12
   Metal Injection Moulding 12
   Additive Manufacturing 13
3.2 - Supporting the Customer 14
3.3 - Human Resources and Information Availability 15
3.4 - Education and Networking Academia-Industry 15
3.5 - Sustainable Development (Green, Resource, Energy) 16
3.6 - Standards and Legislation 16

Future Development Opportunities for the PM Industry
4.1 - Driving Innovation 17
4.2 - Ongoing Process Improvements 18
4.3 - Enhancing Competitiveness by Innovation 19
   Structural PM Components 19
   Hardmetals and Diamond Tools 20
   Hot Isostatic Pressing 21
   Metal Injection Moulding 21
   Additive Manufacturing 22

Summary 23

The PM Process
Appendix 1 - The PM Process 24
   Structural PM Components 25
   Hardmetals and Diamond Tools 25
   Additive Manufacturing 26
   Hot Isostatic Pressing 26
   Metal Injection Moulding 26

References 27

Acknowledgements 27
The European PM Industry Roadmap

For whom it is intended
The report is addressed to those people who are interested in the industry and its science and technology: Companies (especially management), RTO’s, Universities, consultants, Government Departments and Agencies.

How it should be used
It is hoped that the report will be used as a manual for implementation of the recommendations; it also contains considerable detail on the science, technology and design aspects concerned. This information can help serve as the basis for definition of R & D needs, courses and interdisciplinary and cross-sector collaboration.

If you have 2 minutes - Read the pages flagged

If you have 5 minutes - Read the pages flagged

In 30 minutes you have read it all
Executive Summary

The Powder Metallurgy (PM) industry is an excellent example of where the EU is a major industrial player in a Key Enabling Technology with a turnover of €15bn and employs around 40 000 people. PM is a solution provider for manufacturing industry and today has a wide range of process and material options that essentially offer a toolkit for designers and engineers.

PM is of critical importance to a number of sectors including automotive, aerospace and construction and as such gives very high added value to society.

This report is intended to set out the EPMA MEMBERS’ view of those factors, which will determine the future of PM manufacture in Europe over the period 2015-2025. It is a summation of a wide ranging consultation exercise involving companies and organisations throughout the PM supply chain.

There are a whole range of factors - both technical and non-technical - that have to be addressed. The intention is that responses to the issues will be developed among all the role players, i.e. companies, trade associations, research & technology organisations’s (RTO’s), and governments.

To develop the PM Industry’s future the main recommendations of the roadmap are:

- Providing end users with support and information is vital, in particular for new applications, as well as in the development of new standards.

- PM contributes to sustainable development and the high level of European standards as intrinsically PM is a green, lean, low energy consumption technology.

- Priority innovation areas are identified with a focus on new products, novel processing and material technologies.

- Training and education at all levels of companies is crucial.

- Lack of skilled personnel must be avoided by pro-active awareness and recruitment, education, and promotion initiatives.

- Improve support mechanisms for SME niche producers as well as new technologies and start ups.
1.1 Future Developments for the European PM Industry

How the European PM industry wants to be recognised in 2025

• By 2025 PM is recognised as a resource-efficient industrial process by which optimised powders and equipment are used to produce tools and components with unique properties, high quality and superior performance.

• PM is the preferred net shape metal forming process for components with special properties and requirements for a wide range of critical and demanding applications.

• The European PM industry is recognised as the world leader in technology application and productivity leading to enhanced growth and profitability.

• PM is seen as a source of constant innovation for European industry.

By 2025 the European PM industry wants to achieve:

• Enhanced supply chain cooperation and optimisation leading to partnerships with key end users enabling the development of an increasingly responsive industry.

• Flexible production and processes enabling reduced time to market and reduced costs.

• Integration of PM parts into more complex assemblies enabling industry to focus on more value-added, customised and resource efficient products.

• Greater job satisfaction and productivity by more knowledgeable, more technically proficient and better trained staff of PM companies.
1.3 Roadmap Recommendations

For the PM Industry to achieve this the roadmap recommends to:

- Strengthen relations with end users by providing more support and information in particular for new applications.

- Undertake further work towards sustainable development and new international standards.

- Promote PM as an intrinsically green low energy consumption technology with high material utilisation.

- Prioritise identified innovation areas with a focus on new products, novel processing and material technologies.

- Train and educate personnel at all company levels.

- Secure availability of skilled personnel by pro-active awareness and recruitment, education and promotion initiatives.

- Improve support mechanisms for SME niche producers as well as new technologies and start-ups.

