ASM International Pune Chapter

Chapter News Letter

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EDITORIAL . . .

Dear ASM Members, Colleagues, and Friends:

It is a pleasure to share this note with you as a Guest Editor for the August 2025 edition of the ASM Pune Chapter Newsletter. As we reflect on the year so far, it is evident that our Chapter continues to thrive through meaningful technical engagements, student outreach, and industrial collaborations.

Since March 2025, a series of insightful technical talks have enriched our community. These have included sessions on DOE-based yield improvement by Mr. Ajay Tare, safety in heat treatment by Mr. Vinayak Borgaonkar, NABL accreditation explained by Mr. Shrikant Kulkarni, the relevance of additive manufacturing in automotive applications by Mr. N.K. Vaidya and most recently, an excellent talk on smart foundries and sustainability by Mr. Nilesh Shedge. Each of these sessions, attended by students, professionals and academics alike, reflected the diverse and dynamic spirit of our community.

In parallel, student engagement remains a cornerstone of our activities. The Student Materials Camp at Government Polytechnic Pune, along with training programs for industry personnel and visits to metallurgical units that were recently organized, reaffirm our commitment to hands-on learning and industry-academia linkage.

This issue features a technical article on liquid feedstock thermal spraying - an area that is steadily gaining traction in thermal spray research and, in some cases, also industrial practice. The two prominent variants of liquid feedstock thermal spraying involve use of either suspensions containing finely dispersed solid particles or solution precursors that form the desired material upon thermal exposure during spraying. The approach offers several compelling advantages: refined and controllable coating microstructures, ability to deposit materials that are difficult to process as conventional powders and the possibility to uniformly deposit much thinner coatings than those that are powder-derived. Over the past few years, a wide range of functional coatings have been developed using this technique—ranging from thermal barrier coatings, wear-and-corrosion resistant layers, to bioactive and photocatalytic surfaces. Liquid feedstock thermal spraying also enables the deposition of nano-structured coatings and offers the potential to engineer coatings with controlled porosity and composition. With advancements in axial-feed torch designs and atomization strategies, the above approach is poised to play a key role in next-generation surface engineering applications.

Let us continue to strengthen our collective efforts to promote knowledge-sharing and innovation. I encourage each of you to contribute—be it through talks, articles, or volunteering—to keep the momentum going.

Warm regards,
Shrikant Joshi

Volunteer Yourself For Your Chapter!

For more efficient working & expanding network of your ASM International Chapter, please support your chapter by offering your time. Lot of avenues to choose areas of your liking. Options are - Membership Development, Education Programs, Students Outreach, Member Service, Website, News Letter, Technical Program and Social Events. Contact ASM International Pune Chapter asm.pune@gmail.com

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TECHNICAL ARTICLE

Liquid Feedstock Thermal Spraying: Unlocking the Next Generation of Coatings

Summary

Thermal spray techniques have long served as versatile methods for tailoring the surface properties of engineering components by depositing coatings suitable for a variety of intended outcomes: to enhance part longevity, to impart a new functionality, for aesthetics etc. Conventional thermal spraying relies on use of a powder feedstock to deposit a coating, but difficulties mainly associated with powder feeding arise when extremely fine powders are sought to be used to obtain refined microstructures. To overcome these limitations, liquid feedstock thermal spraying has emerged as an exciting pathway. This article provides an extended overview of this exciting approach, explaining its motivation, the prominent categories of liquid feedstocks that can be deployed, the prominent role of axial feed capable plasma torches, and the fundamentals of coating formation when liquids rather than powder are used. It discusses the wide-ranging application prospects of the above approach as well as additional exciting possibilities that can be enabled by using powder-liquid 'hybrid' feedstocks. The intent is to introduce the subject to readers unfamiliar with thermal spraying, while also highlighting the transformative potential of this approach.

What is Thermal Spraying?

Thermal spraying represents a family of surface modification techniques that has, over the last century, become one of the most industrially well-entrenched technologies by virtue of its immense versatility. Thermal spraying is a line-of-sight process that can coat large or irregularly shaped components without being restricted by size or environmental constraints typically associated with vacuum-based in-chamber processes such as physical and chemical vapour deposition. The coating-formation principle associated with thermal spraying is straightforward: the feedstock material is introduced in a high-temperature, high-velocity zone created by a suitable source—such as a combustion flame, an electric arc, or a plasma jet—wherein it is heated and accelerated toward a substrate. When the molten or semi-molten droplets resulting from the heat-transfer impact the surface, they flatten into pancake-like 'splats' and rapidly solidify. Repetition of this process builds up the coating: overlapping of the 'splats' by moving the source or the part enables large area coverage, while layer upon layer deposition produce thicknesses ranging from a few microns to several millimeters.

