Asian Powder Metallurgy Association

Members:
PM Associations from
China, India, Japan, R.O. Korea
Taiwan & Thailand

APMA 2019

5TH INTERNATIONAL CONFERENCE ON

POWDER METALLURGY IN ASIA

Hosted by

India took center stage as the global PM community congregated to attend APMA 2019 in the city of Pune from 19 – 21 February 2019. Conversations revolved around the changes in the industry and the technical developments that will drive future innovations.

Over 500 participants heard 140+ experts and leaders in PM technology from 15 countries share their knowledge and experience in the areas of Press & Sinter technologies, Powder Injection Moulding, Additive Manufacturing (3D printing), Hard Metals & Diamond Tools, Technical Ceramics and New Materials & Alloy Development.

APMA 2019 had large delegations from PM associations in Japan, Korea and Taiwan; many thanks to them. The conference was supported by 6 patron sponsors, 13 conference sponsors, 42 exhibitors and over 500 participants from 15 countries. **Their support helped PMAI create a significant surplus to what it had accumulated during its entire existence & enabled our long standing desire of owning our own real estate property.**

These three days in Pune evolved into an excellent learning ground of opportunities for the several new start-ups, prospective entrepreneurs & first time exhibitors who attended the conference. Several overseas manufacturers exploring the possibilities of investment in India got an opportunity to converse with prospective partners, suppliers & customers. All of them left with the realisation that it was not a question of ***if*** an investment should be made, it was a question of ***when***.

I am sure most of you who attended the conference will describe it as time well spent. For those who could not attend, we have this newsletter!

N. Gopinath, Immediate Past President PMAI & Chairman, Organising Committee of APMA 2019

PMAI thanks Daimler Chrysler for hosting the JPMA delegation at their premise (factory visit).

"I'm very happy to have seen what I have seen. A larger conference than I expected. Very nice papers being presented. Something that is not new but remarkable is the warmth and welcoming of the Indian people. The social activities and shows are just astonishing and something that is not even affordable in the Western countries."

Cesar Molins
Vice President, European Powder Metallurgy Association
& Director General, AMES Group, Spain

Thirty years ago the China PM market was behind the other major PM markets in Asia- Japan was the biggest and most developed. Since then, the China PM market has grown rapidly and will become #1. The China government is providing incentives to produce 1.6L passenger vehicles in the region. Japan, Korea and Taiwan remain stable markets. India has big potential to become a major market in the next 10-15 years.

Mr. C.L. Chu, President of APMA and Executive Director of Porite Group Taiwan

INAUGURAL SESSION

The opening speakers brought a business perspective to the entire conference, highlighting changes in the industry and opportunities, immediate and in the future.

Mr. N Gopinath, immediate Past President of PMAI and Managing Director of Fluidtherm Technology welcomed the delegates who had travelled from 15 countries to attend the event, the sponsors and exhibitors.

Mr. Aniket Gore, the incoming President of PMAI and Director of Ceramet Group delivered a presentation on the State of the Indian PM industry. He spoke about the trends in the automobile industry which will significantly influence the Indian powder based manufacturing industry. He highlighted Government led investments in infrastructure and other initiatives that have made India an attractive manufacturing destination.

Mr. C.L. Chu, President of APMA and Executive Director of the Porite Group (Taiwan) spoke about the significant role Asia plays in the Global PM marketplace. He spoke about the major PM countries in the Asia, changes in production and market conditions in each of these regions. Asia is one of the largest PM markets in the world and all major markets in the region showed strong growth. The India market is smaller in size compared to the markets of Japan, Korea and China but it showed consistent, promising growth.

APMA 2019 was inaugurated by three of the original founding members of PMAI - Emeritus Prof. P Ramakrishnan, Prof. G.S. Upadhyay and Prof. Rama Mohan who lit the ceremonial lamp that invokes knowledge & dispels darkness. This simple ceremony kicked off three days of learning, networking, collaborating and showing off in general.

Press & Sinter technology is growing very slowly in the Western hemisphere. There is a trend towards reduction of engine size and cylinders in IC engines. This reduces weight but unfortunately a number of PM parts. On the other hand, there is a trend to increase speeds and number of transmissions, with increasing popularity of automatic over manual ones. This is a new opportunity for PM parts.

Dr. Cesar Molins, VP- EPMA & Director General- AMES Group Spain

Dr. Cesar Molins, Vice President of European Powder Metallurgy Association and Director General of AMES Group (Spain) spoke about the PM markets of North America and Europe. He spoke of rumours of recession but saw no data to indicate a global slowdown. The North American economy and automobile market showed steady growth. Economic growth in Europe is slow, made worse by the uncertainty of Brexit. European automobile markets are limping back to recovery after over production in the first half of the financial year.

Mr. Mark Braithwaite, President of Höganäs AB, Sweden spoke about how the PM markets will change in the coming decade. He warned of international markets maturing and plateauing and stressed the need for collaboration to drive innovations.

Mr. Alok Nanda, CTO of GE South Asia and CEO of its India Technology Center spoke about the appeal Additive Manufacturing (Metal 3D Printing) has and the inroads it is making in all aspects of manufacturing. He shared GE's success with various metal powders and like Mark Braithwaite, highlighted the need for cross industry collaborations to make this technology more affordable.

SEMINAR ON PRESS & SINTER

Dr. Rohith Shivanath, Director of Metallurgy at Stackpole International (Canada) delivered the plenary keynote on the trend towards electrification and new propulsion systems that challenge traditional PM component manufacturers. If PM is to maintain production tonnage in the light of the growth of electric vehicles, the range of mechanical properties- in particular dynamic strength, has to be increased to match the durability of wrought low alloy steels. Dr. Shivanath looked at tools available to improve properties including optimised designs for lower stresses, highly compressible, cost effective lean alloy powders, high temperature sintering, densification methods and advanced heat treatment.