“These recommendations are seen as critically important for the sound development of the European PM Industry.”
2.1 The Importance of PM to European Manufacturing Industry “PM Inside”

The Powder Metallurgy (PM) industry is an excellent example of where Europe is a major player in a Key Enabling Technology whereby components produced using the PM process form critical elements within the complex systems found in many industries. Europe pioneered PM technology more than 100 years ago, having kept ever since a key innovation and supply chain integration advantage over other regions in the world.

The PM industry in Europe employs approximately 40,000 people, with production sites in 20 member states and a combined turnover of some €15 billion. Europe has a global market share of some 20% and is home to many of the world’s most important PM companies along the supply chain. Metal powders are also present in non-structural forms in numerous other sectors such as welding, coating, filters, electrical contacts etc; but these fall outside the scope of this document.

The PM industry is, due to its ability to make unique materials and parts, of critical importance to a number of sectors including automotive, aerospace and construction. Often it can be said of many products that there is “PM inside”. Therefore as a Key Enabling Technology, PM is increasing its importance in manufacturing engineering since it also demonstrates significant economic, performance and environmental advantages over the longer-established casting, forging and machining routes.

“Nowadays PM processes can produce parts from below one gramme up to 30 tonnes in weight and in volumes up to millions of items per year. Thus it is seen as a flexible toolkit for designers and engineers.”
PM is a green technology; in particular it allows high material yield utilisation and low energy consumption. Around 80% by weight of the raw material used in the manufacture of PM parts is derived from recycled scrap and over 95% is present in the final product, compared with levels often of only 50% for conventional processes. Thus PM helps to master the challenges of the future, like the rare earth supply issue, (less raw material required through PM).

High levels of adaptation have taken place during the last decade in order to cope with the challenge of better integrating the health and safety standards demanded by REACH and other legislation driven by the EU. Increased energy costs are seen by many sectors as a threat. There it is of utmost importance to stress that PM is a relatively low energy consuming technology compared to conventional materials forming technologies and PM has more recently risen to the challenge. However, decreased competitiveness will result where similar costs are not also levied on non-EU companies and this will need to be addressed when balancing sustainability and competitiveness.

"The need to understand the market forces and drivers that are acting upon on the industry and how they drive responses in technology, structure and human resources is vital. This roadmap aims to show how supply chain optimisation is essential to ensure industry’s continuing improvement."

**Vision 2025**
2.2 Toolbox of Processes and Materials

The PM industry can be divided into distinct sub groups like:

**Structural PM Components**

**Hardmetals and Diamond Tools**

**Additive Manufacturing (AM)**

**Hot Isostatic Pressing (HIP)**

**Metal Injection Moulding (MIM)**

These are described in more detail in Appendix I. In practice all of these processes can either on their own or in combination offer a “toolbox” for the designers and users of products. Each one of the five can offer its own unique combinations of cost capabilities and capacity. Therefore, when looking at the opportunities for net shape metallic manufacture, PM becomes a solution provider for a range of sectors. The chart below outlines the way in which the various PM processes overlap so as to enable designers and engineers to cover their cost, performance and material requirements.

![Diagram](image)

**Figure 2:** The relative position of the different segments of the PM industry per batch.
2.3 Generic Advantages offered by the PM route and its products:

In summary these can be identified as:

- Enhanced performance for given materials.
- Unique materials with unique properties.
- Cost reduction compared to other forming technologies.
- Resource preservation through high material yield especially in complex parts.
- Energy saving throughout the production process.
- Sustainable process due to use of recycled raw materials and energy.
- Production of components that are not feasible by conventional manufacturing processes.

A number of key advantages can be identified across these sub sectors that enable it to stand apart from and compete with traditional forming techniques.

---

**Case Study of “PM Inside”**

**Planetary Assembly for Automotive Gearbox**

This part is used in the transmissions of 4WD vehicles. In any of the 6 holes, a shaft is fitted, where planetary gears are turning. The part only works when the short speeds are connected. In any other case, the part is turning free without any workload. So the part is acting as a speed reduction of the transmission shaft.

**Benefits:** PM offers the possibility to join parts during sintering. In this case, a sinter-brazing technique is used to join the front and the rear during sintering, so a joining step is saved. Given the complex shape of the part it is compact with high dimensional accuracy, PM technology also offers the customer significant economic savings.

