VOL. 17. NO. 4 WINTER 2023

FOR THE MIM, CIM AND SINTER-BASED AM INDUSTRIES

PIM INTERNATIONAL

IN THIS ISSUE

PARMACO: MICRO MIM MEETS SWISS PRECISION

CMG: MIM, AM & THE INDO-MIM PARTNERSHIP

ADVANCES IN SINTER-BASED AM

Published by Inovar Communications Ltd

www.pim-international.com

Publisher & Editorial Offices
Inovar Communications Ltd
11 Park Plaza
Battlefield Enterprise Park
Shrewsbury SY1 3AF
United Kingdom
Tel: +44 (0)1743 469909
www.pim-international.com

Subscriptions
PIM International is published on a quarterly basis as either a free digital publication or via a paid print subscription. The annual print subscription charge for four issues is £150 including shipping.

Design and production
Inovar Communications Ltd.
ISSN: 1753-1497 (PRINT)
ISSN: 2055-6667 (ONLINE)

INOVAR COMMUNICATIONS

FOR MIM, CIM AND SINTER-BASED AM

PIM INTERNATIONAL

Celebrating the success of smaller MIM producers

Whilst the MIM industry globally includes many large producers, each with a fleet of continuous sintering furnaces capable of delivering huge volumes of parts for the consumer electronics and automotive sectors, there is a much higher number of small MIM producers.

These MIM SMEs form a crucial part of the industry and they are often focused on specific markets, serving a local region, or offering unique technical capabilities that set them apart.

In this issue we report on visits to two such smaller MIM producers, Switzerland's Parmaco Metal Injection Molding AG and the UK's CMG Technologies Ltd. Both are successful, long-established producers with histories that can be traced back to the early commercialisation of MIM in Europe. Both companies are the leaders in their own domestic markets, and both have developed unique specialisations.

In the case of Parmaco, specialisation comes in the form of the production of micro MIM parts and high-precision MIM parts for the most demanding of applications. Here, the value to customers comes from the highest quality rather than the most competitive price.

In addition to its MIM operation, CMG has leveraged its binder and feedstock expertise to make a name for itself in filament-based metal Additive Manufacturing. The company is now producing its own brand of stainless steel filaments, and partners with the likes of BASF to offer toll debinding and sintering services for the German company's Ultrafuse material. Following its recent acquisition by Indo-MIM, it will be interesting to see how its trajectory changes.

Nick Williams
Managing Director & Editor

Cover image
MIM parts manufactured by Parmaco Metal Injection Molding AG for a robot-assisted surgical system (© 2023 Distalmotion. Image used with permission)

Winter 2023

PIM INTERNATIONAL





21 26 40 61 90

55 **Parmaco Metal Injection Molding AG: Swiss precision engineering that pushes the limits of MIM and micro MIM**

Since the earliest days of Metal Injection Moulding's commercialisation in Europe, in the early 1990s, Swiss company Parmaco Metal Injection Molding AG has been instrumental in perfecting the process for the most advanced applications. As well as a focus on 'Swiss precision', producing MIM parts to the highest dimensional accuracy, the company is also renowned for the production of complex microMIM® components.

Dr Georg Schlieper reports on a recent visit to the company for *PIM International*. >>>

65 **CMG Technologies: The UK's only MIM producer on its acquisition by Indo-MIM and expansion into filament-based AM**

CMG Technologies Ltd, the UK's only producer of components by Metal Injection Moulding, has had a busy few years. Most recently, the company hit the headlines when it was acquired by Indo-MIM, widely considered to be the world's largest MIM producer with significant operations in India and the US. Prior to this, CMG had been expanding its presence in the metal Additive Manufacturing arena, developing its own range of filaments and providing toll debinding and sintering services to users of BASF's Ultrafuse products. Dr Martin McMahon visited the company and reports on developments. >>>

Regular features...

09 Industry news

95 Advertisers' index & buyer's guide

98 Events guide

77 **Insight from Fraunhofer IFAM's 4th Workshop on Sinter-based Additive Manufacturing: A status update**

The 4th Workshop on Sinter-based Additive Manufacturing, organised by Fraunhofer IFAM, in Bremen, Germany, took place from September 13-14 2023. It convened global experts to discuss advancements and challenges in the field. The workshop explored the maturation and potential applications of sinter-based AM technologies and highlighted the latest technical advances.

Sonja Böske da Costa reports on the workshop's presentations and discussions. >>>

89 **Metal Additive Manufacturing micro parts: How Computational Engineering methods can enable new micro robotic applications**

Metal Injection Moulding has been the technology of choice for the micro robotics industry for many years, delivering micro-sized precision metal components in medium to high volumes. As the complexity and number of applications increases, there is an opportunity for accelerated product development and more flexible manufacturing through the combination of sinter-based Additive Manufacturing and Computational Engineering.

Here, Dr Gerald Mitteramskogler, Josefine Lissner and Dr Stefan Bindl consider how these technologies can be combined for the best possible results. >>>

Regular features...

09 **Industry news**

95 **Advertisers' index & buyer's guide**

Discover the leading suppliers of materials and equipment for MIM, CIM and sinter-based AM, as well as part manufacturing partners and more. >>>

98 **Events guide**

View a list of upcoming events for the MIM, CIM & sinter-based AM industries. >>>

Industry News

HP partnership with Indo-MIM to advance its Metal Jet technology

HP has announced a strategic partnership with Indo-MIM headquartered in Bangalore, India. As part of this collaboration, Indo-MIM will invest in three HP Metal Jet S100 Binder Jetting machines.

Two of three machines will be stationed at Indo-MIM's Bangalore facility. One of them will focus on new material development, while the other will be driving application development and cater to customers in the Middle East, India and the rest of the Asia-Pacific region. The third unit will be based in Texas, USA, reinforcing Indo–MIM's commitment to providing localised support to North American clients and expanding their production capabilities.

"We are proud to partner with Indo-MIM to create new possibilities for their customers leveraging our S100 solution and metals additive manufacturing capabilities. We are thrilled to work with Indo-MIM to drive new metals applications, expand material possibilities and increase precision and productivity," stated Savi Baveja, President of Personalization & 3D Printing and Chief Incubation Officer, HP Inc. "We share a common purpose to accelerate innovation, grow adoption and scale breakthrough applications."

Krishna Chivukula Jr, CEO at Indo-MIM also noted, "Our partnership with HP signifies a milestone in our journey to provide cutting-edge production ready 3D metal binder jet solutions to our customers. The acquisition of HP's Metal Jet S100 printers equips us with the latest technology, enabling us to meet the growing demands of our customers with efficiency and precision, as well as expand the library of materials qualified on the HP printer platform."

As well as expanding their Additive Manufacturing capabilities, HP and Indo-MIM are also working to qualify new materials (e.g. M2 tool steel) for the HP Metal Jet. These are anticipated to unlock an array of capabilities, including improved properties and dimensional tolerances. Indo-MIM will also leverage HP's Process Development software to deliver solutions for speed, scalability, and adaptability.

HP's Savi Baveja (left) and Indo-MIM's Krishna Chivukula Jr (right) announced the partnership at this year's Formnext (Courtesy HP)

Mukund Nagaraj, Head of Additive Manufacturing, praised the software, stating, "The HP Process Development software is very impressive for managing application development workflows, while the newly-released Digital Sintering software will help INDO-MIM simulate and speed up the process to reach production quality parts in fewer iterations."

www.hp.com
www.indo-mim.com

Indo-MIM has added three HP Metal Jet S100 machines as part of a wider collaboration with the company (Courtesy HP)

Cadence acquires ARC Florida to bolster its medical device manufacturing

Cadence, Inc, headquartered in Staunton, Virginia, USA, has acquired ARC Florida, a precision manufacturer specialising in Metal Injection Moulding (MIM) and cleanroom plastic injection moulding, from ARC Group Worldwide.

"Acquiring ARC Florida is another major step in our strategy to be a leading medtech manufacturing partner to our customers, providing complete solutions from early-stage development to scaled manufacturing. By adding MIM to the Cadence portfolio, we further expand our vertical manufacturing platform with another cost-effective method to increase volume production as products reach scale," stated Rob Werge, Cadence's president and Chief Executive Officer.

"We look forward to leveraging the company's deep expertise in high-precision Metal Injection Moulding for medical devices and combining it with Cadence's suite of capabilities across seven locations worldwide, to fully realise the value created through our unique integrated model," added Werge.

Cadence has seen significant growth in its medical and drug delivery markets. The acquisition of ARC Florida is expected to further expand Cadence's capabilities and market focus. Earlier this year, the company also acquired Utitec, Inc, which added precision deep draw technologies to its range of capabilities. With the addition of MIM and cleanroom plastic injection moulding, Cadence intends to position itself as a reliable supplier of comprehensive contract manufacturing solutions.

"With the accelerated growth in minimally invasive and robotic assisted surgeries, customers are increasingly looking to consolidate metal suppliers with full capabilities from machining, MIM, stamping, deep draw, laser welding, sharpening and plastic insert moulding to reduce the long tail of metal suppliers," said Werge. "Cadence is now ideally suited to be a contract manufacturer of choice to help drive both innovation and scaled production throughout the product lifecycle, while helping drive metals supplier consolidation."

www.cadenceinc.com
www.arcw.com

CNPC Powder raises $13.6 million for expansion of metal powder production

CNPC Powder, with its head office in Vancouver, Canada, reports that it has successfully raised nearly $13.6 million in Series A funding. The company plans to expand its atomisation capacity by adding over forty production lines. Its product portfolio includes titanium alloys, aluminium alloys, iron alloys, copper alloys, nickel alloys, and a wide array of high-temperature and custom alloys. Currently, the annual output from its China-based production facility surpasses 3,500 tons.

CNPC Powder's Series A funding round was led by Shunwei Capital and included participation from Dunhong Asset. Jupiter Capital provided long-term exclusive financial advisory and strategic support. As well as expanding production lines, the raised funds will be vital for advancing technical research and development and recruiting top talent, among other key initiatives.

CNPC plans to expand its atomisation capacity by adding over forty production lines (Courtesy CNPC Powder)

Since the inception of its AM Campus in 2017, CNPC Powder has been committed to the research and production of metal powder materials for advanced manufacturing. Its products, which the company states are supplied to over forty countries, primarily serve the metal Additive Manufacturing industry, but are also used in Powder Metallurgy, Metal Injection Moulding, electronic materials, and various other fields.

The company is certified to ISO9001, ISO41001, ISO45001, ISO13485, and IATF16949 standards, and states that these certifications demonstrate its technological expertise, which is shown through its proprietary process systems, capabilities in alloy research and development, production capacity, and control of powder size and sphericity.

www.cnpcpowder.com


TEKNA
MIM POWDER
MANUFACTURER
Ti64
Al ALLOYS
W
Ta
Ni ALLOYS
CHARACTERISTICS
Plasma Quality Powder
High Sphericity
High Purity
Traceability
Tekna.com

Holo launches H200 machine for high-volume metal part production

Holo Inc, based in Newark, California, USA, has launched the H200 production metal Additive Manufacturing machine. The H200 uses Holo's PureForm™ AM platform to produce highly-precise metal parts based on a sinter-based Vat Photopolymerisation (VPP) process.

Over the past nine months, Holo reports it has been using the H200 in its Additive Manufacturing services to supply complex metal parts with high resolution and precision. The components demonstrate fine detail up to 50 µm and maintain strict tolerances within +/-25 µm. Unique to PureForm™, the final parts match the surface smoothness of commercial MIM parts, exhibiting a roughness of 1-3 µm Ra. This is said to eliminate the need for additional machining or polishing required by other metal AM technologies.

Holo's PureForm™ commercial material offering currently includes stainless steel grades 17-4PH and 316L, along with pure copper. The portfolio is extending to include Inconel and Ti64 on a pre-commercial basis. All commercial materials from Holo meet the MPIF-35 specifications.

"True to CAD™ from Holo's technology means that our H200 system produces MIM-quality parts without the mould," stated Holo co-founder and Chief Strategy Officer Arian Aghababaie, PhD. "For most applications, our technology does not require parts to go through any post-machining or polishing; it sinters parts to spec for a first-time-right approach suited for demanding, high-volume end-use applications."

Having been developed over multiple generations of machines and with over 10,000 parts shipped to customers so far, Holo's H200 has demonstrated its readiness for commercial use. Customers from demanding sectors such as medical, aerospace and defence, consumer electronics, and the semiconductor industry are reported to be adopting the technology.

"We are thrilled for customers to gain access to the H200," stated Holo CEO Hal Zarem, PhD. "Production volumes of parts in fields like surgical instruments will be within reach, finally fulfilling the promise of Additive Manufacturing as a scalable, production-ready suite."

www.holoam.com

HP and Sandvik collaborate to bring advanced materials to HP's Metal Jet

HP Inc has announced a strategic collaboration with Sweden's Sandvik AB to bring advanced materials, such as superalloys and 316L stainless steel, to HP's Metal Jet Additive Manufacturing technology. The partnership will build on the existing and successful collaboration to develop 17-4PH stainless steel powder for use in the company's Binder Jetting machines.

Ramon Pastor, Global Head of 3D Metals at HP, stated, "This collaboration is a game-changer. Our collaboration with Sandvik broadens Metal Jet's capabilities, empowering industries to revolutionise manufacturing processes and products."

Sandvik and HP are working with Parmatech, an ATW Company, headquartered in Petaluma, California, and Endeavor 3D, Douglasville, Georgia. Alexandre Tartas, Global Head of Go-To-Market, HP Personalisation & 3D Printing, added, "These materials are strategically crafted to empower our valued customers, enabling them to explore groundbreaking applications, especially in the aerospace and industrial sectors."

Andrew Coleman, Head of Additive Manufacturing at Sandvik, commented, "By combining the expertise of our companies, I believe the collaboration will lead to advancements in both materials and manufacturing technology that will ultimately benefit our customers."

www.hp.com
www.home.sandvik

Tekna secures major titanium powder order from leading Asian MIM manufacturer

Tekna Holding ASA, based in Sherbrooke, Quebec, Canada, has received a significant titanium powder order worth CA $2.9 million from a leading Tier 1 component manufacturer in Asia. The customer will use the titanium powder for the Metal Injection Moulding of digital watch cases and dials, designed for use in personal electronic devices.

A similar order, valued at CA $1.7 million, was received from the same customer in May 2023. Deliveries for this new contract are scheduled to begin in 2024.

"This order is for material consisting of the smaller particles from our existing powder production, which is readily available in our inventory. It plays an important role in our strategy to secure sales of Tekna's entire production capacity and aligns with our ambitious growth objectives," shared Luc Dionne, CEO of Tekna. "We are proud to be a part of this innovative manufacturing process and look forward to provide support to this customer in its manufacturing requirements".

Rémy Pontone, VP Sales and Marketing, stated, "Metal powder production processes naturally yield a wide distribution of particle sizes. These powders are subsequently separated into different cut sizes, each becoming a different product. Traditionally in the industry, some cut sizes have been considered of limited use and even discarded as waste. Through collaborative efforts with our customers, we have successfully qualified this smaller cut size for MIM, leading to improved resource efficiency, heightened sales yield and a substantial increase in market share within the consumer electronics components industry."

Tekna's titanium alloy powder is said to offer a high level of sphericity, low oxygen content, high density (bulk and tapped) as well as controlled grain size. In addition to Ti64 titanium alloy powder, Tekna produces tungsten and tantalum powders for MIM applications.

www.tekna.com

HP and Elnik collaborate to optimise sintering for HP's S100 Metal Jet Additive Manufacturing

HP Inc, based in Palo Alto, California, USA, has announced a strategic collaboration with Elnik Systems, LLC, and its sister company DSH Technologies, headquartered in Cedar Grove, New Jersey, USA, to develop a furnace configuration specifically for processing additively manufactured parts produced on HP's commercial S100 Metal Jet machines.

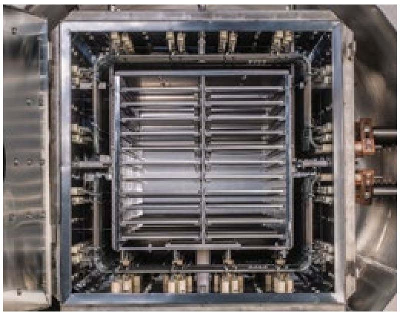
"This collaboration equips customers using HP's commercial S100 Metal Jet Solution with advanced sintering capabilities, opening up new horizons in 3D printing for industries worldwide," stated Ramon Pastor, Global Head of 3D Metals at HP.

Elnik Systems has modified its standard Metal Injection Moulding furnace to meet the needs of Binder Jetting Additive Manufacturing. The partnership is expected to enhance the capabilities of HP's S100 Metal Jet Binder Jetting machine by leveraging the vast sintering expertise and capabilities offered though Elnik's many years supplying the Metal Injection Moulding (MIM) industry.

As part of the collaborative effort, DSH Technologies is also committed to sharing its technical processing knowledge and expertise. This, it was stated, will help part producers with a go-to-market strategy, based on technical awareness and production scale capabilities.

"Working together with the HP team has been amazing," added Stefan Joens, president of Elnik Systems. "The mutual interest to see the metal 3D printing technology advance through team-effort discussion, innovation, and desire is what will help this manufacturing technology become a fully capable processing method of the future."

www.hp.com
www.elnik.com
www.dshtech.com



HP has partnered with Elnik Systems to develop a furnace configuration for processing metal AM parts (Courtesy Elnik Systems)

EPMA issues Call for Papers for Euro PM2024 conference

The European Powder Metallurgy Association (EPMA) has announced its call for papers for presentation at Euro PM2024, scheduled to take place September 29 - October 2, 2024, in Malmö, Sweden. As the leading European Powder Metallurgy conference, the three-day event will attract industry leaders, decision-makers, respected academics and PM related companies and personnel from across the world.

Euro PM2024 will feature a technical programme with around 250 oral and poster papers, as well as a 5,000 m^2 exhibition showcasing the latest developments from the global Powder Metallurgy supply chain. There will also be a number of social events, including the welcome reception and gala dinner, will also provide ideal networking opportunities.

The technical programme, with plenary, keynote, oral and poster presentations, as well special interest seminars, will focus on all aspects of PM, including:

- Powder production
- Consolidation technologies
- Materials
- Applications
- Tools for improving PM

The Euro PM2024 exhibition, held Monday to Wednesday, will showcase the entire PM supply chain, with international exhibitors ranging from metal powder suppliers, press and furnace makers, to tooling producers and quality testing equipment suppliers.

The abstract submission deadline is January 15, 2024.

www.europm2024.com

RAPID + TCT 2024 Additive Manufacturing expo heads to Los Angeles

SME and Rapid News Publications have announced that next year's RAPID + TCT will take place June 25-27 in Los Angeles, USA. The three-day event, to be held at the Los Angeles Convention Center, will include both a conference and an exhibition.

After nearly a decade, the show is returning to the West Coast, seen as the centre of manufacturing output in the US. This region is home to over 36,000 manufacturing firms that employ nearly 1.4 million people.

A call for speakers has been issued for those wishing to present a paper at the conference. Abstracts that focus on case studies, research findings and technical analyses are being requested. The deadline for submitting an abstract is January 5, 2024.

www.rapid3devent.com

Sandvik to acquire US tungsten powder manufacturer Buffalo Tungsten

Sweden's Sandvik AB has announced it is to acquire Buffalo Tungsten, Inc. (BTI), a manufacturer of tungsten metal powder and tungsten carbide powder headquartered in Depew, New York, USA. The acquisition of BTI is set to expand Sandvik's presence in the North American market and strengthen its regional capabilities in the component manufacturing value chain.

The integration of BTI is also expected to provide the opportunity to optimise material sourcing and boost the local production of tungsten metal powder at the Depew facility. The acquisition will complement the production of similar products at Sandvik's Wolfram facility in St Martin, Austria.

"With the acquisition of BTI we take an important step in our strategic ambition to strengthen our presence in the North American market. BTI will enhance our regional capacity to produce tungsten powder locally in the US, which will improve our competitive position," shared Stefan Widing, president and CEO of Sandvik.

BTI was founded in 1987 and currently employs forty-eight people. In 2022, the company generated approximately SEK 333 million in revenue. The impact on Sandvik's EBITA margin is anticipated to be minimal, but the earnings per share are expected to increase.

"With BTI we will be able to better meet the customer demand which will give us great opportunities in North America. BTI's contract for clean hydropower from the Niagara Power Project will also enable us to manufacture tungsten in a more sustainable way," added Nadine Crauwels, president of Sandvik Machining Solutions.

Sandvik will be able to produce tungsten powders in the USA (Courtesy Buffalo Tungsten)

Both parties have agreed not to disclose the purchase price, with the transaction expected to close in Q4 2023. Once completed, Buffalo Tungsten will be reported within the business area segment Sandvik Machining Solutions.

www.home.sandvik

www.buffalotungsten.com

DSB adopts Desktop Metal's complete X-series metal Binder Jetting lineup

DSB Technologies, a manufacturer of Powder Metallurgy and Metal Injection Moulding components headquartered in Janesville, Wisconsin, USA, has adopted Desktop Metal's complete X-Series metal Binder Jetting (BJT) product lineup, including Live Sinter simulation and correction software. DSB currently uses Desktop Metal's InnoventX, X25Pro, and X160Pro machines to deliver customer parts made from a variety of metals, including 316L and 17-4PH stainless steels, 4140, and M2 Tool Steel. The company also intends to utilise Desktop Metal BJT technology for aluminium in the future.

"Binder Jetting really is a forming technology that gives us unlimited design potential," stated Paul Hauck, Chief Operating Officer at DSB Technologies. "We can go from a very simple shape to very complex things you can't produce in hard tooling, taking complexity beyond what's possible with Metal Injection Moulding. Binder Jetting creates applications never produced before, and we want to be a leader in that."

DSB is home to over thirty high-temperature continuous sintering furnaces, which is believed to be the largest installed capacity in North America. Out of the 3,630 tonnes of metal powder processed by DSB annually, approximately 90% are grades of stainless steel. Currently, DSB serves markets including aerospace, automotive, defence, electronics, industrial and medical.

"The exciting part about Binder Jetting is the path from concept to part is all digital," Hauck added. "You're not sending a CAD file over to a tool shop that then creates a reverse image. So, you're taking as few as eight weeks, and maybe as many as sixteen or twenty weeks, out of that process."

DSB has gradually implemented Desktop Metal's BJT technology over the past few years. The InnoventX lab-sized machine, first installed in 2021, is used for material development and testing initial sintering parameters. The X25Pro, installed in 2022, allows the team to scale those successful tests up to application development in a mid-size machine that is also capable of bridge production. The X160Pro, installed in 2023, offers the largest build volume for taking applications to serial production.

Hauck added that the Live Sinter software is highly effective in reducing iterations and saving time, "We now have very useful scientific analytical tools that enable successful outcomes. It's helping us solve application problems, get successful outcomes, and get there faster," he concluded.

www.dsbtech.com

www.desktopmetal.com

Epson Atmix begins construction of its new metals recycling facility

Epson Atmix has begun construction of its new recycling facility (Courtesy Epson Atmix)

Epson Atmix Corporation, a group company of Seiko Epson Corporation, located in Aomori, Japan, has announced it will invest almost $37 million (¥5.5 billion) in a new facility to recycle metal waste in order to produce the raw material for metal powder production.

The company aims to recycle unwanted metals from various sources, including out-of-specification metal powders used in manufacturing processes at Atmix, metal scraps generated within Atmix, and metal end cuts and used moulds discarded by the Epson Group.

The planned facility is also seen as a step towards achieving Epson's goal of becoming completely resource-free by 2050, as outlined in its Environmental Vision 2050.

Atmix produces a range of metal powders for a variety of manufacturing processes, including Metal Injection Moulding and Additive Manufacturing. The company also produces magnetic powders for use in power supply circuits, as coils for IT equipment such as smartphones, and for hybrid cars and electric vehicles.

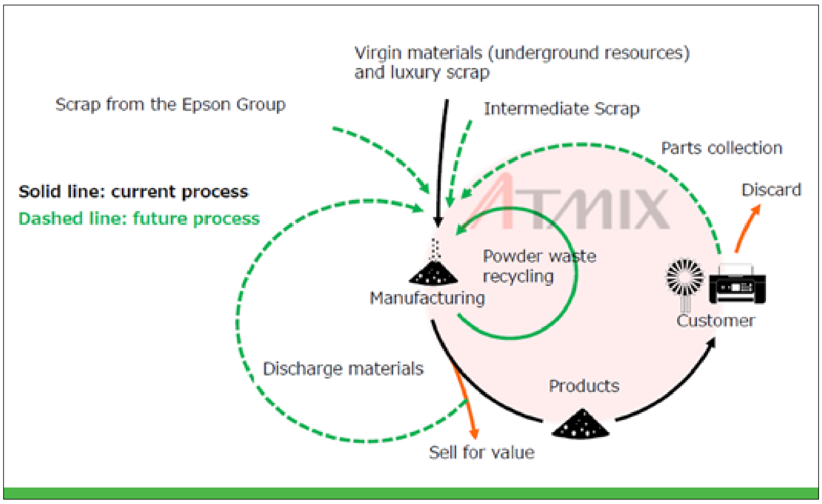


Image highlights the current resource circulation process compared to the future process (Courtesy Epson Atmix)

The new factory will be equipped with a high-frequency induction furnace for melting metals, an AOD refining furnace for removing impurities from metals, and a casting machine for forming ingots.

A groundbreaking ceremony for the new facility was held on October 12 at the Hachinohe Kita Inter Industrial Park, with construction scheduled to start shortly after. The factory is expected to begin operations in June 2025.

www.atmix.co.jp

MPIF names Michael Stucky as president and Stefan Joens as president of its Metal Injection Molding Association

The Metal Powder Industries Federation (MPIF) reports it has elected Michael Stucky as the trade association's 32nd president. Stucky's two-year term began upon the conclusion of the MPIF's annual Business Meeting, held on October 30, 2023.

Stucky, currently Business Unit Director at Norwood Medical, Bellbrook, Ohio, has been with Norwood for the past eleven years. Previously, he worked for another eleven years at NetShape Technologies and ten years at PCC Airfoils.