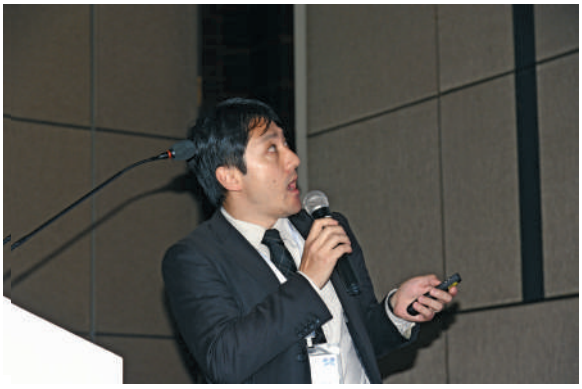
Dr. Wei-Ping Huang of Porite (Taiwan) spoke about the relationship between density and processing deformation in the sizing process. Density and dimensional changes of the workpiece during external force are not linear but phased (porous filling, plastic deformation and local compactness). When the density reaches 6.8 g/cc, the rebound amount after processing slightly decreases. When the density is higher than 6.9 g/cc, the workpiece rebounds and the same processing parameters will no longer increase the workpiece density. The data shows that there is a transition zone at 6.8~6.9 g/cc when the deformation is about 0.35%.

Mr. N. Gopinath, Managing Director of Fluidtherm Technology presented a paper on advanced furnace sintering concepts to achieve higher mechanical properties for PM parts at lower processing costs. The traditional mesh belt furnace has several advantages but is limited by the temperature it can work at, the time taken for transfer from the heated section to the rapid cooling section and the alloy content required for successful sinter hardening. A furnace concept with hybrid transportation systems can overcome several limitations of mesh belt furnaces and find good use in PM part sintering.

Mr. V Srinivasan, MD of Höganäs India (L) and Mr. Rajendra Sethiya, GM of GKN Sinter Metals India (R) were conveners of and session chairs for the Press & Sinter seminar.

The acoustic dampening properties of PM parts will play a key role in EV drivetrains. We need to focus on how we can get densities of 7.4 by single pressing to really challenge wrought steel parts, without sacrificing precision that PM offers.

Dr. Rohith Shivanath, Director of R&D, Stackpole International Canada



Dr. Tomohiro Sato from Kansai University Japan spoke about Al-bronze which has the highest strength and good corrosion resistance amongst the copper alloys. It can be used for bearings for fuel pumps, as a replacement for Cu-Ni alloy, given the high cost and insufficient corrosion resistance of Cu-Ni alloys. However, the friction properties of Al-bronze are inferior. So friction properties were evaluated for Sulfide Al bronze. Sulfide seems to form films on the surface of component. This reduces the coefficient of friction and improves the seizure resistance. However, the more Cu5FeS4 was increased, the more Al Sulfide was increased. As Al Sulfide is hard, it prevents the formation of tribofilm.

Dr. Kalathur (Sim) Narasimhan delivered a keynote on achieving high density PM parts by cold compaction. Changing the particle distribution of atomized powder can help in achieving higher densities. Compaction of FN-0205 mixes using +325 mesh (44microns) revealed that stripping forces after compaction is significantly less with +325 than heated die technology. Cold ambient temperature compaction densities of 7.38 g/cc with a stripping pressure of 18 MPa were observed, compared to warm die compaction of similar mix density of 7.40 g/cc with a strip pressure of 27 MPa.

Other speakers included:

- **Manjeet Dhiman, Stackpole Canada**- PM for next generation of xEV powertrains
- **Linnea Molin, Höganäs Korea**- Powder mix concepts for VVT components
- **Jing Yang, AMES Spain**- Effect of process variables on porosity & properties of PM steels
- **Harb Nayar, TAT Technologies USA**- Gas reaction products during debinding
- **B Sreenu, DMRL India**- HIP parameters effect on microstructure of PM Nickel based superalloys
- **Sudarshan Palve, Speciality Sintered**- Performance of sinterhardened PM gears
- **Sunil Patel, GKN Hoeganaes USA**- Improving machinability response of PM components
- **Makato Sato, Sumitomo Japan**- Partial induction hardening technology
- **Ming-Wei Wu, Taipei Tech Taiwan**- Tensile strain & fracture of Ni-alloyed PM steel
- **Chongxi Bao, NBTM China**- Nitriding of Fe PM components
- **Bikram Konar, Univ of Toronto**- Metal atomization: Effect of thermochemistry on physical prop.
- **Walter Xu, Höganäs China**- Machinability of low alloyed PM steels

& many more. Visit www.apma2019.com for a full list.

SEMINAR ON POWDER INJECTION MOULDING

Dr. Hideshi Miura, Professor at Research Center for Steel at Kyushu University Japan, delivered the plenary keynote. Ti-6Al-4V is used in many industrial fields he said, but it is difficult to produce complicated shapes via machining. Injection molded Ti-6Al-4V alloy compacts were improved by adding another element such as Cr and Mo. They showed high tensile strength and high elongation comparable to wrought materials. However, the fatigue strength was significantly lower. To improve this, a third element like TiB2 powders was added.

Dr. Volker Piotter, Head of the Research Group at Karlsruhe Institute of Technology Germany, shared the process and characteristics of manufacturing MicroMIM parts. Most commonly used powders for these components are gas atomised with mean particle size ranging from 5 to 20 µm (steel powders). Agglomerates can be crushed during compounding when shear forces in the mixing process exceed the binding forces of the agglomerates. Dr. Piotter spoke about the choice of binders and the properties (flowability, strength, de-mixing tendency, wetting characteristics, thermal stability and non-polluting) that are essential for good Micro-MIM parts.