**Product Density:** Front: 6.85 g/cm³, Rear 6.8 g/cm³, Bushing 6.7 g/cm³

**Product Hardness:** Front 230 HV10, Rear 250 HV10

**Tensile Strength:** Front 620 MPa, Rear 600 MPa, Bushing RCS 150 MPa

**Final Weight:** 1.115 kg

**PM Process used:** Press and Sinter
3.1 The Commercial and Industrial Marketplace

**Structural PM Components**

The Structural PM Components sector is dominated in volumes by the vehicle industry: cars, trucks and two-wheelers. These markets cover about 70 - 80% of the production volume. Europe produced around 175,000 tons of PM structural parts in 2014 with a sales value of over €3 billion. More than 50% of the global automotive platforms are developed in Europe or by EU companies. So the EU PM industry is the natural and well-recognised partner in a very large portion of the global vehicle production.

The PM industry is supporting the multiple trends and innovations on-going in the automotive industry like: hybridisation, electrification, downsizing combined with even increased performance, energy saving, improved impact on our environment… By this PM helps to manage the global challenges related to energy consumption and CO2 reduction and the environmental impact of the car industry on our life.

PM is well prepared to design and manufacture at very competitive cost net-shape, high precision components of different metals and alloys. The European PM companies are well-integrated partners of the large 1st tier and OEM (Original Equipment Manufacturers) companies supplying their needs in Europe, but also at their global sites. Even with a flat growth of car production in Europe PM has a very good chance for further growth via innovation in design and improved materials compared to the other conventional parts making processes.
The EU PM industry grows not only by innovation and making the right products for the changing automotive markets but also by globalisation expanding companies’ presence in the fast growing regions in the world like China, India and South-America. Here EU related PM plants supply their global customers with components and services in PM designs and materials through their local presence. It is the nature of the markets to supply the same design and quality of product to the customers at all locations of their production.

“This overall positive growth trend can only be maintained if the financial resources for R&D product and process development are kept at a high level and if it is supported by future investment in smart equipment.”

**End market applications for PM Structural Parts**

![End market applications for PM Structural Parts](image)

**Figure 3:** End market application for Structural PM Parts and Bearings

**Hardmetals and Diamond Tools**

Tooling based on hardmetals and diamonds is the backbone of any manufacturing process. As an example, around fifty machining operations using hardmetal tools are needed in the automotive industry to manufacture a car. The hardmetals sector therefore supplies significant volumes in the automotive and aerospace sectors, but has also a major market in construction and wear applications. A reduction in sales has been seen in these latter applications – in spite of the large potential in this area. This is related to intense pressure from non-European low cost manufacturers and raw material price increases which have led the industry to move to added value and technology driven sales.

There are, however, several other industry sectors including energy, aerospace and electronics, which have the potential for further sales growth. A key success factor continues to be a high level of R&D and sales effort required to develop the processes and materials to successfully enter these new sectors. At a time when margins are under pressure many companies especially SMEs face real difficulties in achieving this objective.
**Hot Isostatic Pressing (HIP)**

HIP has a wide range of capabilities that include large and massive near net shape metal components such as parts for oil & gas sectors weighing up to thirty tonnes, or net shape impellers up to one metre in diameter. Equally it can be used to make small PM HSS cutting tools, or even very tiny parts such as dental brackets. As a result, HIP has developed over the years to become a high-performance, high quality and cost-effective process for the production of many metal components. It faces challenges in that the markets it is trying to enter are often safety critical so the development of data and standards to support the use of HIP components is seen as a major requirement.

Shorter lead-times may also be an important topic to improve response to the market. Also possible future energy savings, processes and the development of new functional materials by HIP processing will support the growth of the PM HIP industry. Increasing the awareness of HIP capability vs cast/forged materials in user industries such as oil & gas, power generation and aerospace will be needed.

**Metal Injection Moulding (MIM)**

MIM technology has, thanks to development in process and materials technology, seen sales in Europe develop from effectively zero to over €250m in the last twenty years in a sector with many specialist SME producers. It continues to grow at rates exceeding 10% per annum and has established supply links into the automotive, medical device, consumer electronic and defence industries. Further developments in production equipment and raw materials will be necessary to expand its reach.

**Figure 4:** European MIM sector by application.
Additive Manufacturing (AM)

AM, also often referred to as 3D printing, is used to build physical models, prototypes, patterns, tooling components and production parts in plastic, metal ceramic and composite materials. Talking about real manufacturing in terms of large scale production of large numbers of products, only a few niche products have reached this state. However, AM is expected to continue strong double-digit growth over the next few years. The revenue from metals for AM grew about 40% to €18 million in 2012 during which year about 200 metal AM systems were sold worldwide. According to Wohlers report the number of machines sold for metal AM grew to 358 (+76% vs 2012) during 2013. At the same time the value of the metal powder market was estimated to 33 MUSD (31%).