Being very active within the MPIF and the Metal Injection Molding Association, Stucky has served on the MPIF Board of Governors as MIMA President. He is currently chairman of the MIMA Standards Committee, a MIMA representative on the MPIF Technical Board and was a co-chair of the PowderMet2023, MIM2017 and MIM2018 conferences. Over the years he also served on the PowderMet and AMPM Technical Program Committees. Stucky received the Distinguished Service to Powder Metallurgy Award in 2019.

The MPIF also announced that Timothy Hackett has also been named president of the Metal Powder Producers Association (MPPA) and Stefan Joens as president of the Metal Injection Molding Association (MIMA). Nicola Gismondi and Christopher Adam, have retained their positions as a presidents of Powder Metallurgy Parts Association (PMPA) and Association for Metal Additive Manufacturing (AMAM), respectively.

www.mpif.org

Over one million tungsten setback pins produced by PTI Tech

PTI Tech, headquartered in Clifton, New Jersey, USA, has now delivered over one million tungsten MIM components to Action Manufacturing Corp, a manufacturer of fuzes based in Bristol, Pennsylvania, USA. Leveraging its Metal Injection Moulding technology, PTI Tech manufactures the high-precision tungsten setback pins used in the M739A1 Point Detonating Fuze on the M107 and M795 155 mm artillery rounds.

PTI Tech was originally contacted by Action Manufacturing Corp to assist with a production issue that they were experiencing with a vendor of tungsten components. Tungsten is a high-value material that is very difficult to work with via conventional manufacturing methods (such as subtractive machining methods) and impossible via other methods, like investment casting. The vendor, employing press and sinter tungsten manufacturing, was reported to be having difficulty meeting shipment deadlines, as well as delivering high levels of non-conforming parts that required visual inspection and sorting.

PTI Tech utilised its MIM technology and advanced multi-cavity mould tooling to manufacture the tungsten setback pin net-shape, maintaining tight tolerances and providing high throughput. With MIM, tungsten and other refractory metals are moulded net-shape, then de-bound and sintered.

In addition to MIM, PTI Tech has advanced polymer and ceramic injection moulding capabilities, supporting the aerospace, medical, defence, and industrial sectors for over 30 years.

www.pti.tech

PTI Tech has produced over one million high-precision tungsten setback pins used in the detonating fuze for artillery rounds (Courtesy PTI Tech)

Markforged reports economic uncertainty leading to restructuring and workforce reduction

Markforged, headquartered in Watertown, Massachusetts, USA, has announced its financial results for the third quarter and nine months ended September 30, 2023. For Q3, the company reported revenue of $20.1 million, down from $25.2 million year on year. In the first nine months of 2023 its revenue was $69.6 million, down from $71.3 million in the first nine months of the previous year.

Markforged stated that a stronger than expected macroeconomic downturn had impacted demand for its Digital Forge and delayed orders toward the end of the quarter, with these challenges continuing into the fourth quarter. The persistent high cost of capital and uncertainty in the macro environment was reported to be restricting capital investment in the short term more than previously anticipated.

In response to the continuing economic headwinds, Markforged announced it has completed a restructuring that, coupled with other cost reduction efforts, is expected to deliver operating costs savings of approximately $9-12 million in 2024. The company added that most of these savings are being driven by a reduction in its workforce of approximately 10%.

"While the medium-to-long-term opportunity for Markforged to help manufacturers reduce costs and strengthen supply chain resiliency remains intact, our third quarter results reflect worsening macroeconomic headwinds in the final weeks of the quarter, which delayed several large deals that we had expected to close," stated Shai Terem, president and CEO of Markforged.

"We remain laser focused on profitability. In light of these headwinds, which have persisted into the fourth quarter, we have implemented cost reduction efforts to align our operating expenses to match anticipated near-term demand. With that, the overwhelming excitement surrounding our new product introductions at Formnext 2023… is a testament to the transformative impact our offerings are set to make in the manufacturing industry. In particular, the customer enthusiasm surrounding the FX10 is reinforcing our confidence that Markforged is well-positioned for strong growth as macroeconomic uncertainty clears."

In Q3 2023, gross margin was 45.7% compared to 48.6% in Q3 2022. Operating expenses were $59.6 million, inclusive of a non-cash goodwill impairment charge of $29.5 million as a result of the company's performance during Q3 and decline in forecasted revenue, compared to $35.1 million. Net loss was $51.4 million compared to the $23.0 million in Q3 2022.

www.markforged.com

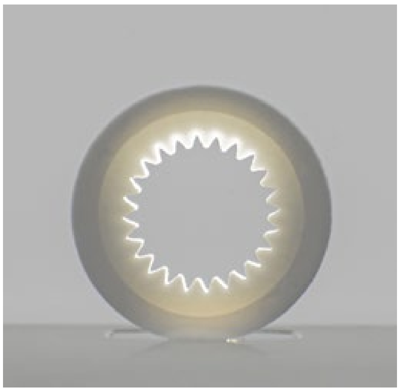
Canada's Dalhousie University expands ceramic processing capability with two Lithoz machines

Lithoz GmbH, Vienna, Austria, has announced the installation of two of its Additive Manufacturing machines at Dalhousie University, Nova Scotia, Canada. The machines, a CeraFab Multi 2M30 and a CeraMax Vario V900, offer unique capabilities for processing high-performance ceramics.

The first machine, the new Lithoz CeraFab Multi 2M30, is capable of multi-material Additive Manufacturing. Thanks to the machine's capability to combine ceramic and metal materials in a single layer and component, Dalhousie will look at incorporating electrical circuitry into ceramic components. The advancement of piezoceramics in this way will support the work of the HI-AM programme, which works across Canada to overcome the obstacles facing the industrial adoption of metal Additive Manufacturing.

The second machine, the CeraMax Vario V900, is based on Laser-Induced Slipcasting (LIS) technology. LIS is designed specifically to manufacture large, thick-walled, and fully-dense ceramic parts. It also enables the processing of dark ceramics such as silicon carbide, whose material properties are highly sought after in many demanding applications under extreme conditions. Dalhousie will employ Lithoz LIS technology to significantly enhance its research and development projects 'on the dark side of ceramics' – specifically silicon nitride, titanium carbide, and silicon carbide. This is also expected to aid in advancing industrial applications.

Working with carbide materials can be challenging due to the difficulties of processing through Additive Manufacturing and the limitations or defects of other processing technologies. However, Dalhousie has stated that LIS is the first Additive Manufacturing technology to achieve high resolutions and simplify the process. Its efficient manufacturing process reportedly eliminates the need for debinding and uses standard industrial slurries. This allows parts to go directly from manufacturing to sintering, speeding up and improving the precision of ceramic part production. As the only technology currently capable of producing sintered silicon carbide parts, states Lithoz, LIS technology is a game-changer for manufacturers interested in dark ceramics.



A multi material AM gear combining alumina and zirconia-toughened alumina produced on the CeraFab Multi 2M30 (Courtesy Lithoz)

The CeraMax Vario V900 (left) and the CeraFab Multi 2M30 (right) have been installed at Dalhousie University in Canada (Courtesy Lithoz)

Prof Kevin Plucknett, IW Killam Memorial Research Chair at Dalhousie University, shared, "With the installation of two new Lithoz printers at our facilities, we are seeing the beginnings of a real 3D printing hotbed at Dalhousie. By offering such state-of-the-art technology, researchers from across North America now have the chance to get in contact and work with Dalhousie using the technology that can really achieve their goals, while the active support and trainings provided by Lithoz as a partner will help us make the most of this process. We look forward to seeing how our 3D printing facilities can drive innovation throughout North America!"

These investments were supported by the Canada Foundation for Innovation (CFI) Infrastructure Fund. Dalhousie's $9 million funding is said to underscore the promising potential of Lithoz technology for both research and industry.

www.lithoz.com
www.dal.ca

Sandvik's science-based targets for GHG emission reduction validated; company rebrand

Sandvik AB has reported that its targets for reducing greenhouse gas (GHG) emissions have been validated by the Science Based Targets initiative (SBTi). These targets are now confirmed to be in line with the latest climate science and consistent with the goals of the Paris Agreement.

Sandvik made a commitment to establish targets that meet SBTi's criteria in December 2021, and submitted the new targets for validation in November 2022.

Sandvik's new target is to achieve net-zero GHG emissions by 2050 at the latest. As a part of these targets,

Targets for reducing greenhouse gas emissions have been validated (Courtesy Sandvik AB)

Sandvik aims to reduce absolute scope 1 and 2 GHG emissions by 50% by 2030 (based on 2019 levels), and to decrease absolute scope 3 emissions by 30%. Furthermore, Sandvik is committed to reducing absolute scope 1 and 2 GHG emissions by 90% by 2040.

"We are very pleased that our emission reduction targets have now been validated by SBTi, and we look forward to continue driving the shift towards strengthened sustainability and productivity in the industries we serve. We can have a big impact through our customer offerings, such as battery-electric and automated mining solutions, productivity-enhancing manufacturing and machining solutions, and energy-efficient rock processing solutions," stated Stefan Widing, president and CEO of Sandvik.

The SBTi is a collaboration between CDP, the United Nations Global Compact, World Resources Institute (WRI), and the World Wide Fund for Nature (WWF). Its main objective is to accelerate companies worldwide in reducing emissions by 50% before 2030 and achieving net-zero emissions by 2050.

In a further announcement, the company introduced a change to its visual branding. The new logo is said to draw inspiration from the 1962 Sandvik logo, paying tribute to the company's heritage and history. Additionally, a new symbol has been introduced as the primary representation of the Sandvik brand and corporate purpose. It symbolises 'progress' and 'circularity,' visually encapsulating Sandvik's commitment to advancing the world through engineering.

www.home.sandvik

Gevorkyan plans US and Mexican factories following €30 million IPO

Powder Metallurgy parts producer Gevorkyan a.s., headquartered in Vlkanová, Slovakia, reports that following last year's successful IPO and listing on the Start Market, part of the Prague stock exchange, the company is planning further expansion and aims to establish new facilities in both the USA and Mexico in the coming months. Gevorkyan is also seeking listing on the other stock exchanges.

In June 2022, the Start Market IPO raised some €30 million for the company and these funds have been used to expand the facility in Vlkanová. This has included acquiring buildings adjacent to its existing site, increasing production capacity and purchasing new presses, furnaces, machining equipment and industrial robots. The facility now also boasts its own nitrogen and hydrogen generation.

Gevorkyan was established in Slovakia in 1996 by Artur Gevorkyan. Having moved from his native Armenia in the early 1990s, he first founded a Powder Metallurgy magnet plant in Ukraine before leaving the region and moving to Slovakia in 1996. The new business expanded its focus to a wider variety of PM and today includes MIM, HIP and metal AM production. Over the years, Gevorkyan has gained a growing list of customers, which now includes companies such as Linde, Komatsu and Siemens. It also cooperates with fashion brands such as Yves Saint Laurent and Versace, for which it produces metal clasps and decorations.

Artur Gevorkyan, Owner & general manager of Gevorkyan a.s. (right) welcomed the Prime Minister of the Slovak Republic, Ľudovít Ódor, during a recent visit to the Gevorkyan facility (Courtesy Gevorkyan)

In 2022, Gevorkyan was the first foreign company to join the Czech Start Market. The exchange is aimed at small- and medium-sized companies, and after a year of trading, Gevorkyan is now looking to enter the main floor of the Prague Stock Exchange. The company is also in parallel negotiations with the Bratislava Stock Exchange.

www.gevorkyan.sk

Metal Injection Moulding used in Casio's flagship G-Shock Mudmaster watch

Casio Computer Co, Ltd, based in Shibuya, Tokyo, Japan, has announced the latest addition to its family of G-Shock watches. The new Mudmaster GWG-B1000, a member of Casio's 'Master of G' lineup, features a complex stainless steel front button guard manufactured by Metal Injection Moulding (MIM).

With its main case made from carbon fibre-reinforced resin, the Mudmaster GWG-B1000 is designed to withstand harsh environments and employs a newly developed guard structure that features components made with stainless steel.

In addition to the MIM front button guard, the other stainless steel guard components include the upper and lower bezel guards. These are machined out of pre-forms that are first forged into bezel shapes, explained Casio. Carbon fibre-reinforced resin is then used for left and right side button guards.

The complex form of the front button guard is achieved thanks to Metal Injection Moulding (Courtesy Casio)

The Casio Mudmaster GWG-B1000 features a front button guard made by Metal Injection Moulding (Courtesy Casio)

MIM enables the production of high-precision metal parts with complex three-dimensional shapes and was said to be the ideal production method for the front button guard. "We use Metal Injection Moulding to achieve a dimensional form befitting the Master of G name," stated Kazuyasu Kojima from the Product Planning Section, Timepiece Business Unit at Casio.

www.casio.com

GKN Additive and HP aim to bring together advanced materials and innovative tooling solutions

HP Inc and GKN Additive have announced a collaboration that aims to bring together advanced materials and innovative tooling solutions. Initially, the partnership will focus on qualifying a range of metal powders for users of HP's Metal Jet S100 Additive Manufacturing machines, beginning with ten different steel grades that include M2 tool steel and a dual-phase steel.

A strategic area of focus of the collaboration will be to advance GKN's efforts to combine HP's Metal Jet S100 Binder Jetting technology with unique material offerings, allowing a precision-focused approach tailored to specific customer challenges. This aims to speed up innovations in the tooling industry, resulting in increased productivity and quality, eliminating the need for traditional machining.

The companies highlighted examples of such innovations, which include:

- No machining: Develop near-net shaped tools, significantly reducing material waste and production time
- Wire/sink erosion: Final contour of tools is achieved through wire/sink erosion, ensuring precision and efficiency
- HIP (Hot Isostatic Pressing): Enhance the density and integrity of additively manufactured components, optimising their performance
- Plasma nitriding: Surface treatment to improve wear resistance and durability
- PVD-coating (Physical Vapour Deposition): Provide tools with enhanced surface properties

It was added that the partners will continue expanding material availability for the tooling industry, leveraging GKN's material and production expertise and HP's process knowledge. Customers can buy powders directly from GKN and access HP's Professional Services to set up a development programme tailored to their specific needs.

www.hp.com
www.gknpm.com

The largest Formnext exhibition yet attracts some 33,000 visitors

This year's Formnext once again brought the global Additive Manufacturing industry to Frankfurt, Germany, with visitor numbers totalling almost 33,000, up an impressive 11% on the previous year.

Now in its ninth year, 2023 proved to be another record year for the event, with 859 exhibitors covering over 54,000 m². Some 59% of exhibitors were from outside Germany. The exhibition, varied events, and special shows demonstrated the wide range of possibilities offered by Additive Manufacturing for numerous user industries, including medical technology, automotive and mechanical engineering, architecture, and aerospace.

"With the unparalleled concentration of innovations, decision makers, and AM experts, the event offered a unique trade fair experience," stated Sascha F Wenzler, vice president for Formnext at event organiser Mesago Messe Frankfurt GmbH. "In the context of an extremely dynamic sector Formnext provides a roadmap for the evolution of cutting-edge manufacturing industries."

The supporting events at Formnext 2023 focused on a wide range of user industries, from automotive and construction through to mechanical engineering. The new service provider marketplace put the spotlight on the special role of service providers in expanding the AM user base. The new multi-stage concept was extremely well received and showcased AM applications, technologies, and innovations while providing a platform for discussions on industry-relevant topics such as sustainability, cybersecurity, and investments.

With a high proportion of international visitors (50%), Formnext once again demonstrated its credentials as the leading international exhibition for Additive Manufacturing and modern industrial production.

Next year's Formnext is scheduled to take place from November 19-22, 2024, in Frankfurt am Main, Germany.

www.formnext.com

Formnext, now in its ninth year, brought the global Additive Manufacturing industry to Frankfurt, Germany, with visitor numbers totalling almost 33,000 (Courtesy Formnext)

Forward AM announces high growth as it continues to drive the adoption of Additive Manufacturing

Forward AM's Ultrafuse range includes both 316L and 17-4 PH filaments (Courtesy Forward AM)

Forward AM, the BASF 3D Printing Solutions GmbH brand based in Heidelberg, Germany, has reported high growth in the first half of 2023 as the company maintains a strategic focus on industry collaboration. Growth of 39% was posted for the first half of 2023, with a 51% increase on material business for its continuous portfolio compared to the first half of 2022.

The company announced it has been creating a new cross-technology approach for customers, said to deliver value through materials, applications, and processes. It is also partnering to develop scalable solutions that meet unaddressed market needs.

"The only way forward is together, and no one can win alone. Additive Manufacturing is just a technology. But the value for customers is created when we align applications, materials and processes into a reliable, scalable solution," stated Martin Back, CEO and Managing Director. "Think of a three-legged stool. If you take away one leg, the stool falls over. To create a stable solution, we need collaboration where partners align collectively behind the goal to provide the best solution and thus iteratively adapt until a stable and scalable solution is created."

Forward AM is reportedly ramping up its efforts for the second half of 2023 as it continues to drive the adoption of AM throughout a variety of industries.

"We have the team and tools in place to scale up our operations and I'm looking forward to the second half of the year," Back stated. "We're going to continue working in tight collaboration with our partners and on delivering innovative solutions that create value for the market and prove that AM is the solution the manufacturing sector has been looking for."

Forward AM offers over 800 machine/material combinations. Included in its Ultrafuse range are 316L and 17-4 PH stainless steel filaments.

www.forward-am.com

Incus launches Hammer Pro40 Additive Manufacturing machine

Incus, GmbH, based in Vienna, Austria, has announced the launch of its new Hammer Pro40 Additive Manufacturing machine. Building upon the principles of the Hammer Lab35 AM machine, the Hammer Pro40 is reported to include an upgraded production capability, while retaining the same level of expertise and familiarity with the technology.

The new Hammer Pro40 is designed to perform multiple jobs without requiring operator intervention (Courtesy Incus GmbH)

The larger build volume is achieved by using two moving or scrolling projectors instead of one stationary projector, without compromising accuracy. With a platform that is six times larger than the Hammer Lab35 AM, the Hammer Pro40 has a high potential throughput of 700 cm^3/hour with a resolution of 40 µm pixel pitch in X/Y.

The Hammer Pro40 is designed for the production of large batches of intricate, specialty parts. It can be used in various applications, such as dental, medical, automotive, micro robotics, and jewellery manufacturing. Compared to the Hammer Lab35, the Pro40 offers a manufacturing speed that is seven times faster and a cost per cm^3 that is four times lower.

The Pro40 achieves a surface roughness (Ra) of 2 µm after sintering, eliminating the need for additional surface treatments like polishing or sandblasting. Additionally, the high strength of the green parts allows for easy automation in their handling.

The Hammer Pro40 is designed to perform multiple jobs without requiring operator intervention. It is equipped with a feedstock supply that can last for at least 2-3 days. Job preparation, setup, and material changeover are efficiently streamlined, reportedly taking less than five minutes, ensuring a seamless and uninterrupted manufacturing process.

"The Hammer Pro40 was strategically developed to fulfil the growing demand for mass manufacturing with AM while still delivering the unique features of our technology," stated Incus CEO, Dr Gerald Mitteramskogler. "This innovation means a leap forward in terms of speed, precision, and cost-effectiveness, but it also opens up new opportunities to leverage the versatility of our manufacturing solution. Within a single print, you can create intricate medical gripping devices, patient-specific dental brackets, personalised jewellery pieces, prototypes for electronic devices, and customised automotive knobs for luxury interior designs – all in quantities ranging from single prototypes to mass manufacturing."

www.incus3d.com

Tritone expands US presence with Delray sales partnership

Tritone Technologies, a provider of metal and ceramic Additive Manufacturing machines headquartered in Rosh Ha'ayin, Israel, has partnered with Delray Systems, Rochester, Michigan, USA, to establish a presence and technical resources in the heart of America's automotive capital.

The move is seen as an important milestone for Tritone as it executes its North American expansion strategy. To date, this has included establishing a subsidiary in the US and installing several new machines. The company's partnership with Delray Systems looks to further enhance its position as a key player in the US Additive Manufacturing market.

"We examine the requirements of our customer base and are aware of the technologies that can drive their business to success," shared Joe Rocca, president and founder of Delray. "Tritone fills a gap in the market where customers want to bring metal AM in-house, but don't want to deal with the challenges of powder-based systems. For these cases, Tritone is the only company with a practical solution."

"The leadership team at Delray has successfully introduced innovative 3D Printing solutions in their markets for over twenty years," stated Ben Arnold, VP Business Development NA, Tritone Technologies. "They have the technical resources and applications focus we look for to build a strong presence in this important region. We are proud to have them as partners and look forward to growing with them."

Tritone offers two Additive Manufacturing machines that utilise its MoldJet technology. The powder-free, sinter-based AM technology enables the fast industrial production of high-quality metal and ceramic parts. MoldJet is specifically designed to produce large quantities of parts with complex geometries. The technology is said to allow for seamless switching between a wide variety of metals and ceramics, facilitating the simultaneous manufacturing of parts in different sizes, shapes, and applications.

www.tritoneam.com
www.3d-printer.com

2024 Powder Metallurgy World Congress opens abstract submission

The Japan Powder Metallurgy Association (JPMA) and Japan Society of Powder and Powder Metallurgy (JSPM) have announced that authors wishing to present at the World PM2024 Powder Metallurgy World Congress, taking place in Yokohama, Japan, October 13-17, 2024, can now submit their abstracts for consideration.

The organisers are expecting the World Congress will attract over 500 papers in both oral and poster sessions. All submitted papers will be reviewed and those accepted will be allocated to oral or poster sessions by the Technical Program Committee.

Topics of technical sessions include:

PM technology

- Powder production
- Processing
- Industrial applications

PM materials

- Sintered materials
- Hard materials
- Functional materials
- Other PM materials

'Hot topics for the better world'

- Carbon neutrality in PM (eco processes & materials)
- Circular economy (reuse, recycle and remanufacturing)
- DX in PM (material informatics & integration)

For oral sessions, twenty minutes will be allocated to each paper including discussion time; there is a possibility that the presentation time will change due to the limits of the time schedule. All presentations must be given in English and are limited to one speaker per presentation. Poster sessions, also in English, will be displayed throughout the event. Authors will be provided with a specific time for one-on-one discussions.

All submitted papers should be original and unpublished. Commercialism in abstracts and presentations will not be accepted. Reduced registration rates will be available for participating speakers.

The abstract submission deadline is January 15, 2024. More information is available via the event website.

www.worldpm2024.com

Arburg receives gold medal from EcoVadis: top 5% of sustainable industrial companies

Arburg GmbH + Co KG, located in Lossburg, Germany, has received a Gold Medal from EcoVadis, placing it in the top 5% of the world's most sustainable industrial companies. EcoVadis is a comprehensive sustainability rating platform that evaluates global supply chains.

The assessment considers environmental impact, sustainable procurement, ethics, labour practices, and human rights. The rankings are based on data from over 100,000 companies and have implemented stricter criteria for earning medal levels starting in 2023.

Sustainability programme now awarded Gold

Since 2019, all of Arburg's activities have been consolidated under the arburgGREENworld programme. This programme has expanded beyond strategies focused solely on resource efficiency and circular economy, and now encompasses a broader perspective on sustainability through its own ESG (environmental, social, governance) strategy.

Clear disassociation from greenwashing

Arburg utilises quantifiable measures to differentiate itself from greenwashing by setting ambitious goals for reducing greenhouse gas emissions. As an example, Arburg has recently adopted the targets validated by the Science Based Targets Initiative (SBTI) as a standard practice. Through its Action Plan Energy, Arburg collaborates with customers to develop efficient, sustainable, and energy-optimised production processes, aiming to further reduce CO_2 emissions.

On the way to becoming the 'greenest' machine manufacturer

Arburg reportedly sees its Gold Medal as a clear lasting confirmation that we are steering the correct course into the future.

"We therefore take a positive view of new legal requirements for European companies, such as the CSRD (Corporate Sustainability Reporting Directive) and other challenges," shared Gerhard Böhm, Arburg Managing Director Sales and After Sales. "We have recognised that sustainability means past, present and future for Arburg and sustainability, like our company, is in constant change. We still value our location, resources, employees and stakeholders as much today as we did when the company was founded and are well prepared with this commitment."

www.ecovadis.com

www.arburg.com

IperionX receives $12.7 million grant and $11.5 million finance offer to grow titanium powder production

IperionX Limited, based in Charlotte, North Carolina, USA, reports it has been awarded a $12.7 million grant from the United States Department of Defense (DoD). The company also announced in a further press release it had received a Letter of Interest (LOI) from the Export-Import Bank of the United States (EXIM) for a provisional finance sum of $11.5 million.

$12.7 million DoD grant

Facilitated through the Defense Production Act Investment (DPAI) Program, the $12.7 million award aims to increase titanium powder production for defence supply chains.

"Robust and resilient defence supply chains are critical to the Warfighting capability of the United States," stated Dr Laura Taylor-Kale, Assistant Secretary of Defense for Industrial Base Policy. "Domestic titanium production is a top priority for the DoD's industrial base programs."

The award will fund the expansion of IperionX's facility in Virginia into a demonstration plant, boosting the company's titanium powder production to 125 metric tons annually. Within five years, IperionX aims to produce 10,000 metric tons of titanium metal powder each year. The company manufactures titanium alloys from either titanium minerals or 100% recycled materials.

As of 2023, the DPAI Program has granted twenty-one awards totalling $674 million. DPAI is overseen by the ASD(IBP)'s Manufacturing Capability Expansion and Investment Program (MCEIP), in the Office of the Deputy Assistant Secretary of Defense for Industrial Base Resilience.

$11.5 million finance offer

IperionX received notification from EXIM that its proposed titanium facility may qualify for equipment finance under two programmes: EXIM's 'China and Transformational Exports Program' and 'Make More in America Initiative'. These programmes allow EXIM to extend its medium and long-term loan and loan guarantee programmes to support projects that aim to reduce Chinese dominance in strategic sectors and promote export-oriented domestic projects.

"Titanium for the US manufacturing sector is currently sourced over long distances from foreign nations," stated Anastasios (Taso) Arima, IperionX CEO. "We are pleased to receive the letter of interest for the provisional sum of $11.5 million in equipment finance from US EXIM that will assist IperionX to re-shore a lower-cost, more sustainable and fully integrated US titanium supply chain that is critical both for the manufacturing of advanced goods as well as for America's national security."