Dr. Chiou-Yau Hung (Dr. Q), Professor at the Advanced Manufacturing College of DGUT China spoke on improved binder systems for MIM. Polyoxymethylene (POM) based binders have swept the Asian MIM industry. The major reasons are improved debinding process & safety of the catalytic debinding equipment. The new recipe Dr. Q shared improves the fluidity that also makes the injection process easier. Catalytic debinding (nitric or oxalic acid) becomes easy.

Dr. T.S. Shivashankar, VP at Indo-MIM was the one of the session chairs at this seminar. He also served as Convener.

Indo-MIM, a patron sponsor, is a leading global supplier of precision-engineered products using Metal Injection Molding (MIM) with manufacturing facilities in India & USA.

There is a strong relationship between fatigue strength and grain size. Further investigation found that fatigue strength ratio tends to decrease as pore diameter with respect to grain size increases. Relating pore size to grain size is very important to obtain high fatigue strengths in all sintered materials.

Dr. Hideshi Miura, Professor at Research Centre for Steel, Kyushu University, Japan.

Dr. N Sreekanth from Indo-MIM's R&D team spoke about the low cycle fatigue properties of medium carbon steels in MIM for use in small arms. He looked at the tensile, impact and low cycle fatigue (LCF) properties at room temperature of MIM 4340, MIM 4630 modified and MIMS7. The effect of chemical composition, hardness and microstructure were correlated with tensile, Impact & LCF for these materials.

Prof. Abu Bakar Sulong of UKM Malaysia described injection moulding of two materials (2C-PIM) to manufacture functionally graded components. He looked at the suitability of stainless steels 17-4PH co-moulded with 316L with palm stearin and polyethylene as the binders by studying the sintering and microstructural characteristics. The shrinkage behaviour between the two materials was also studied. It was found that the difference in sintering shrinkage for both materials was not significant as the coefficient of thermal expansion (CTE) between the two materials is quite similar.

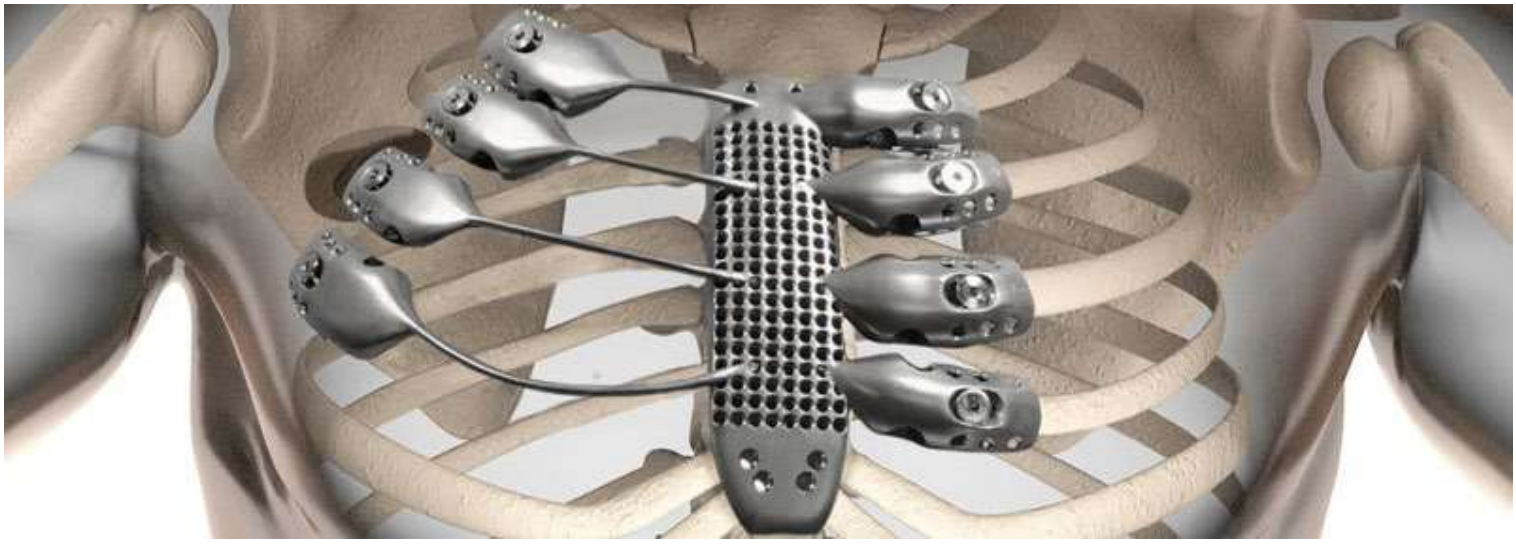
Other speakers included:

- **Sachin Malgave, Indo MIM India**- Comparison of SS310Nb (HK30) material processed via different Manufacturing Technologies
- **Muhamad Norhamidi, UKM Malaysia** - Fabrication of a Porous Titanium Hydroxyapatite Metal-Ceramic Composites via PIM with Space Holder Method
- **Lucas Groning, Sigma Soft Singapore**- Optimisation of MIM Process Parameters And Tool Development
- **Mukund BN, Indo MIM India**- Rheological and mechanical properties of Super Co-400 alloy in Metal Injection Molding (MIM)
- **Sundar Atre, University of Louisville**- Design to manufacture Digital Tools for PIM
- **Pratap Goud, Verder India**- Digital Dynamic Image Technique to analyse particle size & shape of metal powders in AM & MIM

& many more. Visit www.apma2019.com for a full list.