Companies such as Airbus and General Electric are using these machines to produce complex metal parts for next-generation aerospace and medical products. AM is moving rapidly from being a laboratory and proto-typing tool to a full scale production system.

“This explosive growth will need rapid development of the supply chain to be sustained. In Europe the medical and aerospace sectors are already seen as key growth areas for metal based AM.”

AM will likely increase its market penetration as designers start to think more about complex shapes which would traditionally be composed of multiple parts assembled together because of the impossibility of reaching the complex geometries by conventional forming technologies. AM opens a whole new world in shape feasibility, but major improvements can and need to be done relating to precision, material properties and production speed, among others.
3.2 Supporting the Customer

Successful business is more than just shipping the right parts to the right place at the right price. The PM industry has increasingly demonstrated through product innovation that it can widen the customer’s knowledge about their material and energy saving capabilities, bringing material experts and designers in the key application industries to a higher state of understanding the benefits of PM.

Supporting the customers to have a better knowledge about the potential of all the PM technologies is essential for the growth of the whole PM industry. Even well-established PM technologies, can still offer breakthrough advantages if end-user designers and engineers take the risk to open more widely their components portfolio to PM solutions. Numerous support actions are already carried out in the form of brochures, videos, e-learning websites and material databases to provide them with a knowledge support. It is intended to intensify these support actions in the future with all the current and future communication support that are available.

Case Study of “PM Inside”

Component for A320 Turbofan™ Engine

One of the first applications in the field of aero engine construction to use the new additive manufacturing technique, is borescope bosses for the PW1100G-JM engine, which powers the A320neo. The bosses are made by selective laser melting. They form part of low-pressure turbine casing and allow the blades to be inspected at specified intervals for wear and damage using a borescope.

Benefits:
• The technology appreciably cuts development, production and lead times, and brings down production costs.
• Additive manufacturing is particularly suitable for producing parts in materials that are difficult to machine, as, for example, nickel alloys.
• The process allows complex components that are extremely difficult, if not impossible to manufacture using conventional methods to be produced with only small amounts of material and few tools.

Material: Inconel 718
Part weight or dimensions: Volume: 15.6 mm³
LxBxH Boundary Box: 42x72x36
PM Process Used: Selective Laser Melting (SLM)
3.3 Human Resources and Information Availability

Industry surveys show that demand for increased skills at all levels including graduate and post graduate students is high and will grow further. Rather than being seen as a barrier for competitiveness it is instead an opportunity to increasingly differentiate through innovation. It is also seen as a challenge to meet the demand for ever higher skills at technician level including language skills. The PM sector provides an ideal opportunity for the development of a highly skilled workforce, indeed one that contains the attributes and capabilities which government is seeking to promote within its policies on social development.

3.4 Education and Networking Academia-Industry

Education is one of the key issues for Europe to maintain its technological advance in PM. Historically Europe has a wide network of universities and research centres with PM capability - in close cooperation with industry - and there is a significant reservoir of technical knowledge residing in these centres. More coordinated work is necessary to develop more critical mass in certain areas and to give researchers a better understanding of real world industrial processes and problems.

Therefore education and networking with Academia is also seen as a key action to ensure the future of the PM industry. Even if a strong academic network of around 40 R&D centres and universities already are part of the PM community, there is a lack of sufficient knowledge of PM’s capabilities on the academic side in the field of general engineering and design. University curricula in many cases don’t offer a wide enough range of information to future engineers, designers and decision makers to help them take better advantage of the PM industry’s capabilities.

It is intended to widen the whole of academia’s knowledge about the potential of PM technologies, as it is the case for most of the key enabling technologies today.

Increased support actions must take place in the future with all the current and future communications like “Train the Trainer Workshops or “Young Engineer Days”.

Vision 2025
3.5 Sustainable Development (Green, Resource, Energy)

A major challenge facing Europe and the world is the transition to an energy- and resource-efficient economy. As the classical iron, steel and non-ferrous metal industries are seen as high energy-intensive manufacturing sectors, PM differentiates itself as a green technology.

“The PM industry will continue to invest in more energy efficient processes and in improved control over raw material costs and resources by lowering the energy consumption of the furnaces and reducing the dependency on import of scarce raw materials through recycling and increased availability of materials for substitution.”