Today, thermal spray encompasses several process variants that differ mainly in their heat source, particle acceleration, and resulting coating characteristics. Plasma spraying uses a very hot plasma jet (>>10,000 K) to melt or soften feedstock, enabling deposition of even the most high-melting refractory ceramics. High-Velocity Oxy-Fuel (HVOF) spraying relies on combustion of oxygen and fuel to create a high-velocity, moderate-temperature jet that produces dense, well-bonded metallic and carbide coatings, while High-Velocity Air-Fuel (HVAF) spraying uses compressed air instead of oxygen to yield a cooler flame with reduced oxidation and very dense deposits. Cold spray is a solid-state kinetic energy driven process in which powder particles are accelerated to very high (often supersonic) velocities and bond to the substrate by plastic deformation rather than melting, making it ideal for depositing temperature-sensitive materials and for minimizing oxidation. Other variants such as flame spraying, detonation gun, etc. trade cost, temperature and particle velocity to balance density, adhesion, and material compatibility for different applications.

Depending upon the functionality (wear resistance, corrosion resistance, insulation etc.) demanded by the targeted application, a suitable material is used in the form of powder feedstock – virtually any material that does not sublime can be deposited by one or the other among the numerous thermal spray variants that are commercially available today. This versatility explains why thermal spraying is used in many diverse applications. In aerospace, the coating protects turbine blades with insulating ceramic layers – popularly known as thermal barrier coatings. In biomedical devices, the deposition of bioactive ceramic layers promotes fixation of implants. In energy systems, thermal spraying produces protective layers that resist corrosion and erosion. The thermal spray technology has today matured to a point where it is considered a workhorse of industrial coatings. As new demands emerge, there is growing motivation to target superior coating properties by exploring new coating materials as well as by overcoming limitations of conventional powder-based spraying.

Why Move Beyond Powders?

For decades, powders were the dominant feedstock for thermal spraying, typically in the size range of 10 to 100 microns. An impressively large range of thermal spray grade powders (spanning metals, alloys, intermetallics, ceramics and more!) are commercially available today. Powders are robust, easy to store, and straightforward to feed into plasma torches or combustion guns. However, when researchers began seeking coatings with refined microstructures or nanoscale features which demanded use of feedstock with finer particle sizes (under 10 microns), challenges associated with reliably feeding such fine powders soon became apparent with the problems getting increasingly overwhelming with reducing particle size.

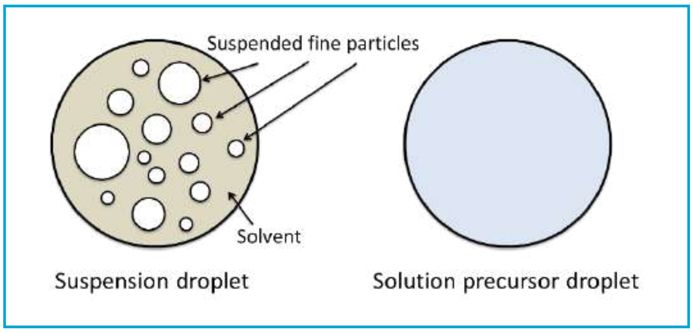
Fine powders in general exhibit poor flowability. They tend to stick together, forming agglomerates and also tend to clog the lines from the powder feeder to the spray torch and/or the spray nozzles. When it comes to sub-micron or nano-sized powders, handling them is also a safety concern, as some of them can pose health risks. Depending upon the thermal spray technique in question, fine powders often lack the momentum to penetrate into the hottest region, resulting in incomplete melting or poor deposition efficiency. This is particularly true in case of plasma spraying due to the relatively high gas viscosity under plasma conditions: in such cases, fine particles with low momentum just tend to “bounce off” the plasma plume.