"All the presentations were high calibre. For the speakers to share this much with the audience of Indian Powder Metallurgists is just fantastic."

Kalathur (Sim) Narasimhan
GKN Engineering Fellow &
President, P2P Technologies, USA



SEMINAR ON ADDITIVE MANUFACTURING

Dr. Dheepa Srinivasan, CTO of Intech DMLS, a company that manufactures additively manufactured parts compared the mechanical properties of Co & Ni based superalloys when using DMLM and DED routes of additive manufacturing. She showcased a few case studies to highlight the technology development in using 3D printing to restore a severely damaged part on a Cobalt based superalloy, after service exposure. She also addressed the effect of variability in properties as a function of build orientation and location.

Dr. Yves Nadot, Professor from ENSMA France, spoke about the fatigue limit related to microstructure of additively manufactured Al alloys. He looked at the influence of the 5 parameter (porosity, melt pool, crystallographic organization, dendrite arm spacing and precipitation) on the fatigue limit of AlSi10Mg SLM material, identifyin g the m ost imp ortant of th ese that had to be controlled.

Dr. Ayano Ogura, an actual doctor of oral medicine at the Osaka Medical College Japan, demonstrated the use of additively manufactured Ti mesh sheet to reconstruct the alveolar bone using bone augmentation. Adequate structural base of osseous tissue is necessary for supporting dental implant. Bone augmentation is needed to make the space before the embedding when there is insufficient bone volume. Adapting a flat titanium mesh sheet to complex bone defect areas comprising curved and flat surfaces is a challenge. With selective laser melting (SLM) this was addressed.

Dr. Deepak Pattanayak, Scientist at CSIR- CECRI was a session chair and keynote speaker at this seminar. He spoke about the application of metal 3D printing in the biomedical field and highlighted the work being done at his laboratory on the fabrication of Ti and Ti-6Al-4V, the development of various porous metallic components and their surface restructuring for better cell-material interaction and faster bone integration.

In precipitation hardened materials whether Aluminium alloys or steel, when there is a high percentage volume of precipitates, irrespective of what the process is, the precipitation will control the mechanical properties.

With Additive Manufacturing you can get mechanical properties that match wrought iron.

Dr. Dheepa Srinivasan, CTO, Intech DMLS

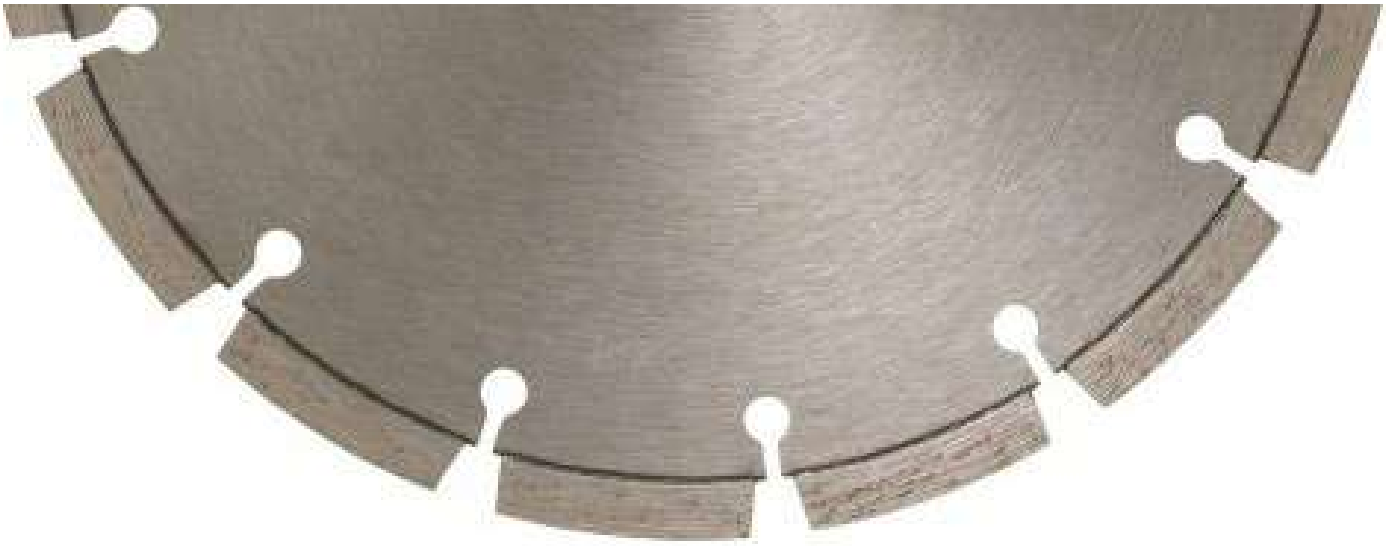
Dr. Sundar Atre, Endowed Chair of Manufacturing & Materials at the University of Louisville, spoke about Laser Powder Based Fusion (L-PBF) experiments conducted with 17-4 PH and 420 SS powders to understand the effects of powder attributes (alloy chemistry, particle size distribution and particle shape) and processing parameters on physical, mechanical and corrosion properties and microstructure.

Dr. Paul Davies of Sandvik Osprey UK presented a paper on ultra-high hardness maraging steel for mould tooling. Conformal cooling of injection mould tools (plastic and rubber moulding) offer 30-50% improvements in productivity gains & reduce scrap rates by employing controlled thermal management of the moulding process. AM by powder bed laser fusion incorporates the cooling channels inside the mould tooling, on a layer by layer basis. He shared results of a new ultra-high hardness maraging steel highlighting the material microstructures (as built and heat-treated), hardness and mechanical properties. A hardness of 60 HRC in the heat-treated condition was produced.