The company is looking to acquire key production assets, such as industrial furnaces and comminution equipment, as it develops its titanium production facility in Halifax County, Virginia. While the LOI is non-binding and conditional, IperionX stated that the potential funding support gives a solid foundation as the company explores various competitive funding options.

www.defense.gov
www.iperionx.com

Hexagon brings simulation, quality assurance and digital twin to ColdMetalFusion Alliance

Hexagon AB, based in Stockholm, Sweden, has joined the ColdMetalFusion (CMF) Alliance. The move is said to mark a significant milestone as it brings simulation, quality assurance, and digital twin capabilities to the CMF Additive Manufacturing technology ecosystem.

ColdMetalFusion is an alliance of industry leaders with extensive experience in sintering, Additive Manufacturing, and industrial manufacturing. The members of this alliance work together to offer services, equipment, materials, software, and expertise to customers who manufacture metal components using the CMF process.

Hexagon brings experience in hybrid and Additive Manufacturing to the alliance, including design for manufacturing, process simulation, quality assurance, and Industry 4.0. By leveraging data-driven insights throughout its end-to-end digital workflows, Hexagon aims to enable manufacturers to enhance their quality and sustainability.

A critical initial contribution to the Alliance is Hexagon's simulations of the ColdMetalFusion sintering process and materials. With this, manufacturers can now digitally replicate and optimise the sintering process, eliminating the need for widespread trial-and-error. This approach speeds up the development process, reduces expensive errors, and enables efficient production and high-quality standards right from the first build.

"We envision a manufacturing future where sustainability, efficiency, and digitalisation are seamlessly integrated," explained Dr Tarik El Dsoki, Managing Director Design & Engineering for the DACH region at Hexagon's Manufacturing Intelligence division. "Through our membership in the ColdMetalFusion Alliance, we are taking steps towards realising this vision. Our commitment to simulation-driven design, scalability, and sustainability aligns perfectly with the goals of the ColdMetalFusion Alliance, and we are excited about the transformative impact it will have on the industry."

www.hexagon.com
www.coldmetalfusion.am

AIM3D debuts Voxelfill slicing software solution

AIM3D GmbH, Rostock, Germany, has entered into a development partnership with software company Create it Real, Aalborg, Denmark, to integrate the Voxelfill process as a plug-in into the system technology of the ExAM 255 and ExAM 510 Material Extrusion (MEX) Additive Manufacturing machines.

The slicing software solution SlicEx, which is based on Create it Real's Real Vision Slicer, will, in future, enable users to make best use of AIM3D's patented Voxelfill technology to overcome inhomogeneous strengths and to achieve selective densities of additively manufactured components made of metals, ceramics, plastics, and fibre-filled plastics.

With Create it Real's new slicing software solution SlicEx, users are given the opportunity to exploit the potential of Voxelfill in the construction of AM components.

The SlicEx plug-in

With the SlicEx plug-in, users of the AIM3D systems ExAM 255 and ExAM 510 are expected to benefit from the fact that they now have comprehensive access to the AM process with Voxelfill. Furthermore, their input and feedback on the subject of slicers can be passed on via AIM3D directly to the developer Create it Real in order to further optimise the process.

"With the development of Voxelfill, the user now has the possibility to use the unique new process of Voxelfill to improve the z-strength and the printing speed," stated Clemens Lieberwirth, CTO at AIM3D. "However, these modules are currently still under development."

Jacob Nissen, CEO of Create it REAL, added, "AIM3D is an ideal partner, backed by a strong academic background and a solid theoretical foundation. Their clear vision aligns perfectly with our capabilities, enabling us to collaborate effectively in achieving their goals."

The two-stage Voxelfill process at a glance

With the Voxelfill approach, components aren't created exclusively in layers, but utilise cross-layer filling by using so-called voxels as volume areas. To do this, the component contour is first created as usual, with the basic structure using one or more webs of the extruded material. A lattice pattern is created inside the component, which defines the boundaries of the volume elements to be filled.

The Voxelfill strategy then comprises two process stages:

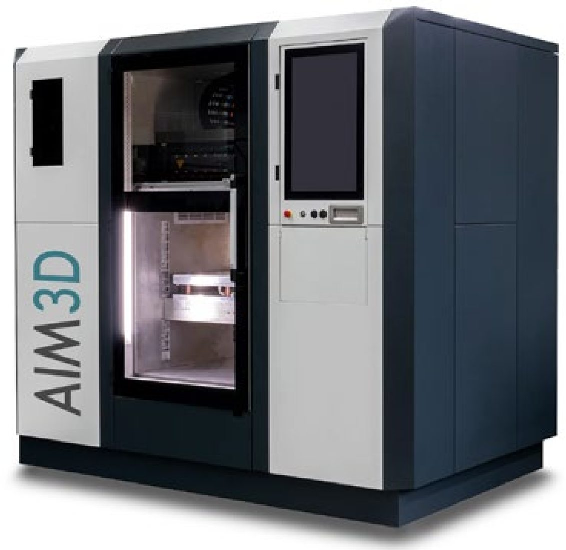
1. Generation of a lattice structure: the CEM system repeats this structure up to a defined height of the volume elements, then at this point the previously created voxels are filled by the extruded material;
2. When the volume areas are filled, this does not include filling all voxels in one plane; this would again result in a Z direction weakness directly in the 'seam' plane. By shifting the volume elements halfway up the voxel, a kind of 'brick-like bond' is created in the component, resulting in the yield line being offset. This results in an enormous increase in strength and also improves the elasticity of the components in the Z direction. In addition, the introduced volume elements greatly reduce the build time for fully filled components and thus significantly increases the cost-effectiveness of the CEM process.

The potential of Voxelfill

Variations of the Voxelfill strategy with the CEM process enable the use of various materials; these hybrid multi-material solutions with different Voxelfill materials and different materials for the contour/structure of the inner walls allow customisable material properties.

Defined component weight, damping properties, elasticity or changes to the centre of gravity can be tailored to the application. By selectively filling only certain volume chambers (selective densities), component properties could be influenced in a targeted manner on the basis of FE simulations. With Voxelfill it is possible to only fill the areas of a component that are absolutely necessary for the flow of forces. As a result, from the outside these components look like conventional parts whilst having the benefits of the AM process, including lightweighting.

www.aim3d.de
www.createitreal.com



The Voxelfill process will be available as a plug-in into the system technology of the ExAM 255 and ExAM 510 machines (Courtesy AIM3D)

Kennametal announces William M Lambert as Chairman of the Board

Kennametal Inc, based in Pittsburgh, Pennsylvania, USA, has announced the appointment of William M Lambert as its new chairman of the board, effective from November 1, 2023.

William M Lambert has been named chairman of the Kennametal board (Courtesy PR Newswire)

Lambert has succeeded Lawrence W Stranghoener, who has served as either the chairman of the board or Independent Lead Director since 2015.

This change is said to align with the company's overall corporate governance and succession planning process. Stranaghoener will continue to serve on the Kennametal Board of Directors and its Audit Committee.

"Bill has been a valuable member of our board of directors since 2016 and is perfectly suited to step into the role of chairman," shared Stranghoener. "His extensive experience in global manufacturing, business strategy, product development and finance will serve the company well as we continue to advance our growth and innovation strategy to drive above market growth and margin expansion and deliver for our shareholders."

Lambert has served as an independent director on the Kennametal Board since 2016 and assumed the role of Audit Committee chair in 2019. Additionally, he is a member of the MSA Safety Incorporated (MSA) Board of Directors. MSA is a global leader in the production and supply of workplace safety products. Lambert, now retired, previously held the positions of president and Chief Executive Officer at MSA from 2008 until May 2018.

Lambert earned his Bachelor's degree in Mechanical Engineering from Penn State University and his master's degree in Industrial Administration from Carnegie Mellon University.

www.kennametal.com

Ricoh and Siemens aim to industrialise aluminium Binder Jetting

Ricoh Company, Ltd, and Siemens Digital Industries Software are collaborating to advance the use of aluminium Binder Jetting (BJT) for mass production. Under the partnership, Ricoh is leveraging Siemens' Additive Manufacturing Network capabilities to maximise the efficiency of the process and to achieve the scale required to take advantage of BJT in an industrial setting. Ricoh will also implement Siemens' AM Network in an effort to optimise the aluminium BJT workflow for production preparation, planning, scheduling, and production management.

Ricoh's BJT process applies the company's inkjet printing technology and expertise to enable the production of complex metal parts that would not be possible with conventional metal processing methods such as machining and casting. Siemens will continue to provide Ricoh with solutions optimised for the aluminium BJT workflow, and both companies aim for early commercialisation of these technologies.

"The production of aluminium parts is a holy grail for the additive industry and we're delighted that Ricoh has chosen Siemens' Additive Manufacturing Network capabilities from the Siemens Xcelerator portfolio of industry software to help them commercialise a much sought-after process," stated Zvi Feuer, Senior Vice President, Digital Manufacturing Software, Siemens Digital Industries Software. "Our collaboration with Ricoh will apply its expertise in Additive Manufacturing with our knowledge and experience in delivering additive-specific operations management technology across a wide spectrum of industries – from order capture, production planning, and manufacturing to part delivery transaction closure. Together, Siemens and Ricoh are working to deliver repeatability and consistency at the scale needed to truly take advantage of using robust and repeatable aluminum additively manufactured parts in the commercial world."

Tokutaro Fukushima, General Manager of Additive Manufacturing Business Center, Ricoh Futures Business Unit, added, "Ricoh will enable our customers to manufacture innovative aluminium components that have never been produced before by any process and will work with them to realise new customer value in the area of electrification of EVs and other forms of mobility. By combining Siemens' powerful solutions and knowledge with Ricoh's aluminium BJT, we will be able to provide our customers with highly reliable and practical systems for mass production applications. We hope to promote electrification together with our customers and contribute to solving social issues such as realising a zero-carbon society."

www.siemens.com

www.ricoh.com

D3-AM reveals its ceramic Micro Particle Jetting technology and LABII Additive Manufacturing machine

D3-AM GmbH, a subsidiary of Durst Group based in Brixen, Italy, unveiled its Micro Particle Jetting technology and LABII Additive Manufacturing machine at this year's Formnext. Developed for high-performance ceramics manufacturing, D3's LABII is reported to allow the direct printing of water-based, highly concentrated suspensions with almost any particle size and distribution. Once formed, the green parts undergo a sintering stage to produce the final component.

Stefan Waldner, D3-AM's Chief Product Officer, stated, "Material Jetting, from a theoretical standpoint, represents the most promising technology in Additive Manufacturing as it enables the construction of objects drop by drop, voxel by voxel. By overcoming material compatibility restrictions, our MPJ technology paves the way for the production of previously deemed impossible components."

D3 reported much interest in its technology at Formnext, leading to the initiation of a number of projects. These included the development of new materials and exploring new applications. Thick walled components and those made from Sintered Silicon Carbide (SSiC) were said to have drawn significant attention.

The LABII uses D3's Micro Particle Jetting technology (Courtesy D3-AM)

Gyroid structures made from sintered silicon carbide like this can be used in thermal and structural applications such as heat exchangers (Courtesy D3-AM)

Christoph Gamper, CEO and co-owner of Durst Group, added, "With our presence at Formnext with the D3 LABII system, we are starting a new chapter at Durst: Material Jetting. The tradeshow has clearly shown that we are onwards in the premier class of materials – ceramics – and we look forward to scaling the printing systems, processes, and materials to open up a world of possibilities."

www.d3-am.com

HYBRID introduces CLOUDFLOW Maker for industrial Binder Jetting

HYBRID Software, a global software solutions provider for the manufacturing industry based in Merelbelke, Belgium, has introduced CLOUDFLOW Maker, an enterprise workflow solution for industrial-scale Binder Jetting. Built on OPC-UA standards, the software guarantees interaction with all connected devices and machines. Furthermore, being fully API-based, it provides simple connections with all other systems, acknowledging the fact that a one-size-fits-all solution does not exist.

Kris Binon, AM Business Unit development manager, commented, "Having decades of experience in jetting the right drop on the right spot is just one thing: industrial printing software is about the ability to provide fast, secure and modular solutions, as well as customer-oriented support, maintenance and upgrades."

To elevate technical standards, HYBRID Software can leverage two other resources. Firstly, its parent organisation, HYBRID Software Group, houses Meteor Inkjet, a leading provider of printhead electronics for Binder Jetting. By integrating its hardware with HYBRID's software, a direct and secure data stream from CAD up to printhead is ensured. Meteor's proficiency in drop formation, binder delivery systems, and waveforms, etc., is unparalleled in the AM industry.

Secondly, HYBRID Software's experienced engineering team, with over twelve years of successful product development in industrial Additive Manufacturing applications such as labels and packaging, will apply their experience to CLOUDFLOW Maker.

Mike Rottenborn, CEO of HYBRID Software Group, stated, "The 3D printing industry is at a crossroads: as printer producers and users turn towards industrialisation, they need software to optimise and streamline their workflows for high-volume production. To achieve this, HYBRID is leveraging our expertise in enterprise workflow for printing to develop value-adding functionalities for Binder and Material Jetting."

www.hybridsoftware.com

Interactions of polymeric components in POM-based binders for titanium MIM

Metal Injection Moulding feedstocks are usually composed of multi-component polymeric mixtures containing a small amount of additives such as stearic acid to promote the coating of the binder mixture to the powder particle surfaces and prevent aggregation. Coating individual particles with a thin layer of binder provides sufficient fluidity to the MIM feedstock to fill the mould during injection moulding. However, obtaining a homogeneous MIM feedstock using multiple polymers is often challenging due to the relatively short chain lengths of stearic acid, and the interlinking strength among the polymeric components is also often weak. Adding polymers with a polar group as interfacial agents among binder components can be beneficial in enhancing the interlinking strength of binder components and improving the adhesion force onto the metal powder surface.

Currently, the interaction of the binder and powder is mainly assessed by rheological and thermogravimetric measurements, but very little is known about the specific interactions among binder components and, in particular, how these interactions affect the feedstocks used in the MIM of reactive powder such as titanium.

Research carried out at the University of Auckland, the University of Waikato, both located in New Zealand, and also at the Kunming University of Science and Technology in the People's Republic of China, has investigated using polyoxymethylene (POM) as the primary binder, polypropylene (PP) as the backbone binder and stearic acid (SA) as a surfactant. To this POM/PP blend were added two different types of compatibiliser — poly(ethylene methyl acrylate-co-glycidyl methacrylate) (EGMA) and ethylene-vinyl acetate (EVA) — and the researchers studied the effects of the compatibilisers addition on improving the binders' homogeneity and also on the interactions between the POM- based binder system and titanium powder.

The results of this research have been published in the paper: 'Interactions of polymeric components in a POM-based binder system for titanium Metal Injection Moulding feedstocks' by K Lim, *et al.*, *Powder Metallurgy* Vol. 66, No. 4, 2023, 355-364.

The authors reported that gas atomised Ti powder, having a particle size of 45 micron, was mixed with a laboratory modified POM, to which was added isotactic polypropylene (PP), plus poly(ethylene-co-methyl acrylate-co-glycidyl methacrylate) (EGMA) and poly(ethylene-co-vinyl acetate) with 40% vinyl acetate (E40) as compatibilisers, and stearic acid (SA) as a surfactant. Table 1 shows the composition in weight percent of the three binder systems studied for MIM-Ti feedstock. The Ti powder loading in the MIM feedstock was 63 vol.%. The homogeneity of the MIM Ti feedstock was determined by randomly selecting five samples from the prepared batch. To ensure the highest possible density with no voids, the injection moulded parts and the crushed injected parts were compared to the feedstock's theoretical density.

The compatibility of the POM-based binder system with and without compatibilisers is illustrated in Fig. 1. Fig. 1 (a) shows an island-like morphology with a clear phase separation between POM and PP blends (feedstock C-0), where the darker regions correspond to PP and the lighter regions correspond to POM. This indicates the high level of immiscibility between the two polymer phases. However, an elongated structure can be seen in the ternary blends after the addition of compatibilisers. Fig. 1(b) revealed that POM-based binder system

Binder	POM (%)	PP (%)	EGMA (%)	E40 (%)	SA (%)
C-0	80	15	0	0	5
EGMA-3	77	15	3	-	5
E40-3	77	15	-	3	5

Table 1 Binder weight content (wt.%) used for MIM Ti feedstock preparation (From paper: 'Interactions of polymeric components in a POM-based binder system for titanium Metal Injection Moulding feedstocks' by K. Lim, et al., Powder Metallurgy Vol. 66, No. 4, 2023, 355-364)

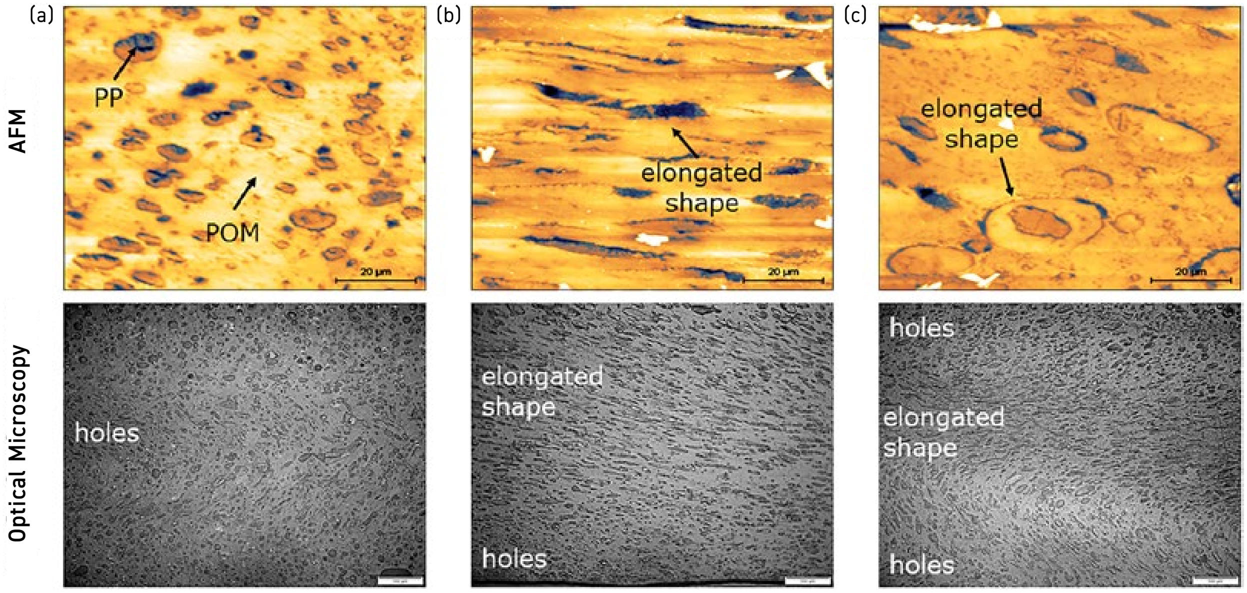


Fig. 1 AFM phase images (with optical micrograph) of the POM-based binder system with formulation (a) C-0, (b) EGMA-3 and (c) E40-3 (From paper: 'Interactions of polymeric components in a POM-based binder system for titanium Metal Injection Moulding feedstocks' by K. Lim, et al., Powder Metallurgy Vol. 66, No. 4, 2023, 355-364)

with EGMA-3 had better miscibility, dominated by more elongated-like morphology dispersed in the continuous phase. On the other hand, the morphology of the POM-based binder system with E40-3 showed both island-like and elongated-like characteristics (Fig. 1 (c)).

The authors stated that for feedstocks containing EGMA-3 and E40-3, the binder is melted and uniformly distributed in the feedstock matrix. No voids were found, indicating a good adhesion of the binder on the Ti metal powder particles. Nonetheless, feedstock EGMA-3 was found to show better wetting between powder and binder than feedstock E40-3. Optical micrographs showed the POM-based binder with E40-3 compatibiliser having many holes dispersed in the continuous phases compared to the binder system containing EGMA-3. Some unfilled voids or gaps were observed at the interface between titanium particles and binder for feedstock C-0.

The authors also measured contact angles for each binder to determine the binder components' wettability and interaction. It was found that the binder system based on POM/PP blends containing EGMA-3 demonstrates the lowest contact angle value at 87.6° and best miscibility, which compares with 98.9° for feedstock E40, and 101.3° for feedstock C-0. This enhanced interaction was said to lie in the chemistry of EGMA, having an active site that reduces the interfacial tension between the components of the POM/PP blend. Subsequently, this creates a positive interaction between the polymers and metal powders, ensuring good adhesion within the feedstock.

A gas pycnometer was used to compare the homogeneity of randomly selected samples from the three feedstock batches being studied. The feedstock containing EGMA-3 compatibiliser was found to be the most homogeneous showing a much smaller standard deviation, 0.009, compared to the worst feedstock C-0 (0.012), as a result of its higher powder-binder interaction. Measurement of the green density of the moulded part showed that feedstock containing EGMA-3 had a slightly higher value at 99.56% compared with feedstock C-0 at 99.28%.

When measuring the rheological behaviour of the feedstocks, the authors found that feedstock-containing compatibiliser EGMA-3 demonstrated a more consistent and higher shear sensitivity value at most temperatures and with a high mouldability index (Table 2), making it suitable for MIM production of Ti parts.

www.tandfonline.com/journals/ypom20

Temperature (°C)	180°C	190°C	200°C
Feedstock C-0			
(n−1)	-0.467	-0.375	-0.293
Mouldability index, α	4.37E-03	4.88E-03	4.30E-03
Feedstock EGMA-3			
(n−1)	-0.441	-0.466	-0.406
Mouldability index, α	7.13E-03	8.31E-03	9.25E-03

Table 2 The (n−1) value and mouldability index for feedstock C-0 and EGMA-3 at three different temperatures (From paper: 'Interactions of polymeric components in a POM-based binder system for titanium Metal Injection Moulding feedstocks' by K. Lim, et al., Powder Metallurgy Vol. 66, No. 4, 2023, 355-364)

Hydro-powered and CO_2-free powder atomisation

Höganäs offers the broadest and most consistent metal powder portfolio for AM, HIP and MIM applications. Our powders cover the full range of additive manufacturing processes and materials, including, nickel, iron, cobalt, with further alloy systems available on request. All powders manufactured in our Advanced AM powder production plant are 100% fossil-free in atomisation.

Our climate tagret is validated by Science Based Targets initiative and AMTGA.

SCIENCE BASED TARGETS
DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

THE NET ZERO STANDARD
APPROVED NET-ZERO TARGETS

AMGTA
ADDITIVE MANUFACTURER GREEN TRADE ASSOCIATION

For more info scan the QR Code

3424HOG

www.hoganas.com

Höganäs

Moldflow simulation used to characterise MIM of pure Cu powder

In the Autumn 2023 issue of *PIM International* (pp 58-61) we reported on the use of the Moldflow simulation program to characterise the processing of 440C stainless steel parts by Metal Injection Moulding based on research carried out at the School of Materials Science and Engineering, Yeungnam University, Gyeongsan, Republic of Korea, and the Kyerim Metal Co., Ltd., a leading MIM producer based in Chilgok, also in the Republic of Korea.

Another group of researchers from the above establishments plus SeA Mechanics Co., Ltd., Gumi, and the Pohang Institute of Metal Industry Advancement, both also based in the Republic of Korea, have additionally undertaken research using the Moldflow program to simulate the effectiveness of the MIM process to produce parts from pure copper powder by evaluating the confidence of fill, quality prediction, and pressure drop in the three regions of a specific green MIM part.

The results of this research have been published in a paper: 'Moldflow Simulation and Characterization of Pure Copper Fabricated via Metal Injection Molding' by W. Bahanan, *et al.*, in *Materials*, Vol.16, 5252, 26 July 2023, 14pp.

The authors stated that no studies have been reported on the use of computational prediction programs for the injection moulding of pure copper powder which, they state, is increasingly being used to produce MIM Cu parts with sophisticated shapes at low cost and having high specific strength and good corrosion resistance for a variety of applications.

The authors therefore set out to establish guidelines for processing copper powder via the MIM method by scrutinising the role of key MIM parameters including injection pressure, injection temperature, and the gate location to produce the copper green MIM parts. The part used in the study was a pure copper outlet-combo charger terminal body which consisted of two-tube channels with different wall thicknesses and diameters joined together in the middle with a ring-shaped reinforcement (Fig. 1).

Fig. 1 (a) shows the final MIM part, (b) the Moldflow model of the green part, and (c) the final product and Moldflow model along the x-axis. The Moldflow simulation program was again used to predict the flow pattern in the injection moulding process because of its superiority in predicting the flow pattern and providing rapid results. Scanning electron microscopy (SEM) and 3D X-ray computed tomography were used to characterise the surface properties and three-dimensional projection of the interior of the final pure MIM copper product.

Pure copper powder, having a spherical shape and average particle size of 5.2 µm, was mixed with a wax binder at a powder/binder ratio of 95:5 (mass%) which was considered optimum for the MIM feedstock. The feedstock was then injected into the mould cavity using an injection temperature of ~180°C and an injection pressure of ~5 MPa. The injection pressure of ~5 MPa was selected despite the fact that the pressure was outside of the typical low pressure range (10 to 500 kPa) used in MIM for metals with a low viscosity.