3.6 Standards and Legislation

PM parts makers are working successfully at the advanced levels of occupational, environmental and safety standards, as defined for instance by REACH and the other EU and national regulations and legislation. In this area Europe is definitely leading the global industry, as all other regions are still implementing, planning or preparing same or similar standards. This has been actively supported and will continue to be further improved by a close cooperation inside the industry, coordinated by EPMA.

Material standards exist for the classical PM grades and products and are going to be expanded for new materials and processes under the well-established roof of the International Standards Organisation and the respective correlated national bodies. Significant resources and commitments from industry will be required if this is to be achieved particularly in the newer sectors such as HIP and AM.

Vision 2025
FUTURE DEVELOPMENT OPPORTUNITIES FOR THE PM INDUSTRY

4.1 Driving Innovation

The Single Market, with 500 million consumers, 220 million workers and 20 million entrepreneurs, is a key instrument in achieving a competitive industrial Europe. One out of four jobs in the private sector in the European Union is in the manufacturing industry, and at least another one out of four is in associated services that depend on industry as a supplier or as a client. 80% of all private sector research and development efforts are undertaken in industry - it is a driver of innovation and a provider of solutions to the challenges which confront our societies. The European Powder Metallurgy industry, as a Key Enabling Technology - Advanced Materials, contributes to this effort.

In order to keep its advantage the PM industry in the next 10 years, intends to address the following challenges and turn them into new opportunities.

Case Study of “PM Inside”

Movement System for rehabilitation of knee joints

The external medical movement system for the adjustment of the position of knees joints during rehabilitation, requests at the same time resistance and lightness.

Benefits: MIM reduces further working treatments on the part, otherwise needed for the complex shape, while the use of TITANIUM alloy Ti-6Al-4V provides the necessary lightness.

Density: 4.25 g/cm³
Tensile Strength: 905 MPa
Weight: 45.8 g for the two parts in Ti-6Al-4V
PM Process used: Metal Injection Moulding
4.2 Ongoing Process Improvements

The PM industry’s competitiveness must be continuously improved to maintain and develop its advantages over other forming technologies. Different areas of improvement can be determined depending on the PM sector according to the commercial realities developed in the prior sections of this roadmap. The six fundamental advantages of PM outlined in section 1.3 allow the PM industry to cover a wide range of products and applications which are sometimes not possible with other manufacturing route.

However, the PM industry still seeks to enlarge the cross sectoral application areas of PM processes by:

- **Improving the existing PM processes** in order to reach better material performances at lower cost. Manufacturing of industry-specific machinery: presses can be further improved to reduce energy consumption, increase speed, improve user interface friendliness and increase precision. Furnaces can be made more energy efficient and capable of optimized and zoned atmospheres. Tools can find improved materials to combine wear resistance, toughness and costs. Process simulation can be improved.

- **Inventing new PM processes** to reach new application areas or even revolutionize design concepts like Metal Injection Moulding or nowadays Additive Manufacturing and maybe in the future other processes, which are not yet in production for example Spark Plasma Sintering etc.

- **Step Changes in Production Economics** whereby larger production units can decrease unit costs of powder and increase possible part sizes to enhance competitiveness versus other production routes. A good example is the development of larger hipping units over the last two decades, which allowed the industry to reposition and lower significantly its cost structure.

“All the above should be fostered by the existing strong collaboration along the entire European PM supply chain, including academia.”
4.3 Enhancing Competitiveness by Innovation

Investment in research and innovation is crucial to European industry's ability to remain globally competitive and key enabling technologies like PM to play an important role in the R&D, innovation and cluster strategies of many industries. Research and innovation are crucial to ensure the competitiveness of European industries in the knowledge economy.

While PM technologies have offered a wide range of innovation to the European industry, the effort should be maintained and even increased in all the PM sectors:

**Structural PM Components:**

The European Structural PM Components industry will increase its competitiveness against other forming technologies by achieving key innovations including:

- High level precision numerical modelling of the behaviour of PM Structural components and their manufacturing process; to include powder flow, pressing and sintering processes, post-processing, properties distribution in compacted components, fatigue etc.

- Powder filling systems (ultrasonic, vibration, additives etc.) to improve productivity and quality.

- Press Development: High temperature compaction – e.g. tool temperature above 700°C, high technology dies – e.g. Strip wound tools to increase productivity and the geometric complexity of PM components.

- Furnace developments: High temperature sintering (1350-1400°C) of PM, High temperature stability furnace belts (above 1200°C) to increase the performance and the material composition of the PM components.