Other speakers included:

- **Tobias Brune, SMS Group Germany**- Powder atomization plants for high grade AM powders
- **Jhewn-Kuang Chen, Taipei Tech Taiwan**- Microstructure & compressive behaviour of EBM and SLM Ti6Al4V
- **Hak-Sung Lee, Korea Institute of Material Sciences**- Machine learning to characterise defects in AM
- **Jin-Chun Kim, ULSAN Korea**- Production, microstructure & mechanical properties of SLS Ti6Al4V part
- **Deepak Pattanayak**, **CECRI India**- AM in biomedicine
- **Snehith M, Intech DMLS**- Al10SiMg alloy- heat treatment optimisation for hybrid builds
- **Pareekshit Allu, Flow 3D USA**- Computational fluid dynamics simulations for additive manufacturing
- **Anil Kumar, ANSYS India**- Prediction & mitigation of buckling type distortion in AM thin walled structures
- **G Padmanabham, ARCI**- Challenges in AM
- **Jae Won Jeong, Korea Institute of Material Sciences**- Microstructure, magnetic prop. of AM Fe-Si-B-C-Cr alloys
- **Andrew Klein, The ExOne Company USA**- Material developments in binder jet 3D printing
- **Shorya Kant, IIT Hyderabad**- Effect of heat treatment on properties of AM steel components
- **Tomotake Hirata, OSRIT Japan**- Changes in microstructure & mechanical prop. of SLM Al alloys after HIP
- **Divya K, ARCI**- Design for additive manufacturing self-supporting features
- **Gururaj Telasang, ARCI**- Dissimilar metal additive manufacturing SS on Cu plate
- **Dheepa Srinivasan, IntechDMLS**- Comparison of microstructure & mechanical prop. of DMLS maraging steels

& many more. Visit www.apma2019.com for a full list



SEMINAR ON HARD METALS & DIAMOND TOOLS

Dr. Janusz Konstanty, Author & HOD of Metallurgy at AGH University of Science & Technology Poland spoke about the trends & advances in the fabrication and applications of diamond tools. He looked at cheaper (than cobalt) pre-mixed powders which are formulated and refined for excellent consolidation behaviour with field performance similar to cobalt. Today the focus is on developing raw materials, tools and production methods that improve their working characteristics and open new applications. For example, iron-rich powders free-sintered to near-full density below 950 ^{o}C, self-brazing powders dedicated to free-sintering of diamond beads, new small-diameter bead designs, as well as fabrication of saw blade segments and core drill segments by high-pressure high-temperature sintering technology.

Dr. Inigo Iturriza, Head of the Metallurgy Department at CEIT-IK4 Spain, spoke about bond development, diamond stability and wear behaviour in diamond impregnated tools for stone cutting. Dr. Iturriza discussed strategies to modify the mechanical properties and sintering behaviour of two pre-alloyed powders- Next 400® (N400) with only 15 wt. %Co and other, known as Cobalite CNF® (CNF) with no Co. The interaction between the work material, the diamond, the bond, the cutting parameters, and machine characteristics was discussed.

Dr. JJ Roa, Professor at Barcelona Tech Spain looked at the micro- and nanomechanical response of different WC-Co grades (cemented carbides). His study assessed the following criteria; intrinsic hardness values and main deformation mechanisms, effective hardness and flow stress of the metallic binder, evaluation of the Hall-Petch parameters for WC-Co, correlation of the microstructure with the hardness and elastic modulus map and the study of the stress-strain response by means of ex/in-situ compression of micropillars.

Dr. N.B. Dhokey, Professor at College of Engineering Pune (L) was one of the session chairs for this seminar. He also served as the convener, along with Dr. Vivek Singal, GM R&D of Stay Sharp Tools (R).

"The era of diamond wire (inspite of production challenges) will continue. Diamond wires have the fastest growing applications in the industry. Emphasis is on very thin wires to minimise wastage. In 2017 a new tool made it possible to produce 4.3 mm diamond wires. In the future the target will be diameters below 4mm."

Dr. Janusz Konstanty, Author & Head of Metallurgy Department, AGH University of Science & Technology, Poland

Mr. Satyanarayana Ande, Head of R&D at Hilti India spoke about emerging trends and challenges the diamond tools industry will face. He spoke about material and technology development, regulatory changes, technology advancements including 3D printing of concrete, demand for autonomous tools and labour pressures. Mr. Ande discussed the impact of these on the design and manufacture of diamond tools of the future.

Ms. Elke Ade of Dr Fritsch Germany spoke about reducing negative impact on humans and environment caused by the manufacturing of diamond tools. She spoke about restrictions in the EU and other countries and discussed future restrictions that are expected to come into place. She offered possible solutions to comply along with field results.

Other speakers included:

- **P Chandra Sekar, Umicore**- Experimental Procedure to Behavior Microstructure to Remove Cobalt in Diamond Impregnated Tools
- **Rajkumar Yembadi, RDT Diamond Tools**- Design of New Bonds With Minimum Cobalt for the Development of Diamond Wire Ropes
- **Prabin A, Kennametal**- Effect of Planetary Milling on WC Powder Characteristics and Sintered Properties of WC-Co Hardmetal
- **Anish Upadhyay, IIT Kanpur**- Effect of Transition Metal Additives on Sintering of Diamond based Particulate Composites
- **S Ingle, SECO Tools**- Manufacture and use of modern Polycrystalline CBN based cutting tools

& many more. Visit www.apma2019.com for a full list.