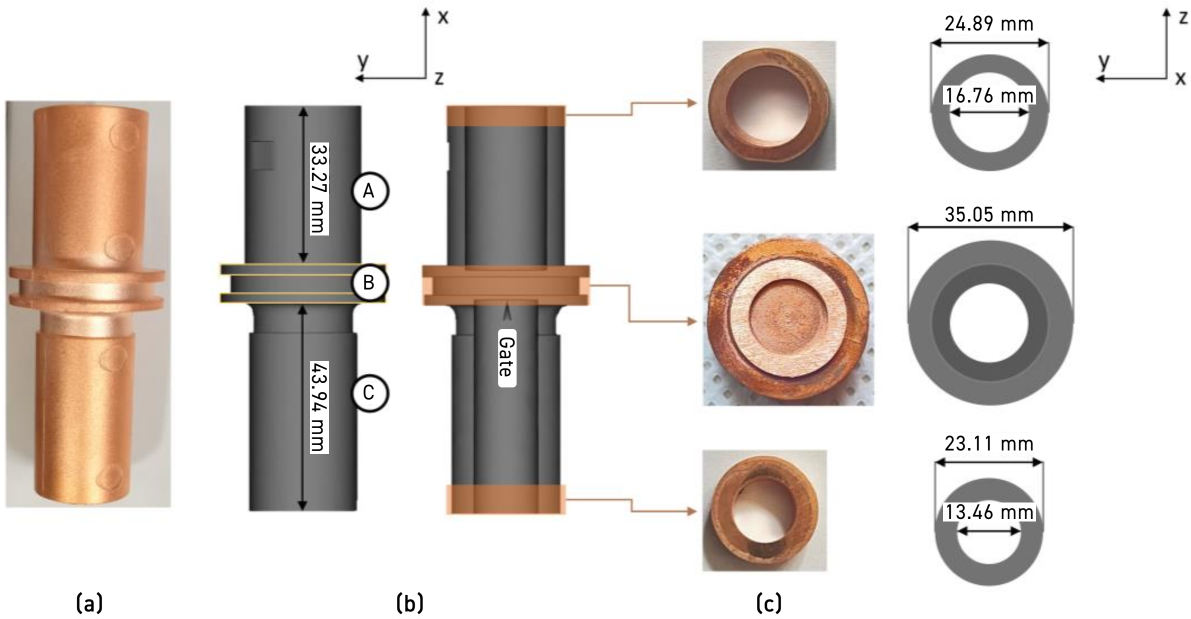
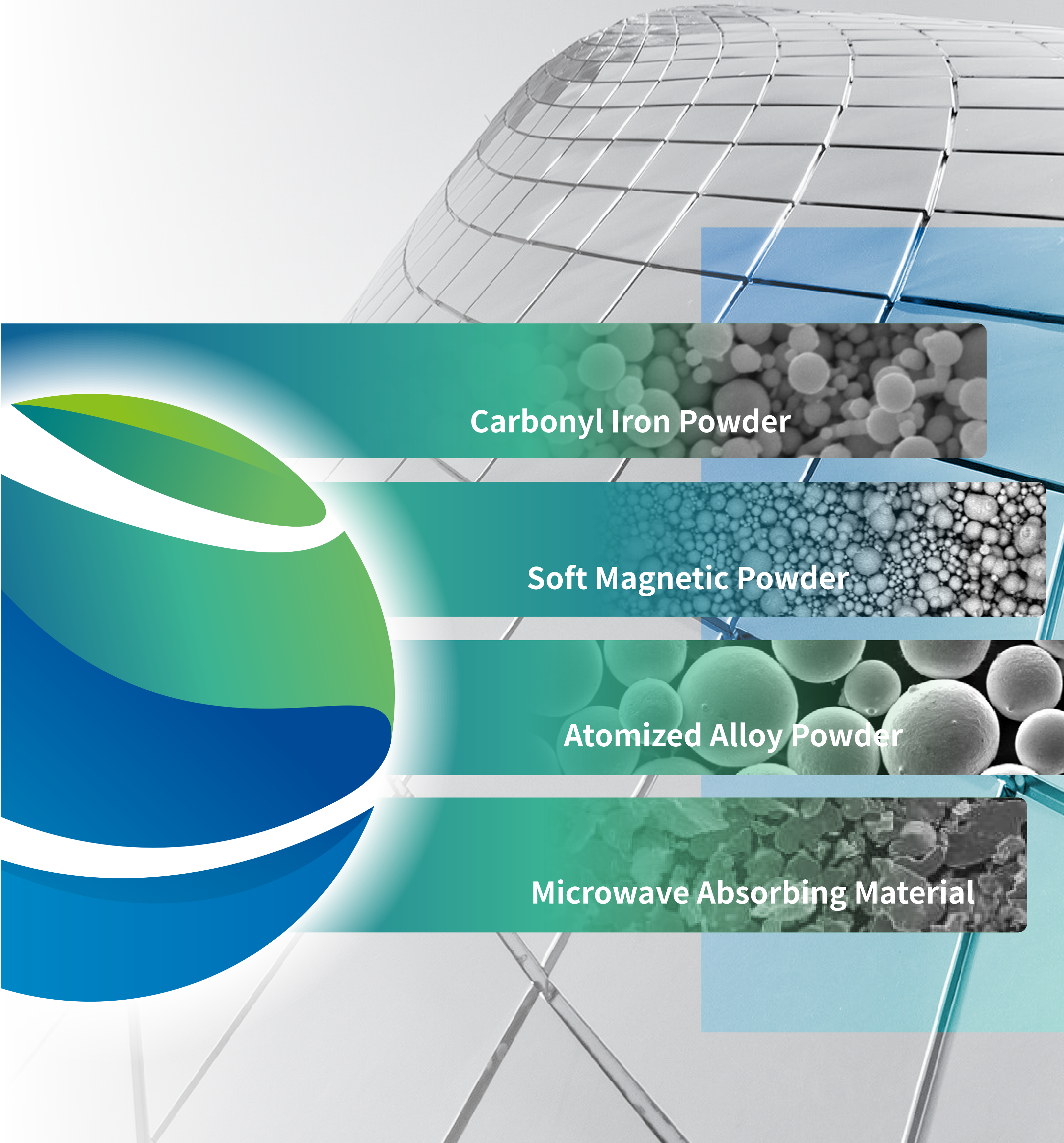


Fig. 1 (a) Final product, (b) Moldflow model of the green part, and (c) final product and Moldflow model along x-axis. A, B, and C represent big-diameter cylindrical, ring (injection site), and small-diameter cylindrical part, respectively (From paper: 'Moldflow Simulation and Characterization of Pure Copper Fabricated via Metal Injection Molding', by W Bahanan, et al., Materials, Vol. 16, 5252, 26 July 2023, 14 pp.)

YUEAN 悦安



www.yueanmetal.com
oversea@yueanmetal.com

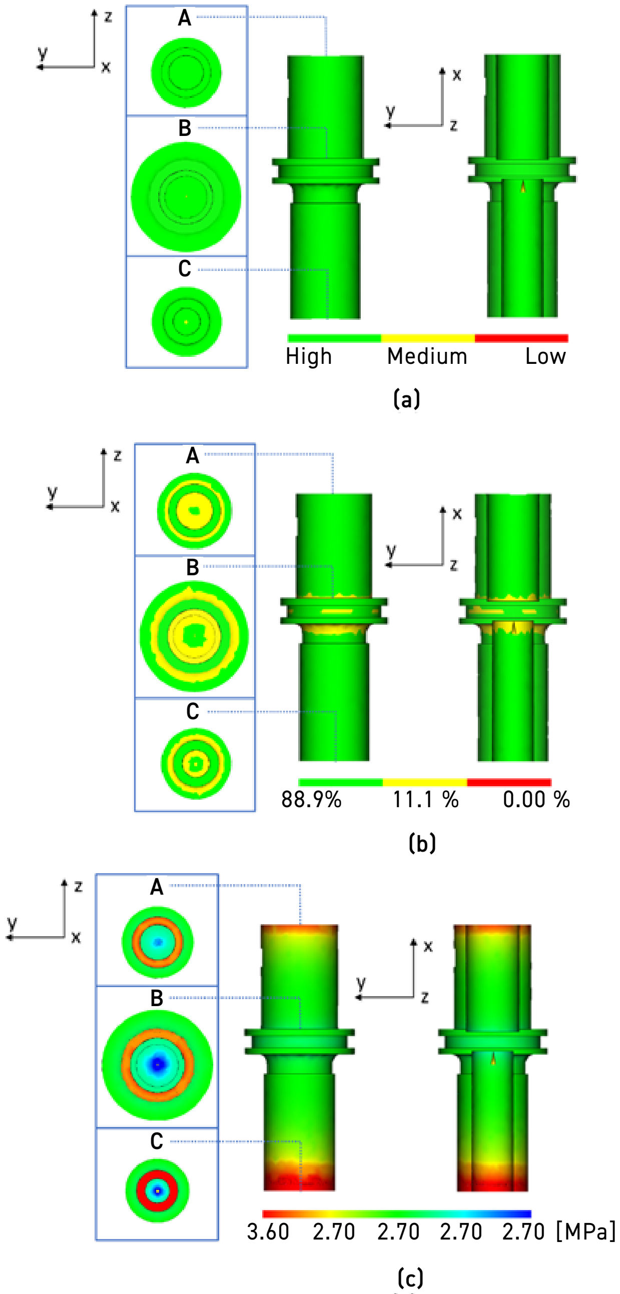


Fig. 2 Moldflow modelling results on the (a) confidence of fill, (b) quality prediction, and (c) pressure drop of the A, B, and C part (From paper: 'Moldflow Simulation and Characterization of Pure Copper Fabricated via Metal Injection Molding', by W Bahanan, et al., Materials, Vol. 16, 5252, 26 July 2023, 14 pp.)

The feeding system consisted of one specific gate, shown as B in Fig. 1 (b). The authors stated that the positioning of the gate is critical to promote homogeneous distribution of the feedstock in all directions and to mitigate issues relating to binder separation. The green pure MIM copper part underwent debinding at 730°C for 1 h to generate a binder-free product (brown product), which was then sintered at 1050°C for 1 h. The final sintered product was examined for surface analysis, interior analysis, and microhardness.

A computational analysis based on the Moldflow program was used to simulate the effectiveness of the injection moulding process by evaluating the confidence of fill, quality prediction, and pressure drop of three distinctive regions in the green part. The results shown in Fig. 2 suggest that the ring and edge regions of the green parts showed localised behaviour, which was related to processing parameters including the position of the gate.

Fig. 2 (a) shows a high value in terms of confidence of fill (green colour) for the whole and half-cut body of the green MIM part. This suggested that the green part will definitely be completely filled and may not have quality problems. Fig. 2 (b) shows a noticeable difference in terms of the quality prediction value for section B of the green part, which the authors suggest might be attributed to a higher level of complexity as compared to sections A and C of the green MIM part. The colour code defined the estimated quality for the green part, such that 88.9%, 11.1%, and 0.00% were the mean values for acceptable, less acceptable, and unacceptable part quality, respectively. A green MIM part with a decreased value of quality prediction will have a higher chance to develop phase separation. Fig. 2 (c) shows the pressure drop especially at the outer edges (as shown in a red colour) of the cylinder in both sections A and C of the green MIM Cu part, which is likely due to an insufficient injection pressure. The authors stated that it is known that the pressure drop is one of the factors that determine the value of confidence of fill.

A microstructural observation using SEM and a 3D X-ray revealed that both the surface and body matrix consisted of pores with some agglomeration of micro-pores on the edges and ring part, while any critical defects, such as a crack, were not found. Consistent with the Moldflow analysis findings, microhardness analysis showed that the three regions exhibited a reasonable uniformity with a slight difference in one specific part mainly due to the localised pore agglomeration. The Moldflow simulation results showed a good agreement with the microstructures and microhardness data and should provide sound guidelines for the production of complex shaped pure copper powder components by MIM.

www.mdpi.com/journal/materials

MIM nickel-base superalloy produced using BNi-2 powder as liquid phase sintering additive

Precipitation hardened nickel-base superalloys, including those produced using the Powder Metallurgy and Metal Injection Moulding processes, are particularly suitable for components used in the high temperature areas of advanced aero engines due to their excellent mechanical properties. These Ni-based superalloys derive the majority of their high temperature strength from a combination of finely dispersed gamma prime precipitates (γ') and discrete grain boundary carbide particles. The presence of the discrete grain boundary carbides reduces grain sliding by pinning the grain boundaries, increasing the creep resistance. However, grain boundary pinning is known to inhibit grain growth in Ni-superalloys, especially in those Ni-superalloys containing high amounts of refractory metal elements such as W and Ta.

MIM Ni-superalloys (MIM-NiSA) generally exhibit fine-grain structures on the scale of 20 to 30 µm which limits their high temperature creep resistance. This is particularly the case in Ni-superalloys containing high amounts (0.5 to 10 wt.%) of Mo, Ta, and W, and research has been undertaken at the Dalhousie University in Halifax, NS, Canada, to evaluate the use of a liquid phase sintering (LPS) approach as a method of increasing the grain size of a MIM Ni-SA containing high amounts of refractory elements. The results of the research carried out by Addison J Rayner and Stephen F Corbin have been published in a paper: 'Liquid Phase Sintering of a Metal Injection Molded Nickel-Based Superalloy With Additions of BNi-2 Alloy Powder Using Differential Scanning Calorimetry' in *Metallurgical and Materials Transactions A*, available online September 8, 2023, 13 pp.

The authors stated that the LPS approach involves adding a lower melting point alloy powder to the primary superalloy powder, with liquid phase sintering being carried out at a temperature above the melting point of the additive, but below the solidus of the primary alloy powder. The liquid phase migrates through the porous structure under capillary forces and acts as a diffusion and mass transport pathway. The presence of a liquid phase also enables grain re-arrangement and the net effect is rapid densification of the powder structure. The volume fraction of the low melting point additive must be properly selected to form a liquid fraction which will sinter the material to full density without shape loss.

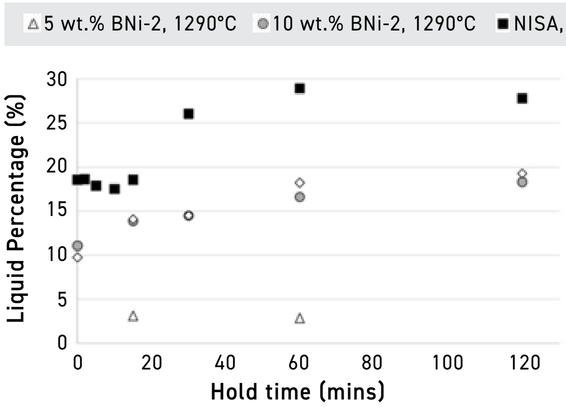


Fig. 1 Final liquid percent with increasing hold time for the 5 wt.% BNi-2, 10 wt.% BNi-2 at 1290°C, and for the pure NiSA at 1340°C and 1345°C (From paper: 'Liquid Phase Sintering of a Metal Injection Molded Nickel-Based Superalloy With Additions of BNi-2 Alloy Powder Using Differential Scanning Calorimetry' by A J Rayner and S F Corbin, published in Metallurgical and Materials Transactions A, online September 8, 2023, 13 pp.)

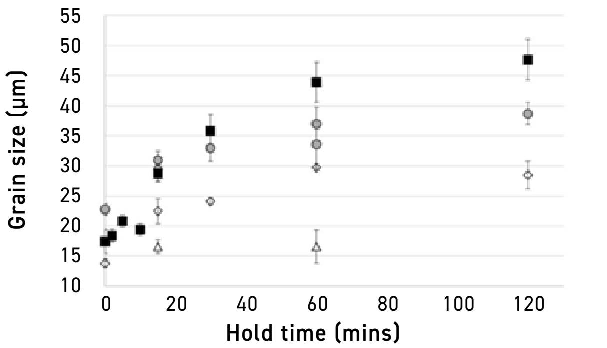


Fig. 2 Average grain size as a function of hold time for the 5 and 10 wt.% BNi-2 alloys at 1290°C, and for the pure NiSA at 1340°C and 1345°C (From paper: 'Liquid Phase Sintering of a Metal Injection Molded Nickel-Based Superalloy With Additions of BNi-2 Alloy Powder Using Differential Scanning Calorimetry' by A J Rayner and S F Corbin, published in Metallurgical and Materials Transactions A, online September 8, 2023, 13 pp.)

The authors reported that comprehensive research has been completed on transient liquid phase bonding (TLPB) of Ni-superalloys with a filler metal alloy, such as BNi-2 (Ni-7Cr-4.5Si-3Fe-3B), thereby making it a suitable low melting point additive to study in an LPS application. The BNi-2 alloy contains the fast diffusing melting point depressant (MPD) elements B and Si to suppress the solidus temperature for brazing and enable the diffusional solidification process.

In addition, the high surface area associated with fine metal powders used in these MIM Ni-SA materials increases the contact area available for rapid solute uptake to occur. Since the BNi-2 loadings are low, there is also more NiSA volume available to uptake B and Si. Considering these factors, the authors stated that it was reasonable to expect the BNi-2 liquid to undergo rapid diffusional solidification upon contacting and wetting the adjacent NiSA particles.

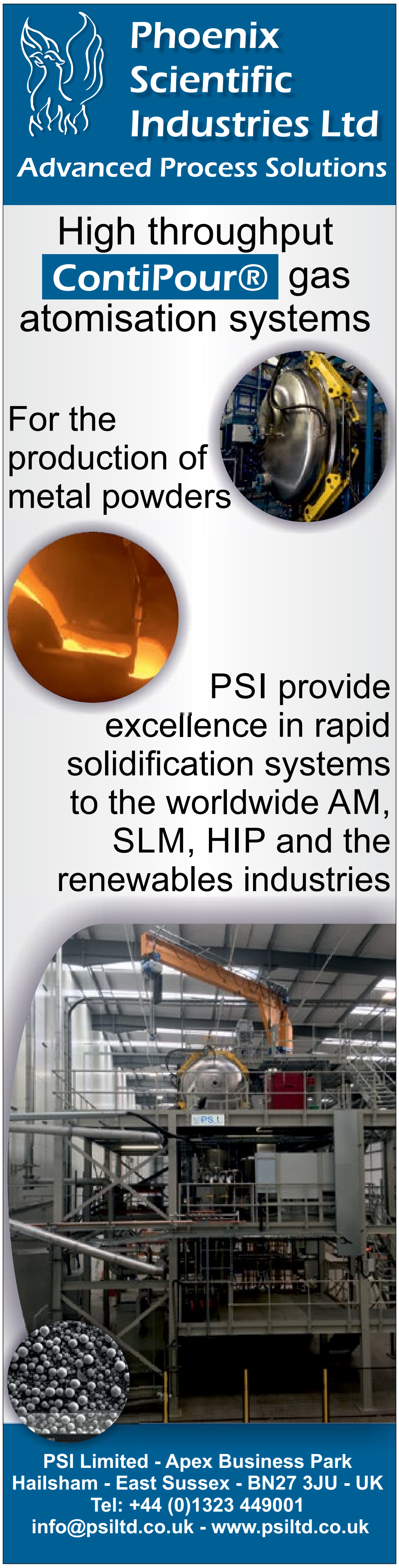
The Ni-base superalloy (NiSA) powder used in the research contained Al, Co, Cr. Ta, W with the balance Ni and minor additions of other refractory metals. Both the NiSA and the additive BNi-2 powders used for the MIM feedstock were gas atomised and had similar d_{10} and d_{50} particle size distribution (PSD) with BNi-2 having the larger PSD throughout. However, the d_{90} of the two powders deviated significantly, with the NiSA having a d_{90} of 22 µm and the BNi-2 powder containing larger particles than the NiSA.

MIM NISA feedstock used in the research was produced with BNi-2 powder loadings of 5 and 10 wt.%. Thermoplastics such as waxes and polymers were used as binders. The feedstock was injection moulded to produce MIM green samples in plate form having a thickness of 3.65 mm. The green samples were then sectioned into appropriate sizes for differential scanning calorimetry (DSC). The top and bottom of the cut green samples were not altered in order to maintain a constant sample height and parallel injection faces which would maintain good contact with the bottom of the crucible used for DSC.

The sectioned green-state samples were packed in an inert Al_2O_3 powder support media within an Al_2O_3 crucible for de-binding, which was done under flowing high purity argon gas with isothermal holds at 180°C and 850°C. DSC analysis was performed on de-bound MIM LPS NiSA samples in order to characterise the sintering behaviour of the BNi-2 modified samples.

Sintering of the debound MIM NiSA samples was carried out in the DSC to a peak temperature of 1290°C under argon gas using a Zr getter ring in the DSC furnace to remove any oxygen from the argon atmosphere. The samples were isothermally held at 1290°C for 0, 15, 30, 60, and 120 minutes before being cooled to room temperature. Additional debound samples with the 5 and 10 wt.% BNi-2 additive loadings were heated to 1050°C for 30 minutes in the DSC. This interrupted test was used to assess the extent of wetting and spreading of the BNi-2 liquid after the first heat above the solidus temperature of BNi-2 (968°C).

The authors reported that DSC coupled with SEM-EDS analysis revealed that the NiSA and BNi-2 alloys create a diffusionally solidified product during sintering which melts at 1240°C in the 5 wt.% BNi-2 loading and at 1200°C in the 10 wt.% BNi-2 loading. The liquid percentage (Fig. 1) and grain size (Fig. 2) were determined for various hold times for the BNi-2 modified



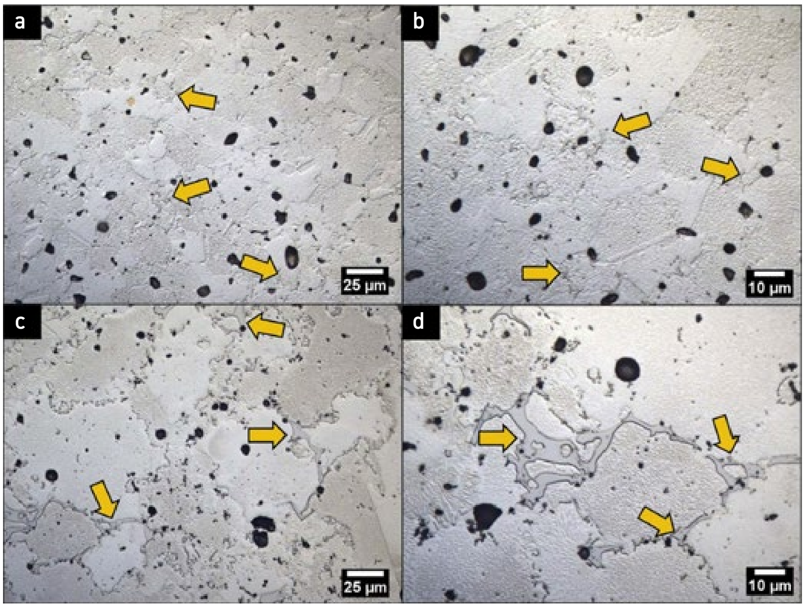


Fig. 3 High magnification microstructures of the 5 wt.% BNi-2 NiSA (a, b) and the 10 wt.% BNi-2 NiSA (c, d) sintered at 1290°C for 1 h. Arrows indicate script-like boride phase locations(From paper: 'Liquid Phase Sintering of a Metal Injection Molded Nickel-Based Superalloy With Additions of BNi-2 Alloy Powder Using Differential Scanning Calorimetry' by A J Rayner and S F Corbin, published in Metallurgical and Materials Transactions A, online September 8, 2023, 13 pp.)

alloys sintered at 1290°C and for pure NiSA sintered at 1340°C and 1345°C, the latter two taken from published literature. The average grain size of the sintered specimens was measured using the line intercept technique. The average grain size was determined over 5 fields at 9200 magnification using 10 lines per field. A total of 50 lines were measured per specimen.

The 5 wt.% BNi-2 material was found to exhibit no grain growth after 15 and 60 minutes hold times at 1290°C, maintaining the initial sub-20 µm grain size. In contrast, the 10 wt.% BNi-2 alloy exhibited grain growth behaviour at 1290°C which is greater than the pure NiSA sintered at 1340°C, despite similar liquid fractions. The 10 wt.% BNi-2 NiSA displayed similar grain growth to supersolidus liquid phase sintering (SLPS) of the pure NiSA at 1345°C for up to 40 minutes, despite the NiSA (1345°C) having a higher liquid fraction. A maximum grain size of 39 µm was achieved in the 10 wt.% BNi-2 NiSA alloy after 2 hours while SLPS of the pure NiSA achieved 28.5 and 48 µm after 2 hours for the NiSA (1340°C) and NiSA (1345°C) respectively.

The authors concluded that the smaller scale and more homogeneous distribution of fine script-like borides in the 5 wt.% BNi-2 alloy, which showed no grain growth, is thought to be less detrimental to the overall properties of the alloy than the microstructures observed at the 10 wt.% BNi-2 loading. However, despite having a more homogenous microstructure and properties similar to the base NiSA, the 5 wt.% BNi-2 content does not activate grain growth as desired. At 10 wt.% BNi-2 loading, substantial grain growth is observed in the MIM NiSA, but the final microstructure contains deleterious non-equilibrium solidification products. These phases are expected to limit the useful temperature of the alloy due to the number of eutectic phases formed.

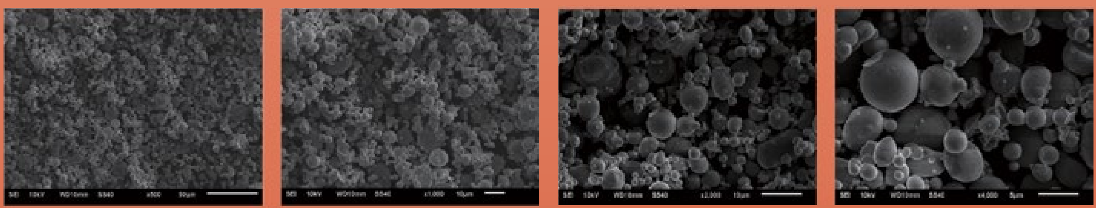
www.springer.com/journal/11661

LD METAL POWDERS

Yingtan Longding New Materials & Technology Co., Ltd - Beijing Branch

The company provides various types of structural material powders, magnetic material powders, and other alloy powders in a variety of particle sizes and tap density based on the demands of the customers. The product line includes 316L, 304L, 17-4PH, 4J29, F75, HK30, 420W, 440C, Fe2Ni, 4140, and FeSi. The customers have received the products with high acclaim

Item	T.D(g/cm^3)	S.S.A(m^2/g)	S.D(g/cm^3)
316L	4.8	0.34	7.9
17-4PH	4.7	0.34	7.7
304L	4.8	0.34	7.8
HK30	4.7	0.34	7.7
4J29	4.9	0.34	7.95
F75	5.0	0.34	8.1



Address: 5 Floor, Block A, Courtyard 88, Caihuying, Fengtai District, Beijing, China.
Fax: +8610-62782757 Tel: +8610-62782757 Contact: Mr. Cheng Dongkai Mobile: 13911018920
Email: chengdongkai@longdingpowder.com Website: www.ldpowder.com

Parmaco Metal Injection Molding AG: Swiss precision engineering that pushes the limits of MIM and micro MIM

Since the earliest days of Metal Injection Moulding's commercialisation in Europe, in the early 1990s, Swiss company Parmaco Metal Injection Molding AG has been instrumental in perfecting the process for the most advanced applications. As well as a focus on 'Swiss precision', producing MIM parts to the highest dimensional accuracy, the company is also renowned for the production of complex microMIM® components. Dr Georg Schlieper reports on a recent visit to the company for *PIM International*.