- Online non-destructive testing methods and machines to improve the productivity and the acceptance of PM Structural components as zero defect products by the end user industries.
Hardmetals and Diamond Tools:
The European Hardmetals and Diamond Tools industry faces two major challenges: pressure from low cost manufacturers and raw material supply chain disruption.

The industry is therefore moving to added value and technology driven sales and using recycling at a large scale. Therefore the industry is looking to an ambitious innovation effort in the following key areas.

- Modelling – from atoms through meso-scale to continuum: Processing, performance and system modelling, model sensitivity to data, data generation methods, model validation, physical property models.

- Advanced High Resolution Characterisation Methods: Baseline structures (3D, optical and electron methods, APM), deformation and damage development, length scale dependence of properties, heterogeneity.

- Engineered Structures: Multifunctional coatings, surface engineering, composite structures, hybrid structures, residual stresses.

- Extreme Environments: Strength, fatigue and fracture at elevated temperatures; dynamic properties; corrosion and wear synergies; application related tests.

- Development of new hard materials: Alternative metallic binder (beyond Co) and carbides (beyond WC).

- Supporting Business Drivers: Recycling technologies, raw material supply and processing; additive manufacturing with HM powders (e.g. WC-Co). Energy efficiencies, powder characterisation and processing.

Case Study of “PM Inside”

Valve body for offshore subsea stations

Category: PM HIP Near Net Shape
Material: duplex stainless steel
Part weight: 250 kg to 2 tons

Benefits
- Improved strength properties vs. cast materials
- Easy inspection (reliable inspection by ultrasonic)
- No weld
- Less machining
- Optimized wall thickness
- Clad design also possible
- No need for repair welding
- Fast and reliable manufacturing route
PM Process used: Hot Isostatic Pressing

Vision 2025
Metal Injection Moulding (MIM):

The European MIM industry is a low cost, resource efficient alternative to conventional forming processes like micro investment casting. Further capital investment in production equipment and raw materials will be necessary to enhance the sector’s competitiveness against, among others, low cost manufacturers and reduce the current limitations of the process technology.

The objective of the MIM industry is therefore to use interdisciplinary research supported by industry to better understand the whole process chain from powder to the finished component, including simulation. The main innovation areas that the MIM industry intends to achieve by 2025 are:

• Improve raw material quality and specification methods (powders, as well as binders and feedstocks).
• Development of new materials and powder grades.
• Simulation of the process chain.
• Widen the size range of commercially viable components (micro and macro).
• Improve energy efficiency along the process with a focus on sintering.
• Advanced processes to include more functionality into components.
• Tailored properties of MIM components.
• “Zero defect” programme.
• Ensure the biocompatibility of materials as the medical market is of significant importance for the MIM industry.

Hot Isostatic Pressing (HIP):

As a unique forming process for high quality large complex parts the (HIP) sector is sometimes seen as a new player still to become a widely adopted standard production route for main stream materials manufacturing.

Further developments need to be generated to make HIP the first choice manufacturing route for demanding applications and these include:

• Research about kinetic vs pressure effects for phase transformation to promote materials development.

• Alloy systems that are innovative and more optimised than standard cast/forged alloys need to be developed.

• Hardenability of materials in the HIP during cooling, including reduction of thermal stresses need to be studied to promote PM-HIP.

• Other gas systems need to be developed for PM-HIP to optimise materials.

• Computer models to predict shrinkage of capsules must be more accurate.
Additive Manufacturing (AM):
The Additive Manufacturing industry is an emerging industry, which has benefited from large capital investment and shows high commercial potential. However, there are several fields where the European Metal AM industry will have to enhance its effectiveness and competitiveness if it intends to become a key enabling technology of tomorrow.

- Faster product development cycles through integrated solutions (software modelling, processing equipment, inspection systems).

- Laser processing of advanced materials, heat treatment processes e.g. HIP standards for AM.

- Improving the AM process robustness and performance by better powder handling, integration of post processing etc. Process development like speed, part size, standardized machines in order to run them with any powder.

- Decreasing AM Part Costs: Material efficiency, batch-to-batch consistency, machine-to-machine consistency, recycling, productivity and faster response to market by developing high volume machines, moving from batch to series production, developing on line quality control etc.

- Improved AM Component Performance: Feedstock or powder based AM techniques which can be easily transferred to other PM techniques, non-destructive testing and quality control of AM parts, improved homogeneity and surface roughness.