SEMINAR ON TECHNICAL CERAMICS & COMPOSITES

Dr. Thomas Graule, Head of the High Performance Ceramics laboratory at EMPA Switzerland spoke about the efficient stabilisation of ceramics based nanopowders as a prerequisite for the achievement of highly reliable ceramic materials. He spoke about the need for sophisticated powder treatment and handling and the benefits additive manufacturing offers. Agglomeration or re-agglomeration due to Van der Waals forces can be avoided or even controlled (like in spray granulation) using different concepts to increase the separation barrier by electrostatic or steric means. Dr. Graule shared the result of his studies to stabilize alumina and zirconia submicron and nanoparticles. The findings were applied to anion type and cation type comb copolymers as promising alternatives.

Prof. Sandeep Butee from College of Engineering Pune spoke on the mechanisms of synthesis of Zinc niobate ($ZnNb_2O_6$), a microwave dielectric ceramic by co-precipitation to achieve better homogeneity at a microscopic level. It was found that instead of the expected co-precipitation of ZnO and Nb_2O_5 particles, Nb_2O_5 particles acted as polynuclear sites for nucleation, followed by their rapid initial growth and precipitation. This resulted in relatively fine ZnO particles precipitating on Nb_2O_5 nuclei. These powder particles were characterised.

Dr. Roy Johnson from ARCI spoke about the manufacture of polycrystalline transparent ceramics. Negligible interaction with electromagnetic radiation is required. Therefore samples need to be made fully dense. However this leads to large grain sizes, leading to a trade-off between transparency and mechanical properties. This can be countered in non-cubic polycrystalline ceramics with birefringence effect, but this requires advanced processing to achieve the twin objectives of full densification with sub-micron grain sizes.

Prof. Ajit Kulkarni of IIT Bombay was one of the session chairs for this seminar, as well as the convener along with Prof. Sandeep Butee.

"When it comes to high performance ceramics you need to work with ceramic powders of 100-500 nm to improve quality. For strong but brittle ceramics, if you can reduce defect size you can achieve strength values of several gigapascals. To further improve quality, surface chemistry becomes very important."

Dr. Thomas Graule, Head of Laboratory- High Performance Ceramics, EMPA Switzerland.

Dr. Amit Sinha of the Baba Atomic Research Centre spoke on phase stabilisation in dysporium titanate based ceramics commonly used as control rod material for thermal nuclear reactors. Formation of desired point defects in this ceramic system can be achieved by introduction of alio-valent dopants in the starting composition that in turn results in desired phase purity and microstructure in the sintered specimens of dysprosium titanate ceramics.

Dr. Yung-Chin Yang of National Taipei University of Technology spoke about how the preparation of Solid Oxide Full Cell (SOFC) by thermal spraying can effectively reduce the processing time and cost. Yttria-stabilized zirconia (YSZ) nano powders are dispersed in an organic solvent and injected radially into the torch for spraying. The 8YSZ powder in the suspension can be completely melted with a spray distance of 3 cm and a feed rate of 0.6 ml/min, and the coating has the lowest porosity (8.3%). The performance test of the single cell showed that the OCV is about 0.057 V at 800 °C, and the power density is 0.11 mW/cm2. However improvements in spraying processes was needed to achieve better properties.

Other speakers included:

- **Amit Sinha, BARC**- Synthesis and characterisation of lithium based ceramics for fusion blanket applications
- **Dheepa Srinivasan, Intech DMLS**- Advanced Coatings Technologies for Structural Component Repair
- **RV Krishnarao, DMRL**- Formation of dense MoSi2 coating on niobium alloy C-103 for oxidation protection
- **RK Lenka, BARC**- Effect of Cu addition on the electrochemical performance of LaNi0.6Fe0.4O3 cathode materials for SOFC applications
- **Tilak Joshi, AMPRI**- Performance of Aluminium Matrix Composites at Elevated Temperature

& many more. Visit www.apma2019.com for a full list

SEMINAR ON NEW MATERIALS FOR EMERGING APPLICATIONS

Prof. Hyoung-Seop Kim of POSTECH Korea, spoke about PM processed high entropy alloys (HEA); a new series of alloys with a unique alloy design concept. Unlike the design of conventional alloys, HEAs are designed with more alloying elements with the composition of each constituent element in the range of 5–35 %. The HEAs are considered as emerging advanced materials for next-generation structural materials for various applications due to unique characteristics such as sluggish diffusion and lattice distortion, excellent cryogenic properties, high-temperature resistance, and corrosion resistance as well as high strength and elongation.

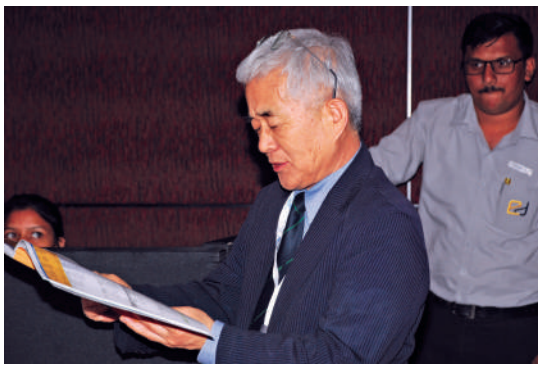
Dr. Sea-Fue Wang, Distinguished Professor and President of Taipei Tech Taiwan described the fabrication of highly efficient tubular SOFCs based on highly durable LSMO (La9.8Si5.7Mg0.3O26) electrolyte. The LSMO electrolyte tubes were sintered at 1550 °C before bi-layer anode coating. The anode function layer and current collector layer were dip-coated on inner surface of the electrolyte tubes, and then co-fired at 1350°C. The cathode was dip-coated on the outer surface of the tubes, and subsequently sintered at 1100°C. The effect of different anode layers on the cell performance and the power density of TSOF cell was measured to 62 mW/cm2 at 895°C.