The small town of Fischingen, in eastern Switzerland, is home to one of Europe's longest established manufacturers of MIM parts. In 1992, Georg Breitenmoser acquired a technology licence from the process pioneer, Parmatech Corporation, based in Petaluma, California, USA, and founded Parmaco Metal Injection Molding AG. The company is still Switzerland's leading MIM producer and, to this day, Breitenmoser steers the fortune of the company as the sole owner and president of the board of directors, though he handed over management responsibility for daily operations to Kai Hermes, Parmaco's General Manager, in 2020.

For a medium-sized company, employing about sixty people, Parmaco has a relatively large product development department. This consists of eight employees who take care of the introduction of new parts, as well as the automation and optimisation of the production process. Around forty employees work in production, quality assurance, and maintenance, while the rest work in sales and administration. The plant has a production area of about 4,000 m^2 (Fig. 1).

Parmaco's MIM process

From the very start, Parmaco has produced its feedstock in-house. The binder technology used has, of course, evolved over the decades,

Fig. 1 Buildings at the Parmaco MIM facility in Fischingen, Switzerland (Courtesy Parmaco)

Fig. 2 A batch of green MIM parts being loaded in a furnace (Courtesy Parmaco)

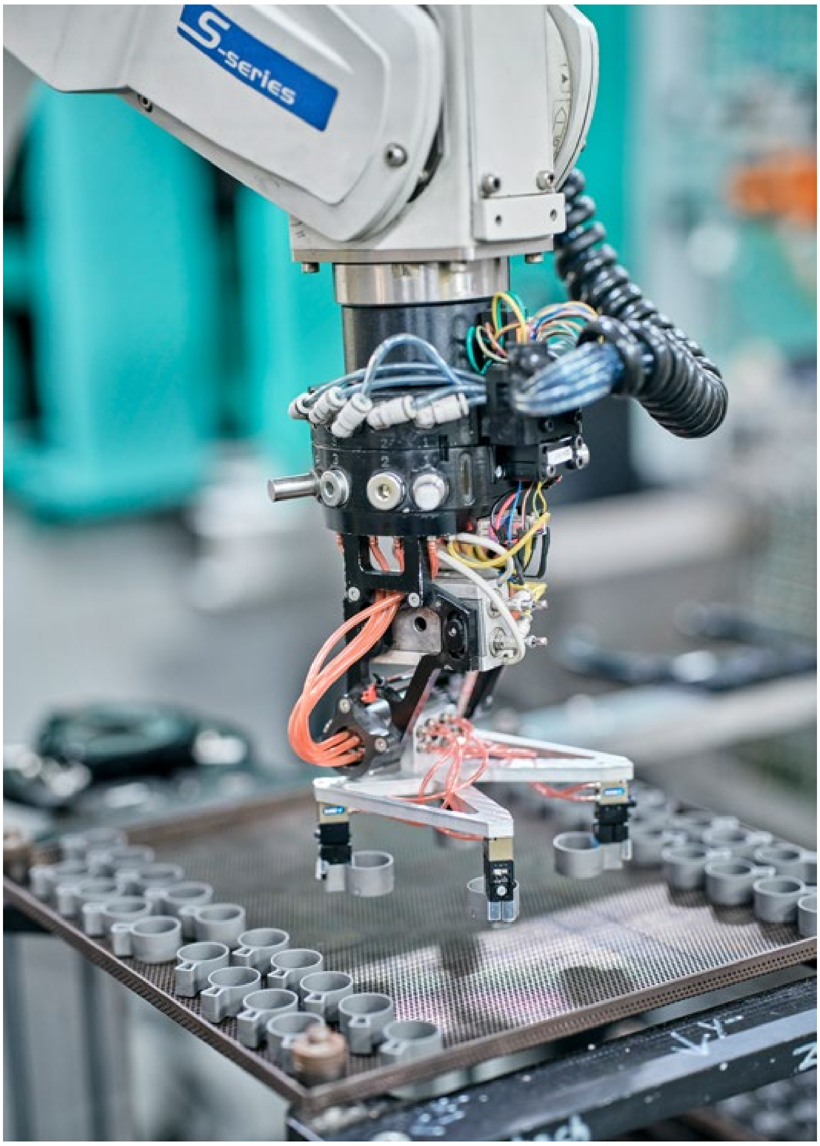


Fig. 3 A pick-and-place robot in action (Courtesy Parmaco)

but the recognition of the value of having control over feedstock production remains. Breitenmoser appreciates the flexibility of in-house feedstock production for a number of reasons: on the one hand, binder compositions can be quickly adjusted if the moulds for particularly thin-walled parts are difficult to fill, or if other filling problems arise such as sink marks or voids; on the other hand, the binder composition can be adjusted if a part requires a particularly high green strength.

Parmaco's debinding and sintering is done in a batch process (Fig. 2). Debinding is divided into two sub-steps. Firstly, the parts are debound in a special solvent. Secondly, the residual binder is thermally removed in a reducing atmosphere before sintering. Hermes emphasised that the maintenance and servicing – especially of the sintering furnaces – is of paramount importance, because the more carefully the equipment is maintained, the more durable and reliable it is.

Wherever it is possible and economically viable, production is automated. Green parts are removed from the injection moulding machine by pick-and-place robots or six-axis robots and placed on trays for further processing (Fig. 3).

Ideally, parts will be ready for use by the customer after sintering, but this is not always the case. If a straightening process is necessary to comply with particularly tight dimensional tolerances which are not possible without reworking, this is carried out in-house. Other secondary processes such as machining, heat treatment, vibratory finishing, coating, etc. are carried out externally.

A certified quality management system according to ISO 9001:2015 with periodical re-certifications is in place at Parmaco. High-precision measuring instruments are used to ensure the consistently high dimensional accuracy of tools and components (Fig. 4). In addition to dimensional inspection, metallographic inspection is also of great importance (Fig. 5).

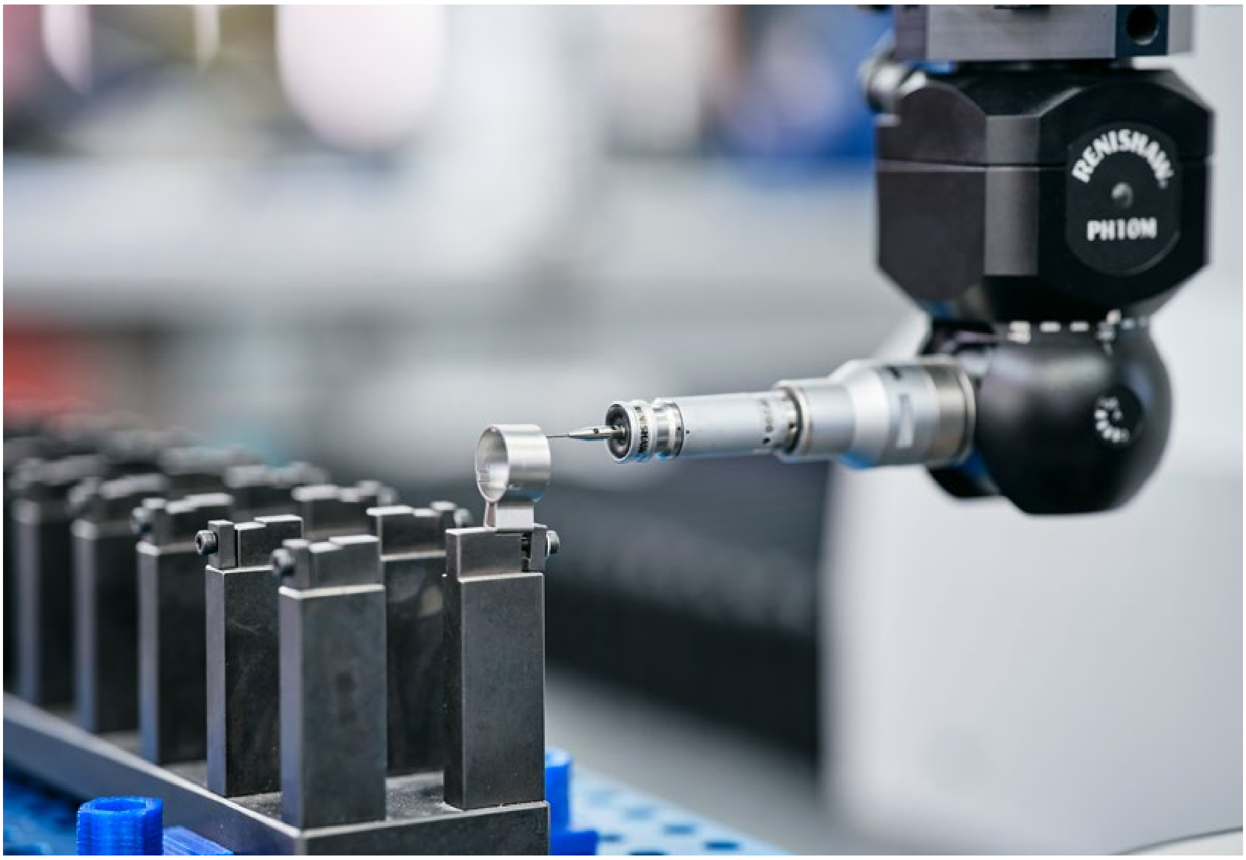


Fig. 4 Precision measurement of part dimensions (Courtesy Parmaco)

Product development

Parmaco develops about thirty new MIM parts a year. The required injection moulding tools are designed and specified by the company's own tool experts (Fig. 6) and then manufactured by external specialists. There are a number of qualified toolmakers in the vicinity who are commissioned with the production. Depending on the requirements of the tool, delivery time, and price, the best-suited toolmaker receives the order. "Minor tool repairs and maintenance work are done in-house, but in-house toolmaking is not economically viable," shared Hermes.

"When developing new parts, very close cooperation with the customer is essential," added Breitenmoser. "We need to understand what functions and characteristics the customer wants the part to have so that we can optimise the design for the MIM process. It may even be

Fig. 5 In addition to dimensional inspection, metallographic inspection is also of great importance (Courtesy Parmaco)

Fig. 6 A MIM tool design engineer using simulation software (Courtesy Parmaco)

possible to integrate the functions of two or more parts into one MIM part." In addition, MIM can often provide added value that customers who are not so familiar with the process are often unaware of. For example, markings, labels or company logos can be integrated into the tool. "Our goal is to always create added value in dialogue with the customer through MIM production," stated Hermes.

In the case of new injection moulding tools, minor changes or adjustments may still have to be made after commissioning, for example in relation to the venting of the moulds or to manage burr formation. "In most cases, initial part dimensions correspond very well with the specification, at least if the tolerances are not exceptionally tight," Breitenmoser explained. "However, we are usually operating at the limit of what is feasible with our dimensional tolerances. Since we are located in Switzerland, our strategy focuses on exceptional quality and tight tolerances. This is the only way we can justify Swiss prices."

In the early days, Parmaco primarily produced low-alloy Fe-Ni MIM parts. This group of materials still makes up a considerable percentage of production, as many parts run for years, sometimes decades. Newer projects are predominantly produced with high-alloy steels. Parts made of nickel-base alloys and heavy metal alloys are also in production, but to a lesser extent. "We are able to offer the full range of available MIM materials and our development department has the expertise to develop special materials in a short period of time, if this is required by customers," said Breitenmoser.

Computer simulations are used in tool design with the aim of achieving the required dimensional accuracy in as few iteration steps as possible (Fig. 6). As far as furnaces are concerned, reliance has, so far, been placed on empirically determined temperature profiles. The work on the simulation of furnace processes is known, but has not yet been applied in practice.

Depending on the production volume, multiple tools with up to sixteen mould cavities can be used, though the majority of tools have two to four mould cavities. "Hot runner technology is often used, but if heat transfer from the hot runner to the part is a problem for very small parts, we do not use this solution," said Hermes.

Success in micro MIM

Parmaco is a specialist in the production of microMIM parts, a term that Breitenmoser described as applying to "parts that weigh less than 1 g and also have particularly fine features. Such parts are also associated with particularly high dimensional accuracy requirements, and microMIM offers a proven route to meet these requirements. Of course, this also places particularly high demands on the precision of the injection moulding tools."

"Apart from the higher accuracy requirements, there is no significant difference in the production of microMIM parts compared to traditional MIM parts. After injection moulding, they also go through the debinding and sintering processes. However, microMIM parts generally have to be ready for use after sintering, because reworking is usually no longer possible," stated Breitenmoser.

Innovation at Parmaco

A key driver of innovation is the need to reduce the time it takes to prototype a new MIM part. Parmaco has introduced special prototype injection moulds that have a modular design. The cavities for these prototypes are incorporated into prefabricated tool inserts, thereby enabling prototypes to be produced in only a few weeks. Such tools allow Parmaco to economically manufacture even small batches of MIM parts with what is described as a "tried-and-tested" technology.

As far as Additive Manufacturing processes are concerned, Parmaco is constantly investigating which technologies bring benefits to the company. Experience has already been gained with Binder Jetting and, in cooperation with the Swiss company Injex, injection moulds and MIM prototypes have been additively manufactured. This has enabled Parmaco to provide customers with prototypes of new MIM parts in the shortest possible time. "The surfaces of the prototypes produced in an additively manufactured injection mould were comparable to MIM series parts and significantly better than with Binder Jetting; however, the dimensional distribution was not always as good as conventional MIM tools," stated Breitenmoser.

Another innovation for prototyping is the use of additively manufactured tool inserts made of a material that can be removed in solvent. Parmaco's feedstock is injected into these tool inserts, then the entire tool insert is ejected. The tool insert is then dissolved in the solvent. What remains is the green MIM part, which is further processed using the usual technology. According to Breitenmoser, quite good surface qualities can be achieved if the tool inserts are manufactured with a very low build rate of around 10 μm per layer. "This process is ideally suited to prototyping microMIM parts, primarily because it is – at first – unnecessary to worry about ejecting the part from a mould," said Breitenmoser.

Fig. 7 A housing accommodating the electronic parts of a sensor used in the food industry to assess the quality of frying oil, made from 316L stainless steel (Courtesy Parmaco)

"A key driver of innovation is the need to reduce the time it takes to prototype a new MIM part. Parmaco has introduced special prototype injection moulds that have a modular design. The cavities for these prototypes are incorporated into prefabricated tool inserts, thereby enabling prototypes to be produced in only a few weeks."

Fig. 8 These jaw housings are an integral part of an assembly for vascular sealing instruments used in both open and laparoscopic surgery. These instruments are used in various surgical disciplines, including general surgery, gynaecology, urology, and thoracic surgery (Courtesy Parmaco)

"As part of a development project, Parmaco is investigating opportunities for the use of Artificial Intelligence (AI) in order to derive new process insights. The ambition is to further improve product quality through the huge amounts of data collected over decades."

In more than thirty years of MIM manufacturing, Parmaco has learned to effectively master its own processes. Through the extensive documentation of process parameters and quality checks, the foundation has been laid for reliable process monitoring. This makes it possible to detect deviations from 'safe' values at an early stage and to take countermeasures. As part of a development project, Parmaco is investigating opportunities for the use of Artificial Intelligence (AI) in order to derive new process insights. The ambition is to further improve product quality through the huge amounts of data collected over decades.

Marketing strategies

By international standards, Parmaco is not a company that wins customers through low prices; it is, after all, only through cost-covering prices that the company can pay Switzerland's high wages to its employees. "As a technology-driven company, Parmaco makes every effort to push MIM technology to its limits and to extend those limits further," said Hermes. "This builds trust with customers because they benefit from our technology, and they are willing to work closely together with Parmaco in the development of their products."

Compared to other MIM producers, Parmaco manufactures relatively small parts. According to Breitenmoser, the average part weight is 6 g. The smallest parts weigh significantly less than 0.05 g.

"With our sales activities, we are targeting the market leaders in the industries we supply," said Breitenmoser. Parmaco sees itself as one of the market leaders in MIM technology and the company's management sees that market leaders in end-user sectors appreciate Parmaco's superior technology.

"It is in our DNA to never stand still. Even if a part is already being mass-produced, there are always opportunities to further optimise production – be it automation, furnace process control, a better understanding of the scientific background – and to convert the results into stable, safe processes," explained Breitenmoser.

In Parmaco's early days, components for defence applications were of great importance and, to this day, Parmaco manufactures parts for this industry, but applications in the growing lock, sensor and medical device industries have become much more important. Minimally invasive surgical devices are often single use and the quantities consumed are highly-suited to MIM.

Application examples

Parmaco successfully manufactures components for laparoscopy, a minimally invasive surgical procedure for abdominal operations. A laparoscope (a device with a built-in camera, light source, and rinsing and suction device) is inserted through a small opening in the abdomen and can be used to diagnose organs in the abdomen, or for surgery. The requirements for MIM parts for laparoscopes are extremely high in terms of geometrical complexity and dimensional accuracy. This and other fields of medical application are very attractive for Parmaco.

Some examples of Parmaco's MIM products are shown in Figs. 7-11. Applications range from a sensor housing (Fig. 7) to laparoscopic instruments (Fig. 8 and Fig. 9) and robotic devices in medical technology (Fig. 10 and Fig. 11). All of the parts shown have extremely tight tolerances. These strict toler-

Fig. 9 These inserts are critical control components in vessel sealing instruments. The part is overmoulded with thermoplastic and serves as a lever for actuating the vessel seal. This insert is made from 17-4 PH stainless steel (Courtesy Parmaco)

"The requirements for MIM parts for laparoscopes are extremely high in terms of geometrical complexity and dimensional accuracy. This and other fields of medical application are very attractive for Parmaco."

Fig. 10 The tip core (upper part) is an articulated piece of an instrument control system for robot-assisted surgery, made from 17-4 PH stainless steel. The lower parts form a pair of scissors that are used as a cutting instrument in robot-assisted surgery and are made of AISI 420 martensitic stainless steel (© 2023 Distalmotion. Image used with permission)

ance specifications ensure the highest precision and reliability of surgical instruments and other assemblies. After manufacturing, most parts are subjected to heat treatment to optimise surface properties and increase surface hardness.

Sustainability and climate protection

Sustainability and climate protection are high on Parmaco's agenda. Breitenmoser ensures that measures are taken to both protect the environment and save on costs, whilst expecting politicians to also work to ensure that the wider industry is encouraged to take measures to protect the environment. As an example, he cites the CO_2 tax, which rewards companies that reduce their emissions of climate-damaging gases. Reductions in electricity consumption are also an issue. Next year, Parmaco plans to install solar panels on all roofs of company buildings, thereby generating around 25% of the energy it needs sustainably. It should, of course, be noted that around 60% of Switzerland's electricity comes from hydro-power, with a further 29% coming from nuclear.

However, he believes that there are limits to these measures. "If you want good quality, you should not overdo the savings," Breitenmoser said. This applies to both the consumption of process gases and to energy consumption.

> ***"Sustainability and climate protection are high on Parmaco's agenda. Breitenmoser makes sure that measures are taken to protect the environment and save on costs, whilst expecting politicians also work to ensure that the wider industry is encouraged to take measures to protect the environment."***

Life Cycle Assessments (LCA) are used to determine the consumption of gases, water and electrical energy in the company as well as the amount of waste in order to identify potential savings. Currently, the Fraunhofer IFAM institute in Bremen is developing standards for LCAs on behalf of the European Powder Metallurgy Association (EPMA) so that uniform methods for assessing sustainability can be applied in PM and other industries, enabling comparable results. In addition to the consumption values of the company's own operations, the CO_2 footprints of the raw materials used must also be included in the calculation. For Breitenmoser, it is essential that such methods are internationally applicable and provide meaningful comparative values.

For many years, Breitenmoser has also been actively involved in the EPMA and the German MIM Expertenkreis. These organisations offer a forum for an exchange between the participating organisations and also provide suggestions for development projects that benefit the entire MIM industry. Parmaco sees high value in these networking activities.

Conclusions

Since the beginning of the industrialisation of MIM technology in the early 1990s, Parmaco Metal Injection Molding AG has maintained a leading position in the European MIM industry. This achievement of Georg Breitenmoser cannot be overestimated, particularly since the conditions for the production of metal components are particularly challenging in a high-wage country such as Switzerland. With great perseverance, innovation and commercial prudence, he has guided the company through all of the past market challenges. Parmaco's team is determined to continue its success into the future.

Fig. 11 This fork is an articulation part used in the instrument control system of a robot-assisted surgical device. It is made of 17-4 PH stainless steel and is shown in the green and as-sintered states (© 2023 Distalmotion. Image used with permission)

Contact

Parmaco Metal Injection Molding AG
Fischingen,
Switzerland
www.parmaco.com

Kai Hermes
khermes@parmaco.com

Georg N Breitenmoser
gbreitenmoser@parmaco.com

Author

Dr Georg Schlieper
Essen, Germany
georg.schlieper@hotmail.de

Acknowledgments

Figs. 10 and 11 are published courtesy of Distalmotion, Épalinges, Switzerland

CMG Technologies: The UK's only MIM producer on its acquisition by Indo-MIM and expansion into filament-based AM

CMG Technologies Ltd, the UK's only producer of components by Metal Injection Moulding (MIM), has had a busy few years. Most recently, the company hit the headlines when it was acquired by Indo-MIM, widely considered to be the world's largest MIM producer with significant operations in India and the US. Prior to this, CMG had been expanding its presence in the metal Additive Manufacturing arena, developing its own range of filaments and providing toll debinding and sintering services to users of BASF's Ultrafuse products. Dr Martin McMahon visited the company and reports on developments.

Perhaps one of the UK manufacturing sector's best kept secrets is the success of a small Suffolk-based firm with the unrivalled position as the only UK-based Metal Injection Moulding (MIM) company, whose expertise further extends to feedstock production and sinter-based Additive Manufacturing. The intrigue of this alone was reason enough to warrant a visit, but recent events at the company pushed me to make the journey across the East Anglian countryside.

Readers familiar with the British landscape may be surprised by this; the region is often misunderstood, with most seeing this part of the country as being dominated by agriculture. Certainly, the journey through narrow wooded lanes, bordered by seemingly endless green fields, appeared to confirm this impression.

However, this region also holds a legacy from World War II and the Cold War, with various disused airfields spanning the landscapes. Several of these sites are now home to a growing number of manufacturers, start-ups and even some well-established firms. It was one of those locations that hosted my meeting with Rachel Garrett, Managing Director of CMG Technologies Ltd. I joined Rachel to learn about the company's journey to the forefront of the MIM sector in the UK, and understand more about the acquisition made by Indo-MIM in July – one of the world's largest MIM companies, as well as a metal powder producer, with operations in India and the US.

Fig. 1 A geared MIM part for use in a medical application, made from 17-4 PH stainless steel (Courtesy CMG Technologies)

Fig. 2 CMG Technologies' manufacturing operations are located on a disused military airfield, one of several such sites in the region that are now home to a growing number of manufacturing firms (Courtesy CMG Technologies)

Fig. 3 Members of the CMG Technologies team, including Rachel Garrett (far left) and Phil March (far right) (Courtesy CMG Technologies)

The history of CMG

CMG Technologies Ltd has been providing injection moulded components to the medical and opto-electronics sectors for over twenty-five years. The beginnings go back to the mid-1970s when Europlus was formed as a dedicated precision machining company. It later expanded into plastic injection moulding and built up a very successful business supplying the the emerging fibre optic telecommunications sector. It was as a result of this growth that Chris Conway was recruited into the business from Hewlitt Packard, taking on the role of Managing Director.

When MIM was first introduced, Conway brought in Phil Marsh, from Manganese Bronze, and Martin Scripps for their expertise in Powder Metallurgy and the new MIM process. Between them, the three men grew a very successful business until – through their perseverance and dedication to MIM technology – the company was acquired by one of its leading customers, France's Egide, in 2002.

This came right at the end of the dark days following the telecoms 'boom and bust' period that started in the spring of 2000. This forward-thinking team then continued to run the business for more than a decade, the end of which saw the retirement of Scripps from the company. In 2013, Egide decided to move away from precision component manufacturing, leading Chris, Phil, and now Rachel Garrett, who had moved up to the management team, to complete a Management Buyout (MBO) to form Conway Marsh Garrett Technologies, and the company now known as CMG Technologies was established.

Today, the company is being steered by Garrett, who could never have imagined taking the reins when she first joined the business in 2004, when the company was still owned by Egide and run by her late father Chris Conway. She works alongside the other director of the business, Phil Marsh, who joined the company in 2000.

Current operations

During my visit, I found a company that was small enough to still be called a family business, a fact underlined by many aspects of the operation. And yet it remains innovative and modern in its approach to dealing with the ever-changing world. From its modest beginnings with just one injection moulding machine and practically one customer, the company now operates eight injection moulding machines, a robotic system for the automatic removal of moulded parts, six debinding furnaces, and four sintering furnaces, including vacuum furnaces. To this, CMG has also added three in-house feedstock mixing machines and a small selection of filament-based Material Extrusion (MEX) machines – a process also referred to as Fused Filament Fabrication (FFF).

It is often difficult for small companies deeply rooted in the local environment to find new ways of working, but CMG Technologies has avoided this trap because another innate aspect of its culture is that of innovation. With a mix of parts that uses either commercially available feedstock from the likes of BASF, or its own in-house developed and mixed feedstock, CMG has the flexibility to select the best solution for any given application.

CMG Technology's management team is always seeking to make improvements and, rare amongst those in manufacturing, not afraid to introduce change. In relation to its feedstock expertise, the company's output now also includes metallic filaments for use in a range of filament-based AM machines, which coincided with the introduction of Additive Manufacturing as a service in 2021. "Having that know-how on making MIM feedstock meant it was only a small incremental step that was quite logical for us," explains Garrett. As she went on to describe the process to formulate the compounds necessary to make the filaments, it was easy to see how the company is also able to utilise the debinding and sintering expertise that it has developed in-house.