Case Study of “Metal Cutting Tool Inserts”

The machining part of the cutting tool is tipped with a replaceable insert and has typically multiple usable cutting edges that can be flipped or rotated after use, without a change in tool dimensions.

Benefit: Indexable metal cutting inserts are in more than three thousand product variations for turning, milling, drilling, reaming etc. produced in millions per day in automatic powder metallurgy production processes. It is estimated that on average about one insert per automobile is consumed, even though more than 200 different tools go into the manufacture of about 2000 components in a car.

Typical material properties of the inserts
Density: 14.5 kg/m³
Part Weight: 10 g
Dimension: 12.5 x 12.5 x 4 mm³
Tensile Strength: 1500 MPa
Hardness: 1600HV10

Majority of the inserts are coated with a few micrometer thick hard wear resistant layer (e.g. TiC, TiCN, Al₂O₃)
PM Process used: Hard Materials and Diamond Tools
SUMMARY

The PM industry has an opportunity to increase its footprint in key component manufacturing in almost all major industries where it is already present: Automotive, construction, aerospace, medical, consumer goods, electronics, etc… but it also intends to develop in new markets such as fuel cells, electric power generation and energy storage systems.

This should be done by combining several levels:

• Innovation in PM processes as well as improving the performance of PM materials and components.

• Developing new product opportunities, such as PM products corresponding to the needs of the new generations of cars.

• Supporting the customers to widen their knowledge about the current and future potential and benefits of PM. Wider dissemination and distribution of technical information and results will enable faster realisation in industrial applications.

• Increased effort to develop and promote international standards.
PM is understood in this document to mean the processing of metals in powder form to manufacture components, either sintered or bonded. The PM industry covered in this Roadmap comprises the following segments these being defined by the specific process route:

**Structural PM Components**

**Hardmetals and Diamond Tools**

**Additive Manufacturing (AM)**

**Hot Isostatic Pressing (HIP)**

**Metal Injection Moulding (MIM)**

The conventional route for PM processing is otherwise known as “press and sinter” due to the two main phases of the process route these are:

- **Pressing**: loading the powder into a die and applying pressure to produce a green compact having sufficient cohesion to enable it to be handled safely and transferred to the next step.

- **Sintering**: heating the compact, usually in a protective atmosphere, to a temperature just below the melting point of the main constituent.

For further information go to www.epma.com/process
Structural PM Components

Structural components both ferrous and non-ferrous represent the dominant sector in terms of tonnage: the near net shape forming of engineering (largely Automotive related) components, where PM is preferred on economic grounds. The conventional PM sector is now a mature technology, which can produce net-shape with high cost benefit. No other volume production technology can compete with PM regarding ISO tolerance reproducibility hence PM is net-shape and high precision.

However because of press tonnage considerations, PM is generally only available to produce parts of diameter less than 300mm. Therefore it is best for high volume; high value small items, automotive engine and transmission parts are a classic example of its success.

Structural PM is also the basis for two sub sectors being:

a) Powder forging whereby a powder blank is formed into a simple shape which is then forged into a near net shape with very high density. This technique is commonly used for components for the automotive and aerospace industry.

b) Production of magnets. Of the two major types of magnets produced, around 80% of hard magnets are produced using PM, but less than 10% of soft magnets are currently produced by this method. The European share of the €10 billion/year magnets market has declined in recent years as the Chinese have become dominant producers. Those remaining suppliers focus on integrated systems and more complex applications.

Hardmetals and Diamond Tools

Hardmetal is the term used to signify a group of sintered, hard, wear-resisting materials mainly based on the carbides or nitrides of one or more of a range of elements including tungsten, molybdenum, titanium and vanadium. These are bonded with a metal of lower melting point, usually cobalt, nickel or iron. Tungsten carbide is the most widely used and European production of Hardmetals and Diamond Tools amounts to c. 15,000t per year with a value of €7 billion.

Their range of application is extremely wide. The majority of applications are cutting tools for metal, wood, plastic and natural materials (e.g. mining). Hardmetals are also used as structural and wear parts like seal rings, extrusion and forming dies, nozzles, balls etc. across virtually all engineering sectors.

Diamond Tools are a sub set of this industry, which utilises the fact that Diamond is the hardest substance available for cutting. The majority of diamond impregnated tooling is made using the PM route. Currently they are extensively employed in stone processing, road repair, machining of glass, ceramics and metals, but one of the main and rapidly growing uses is cutting non-metallics, e.g. granite, marble, concrete etc.
**Additive Manufacturing (AM)**

It is a relatively new and nascent technology, but one with huge potential. The term Additive Manufacturing (AM) is understood here as “making parts based on 3D model data by classical layer-by-layer manufacturing techniques”.