Prof. Bharat Panigrahi of IIT Hyderabad presented a comparative study of mechanical properties of AlCoCrFeNi high entropy alloy produced through pressureless sintering and hot-pressing. Sintering these alloys to high density components is difficult under pressureless sintering conditions. He outlined a process by which nearly fully density could be achieved at about 1275°C and compared it to mechanically alloyed powders that were hot pressed at a temperature of 1100°C at a pressure of about 30 MPa. Phase evolution behaviour, microstructure evolution and mechanical properties of the components were studied and it was found that pressureless sintered components were comparable to hot pressed samples.

The same factors that lead to densification also lead to microstructural coarsening. Increasing temperature leads to greater densification in some alloys. However there are systems where higher sintering temperature and prolonged sintering time does not work. As a matter of fact it impedes densification as porosity moves from powder-powder interfaces to within the grain. To remove them you need to use volume diffusal which is a slow process.

Dr Anish Upadhyay, Professor- IIT Kanpur

Prof. Anish Upadhyay of IIT Kanpur delivered a plenary keynote, critically assessing new paradigms in the development of new materials & alloys for PM. He spoke of recent developments that help understand parameters that influence the densification and microstructural evolution during sintering. The phenomenological models relating various microstructural attributes to densification were discussed, both for solid-state and liquid phase sintering. Ongoing efforts to correlate the microstructural evolution during sintering and the effect of thermo-mechanical processing on the sintered microstructure were discussed.



Prof. Jai-Sung Lee of Hanyang University Korea, spoke on high density (density range 15- 19 g/cc) W-Cu alloy (with less than 10% by weight of Cu) from nanopowders. To optimize the condition of powder synthesis, the effect of Cu content on hydrogen reduction behaviour of ball-milled WO3 and CuO nanocomposite powders was investigated. Hydrogen reduction kinetics were characterized by thermogravimetry and hygrometry. The W-5wt.%Cu nanocomposite powders were compacted at 1250 MPa into disc (10 mm diameter, 1.5 mm height) to have relative green density of 48% theoretical density. Sintering was performed at 1623°K for 2h in hydrogen. Sintering properties of the W-Cu including densification process and mechanical properties were investigated along with microstructure development.

Other speakers included:

- **Chih-Kai Yao, Porite Taiwan**- The feasibility study of porous metal structure fabricated by PM process for protection application
- **Feng Peizhong, CUMT China-** Porous NbAl3/TiAl3 intermetallic composites prepared by thermal explosion using NaCl space holder
- **Jung-Goo Lee, KIMS Korea**- Fabrication of Anisotropic Nd-Fe-B magnet by Hot deformation Process
- **AP Moon, Höganäs**- New Generation of Iron powders for Brake Pad Applications
- **Anish Upadhyay, IIT-K**- Effect of Activators on Sintering of W, W-Cu and WCu- Sn System
- **Chih-Liang Chien, Superrite Taiwan**- The Study of Demagnetization Effect On C-Type Anisotropic Hard Ferrite Magnet Simulation
- **R D Purohit, BARC**- Fabrication of Iron Oxide based Foam Catlysts for I-S Process of Hydrogen Production
- **Gaurav K Gupta, AMPRI**- Effect of Al- 12Si addition, compaction pressure and atmosphere on mech & elec prop. of sintered and age-hardened 2014 Al-Cu-Si alloys

& many more. Visit www.apma2019.com for a full list.

The student volunteers from College of Engineering Pune provided a much appreciated service of manning the delegate registration desks, providing local hospitality and transportation to overseas delegates from the airport to the conference venue & back. The College of Engineering Pune is one of the top engineering colleges in India.

AWARD WINNERS

Mr. N Gopinath (R), Managing Director of Fluidtherm Technology was conferred with the title of Fellow of Powder Metallurgy Association of India.

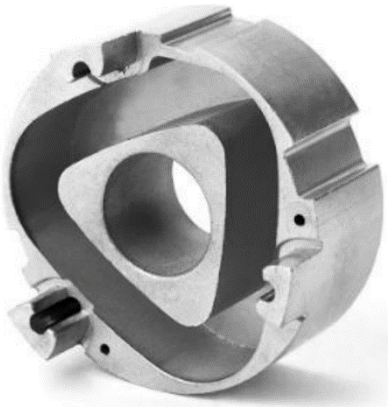
The three criteria for fellowship of PMAI are contribution to the-

- **Science and practice of powder metallurgy**
- **Indian powder metallurgy industry &**
- **Growth of PMAI.**

Mr. N Gopinath is a rare individual who has met all criteria and in abundance; by developing unique processes & world-class furnaces for powder metallurgy, making these available around the world, and for his efforts that has made PMAI an internationally recognised body.

Mr Gopinath in his acceptance speech joked that for the 6 years that he served as President of PMAI this was the credit he received ; personally he would have preferred cash.

Prof. P Ramakrishnan, Professor Emeritus, IIT Bombay and Fellow of PMAI discussing the manufacturing process of parts submitted for the best parts awards.



Speciality Sintered Products Pvt Ltd Pune won the Best Press & Sinter PM Product Award for “Magnet Housing” which is a part of the assembly of electromagnetic clutches and brakes.

Dr. Cesar Molins, VP- EPMA judging the best PM product entries.

Indo-MIM won the Best MIM Product Award for “Stopper Slide” which has applications in Defence.

SPONSORS

PMAI thanks its sponsors for APMA 2019 without whom it would have been very difficult to pull off a world-class PM conference.