Over the years, the company has had many order enquiries which don't always fit with its standard 316L and 17-4 PH stainless steel feedstocks. This led the team to develop tailored solutions, an area in which the expertise of co-founder, Phil Marsh, has been paramount. Being able to provide MIM solutions through the development of feedstocks to produce parts in advanced engineering alloys (e.g. Inconel, Hastelloy, and Kovar) has positioned CMG at the forefront of this niche in the market. I was told about one customer that had started to experience issues in the field with some components that were not strong enough. The CMG team was able to transition this part from steel to one of the Ni-based superalloys, without any significant cost increase to the customer.

Fig. 4 An Arburg injection moulding machine with a robotic system for the removal of parts from the mould (Courtesy CMG Technologies)

Fig. 5 Visual quality inspection of MIM parts (Courtesy CMG Technologies)

"In relation to its feedstock expertise, the company's output now also includes metallic filaments for use in a range of filament-based AM machines, which coincided with the introduction of Additive Manufacturing as a service in 2021."

Fig. 6 A view of CMG Technologies' manufacturing facility (Courtesy CMG Technologies)

CMG has not only taken a lead in terms of the technology and materials, but also in its approach to everyday work. Take, for instance, its introduction of a four-day working week in 2015, several years ahead of the UK's mainstream trial last year. This has allowed all employees more time with their families and to pursue other activities, whilst the company still runs a double shift pattern with continuous production, seven days a week. That's almost unheard of anywhere else in the British manufacturing sector, and Garrett attributes much of the company's current successes to this way of working.

Family is obviously a very important part of the business culture; taking over the role in 2018 after her father passed away, Garrett works part-time as Managing Director of the business in order to spend time with her own family. She's also joined in the company by her partner, who is responsible for maintenance engineering. Garrett stated that many others in the company also work with partners and family members.

"Take, for instance, its introduction of a four-day working week in 2015, several years ahead of the UK's mainstream trial last year. This has allowed all employees more time with their families and to pursue other activities, whilst the company still runs a double shift pattern with continuous production, seven days a week."

The UK MIM market

Talking about the status quo of MIM in the UK, Garrett commented on the pros and cons for the small company: "We're the only ones in the UK doing the complete MIM process from scratch, which is nice because if someone wants a UK-based company, then that's a positive for CMG." However, she then went on to say, "There's also a downside, because we're the only company in the country talking about MIM and trying to promote the process." This can be a very difficult situation for any business trying to introduce an alternative solution into any sector, and often success largely depends on the passion of an individual. Here, Garrett talked about her father's passion for the MIM process, and his determination to see it succeed for their business when others had turned away, failed, or simply chose to outsource to Asia.

The more common model in the UK is that of companies offering MIM sales but with all production carried out overseas, mainly in Asia. However, being the sole MIM producer is not always a hindrance, and indeed the company's growth and current position has partly come about because of customers that have come to them as a result of cessation or poor service by an overseas producer.

Given the above, one would have imagined that the UK domestic market alone would saturate demand for CMG's services. However, as a result of the steady growth that has come about by responding to the right opportunities, the company now gets 25% of its business from overseas. These exports are primarily to mainland Europe, but also include a small fraction to the US. This is impressive considering that CMG has never had a dedicated salesperson, with all business being won either through historical relationships, or by the management team themselves hitting the road. This is about to change though, as the new owners plan for growth through the addition of a Technical Sales Manager to the team.

Customers

Serving a selection of customers in light industries, with some business coming from the consumer market and some from automotive, CMG's main business currently comes from the medical sector, and it is very likely that this will remain a key area for the company under the new ownership. As a vital producer for companies that are supplying into the UK's National Health Service (NHS), and with the current backlog of operations that increased significantly due to effects of the COVID-19 pandemic, CMG has a pipeline of business for a good few years into the future.

This is particularly aided by the fact that many of the MIM parts produced are for items classed as single-use under current NICE (the UK's National Institute for Health and Care Excellence) guidance. Take, for example, the many types of jaws used at the end of surgical manipulators and lances for keyhole surgery and biopsies – it's considered too time-consuming and expensive to clean and sterilise these parts, so

Fig. 7 A selection of MIM parts produced by CMG Technologies for applications in the medical, industrial, instrumentation, jewellery and fibre optic industries. The materials used are 17-4 PH and 316L stainless steels (Courtesy CMG Technologies)

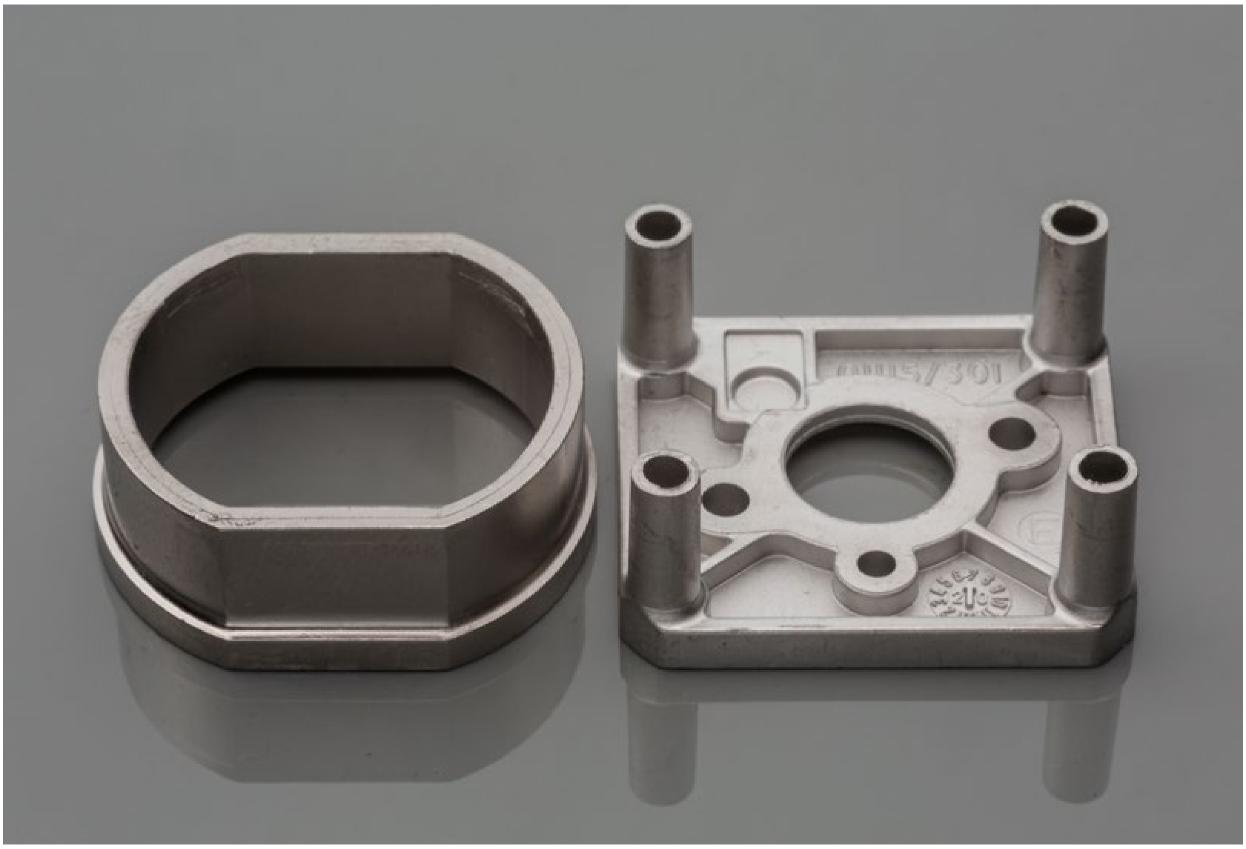


Fig. 8 Components used in a ventilator's gas analysis system. There was a significant ramp up in the production of these parts during COVID-19. The left part is made from nickel iron, and the right part from 316L stainless steel (Courtesy CMG Technologies)

they are simply replaced after each use. "We found that MIM really came into it own around these types of projects, where you still needed the complexity, but you also wanted it at low cost," Garrett shared.

The medical sector was also the reason CMG was able to stay fully operational during the COVID-19 pandemic and its related lockdowns. Other areas of the business may have slowed down in this period but, due to one customer that required critical parts for its ventilators, CMG was actually able to increase production. Speaking about two such components, Garrett commented, "We would normally make about 1,000 a month, but, during COVID, in one month we made 20,000 of each type of part; it was a really crazy time for us and we actually employed a couple of additional people."

So, there you have it: a little known, but uniquely successful, business tucked away close to the coast of Suffolk, managing to hold its own in a world dominated by international players. A company growing at a slow and steady pace and very comfortable in what it has been achieving and is able to deliver. This is precisely where Indo-MIM comes into the story. Not looking to be acquired and happy with their lot, Rachel Garrett and Phil Marsh, the two remaining shareholders of CMG, were quietly approached in the latter part of last year. That's when CMG's journey started to take a new direction.

Interest from Indo-MIM

Following some rapid negotiations during frequent meetings between CMG and Indo-MIM, the deal was concluded in just a matter of months. It was during the latter part of the summer that we heard of the takeover by Indo-MIM; a surprise move I'm sure no one from inside the sector would have seen coming. Why would Indo-MIM, an international leader in the field of MIM with annual turnovers of between £120-170 million, want to acquire this small UK-based firm with its modest turnover of £3-4 million?

The answer to this question tells a story of aspirations and of recognition of the value of a business that has grown from humble beginnings through the hard work of a dedicated management team.

When Indo-MIM initiated its search for a business to buy in Europe or the UK, it wanted a MIM business that had stability, a mindset for growth, a management team which would stay on through the transition. As luck would have it, CMG met its criteria perfectly, and both Rachel Garrett and Phil Marsh will continue to lead the company into the future, only now with the support of a robust overseas supply chain that encompasses all key aspects of the MIM process, from powders to an even wider global customer base.

Let's be clear: CMG wasn't a company looking for a buyer and it was enjoying steady growth, with particularly loyal customers in the medical sector and fibre optics sector. This can partially explain the motivation of Indo-MIM for the acquisition, since it serves it well to own an operation that could continue to stand alone and operate without intervention. At the same time, this gives Indo-MIM a firm foothold in the UK and serves as an ideal launchpad into the rest of Europe, which is already strongly supported by a sales office in Germany.

CMG welcomed this takeover as it had always recognised Indo-MIM's success within the Metal Injection Moulding supply chain. The company management team knew that this would be an ideal way to help it grow far faster than it could manage by itself.

As stated, this acquisition took place very quickly. With visits to India to see the scale of the operations in and around the city of Bangalore, and respective visits to Suffolk, there was an almost instant realisation that it was a good fit for both parties. One, a global family-led business with a strong tradition of bringing its employees along on its journey, and the other, a small company that has become a family of sorts in itself, with management and team members that have been there for decades. Looking at it from the outside, it's not difficult to interpret the arrangement as more of an adoption than a traditional acquisition.

Fig. 9 Part of an anti-collision radar system used in automotive. The material is nickel iron, which is then gold plated (Courtesy CMG Technologies)

Fig. 10 The head of a traditional razor, made from 316L stainless steel (Courtesy CMG Technologies)

The future under Indo-MIM

"The integration between our companies is still at an early stage, so the directions aren't completely set. But keeping our culture alive and maintaining existing customer relationships is a key priority for Indo-MIM," Garrett shared. But does this signify the start of greater expansion by Indo-MIM into the UK and across Europe?

That remains to be seen, but this acquisition has created a unique synergy allowing Indo-MIM to concentrate on MIM projects that are really high volume, and where the part costs are very low. CMG, on the other hand, targets comparatively low-volume products and concentrates on maintaining a good margin. Where previously each company would have had to turn down projects due to either too high a cost for low volume or a lack of capacity for high-volume work, respectively, they can now offer that service to their customers.

Both companies have identified areas where they can now return to previous opportunities to add orders for their businesses. This will no doubt also enable them to seize more business globally, which sits well with the plans for growth at the site in Rendlesham.

Garrett explained that the current site will be CMG's initial point of growth and it seems that investment into that site will enable further development of its automated lines, with planned installations for additional robotic systems in the coming

Fig. 11 Dr Samuel Wilberforce, R&D Head, 3D Printing, at CMG Technologies Ltd working with the company's CMG Tech-X filament (Courtesy CMG Technologies)

years, as well as greater sintering capacity when the company adds another furnace to the facility in the coming months. Garrett added, "We have automation on the moulding line, but now we'll be looking at automation on the staging part of the process as well, and, whilst there's investments being made in automation, this will create opportunities for our current employees to extend their skill set as well and learn different parts of the process in the automation side of things."

More sintering capacity and more automation will optimise what is already in place. One niche which would suit more automation is when parts coming out of a furnace need a secondary operation, like a coining step; any such additions to CMG's lines will only improve its throughput. It doesn't just stop at the factory floor hardware either, and Garrett explained that the company is eager to modernise operations with the introduction of specific MES software. Like many similar small operations that have grown organically, software wasn't the first thing that was considered when looking at making improvements. When the company was able to make further investments, it has always been in increasing capacity. Managing the production schedule has been reliably managed from inside a workbook, manually manipulating spreadsheets on a day-to-day, week-by-week and month-to-month basis.

"When Phil and I have had the ability to make investments in the past, we've wanted to invest in equipment since the management of 'work in progress' we can do ourselves, it doesn't optimise it, but we can get the job done," Garrett stated. New ownership, with greater investment potential, means the company is now ready and able to modernise in this area too.

Filaments for sinter-based metal Additive Manufacturing

To some, there is an obvious link between MIM and metal Additive Manufacturing, because of the more commonly associated reliance of the latter on metal powders. If we consider polymer AM for a moment, it was through the link to injection moulded plastics that the process first came into popular industrial use. It was quickly established that it was easier and cheaper to make additively manufactured prototypes before having to commit to expensive mould tooling. CMG simply made that connection themselves for MIM. "Our main reason for pursuing Additive Manufacturing was because we saw an opportunity to offer to customers the chance to see what their parts would be like without having to make the upfront investment in the tooling.

We felt if they had the opportunity to see and feel their parts then that would encourage them to progress with the MIM process," Garrett commented.

After having assessed that Binder Jetting was still underdeveloped and too expensive, the company opted for filament-based Material Extrusion (MEX,FFF) using metal-containing filaments that were available on the market. This quickly proved to be a good decision for the business, but being the type of company that can identify opportunities and react to them in an agile way, it was a logical step for CMG to produce its own filaments. This meant that it could start to offer more alloy types than what was commercially available, and it accomplished this without having to bring in any additional equipment.

CMG relies upon its existing systems for developing and mixing its MIM feedstock, whilst sub-contracting the actual extrusion and spooling. However, CMG didn't set out to be a materials supplier to the maker community. Over a period of time that it has gone from catering to the needs of its own business to gradually realising that there was an opportunity to market the filament to other users of these systems.

It certainly seems there's plenty of room for sales growth with these materials, and CMG claims that its particular type of filament is highly-suited to both small-scale prototyping and industrial use, with an ever-increasing range of alloys becoming available. These include typical stainless steels 316L and 17-4 PH, low-alloy steel, H13 tool steel, copper, and Ni-625.

During the visit, I talked with Sam Wilberforce, someone else with an infectious enthusiasm for metal Additive Manufacturing, and he explained the company's plans to also develop filaments for both titanium and tungsten. It remains to be seen if these become successful but, judging by the way that the AM market is still growing and developing, it would not come as a great surprise to hear about it in the near future. Being part of the Indo-MIM family should give

Fig. 12 A 17-4 PH stainless steel part manufactured by MEX/FFF from CMG Tech-X filament (Courtesy CMG Technologies)

Fig. 13 A 17-4 PH stainless steel propeller manufactured by MEX/FFF from CMG Tech-X filament and used in Safety Of Life At Sea (SOLAS) boats (Courtesy CMG Technologies)

Fig. A 17-4 PH stainless steel decorative part manufactured by MEX/FFF from CMG Tech-X filament (Courtesy CMG Technologies)

Fig. 15 Filament-based Material Extrusion/FFF machines at CMG Technologies (Courtesy CMG Technologies)

Fig. 16 A spool of CMG Tech-X filament (Courtesy CMG Technologies)

CMG the resources required to accelerate this, if needed, and certainly access to markets further afield.

Something else that works in the company's favour is that the debinding solution used for its filament is acetone. Since the filaments are suitable for use in a range of entry-level FFF AM machines, this makes the process very affordable for anyone wishing to explore AM before making bigger investments. "Because of our expertise in selecting and blending MIM feedstocks, we have produced a filament that results in parts with an excellent surface finish compared to other metallic filaments," explained Wilberforce excitedly. He then went on to show me some of the customers' finished parts that enabled CMG to gain customers in the medical sector, as well as the fashion industry and other niche applications.

A provider of toll debinding and sintering services

Not resting on its laurels, CMG has also quietly been developing other services and positioning itself for further growth as a service provider of toll debinding and sintering services for both MIM and AM parts. Already working to support BASF with the debinding of customers' parts made from its ultrafuse filament range, as well as 3DGBIRE from the northwest of England, with toll debinding and sintering, CMG also started advertising this service in the past few years for any customers that don't have the capability to do this on their own.

It's a compelling offer and works hand-in-hand with the company's own Additive Manufacturing capability so that, for any company that wants either small volumes of MIM or additively manufactured parts, CMG can offer the whole process up to the stage prior to finish machining; this is still currently outsourced. CMG has a modest tool and machine shop, used mainly for maintenance of the mould tooling – all of which is also currently outsourced – and other systems.

Fig. 17 A 17-4 PH stainless steel surgical handle produced by Metal Injection Moulding and used in the UK's National Health Service (Courtesy CMG Technologies)

CMG also hopes for more widespread adoption of metal AM into the consumer-based market, for which it feels ideally positioned due to its service offering. Many home-based users of polymer FFF machines can now also make metal parts using the metal filaments that CMG has developed, and then have CMG finish the process for them as well. It's perhaps the first time that this author has been tempted into this area of the sector. It represents a very affordable way for individuals or very small companies to start making their own parts.

Concluding thoughts

It is clear that CMG Technologies' primary focus remains on the MIM process and there's still a lot to be explored between the new owners, Indo-MIM, and CMG's directors, Garrett and Marsh. AM, however, presents a significant new opportunity and there is a continued ambition to embrace innovation. With the backing of Indo-MIM, bigger opportunities to expand and explore new areas are now within reach.

Author

Dr Martin McMahon
Technical Consultant, *PIM International* magazine, and founder of M A M Solutions.
martin.mcmahon@mamsolutions.uk

Contact

Rachel Garrett
Managing Director
CMG Technologies – 3D Metal Moulding
rgarrett@cmgtechnologies.co.uk
www.cmgtechnologies.co.uk

Insight from Fraunhofer IFAM's 4th Workshop on Sinter-based Additive Manufacturing: A status update

The 4th Workshop on Sinter-based Additive Manufacturing, organised by Fraunhofer IFAM, in Bremen, Germany, took place from September 13-14 2023. It convened global experts to discuss advancements and challenges in the field. The workshop explored the maturation and potential applications of sinter-based AM technologies and highlighted the latest technical advances. Sonja Böske da Costa reports on the workshop's presentations and discussions.

At the 4th Workshop on Sinter-based Additive Manufacturing, organised by Fraunhofer IFAM in Bremen, Germany, the 'who's who' of this dynamic branch of metal AM made it their mission to address the biggest challenges that this area of the technology faces, consider if and where progress has been made, and explore what happens now, after the 'AM hype' of recent years.

Without giving it all away, by the end of the event the answer was clear: the technology has matured immensely over the past few years and, as a group of manufacturing processes, sinter-based AM has found more than just a niche. Every aspect of the technology is constantly developing and maturing, from powders to binders, furnaces to process automation.

The audience at the workshop was an international mix of suppliers, researchers, and users. During and between presentations, the discussions were very open about understanding the current *status quo*, the challenges, and exploring the *quo vadis*. On the first day, following a welcome by Fraunhofer IFAM's Dr Sebastian Boris Hein, Head of Department Powder Technology, the opening session featured a statistics-based presentation on current and future addressable markets for sinter-based AM by Bastian Barthel, AMPOWER, and a hands-on 'how to' talk on debinding and sintering technology by Stefan Joens, Elnik Systems LLC.

Both agreed that the Binder Jetting (BJT) technology landscape is maturing. From stainless steel valves to surgical jaws and smart watches – anything appears to be possible. Barthel presented a projection that forecasts that Binder Jetting will see a significantly increasing share of metal AM machine sales between now

Fig. 1 Delegates at the 4th Workshop on Sinter-based Additive Manufacturing, in Bremen, Germany (Courtesy Fraunhofer IFAM))

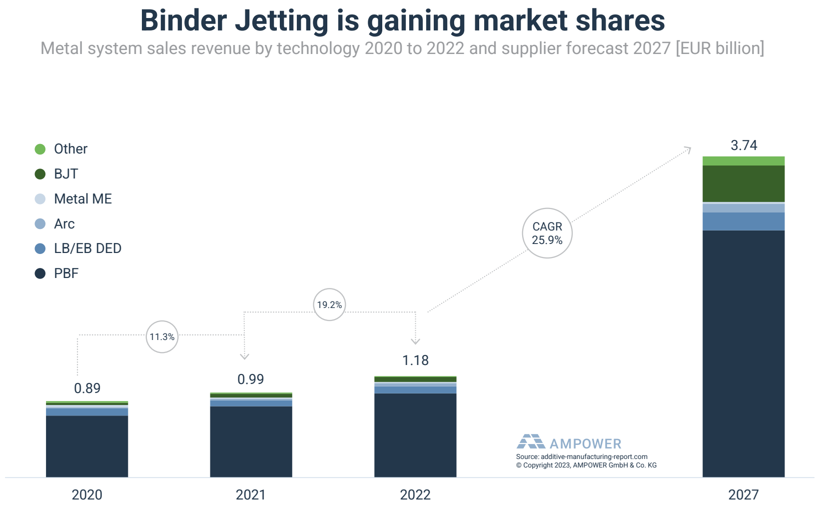


Fig. 2 Binder Jetting is projected to see a significantly increasing share of metal AM machine sales between now and 2027 (Courtesy AMPOWER)

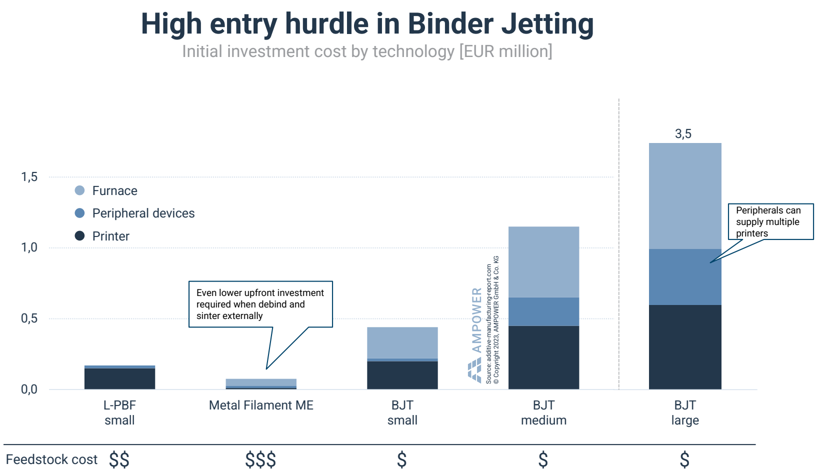


Fig. 3 The current initial cost of entry for both small, medium and large-scale Binder Jetting operations are significantly higher than other metal AM processes (Courtesy AMPOWER)

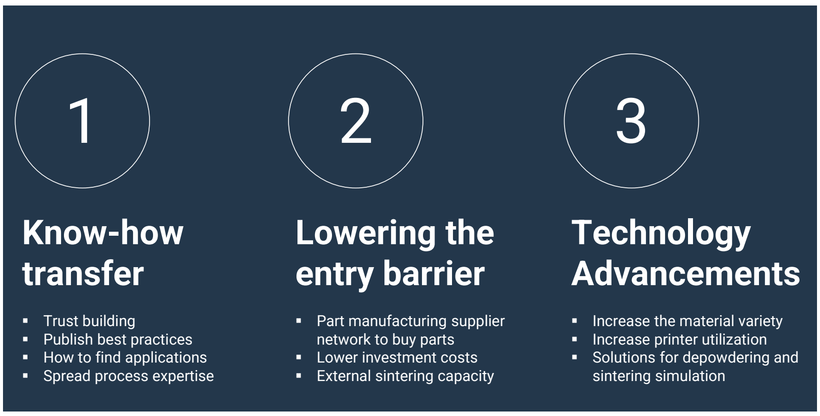


Fig. 4 Critical success factors to capture the addressable market for BJT, according to AMPOWER (Courtesy AMPOWER)

and 2027 (Fig. 2). Yet, the question remains as to why the most likely application areas for the technology are only slowly being adopted by the mass market. As in any industry, the lower the cost of a technology, the bigger its potential market becomes. Cost reduction, it was agreed, is therefore key. Fig. 3 shows that the current initial cost of entry for both small, medium and large-scale Binder Jetting operations are significantly higher than other metal AM processes. To capture the addressable market, three goals (Fig. 4) were identified:

1. The effective transfer of expertise/knowledge
2. Lowering of barriers to entry
3. Technology advancements

These relate closely to what Joens focused on when he defined his mission as "turning the black box situation in sinter-based Additive Manufacturing into a glass box."

He also shared an 'insider's tip' with participants: focus on fewer binder types, and use Thermogravimetric Analysis (TGA) to fully understand your debinding process. All binders are different, he stated, and he encouraged participants to perform TGAs using the processing environment which will be used for volume production. His rules for TGAs were outlined as follows:

1. Ramp rate should be 1-2°C per minute - not more!
2. Perform the TGA with the same gas as used for debinding
3. Ramp up to 600-700°C

His key message? You can't over-debind your parts, but you can certainly under-debind your parts, and TGA will show you what is happening.

Another process consideration highlighted was build density – the denser, the better – but strive for build density consistency. Residual stresses resulting from the build direction are usually only noticeable after sintering, when it is too late, so the use of sinter simulation software may help to prevent scrap.