AM at present is not a means for classical mass production of millions of identical parts, but is more for prototyping and low volume but highly complex components. Its advantages derive from its extremely high flexibility as this enables production of parts directly from a CAD model without any tooling being necessary, thus dramatically reducing the lead-time to production.

AM is able to produce almost any geometry which can be designed. Until now the outer geometry of a part and its function/strength were of main interest for the user, but AM allows the integration of additional functions and new fields of application of technical parts. The most famous example of the ability of AM systems to integrate functionality, is the production of parts with conformal cooling or vacuum channels running directly below the surface of an injection moulding die, or of an extrusion tool.

**Hot Isostatic Pressing (HIP)**

Hot Isostatic Pressing (HIP) is a process to densify powders or cast and sintered parts in a furnace at high pressure (1000-2000 times atmospheric pressure) and at temperatures from 900 to 1250°C. The gas pressure acts uniformly in all directions to provide isostatic properties and 100% densification.

It provides many benefits and has become a viable and high performance alternative to conventional processes such as forging, casting and machining in many applications. Its positioning is very complementary to other PM processes and is even used in combination with these PM processes for part densification.

**Metal Injection Moulding (MIM)**

MIM Process comprises four main stages namely:

- feedstock production
- single axis injection moulding
- debinding
- sintering

The sintering here is slightly different from the usual sintering step mainly because it involves higher temperatures, larger shrinkages, and almost full final density of the product.

MIM technology is a well-established manufacturing process for small precision components, which would be costly to produce by alternative methods. It is capable of producing complex shapes from almost all types of materials including metals, intermetallic compounds, and composites in both small and large volumes.
References

i: EU Manufacturing Industry: What are the Challenges and Opportunities for the Coming Years? Page 13.


iii: Key Enabling Technologies
http://ec.europa.eu/enterprise/sectors/ict/key_technologies/index_en.htm
“A European strategy for Key Enabling Technologies - A bridge to growth and jobs” Communication adopted on 26 June 2012. (June 2014)


v: Page 16, Figure 5: V. Kruzhanov, V. Arnhold, Energy consumption in powder metallurgical manufacturing, Powder Metallurgy (UK), Vol. 55, no. 1, p. 14-21, 2012

Acknowledgements

EPMA would like to thank the following companies for supplying images that have been used throughout this brochure:
AMES S.A.
Aubert & Duval
Ceratizit
Fraunhofer IFAM in co-operation with Scholz GmbH
FUSIA-ESTEVE
GKN Sinter Metals
Iscar
Lamina Technologies SA
Metso
MIMEST SPA
MORRIS Technologies
MTU Aero Engines
Plansee GmbH
PMG Fussen GmbH
Rolls Royce
Sandvik Coromant
Sandvik Powdermet
Schunk Sintermetalltechnik
Silicon Plastic S.R.L
SLM Solutions GmbH
Snecma
The AMRC with Boeing

Acknowledgements and thanks to the Steering Committee and all EPMA Members who assisted in the support and development of this revised Roadmap.

Copyright © European Powder Metallurgy Association 2015, Version 1.0.
About the EPMA

The European Powder Metallurgy Association (EPMA) was established in 1989 and is the trade association for the European powder metal manufacturing industries. Our objectives are Promoting PM technology, Promoting the European PM industry and Representing the European PM industry at an International level.

The EPMA members are a mixture of PM parts manufacturers, their suppliers and end users. They cover a variety of materials, processes and equipment from a total of 30 countries. Amongst the other EPMA activities members participate in industry statistics production, networking and benchmarking.

The Association also organises annually the major European scientific PM congress as well as other smaller workshops and seminars available to both industry and academia.

Finally our other major area of activity is training and education which includes an annual summer school for young graduates. E-learning materials include the “DesignforPM” courses for end-user designers and engineers and the Global PM Property Database a unique on-line resource developed by the PM industry.

The EPMA is one of the few European-level organisations with direct industry membership, which enables better industry contact and responsiveness. It is via our seven sectoral and working groups that much of the detailed guidance and actions for these activities are derived and this is an absolutely necessary function for us to remain an industry-led organisation. These sectoral groups have played a key part in the development of this roadmap.

For more information on Powder Metallurgy and the EPMA see our comprehensive website www.epma.com.