Our patron sponsors were;

Fluidtherm Technology - manufacturers of furnaces for powder metallurgy (www.fluidtherm.com)

Höganäs India - manufacturers of metal powders (www.hoganas.com)

Indo-MIM - manufacturers of MIM components (www.indo-mim.com)

Porite Group - manufacturers of PM components (www.porite.com)

Sintercom India - manufacturers of PM components (www.sintercom.co.in)

Speciality Sintered Products - manufacturers of PM components (www.specialitysintered.com)

Our conference sponsors were

AMETEK SPECIALTY METAL PRODUCTS

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International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI)
An Autonomous R&D Centre of Dept of Science & Technology, Government of India

MAKIN METAL POWDERS

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RioTinto

RVB SHORLUBE

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SP

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EXHIBITION

Forty four of the top PM companies from around Asia exhibited at APMA 2019. These included-

- **Alvier AG (Switzerland)** - PM tooling
- **AMETEK (USA)** – Alloy PM powder
- **ARCI (India)** - PM R&D facility
- **Chang Sung Corp (Korea)** - Metal powders and magnetic powder cores
- **Chung Yi Mold (China)** - PM Tooling
- **Codina Furnace Belts (Spain)** - Furnace belts
- **Desktop Metal (USA)** - 3D binder jet printer
- **Dorst Technologies (Germany)** – Presses for PM
- **EPSI (Belgium)** - High pressure isostatic equipment
- **East Precision Machinery (China)** – Presses for PM
- **Fluidtherm Technology (India)** - Furnaces for PM
- **Hexagon Product Development (India)** - 3D powder mixers
- **Haili Press (China)** – Presses for PM
- **GKN Hoeganaes (USA)** - Metal Powders
- **Höganäs (Sweden & India)** - Metal Powders

- **Indo-MIM (India)** - MIM parts
- **Innomet Powders (India)** - Alloy Metal powders
- **Innovar Communication (UK)** - Publishers of PM, MIM & AM magazines
- **Jiangxi Yuean Superfine (China)** - Metal powders and MIM feedstock
- **Junghwa Press (Korea)** – Presses for PM
- **Makin Metal Powders (Germany) -** Non ferrous metal powders
- **Malvern Aimil (India)** - R&D instruments & testing services
- **Meetu-Raj Industries (India)** - MIM parts
- **Newmet (India)** - Presses for PM
- **Osterwalder (Switzerland)** – Presses for PM
- **Pometon (Spain)** - Metal powders
- **Porite (Taiwan)** - PM parts

““I’m very happy with the exhibition. It is going very well for us, as well as I think for the other participants.”

Cristina Diaconu
GKN Hoeganaes

EXHIBITION

- **PVA Industrial Vacuum (Germany)** - Vacuum furnaces
- **Rio Tinto (Canada)** - Metal powders
- **RVB Shorlube (India)** - PM parts
- **SACMI (Italy)** - Presses for PM
- **Sarda Industrial (India) -** Metal powders, fiber & chips
- **Shangxi Golden Kaiyun (China)** - Isostatic presses
- **SIMO Corporation (India)** - Metal powders
- **Singhal Sintered (India) -** PM parts
- **SLM (India)** – Metal powders
- **Speciality Sintered (India) -** PM parts
- **The ExOne Company (USA)** - 3D printers
- **Tianyi Ultrafine (China)** - Carbonyl metal powders
- **Uralelectromed (Russia)** - Copper powders
- **Verder Scientific (USA) -** Scientific instruments
- **WuXi Sincere Ceramics (China)** - Ceramic products
- **Xitiz Technomech (India)** - Vacuum furnaces
- **Yuelong Powders (China)** - Carbonyl iron powders

"The exhibition is very well organised. We are very excited with the opportunities we have received here."

Julia Bondarenko
Uralelectromed

ENTERTAINMENT: THE APMA & GALA DINNERS

The APMA Dinner featured classical Indian mythology in different dances styles; Kathak & Bharatnatyam in three sequences. The first, to the vibrant beat of the song *Aigiri Nandini* depicts the goddess Shakti (strength) as the nurturing mother of the Universe who does not hesitate to use bloody violence to destroy evil. The second dance set to another heady beat of the song Shiva Sthrotam depicts the character of Lord Shiva, the hindu god of destruction. As a break from all this violence, Lord Krishna was presented through Krishna Leela, a sketch of love & devotion his female followers had for him. Lord Krishna is a central figure in the Bhagavat Gita, one of the two main epics of Hinduism.

The Gala Conference Dinner featured a medley of different Indian classical dances depicting the story of Ramayana in four parts.

Ayodhya: Prince Rama strings a bow that no other suitor can, as a condition to marry Princess Sita. Both return home to Ayodhya. However Rama's step mother Queen Kaikeyi demands that Rama be banished. Rama obediently leaves with his new wife and faithful brother Lakshmana to live in the forest for 10 years.

Abduction: The demon king Ravana, a devotee of the Lord Shiva kidnaps Sita to avenge the attack by Lord Rama and Lakshmana on his demon sister. He takes the form of a golden deer to draw Rama and Lakshmana away from the ashram. He then returns as a sage & is welcomed by Sita. He transforms to his true (handsome) demon form, grabs Sita & gets into his flying chariot. The noble bird Jatayu tries to stop him and dies, but not before telling Rama what happened.

Drums of War: Rama puts together his army and builds a stone bridge to Lanka (now Sri Lanka) where Ravana is holding Sita. Rama's devoted helper Hanuman visits Lanka and sees that Sita is unharmed. He tells her that Rama is on his way.

Death & Destruction: Rama kills Ravana in battle and returns to Ayodhya with Princess Sita and Prince Lakshmana. Their return is celebrated every year till today in a festival of lights, happiness & family values called Diwali.