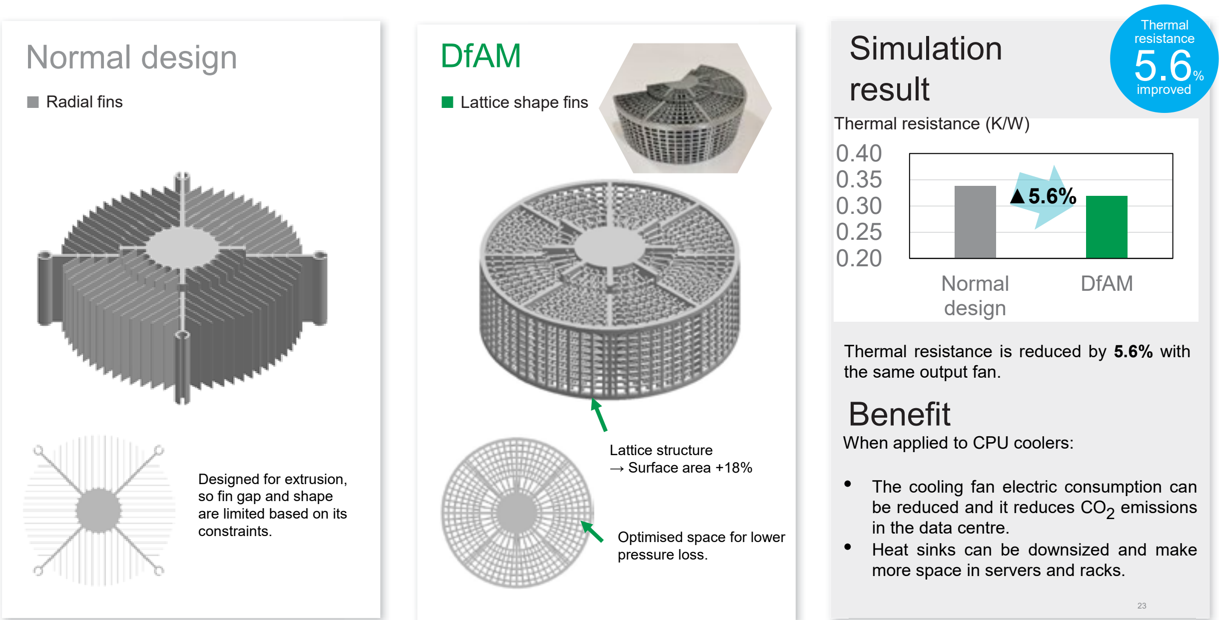


Fig. 5 Ricoh's Takafumi Sasaki presented this case study of a forced air AlSi heat sink (Courtesy Ricoh)

Lightweight and reactive materials

The opening session was followed by discussions on the Binder Jetting of lightweight and reactive materials – with Takafumi Sasaki, Ricoh Company Ltd., and Matteo Zanon, Kymera International, focusing on aluminium alloys. Pierre-Victor Sabatier, Desktop Metal, also considered lightweight metals, including titanium alloys.

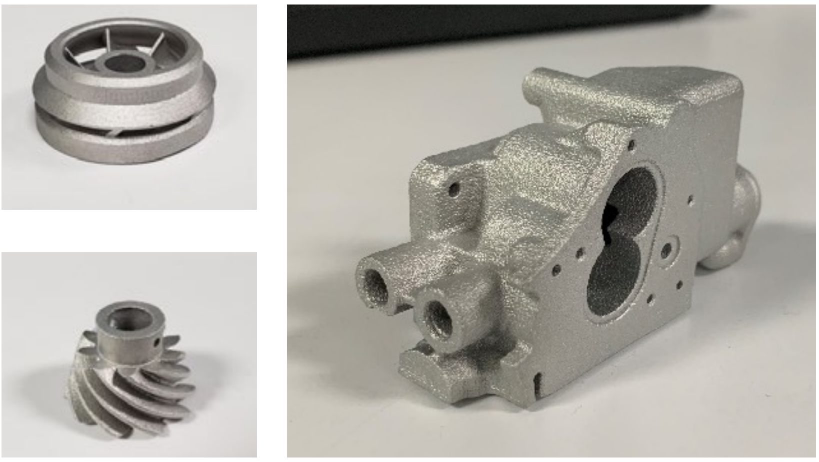


Fig. 6 Aluminium (Al6061) BJT parts presented by Desktop Metal. Top left, an ExOne pump impeller; bottom left, an Eaton helical screw; right, an Eaton pump housing (Courtesy Desktop Metal)

Commercialising aluminium BJT

Ricoh's Takafumi Sasaki stated that it was his mission to commercialise aluminium Binder Jetting. The difficulties of sintering aluminium are well-known. Sintering at a temperature that breaks the oxide layer will melt the aluminium as well, making it impossible to retain the shape of the green part. Ricoh's solution to the problem is an optimisation of Liquid Phase Sintering. The company had introduced three strategies to retain green part shape:

1. Precise temperature control
2. Advanced support strategies including setters and ceramic powders
3. Design for AM – knowing the limits of the technology and geometry.

Ricoh's presentation concluded with two case studies and two life-cycle cost analyses, which considered not only material and production costs, but also the parts' respective carbon footprint. Fig. 5 shows one example of an aluminium alloy (AlSi) BJT part produced by the team at Ricoh.

BJT process safety, stability, and repeatability

David Wonn and Pierre-Victor Sabatier from Desktop Metal added their latest developments on printing and sintering aluminium in an inert atmosphere, which ensures process safety and process stability as well as the repeatability that is indispensable with regards to industrialisation. A number of sample parts were presented, including those shown in Fig. 6.

	Green density%	Sinter density %	Δl (length) %	Δb (width) %	Δh (height) %	Δm %	T6			
							Brinell Hardness HB2.5/62.5	Rm N/mm²	Rp 0.2 N/mm²	Elongation (plastic)
BJT	51%	98.9%	-16.0%	-16.5%	-21.0%	-2.0%	118	350	300	2.5
FFF	59%	99.7%	-13.6%	-15.2%	-18.1%	-10.5%				

Table 1 Green and sintered properties for BJT and FFF with AA6061 (Courtesy Kymera International)

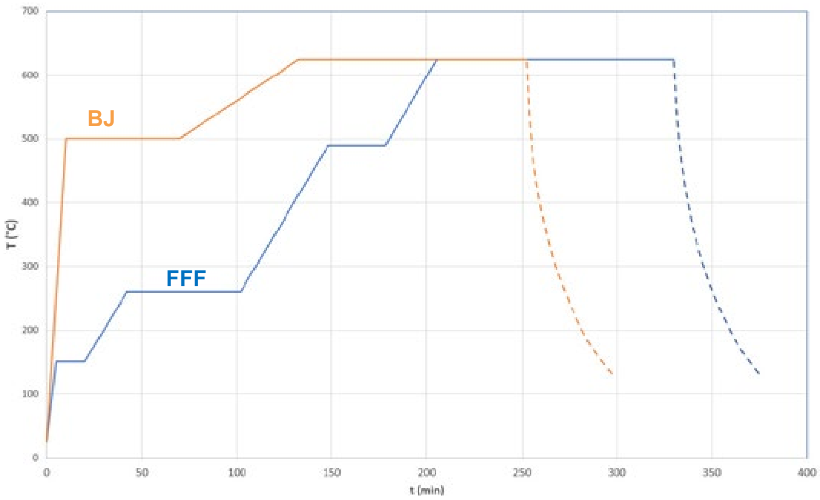


Fig. 7 BJT and FFF debinding and sintering cycles compared (Courtesy Kymera International)

> *"Filament-based MEX and BJT have similar properties. Whilst the mechanical properties are comparable, the green density of filament-based MEX is higher, which leads to a lower shrinkage rate and therefore more exact dimensional control."*

The biggest challenge in general is variability – that the results vary from day to day. One key factor behind the successful development of aluminium Binder Jetting, Wonn and Sabatier stated, is the use of Live Sinter, Desktop Metal's sintering simulation and distortion compensation software. The second key factor is the development of new binder systems, together with Fraunhofer IFAM in Bremen, for reactive materials such as aluminium and titanium, in order to control carbon content and improve green strength for safe handling.

Binder Jetting vs. Material Extrusion

Kymera's Matteo Zanon elaborated on the Binder Jetting of aluminium versus filament-based Material Extrusion (MEX), also known as Fused Filament Fabrication (FFF). He stressed that the binder is one of the most important parameters of the process, and that deformation after sintering is the biggest challenge which jeopardises the repeatability of results.

Filament-based MEX and BJT have similar properties. Whilst the mechanical properties are comparable (Table 1), the green density of filament-based MEX is higher, which leads to a lower shrinkage rate and, therefore, more exact dimensional control. Thus the *raison d'être* for both processes is legitimate, and the actual application needs to be validated for each business case. A comparison of the debinding and sintering cycles is shown in Fig. 7.

Binder Jetting: Gas, HIP, and technology accessibility

The first day of the workshop was rounded off with insights on hardware and processing-related considerations for Binder Jetting – with a focus on the role of gases from Kai Zissel, Linde GmbH, post-sintering heat treatments by Fredrik Berg Lissel, Markforged, and upscaling of complex metal part production by using cost-effective solutions from Eren Tigrel, Sintertek.

The role of gases in the complete process chain

Kai Zissel elaborated on the role of gases along the Binder Jetting value chain and started with the atomisation process, where gases play a major role in improving the process. The storage of powder in a protective environment then ensures consistent powder quality. An inert environment during printing & curing, he stated, enhances the choices of processable materials by reducing safety risks as well as improving process robustness and powder reusability by limiting oxidation. Linde, it was stated, is developing an argon/oxygen mixture for efficient debinding, while limiting oxidation. For sintering, Linde has developed an 'office-friendly' ADDvance® Sinter250 product, an argon/hydrogen mixture for improved sintering performance. Linde AM's R&D centre in Munich, which features a Desktop Metal Production System P1 along with post-processing and analysis equipment, supports the company's work on process gas optimisation for BJT (Fig. 8).

Post-sintering HIP of BJT-processed H13 tool steel

Frederik Berg Lissel provided an overview of different post-sintering heat treatment approaches at Markforged, based on the BJT technology it acquired from Digital Metal, to improve the mechanical properties, especially the impact toughness, of BJT H13 tool steel.

Different combinations of sintering temperature and HIP cycle with a view to grain refinement were applied, and the resulting material properties were examined. HIP and grain refinement have a significant impact on the elongation of hardened and tempered H13, whereas yield strength and ultimate tensile strength is only marginally affected by the microstructural changes. Low temperature sintering provides for lower density, but it is still possible to HIP and achieve significant grain growth (Fig. 9).

Why aren't more people 'doing' AM?

Eren Tigrel attempted an answer to the question: why is everybody talking about Additive Manufacturing, but few do it? He mirrored the earlier suggestion that high initial barriers to entry are surely a leading explanation for this. His ranking of barriers was as follows:

1. High initial costs
2. Complexity in process parameters
3. Limited access to training
4. Post-processing challenges
5. Material limitations

Fig. 8 Linde AM's R&D centre in Munich supports the company's work on process gas optimisation for BJT (Courtesy Linde)

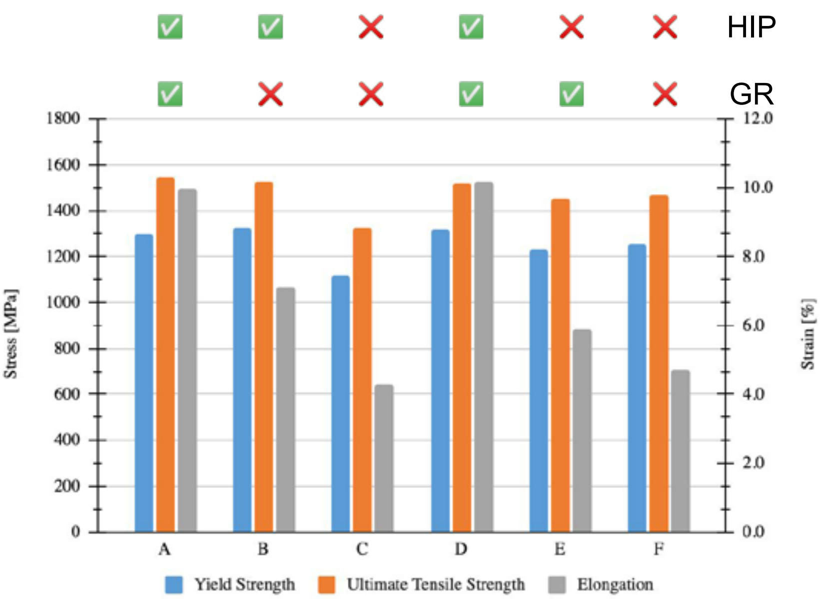


Fig. 9 Different combinations of sintering temperature and HIP cycle with a view to grain refinement were applied to BJT H13 tool steel (Courtesy Markforged)

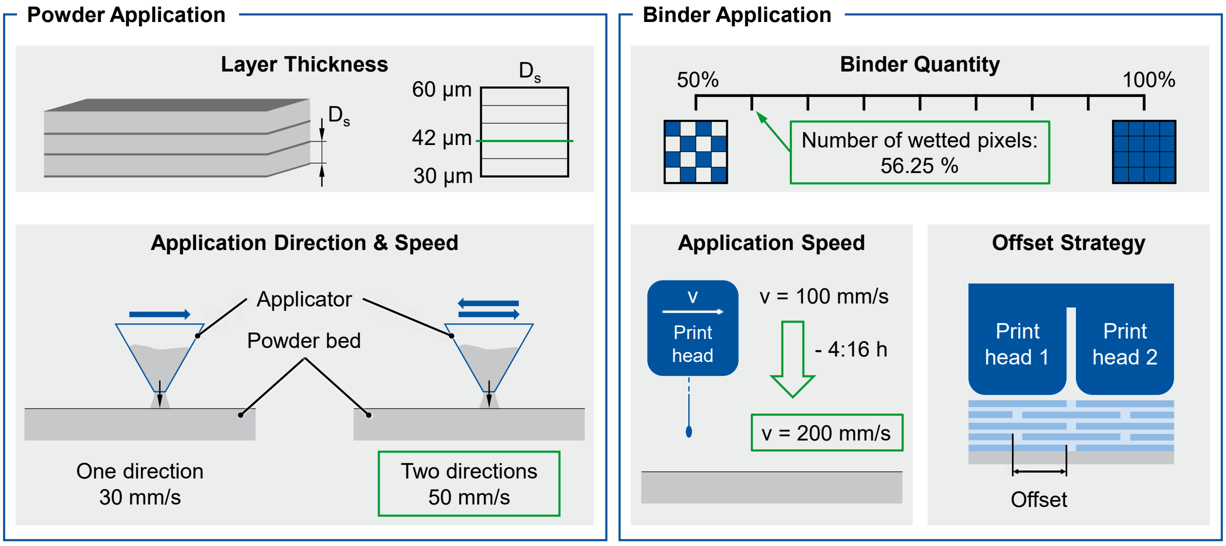


Fig. 10 Control variables for the optimisation of BJT gears - powder and binder application (Courtesy RWTH Aachen)

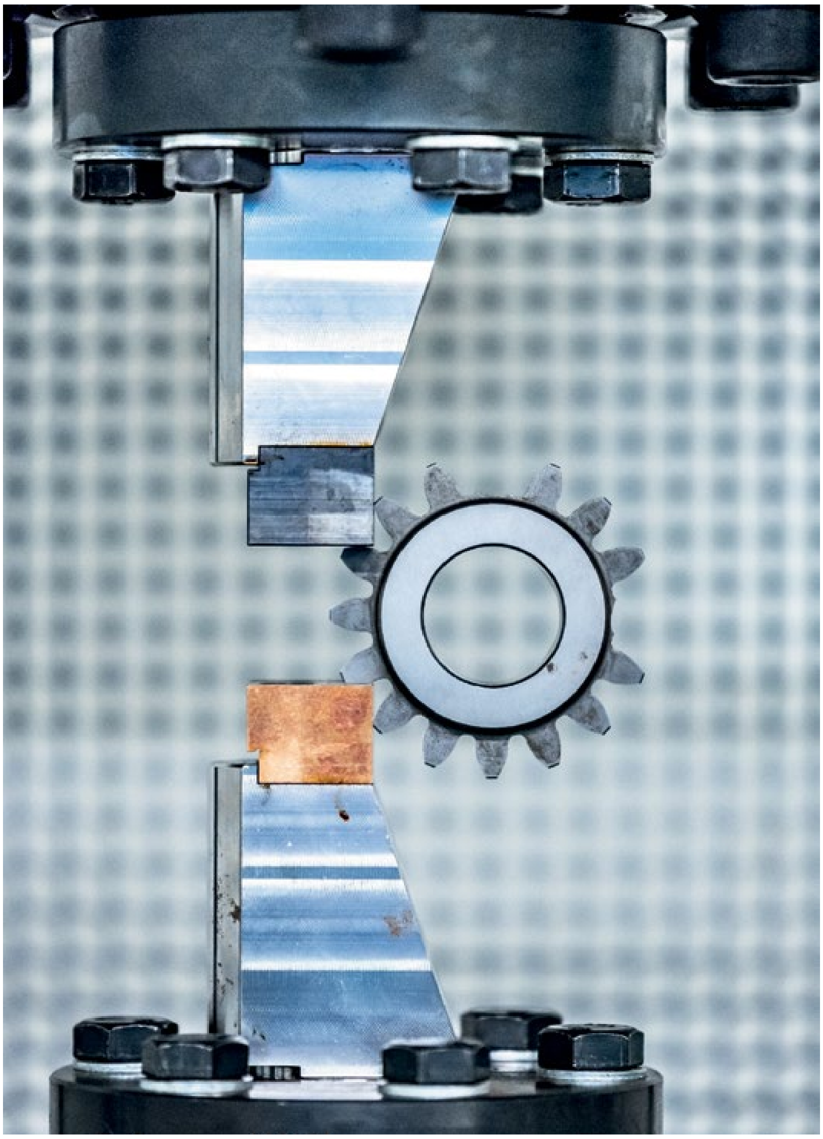


Fig. 11 Testing the 17-4 PH stainless steel BJT gear (Courtesy RWTH Aachen)

Accessibility is key, he stated, and the more a technology is used, the more everyone can benefit from the insights and learnings.

Material and process-related developments

The second day started off with a session on material and process developments. This began with the presentation of a project on the manufacturing of highly-stressed powertrain components by Gerrit Hellenbrand, from the Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen, followed by a discussion of the potential opportunities in the area of high-speed steels led by Dr Ing. Patrick Koehnen, GKN Additive Manufacturing. The session concluded with insight into the benefits of fine gas atomised powders by Dr Paul Davies, Sandvik Osprey Ltd.

Evaluating a BJT powertrain gear

Much work has been done on the production of automotive gears via the 'press and sinter' Powder Metallurgy route, with some successes. Gerrit Hellenbrand and colleagues are taking the use of metal powder-based processes a step further by evaluating the performance of gears produced by Binder

Jetting. Motivations include the ability to easily rapid prototype gears, the ability to significantly reduce part weight (hence impedance) and material usage, improved management of noise, vibration and harshness (NVH), and reduced overall energy consumption in manufacturing and operation.

To achieve a high green part density, 17-4 PH stainless steel was used for the gears featured in this presentation. Much effort was made to understand and control the process variables for the optimisation of BJT gears, including in relation to powder and binder application (Fig. 10) The produced gears were tested either by a running test or by an analogy test of the tooth root (Fig. 11). The endurance limit for the tooth root load capacity of Binder Jetting gears made from 17-4 PH was improved by 96% compared to 316L. Future work will include the development and certification of further materials, in particular case hardenable steels.

An exploration of BJT for high speed steels

Patrick Köhnen, GKN Additive Manufacturing, focused on the potential of industrial metal Binder Jetting in the field of high-speed steels. He stressed that sintering simulation software is key for highly complex parts. The wider challenge, of course, is that metal AM is an expensive endeavour, but there is great potential for the serial production of high-speed steels via sinter-based AM. Supersolid liquid phase sintering helps in achieving high densities, it was stated, but, as pointed out by the previous speakers, process control is key to shape loss in sintering.

The results presented showed part densities that varied between 99.6 and 99.7% without HIP treatment. It was shown that a high (and finely distributed) carbide content resulted in excellent hardness and wear-resistance (Fig. 12). The benefits of using BJT were stated as 50% higher productivity, 67% higher tool lifetime and 70% less raw material compared with conventional production.

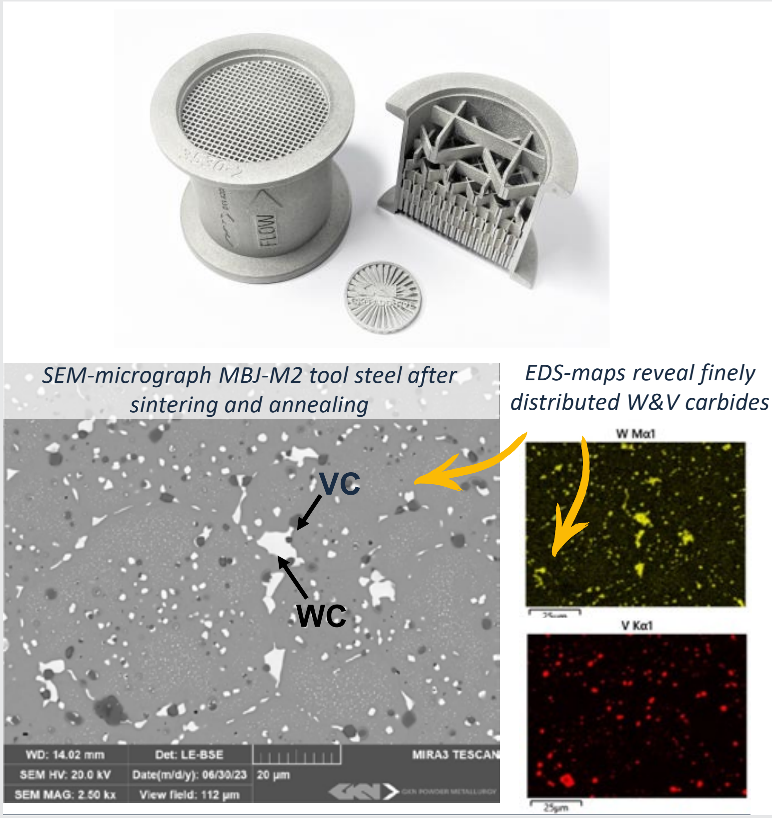


Fig. 12 Köhnen stated that only sinter-based AM can efficiently produce hard and non-weldable materials. A high carbide content exhibits excellent hardness and wear-resistance (Courtesy GKN Additive Manufacturing)

Powder selection for high density parts

Paul Davies explained how Sandvik's fine gas atomised powders can make a significant contribution to sinter-based AM technologies. For example, the material properties of 316L stainless steel powder (<22 µm) processed by BJT can meet and exceed minimum requirements, as defined by relevant ISO, ASTM and MPIF standards developed for MIM, if the porosity level is reduced to less than 2%, and ideally less than 1%.

To achieve maximum sintering density, Davies stated that the powders should be as fine as possible and have a high sintering activity, which is typically inversely proportional to the flow character-

"…AM is an expensive endeavour, but there is great potential for the serial production of high-speed steels via sinter-based AM. Supersolid liquid phase sintering helps in achieving high densities, it was stated, but, as pointed out by the previous speakers, process control is key to shape loss in sintering."

Fig. 13 An expert panel discussion had a focus on the implementation of sinter-based AM (Courtesy Fraunhofer IFAM)

> *"In general, setting the right expectation for sinter-based AM processes is essential. It is important to push customers to define their needs clearly and consecutively, to be transparent about the process chain and machinery that has to be included, as well as the price of the part."*

istics. He stated that the latest Binder Jetting technologies incorporate techniques to mitigate the limited bulk flow characteristics of fine powder, and a great deal of research has focused on the powder size distribution, morphology, and surface chemistry and even additions of flow aids like fumed silica, provided some promising results regarding increased apparent, tap and powder bed density, and in turn increased green and sintered density.

He concluded by stating that the range of alloy powders is expanding as new applications emerge, including high-conductivity copper alloys and tungsten carbide powder, which are suitable for Binder Jetting.

Expert panel discussion

An expert panel discussion had a focus on the implementation of sinter-based AM. This proved to be lively and insightful, with experts from both suppliers as well as end users on the panel. Initial advice was to start small, bring the experts to the table, and collaborate more.

In general, setting the right expectation for sinter-based AM processes is essential. It is important to push customers to define their needs clearly and consecutively, to be trandrsparent about the process chain and machinery that has to be included, as well as the price of the part. Creating new business models is a multi-stage process, and educating the market about the need for a complete 'production system' for Binder Jetting is still a big task.

With regards to the question of competition from China, the panel showed little concern. The consensus was 'the more, the merrier' – competition in general is beneficial for a new technology.

Where concern was expressed for the BJT process, it was with regards to the so-called 'archaeological' work of depowdering parts. Some suggested that this is – and in some cases always will be – a manual and time-consuming task and with potential health risks if the necessary precautions against exposure to metal powder are not taken.

The overall conclusion was that it is necessary to clearly define the remaining problems that must be addressed and to narrow down which technology can solve them best. Communication with users is key to create the success stories this technology needs. All panel participants agreed that sinter-based AM technology has made its mark, but is yet to see a successful widespread breakthrough to mass production.

Alternative sinter-based AM processes

The afternoon's programme had a focus on alternative sinter-based processes. Vat Photopolymerisation (VPP), also referred to as Lithography-based metal Additive Manufacturing, was covered by Denise Mödder, Incus GmbH. The Cold Metal Fusion (CMF) process was introduced by Christian Staudigel, of Headmade Materials GmbH, and Spark Plasma Sintering technology (FAST/SPS) was covered by Arnaud Fregeac, Norimat Group.

Vat Photopolymerisation for metal AM parts

As Denise Mödder elaborated, VPP or lithography-based metal AM, is a two-stage process in which a green part is created in a vat of photo-reactive liquid, followed by a debinding and sintering process that sees 18-20% shrinkage. Final part density can be up to 99% and the material that is left after the 'de-caking' process can easily be reused. With the new Hammer Pro machine from Incus, the build volume of lithography-based metal manufacturing is increasing, and MIM size-range parts in high quality and quantity, such as the very small laparoscopic tool mini-gripper, shown in Fig. 14, are now possible.

Cold Metal Fusion (CMF)

Christian Staudigel introduced the Cold Metal Fusion (CMF) technology to the participants. The process was reported to have several benefits, including the use of widely-available PBF-LB machines for processing polymer parts, a wide range of materials, scalability, and low costs, as well as strong green parts and uniform shrinkage.

The green parts, formed in polymer PBF-LB machines, are created from polymer-coated metal powders, so the processing temperature to form the green parts is a modest 50-70°C. After depowdering, the powder can be fully reused. As shrinkage in general is a problem, the good news here is that the homogeneous green parts produced by CMF display a homogeneous shrinkage behaviour.

The mechanical properties of CMF Ti-6Al-4V samples correspond with mechanical properties achieved by MIM. Additionally, CMF materials can be processed by both fibre lasers (as used in the Sintratec S2) and

Fig. 14 A laparoscopic tool mini-gripper produced by Vat Photopolymerisation (Courtesy Incus)

"Communication with users is key to create the success stories this technology needs. All panel participants agreed that sinter-based Additive Manufacturing technology has made its mark, but is yet to see a successful widespread breakthrough to mass production."

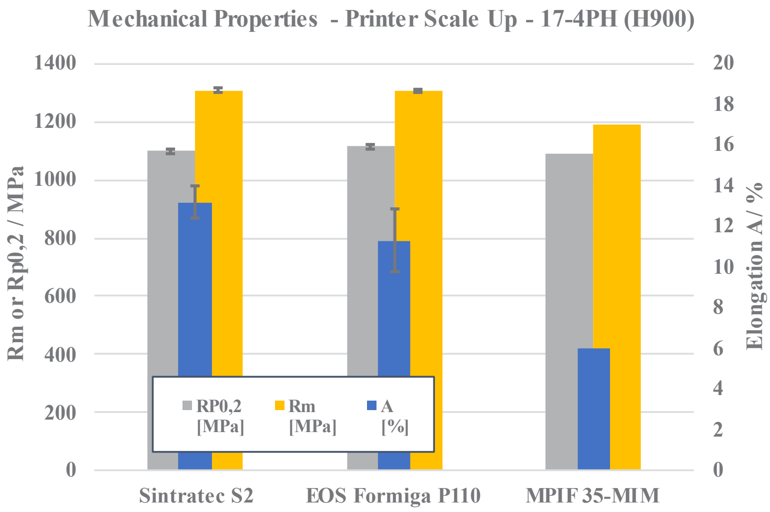


Fig. 15 CMF feedstock can be processed with both fibre lasers (Sintratec S2) and CO_2 lasers (EOS Formiga P110) and identical mechanical properties achieved (Courtesy Headmade Materials)

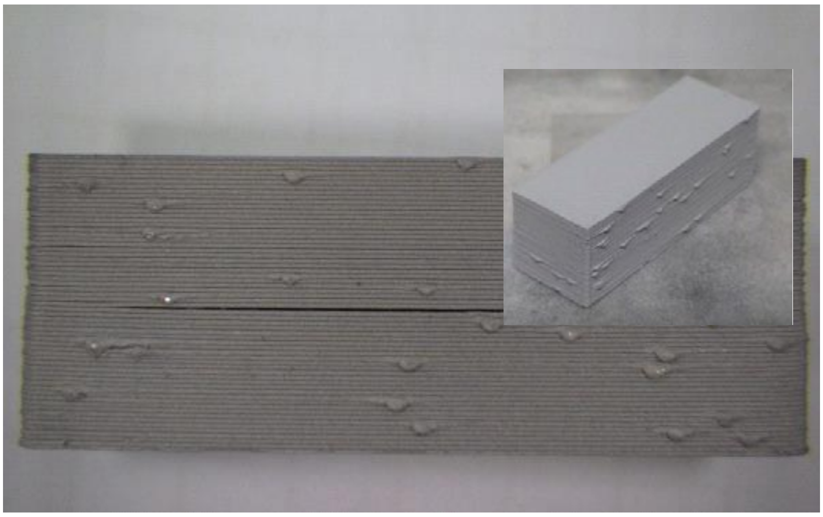


Fig. 16 The 'cracking' of filament-based MEX (FFF) components buring debinding is a result of rapid heating, which leads to rapid binder decomposition. It is the high internal pressure of the degrading binder products that leads to the formation of cracks (Courtesy Fraunhofer IFAM))

Fig. 17 A visual example of how powder moisture content can impact spreadability in the Binder Jetting process (Courtesy National Research Council Canada)

with CO_2 lasers (as used in the EOS Formiga P110), achieving identical material properties (Fig. 15).

Spark Plasma Sintering

Arnaud Fregeac introduced FAST/SPS, a high-performance Spark Plasma Sintering and densification post-process, where a current and pressure is directly applied to the mould to influence and fine-tune the microstructure. One clear advantage of this hybrid AM and SPS process is that a rapid debinding and sintering is carried out in one step. Thanks to SPS, energy consumption is optimised and all types of materials can be used. Material consumption is very low, and any scrap can be reused. It was stressed that this is not a 'small batch' process – it is already being applied in mass production, as impressively demonstrated by several case studies.

Sinter-based AM process analytics

The two-day workshop ended with a spotlight cast on supporting process analytics such as IR-spectroscopy, presented by Dr Ing. Johannes Trapp, Fraunhofer IFAM Dresden, moisture monitoring in metal powders by Louis-Philippe Lefebvre, National Research Council Canada, and a final presentation by Fraunhofer IFAM's Dr Sebastian Boris Hein, who discussed advanced analytical tools for Binder Jetting.

IR-spectroscopy in sinter-based AM

IR-spectroscopy is an efficient tool for achieving low impurities after debinding. Titanium, for example, easily becomes brittle if binder components remain in the part when it is sintered. Process gas analysis, in which the gas composition is monitored in real time to identify and measure debinding products, has been used to great success in the MIM industry and it is regarded as an essential tool to understand the breakdown and removal of the new generation binders used in Binder Jetting and other sinter-based AM processes. The resulting data can be used to optimise processes and ensure the full removal of impurities stemming from the binder.

At the same time, the costs for process gas and the energy required for furnace heating can be reduced, and the output product is optimised, with a reduction in defects caused, for example, by trying to debind parts too quickly (Fig. 16).

The effects and the measurement of moisture in AM powders

Louis-Philippe Lefebvre focused on the effects and the measurement of moisture in AM powder feedstock, which can have a major impact on final results, depending primarily on the type of material and the BJT system used (Fig. 17). Moisture, he stated, can accumulate in different stages of the process – from powder production to shipping and storage, as well as handling and during processing. The effect is rapid but reversible: drying treatments reduce the moisture – depending on the powder – but they are not 100% effective and may cause oxidation.

Use the full suite of tools for a complete understanding of your process

The 'last man at the mic', Dr Sebastian Boris Hein, pointed out that a lot of hidden potential lies in additional analytical tools for a deeper understanding of the metal Binder Jetting process. Tools under development target the ability to optically quantify the amount of powder building up in front of the roller (Fig. 18), as well as the thermal analysis of the powder bed surface during the process, and an optical geometric analysis of green bodies during the process.

As stated by other speakers before him, Hein referred to the fact that metal Binder Jetting is a complex process and stressed that there is still a lot of room for research and new analytical tools. Fraunhofer IFAM, he stated, is working on developing these tools to generate more data for a deeper understanding of the process.

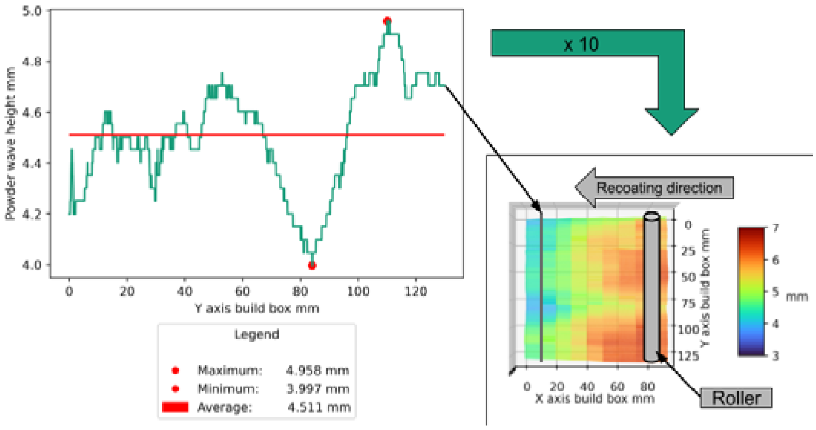


Fig. 18 A study of powder build up detection in Binder Jetting. It was found that powder wave edges are detected reliably, the height of the powder wave varies in the course of a print job, and faults in the recoating process such as missing powder, or partially-clogged sieves are easy to identify. Trials are now planned to make use of the developed tool for identifying correlations between powder wave and green part properties (Courtesy Fraunhofer IFAM)

Conclusion

Participants went home with a suitcase full of new insights and ideas on markets, applications, and processes, as well as new connections. All of this will likely push the 'fast forward' button for the future industrialisation of Binder Jetting and the wider landscape of sinter-based AM technologies.

There was full agreement that sinter-based AM is definitely 'going places' and that there is huge potential with regards to industrialisation and the development of a wide range of applications.

One thing is for sure: next September, at the 5th Workshop for Sinter-based AM, the industry in general will be presenting more insights and a better understanding of all the parameters in the black box called Sinter-based Binder Jetting and, without doubt, there will be more of those success stories that everybody is craving!

As we say in Germany: *Gut Ding will Weile haben und vortreffliche Sachen werden ohne große Mühe und Arbeit nicht erworben* – good things take time and excellent things are not acquired without great effort and work!

Author

Sonja Böske da Costa
Head of Corporate Communications
Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM
Wiener Strasse 12
28359 Bremen
Germany
sonja.boeske@ifam.fraunhofer.de
www.ifam.fraunhofer.de

Save the date

September 11-12, 2024
5th Workshop Sinter-based Additive Manufacturing

Metal Additive Manufacturing micro parts: How Computational Engineering methods can enable new micro robotic applications

Metal Injection Moulding has been the technology of choice for the micro robotics industry for many years, delivering micro-sized precision metal components in medium to high volumes. As the complexity and number of applications increases, there is an opportunity for accelerated product development and more flexible manufacturing through the combination of sinter-based Additive Manufacturing and Computational Engineering. Here, Dr Gerald Mitteramskogler, Josefine Lissner and Dr Stefan Bindl consider how these technologies can be combined for the best possible results.

Resources and their intelligent usage is rapidly becoming a key topic for society. As a result, the way we engineer and manufacture products is having to adapt to these needs. One result is the requirement to deliver smaller, more efficient products. The combination of Artificial Intelligence (AI)-supported designs, as well as innovative manufacturing methods, is recognised as one key to unlock significant improvements.

The field of micro robotics in particular is rapidly expanding, finding applications in diverse sectors, but particularly in medicine. The smaller these robots get, the less energy is required to produce and operate them and, very often, miniaturisation is a key feature for the application itself – as is the case with surgical instruments.

A significant challenge faced by micro robotics engineers is the packaging of intricate mechanisms into compact design spaces, including optimising components for mass reduction and power efficiency. Computational Engineering (CE) is one tool with which to address these challenges, with production enabled through the leveraging of Additive Manufacturing technologies.

This article considers the use of Vat Photopolymerisation (VPP) AM for the production of highly precise parts and assemblies. The integration of CE and this unique form of sinter-based AM, paired with the focus on serial manufacturing, offers a comprehensive solution to the design, cost, and capabilities of micro robotics. In addition, fast iterations and efficient prototyping is enabled, accelerating product development.

Fig. 1 As-sintered parts designed by Leap 71 and additively manufactured with Incus' Hammer Lab35 AM machine (Courtesy Incus GmbH)

Fig. 2 Incus' Hammer Lab35 AM machine (Courtesy Incus GmbH)

"The rapid growth of the micro robotics industry, particularly in fields like medicine, presents an array of challenges to engineers. As the size of robotics systems decreases, the complexity of packaging intricate mechanisms into confined spaces becomes increasingly demanding."

A collaboration between three companies

LEAP 71 is a software and engineering company based in Dubai, UAE. It is a pioneer in the field of Computational Engineering, in which engineers encode their knowledge into computer algorithms. The resulting Computational Engineering Models (CEMs) can automatically design highly complex machinery based on encoded rules. As it is a software-driven process, variations can be generated in minutes, with the resulting geometries within the constraints of the desired manufacturing process. LEAP 71 collaborates with leading companies in specific industrial sectors to digitise engineering knowledge. As well as medical devices, work is underway on electric motors, heating and cooling, space technology, bioprinting and large-scale structures.

Incus GmbH, based in Vienna, Austria, is a developer of machines for the sinter-based Additive Manufacturing of high-performance metals. Its Lithography-based Metal Manufacturing (LMM) technology, a VPP process, offers an economical method for prototyping and the small- to mid-scale production of components whose quality, mechanical performance and surface finish is a close match to parts produced by Metal Injection Moulding. The AM machine offered by Incus can be integrated into existing MIM production lines or R&D departments, since the same debinding and sintering equipment can be used. LMM is most applicable for the manufacturing of functional prototypes and pre-series manufacturing, as well as for the production of low to medium lot sizes of MIM-sized components.

AM Global, based in Starnberg, close to Munich, supports the development of AM serial applications. Recognising that many companies struggle with the implementation of Additive Manufacturing as a production technology, the company identifies and addresses the knowledge gaps that exist when a company transitions from prototyping to series manufacturing. In order to demonstrate a technology's ability to meet target costs, quality, and lead times, AM Global sets up manufacturing cells and supports a customer as it scales its operations. The focus is always on utilising the best technology for the specific application and delivering an economically viable solution.

The challenge of micro robotics design and manufacturing

The rapid growth of the micro robotics industry, particularly in fields like medicine, presents an array of challenges to engineers. As the sizes of robotics systems decrease, the complexity of packaging intricate mechanisms into confined spaces becomes increasingly demanding. A critical factor in the production of micro robotics is the need for mass reduction due to limited power availability and miniature drives. Moreover, the requirement for functional prototypes and low-quantity production runs for design validation poses a challenge, especially when considering traditional manufacturing methods.

The growing demands in the quantities of high-precision parts in various design derivatives can, therefore, translate to tremendous challenges in the supply chain. Additive Manufacturing has the potential to play a decisive role in this area in particular.

The role of Computational Engineering

Computational Engineering emerges as a powerful tool in micro robotics design due to its capacity to handle complex tasks that commonly-used Computer-Aided Design (CAD) software may struggle with. CE not only aids in conceptualising designs, but also directly incorporates considerations relating to the chosen manufacturing method into the design process.

By dynamically adjusting geometry to accommodate manufacturing constraints, CE streamlines the transition from design to production. This integration minimises errors and enhances the overall efficiency of the development cycle.

LMM: a perfect fit for micro robotics

Lithography-based metal AM offers a viable solution for the production of high precision parts, thus lending itself to the micro-robotics domain. The technology enables the creation of intricate parts with detailed features, and LMM's precision and smooth surfaces, which are akin to MIM surfaces, ensure that the parts generated are in accordance with the quality standards of the final product.

In addition, cost per part is competitive when it comes to complex geometries and geometry adaptations for various derivatives of the mechanisms. The constraints of the manufacturing technology can easily be implemented into the CE design algorithms.

Fig. 3 As-sintered parts designed by Leap 71 and additively manufactured with Incus' Hammer Lab35 AM machine (Courtesy Incus GmbH)

Instant design feedback loop with CE and LMM

The integration of CE with LMM unlocks a new level of efficiency in micro-robotics design and prototyping. By utilising LMM for rapid functional prototype production, engineers can receive tangible design feedback within a mere twenty-four hours. This accelerated feedback loop facilitates faster iterations, enabling engineers to refine their designs rapidly. Furthermore, the incorporation of 3D scanning technologies enhances the feedback process by providing accurate measurements and assessments of prototype performance.

"The integration of CE with LMM unlocks a new level of efficiency in micro-robotics design and prototyping. By utilising LMM for rapid functional prototype production, engineers can receive tangible design feedback within a mere twenty-four hours."

Fig. 4 Incus' Hammer Lab35 AM machine is capable of producing parts with mechanical performance and surface finish that is equivalent to Metal Injection Moulding (Courtesy Incus GmbH)

Scalability and production considerations

While the discussion thus far has centred around functional prototypes, it is crucial to address the scalability and production potential of the proposed solution. Although Metal Injection Moulding might be a viable option for larger quantities and a wide range of designs, Additive Manufacturing technologies, such as LMM, enable new opportunities for alternative product development methods.

Whilst established production processes such as MIM have already addressed the challenges of quality assurance, scrap rates, and supply chain reliability, these concerns are now also being addressed within Additive Manufacturing. This creates an alternative production route for some existing MIM parts, as well as accelerating the creation of completely new designs, such as those based on Computational Engineering.

"Although Metal Injection Moulding might be a viable option for larger quantities and a wide range of designs, Additive Manufacturing technologies such as LMM enable new opportunities for alternative product development methods."

Conclusion

In the evolving field of microrobotics, the challenges of compact design, mass reduction, and efficient prototyping demand innovative solutions. Computational Engineering emerges as a superior approach for tackling these complexities by seamlessly integrating manufacturing considerations into the design process.

When combined with metal Additive Manufacturing, CE unlocks a powerful feedback loop, enabling engineers to rapidly iterate and refine their designs. This synergy holds the potential to revolutionise micro-robotics development, paving the way for more efficient, precise, and impactful micro-robotic systems.

Furthermore, the advancements in manufacturing technologies provide high detail resolution as well as excellent surfaces. LMM technology, in particular, answers both concerns and is a preferred method to produce tiny parts as utilised in the field of micro-robotics.

In order to scale the production capabilities, companies provide business models to de-risk the setting up of AM production. For many, the chasm between interest in the available technologies and the ability to implement them is the lack of knowledge and the high cost to develop the application and a coherent production chain. Co-development initiatives, as well as the setting-up and transfer of production plants (when technically and economically viable), decreases this hurdle dramatically.

Authors

Dr Gerald Mitteramskogler
CEO, Incus GmbH
www.incus3d.com

Josefine Lissner
CEO and Co-Founder of LEAP 71
www.leap71.com

Dr Stefan Bindl
Director Engineering
AM Global Holding GmbH
www.amg-h.com

Advertisers' index & buyer's guide

PIM International is the only business-to-business publication dedicated to reporting on the technical and commercial advances in the MIM, CIM, and sinter-based Additive Manufacturing industries.

Available in both digital and print formats, *PIM International* is the perfect platform to promote your company to a global audience.

Metal powders

Advanced Technology & Mat. Co., Ltd. 43
www.atmcn.com/english

Epson Atmix Corporation 08
www.atmix.co.jp

Höganäs AB 45
www.hoganas.com

Indo-US MIM Tec Pvt Ltd 35
www.indo-mim.com

Jiangsu Tianyi Ultra-fine Metal Powder 49
www.cip-world.com | www.tycx.cn

Jiangxi Yuean Advanced Mat. Co., Ltd. 47
www.yueanmetal.com

LD Metal Powders 53
www.ldpowder.com

Metalpine GmbH 13/15
www.metalpine.at

Sandvik Additive Manufacturing 19
www.metalpowder.sandvik

Tekna 11
www.tekna.com

Ultra Fine Powder Technology 31
www.ultrafinepowder.com

Injection moulding machines

Arburg GmbH & Co. KG OBC
www.arburg.com

MIM, CIM & AM parts producers

AMT Pte. Ltd. 16
www.amt-mat.com

Indo-US MIM Tec Pvt Ltd 37
www.indo-mim.com

KRAHN Ceramics GmbH 41
www.krahn-ceramics.com/en

Schunk Sintermetalltechnik GmbH 23
www.schunk-mobility.com

Visottica Industrie S.p.A. 29
www.visotticagroup.com

Alphabetical index

Advanced Technology & Materials Co., Ltd. 43
America Makes 93
AMT Pte. Ltd. 16
Arburg GmbH & Co. KG .... OBC
Asahi Kasei Corporation 27
Centorr Vacuum Industries, Inc 17
ceramitec 2024 64
CM Furnaces Inc. 25
Cottrill & Co 50
Desktop Metal, Inc. 04
Elnik Systems 06
Epson Atmix Corporation 08
Erowa AG 32
Euro PM2024 .... IBC
Höganäs AB 45
Indo-US MIM Tec Pvt Ltd 35/37
INMATEC Technologies GmbH 38
Jiangsu Tianyi Ultra-fine Metal Powder 49
Jiangxi Yuean Advanced Materials Co., Ltd. 47
Kerafol GmbH & Co. KG 28
KRAHN Ceramics GmbH 41
LD Metal Powders 53
LÖMI GmbH 24
Metalpine GmbH 13/15
MIM2024 54
Mut Advanced Heating GmbH 14
Nel Hydrogen 39
Nishimura Advanced Ceramics Co.,Ltd 42
Phoenix Scientific Industries Ltd 52
PM China 2024 94
PolyMIM GmbH 20
PowderMet2024 / AMPM2024 76
Ryer Inc. .... IFC
Sandvik Additive Manufacturing 19
Schunk Sintermetalltechnik GmbH 23
TAV Vacuum Furnaces SpA 33
Tekna 11
Tisoma GmbH 12
Ultra Fine Powder Technology 31
Visottica Industrie S.p.A. 29
World PM2024 88

Binders & feedstocks

Asahi Kasei Corporation 27
www.asahi-kasei-plastics.com

INMATEC Technologies GmbH 38
www.inmatec-gmbh.com

KRAHN Ceramics GmbH 41
www.krahn-ceramics.com/en

Nishimura Advanced Ceramics Co.,Ltd 42
www.nishimuraac.com

PolyMIM GmbH 20
www.polymim.com

Ryer Inc. IFC
www.ryerinc.com

Furnaces & furnace supplies

Centorr Vacuum Industries 17
www.vacuum-furnaces.com

CM Furnaces Inc. 25
www.cmfurnaces.com

Elnik Systems 06
www.elnik.com

Kerafol GmbH & Co. KG 28
www.kerafol.com

Mut Advanced Heating GmbH 14
www.mut-jena.de

TAV Vacuum Furnaces SpA 33
www.tav-vacuumfurnaces.com

Tisoma GmbH 12
www.tisoma.de

Tooling and associated technology

Erowa AG 32
www.erowa.com

Debinding systems

Elnik Systems 06
www.elnik.com

LÖMI GmbH 24
www.loemi.com

Powder atomisers

Phoenix Scientific Industries Ltd 52
www.psiltd.co.uk

AM technology

Desktop Metal, Inc. 04
www.desktopmetal.com

Auctions

Cottrill & Co 50
www.cottandco.com

Atmospheres & gas generation

Nel Hydrogen 39
www.nelhydrogen.com

Events

ceramitec 2024 64
www.ceramitec.com

Euro PM2024 IBC
www.europm2024.com

MIM2024 54
www.mim2024.org

PM China 2024 94
en.pmexchina.com

PowderMet2024 / AMPM2024 76
www.powdermet2024.org / www.ampm2024.org

World PM2024 88
www.worldpm2024.com

Consulting/ Associations/ Institute

America Makes 93
www.americamakes.us

Industry events

PIM International is dedicated to driving awareness and development of the MIM, CIM and sinter-based AM industries and their related technologies. Key to this aim is our support of a range of international partner conferences. View our complete events listing on www.pim-international.com

2024

ImplementAM 2023 – Austin
January 17, 2024
Austin, TX, USA
www.implement-am.com/register

TCT Japan
January 31–February 2, 2024
Tokyo, Japan
www.tctjapan.jp

Additive Manufacturing Strategies
February 6–8, 2024
New York City, NY, USA
www.additivemanufacturingstrategies.com

MIM2024
February 26–28, 2024
Raleigh, NC, USA
www.mim2024.org

PM China 2024
March 6–8, 2024
Shanghai, China
en.pmexchina.com

AMUG 2024
March 10–14, 2024
Chicago, IL, USA
www.amug.com

EPMA Energy Seminar
March 12–13, 2024
Le Creusot, France
seminars.epma.com/event/energy-seminar-2024/

AM Forum Berlin
March 20–21, 2024
Berlin, Germany
www.am-forum.de

ceramitec 2024
April 9–12, 2024
Munich, Germany
ceramitec.com

Hannover Messe 2024
April 22–26, 2024
Hannover, Germany
www.hannovermesse.de

Ceramics Expo 2024
April 30 – May 1, 2024
Novi, MI, USA
www.ceramicsexpousa.com

The Advanced Ceramics Show
May 15–16, 2024
Birmingham, UK
www.advancedceramicsshow.com

PowderMet2024 / AMPM2024
June 16–19, 2024
Pittsburgh, PA, USA
www.powdermet2024.org / www.ampm2024.org

RAPID + TCT 2023
June 25–27, 2024
Anaheim, CA, USA
www.rapid3devent.com

PMTi 2024
September 4–6, 2024
Madrid, Spain
www.pmti2024.com

Euro PM2024
September 29 – October 2, 2024
Malmö, Sweden
www.europm2024.com

World PM2024
October 13–17, 2024
Yokohama, Japan
www.worldpm2024.com

2025

Fraunhofer Direct Digital Manufacturing Conference DDMC 2025
March 12–13, 2025
Berlin, Germany
www.ddmc-fraunhofer.de

Event listings and media partners

If you would like to see your CIM, MIM or sinter-based AM related event listed in this magazine and on our websites, please contact Merryl Le Roux:

merryl@inovar-communications.com


HIGHLY VERSATILE
LOW-CONSUMPTION
SAVES MONEY AND GIVES EVERYTHING
OPERATES
ELECTRICALLY
PERFORMS WELL
IDEAL FOR ROUTINE TASKS
IS FAST
100 YEARS 1923-2023
OF THE HEHL COMPANY
ARBURG
ALLROUNDER 570 E
GOLDEN
WIR SIND DA.
Your entry into the world of electric injection moulding: the GOLDEN ELECTRIC combines the unbeatable quality of our hydraulic GOLDEN EDITION with the efficiency of the electric drive. To the benefit of your customers and your controller.
www.arburg.com/info/pim
ARBURG