The above challenges have motivated the development of liquid feedstock thermal spraying. Instead of attempting to directly inject fine powders, researchers began to investigate whether the use of a liquid carrier for such powders could mitigate the feeding problems and have made quite some progress on this front. Yet other thermal spray groups explored if one could completely dispense with the need for powders by utilizing appropriate solution precursors that were capable of forming the particles of interest in situ. While early interest in these liquid-based approaches was largely driven by the fact that the liquids are easy to pump and atomize, exciting results that ensued have served to fuel considerable interest in use of both the above types of liquid feedstocks. This innovation has not merely bypassed difficulties in handling sub-micron or nanosized powders but opened new avenues for thermal spray practitioners.

Suspensions and Solution Precursors

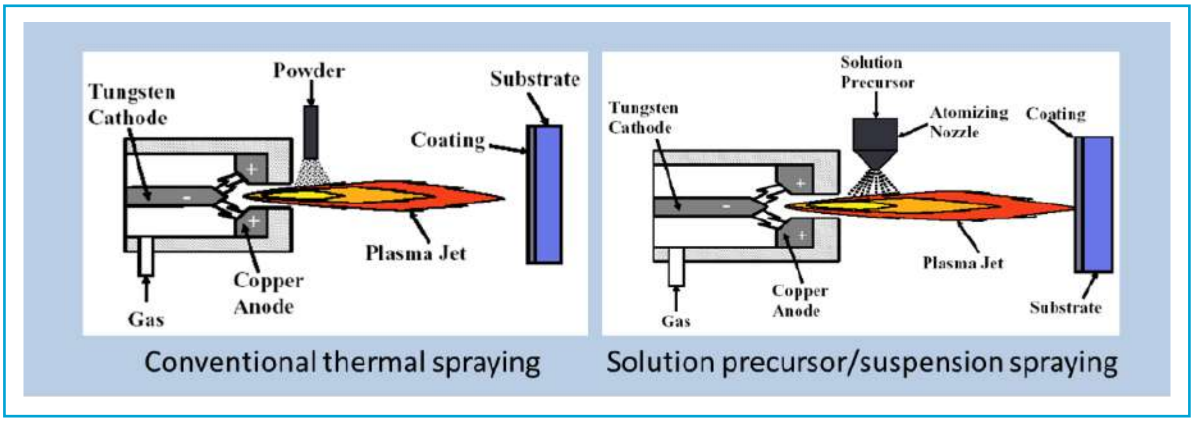
Liquid feedstocks can be broadly divided into two categories: suspensions and solution precursors. Each represents a different philosophy of how to deliver fine material into a plasma jet and subsequently form a coating.

Suspensions: These are dispersions of fine particles, often in the range of 100 nanometers to 2 micrometers, in a liquid medium, typically water or ethanol. Sometimes, to enhance stability of the suspension, dispersants and stabilizers are added that prevent the particles from settling or agglomerating. The suspension is injected into the plasma, atomized into small droplets, and as the solvent evaporates, fine particles or their clusters are exposed to the plasma plume to be melted and deposited. The obvious attraction of utilizing suspensions originally lay in their ability to exploit fine powders without either encountering feeding problems or having to go through an intermediate agglomeration step using methods such as spray drying to 'convert' them into larger particles for avoiding challenges associated with feeding. However, as discussed later, use of the finely suspended particulates as feedstock has been found to yield interesting microstructures not achievable with conventional spray-grade powders.



Solution precursors: Imagine a thermal spray approach that could result in a coating without resorting to use of powders at all. The use of solution precursors has exactly this motivation at its heart. Instead of starting with powders, one begins with soluble salts or organometallic compounds dissolved in a suitable solvent. When injected into the plasma plume, the available thermal energy promotes rapid solvent evaporation, which is successively followed by gelation, break-up, nucleation & growth and eventually pyrolysis to form oxide or other ceramic particles in situ. These nascently formed particles can then melt and participate in coating formation as powder particles typically do in thermal spraying. The advantage of solution precursors is their flexibility: one can create compositions and phases that may not be available in powder form.

Both suspensions and precursors expand the design space of thermal spraying. Suspensions are closer in spirit to powder spraying, while precursors bring a strong element of chemistry into play. As can be imagined, the spray variants involving use of liquid feedstock are inherently thermal energy intensive as they demand additional steps such as solvent evaporation in case of suspensions and the extra stage of pyrolysis when solution precursors are involved. Due to this need for additional thermal energy, a vast majority of studies involving liquid feedstocks have been with plasma spray systems. Consequently, the terms suspension plasma spraying (SPS) and solution precursor plasma spraying (SPPS) are more prevalent in thermal spray literature although liquid feedstock has also since been used in tandem with

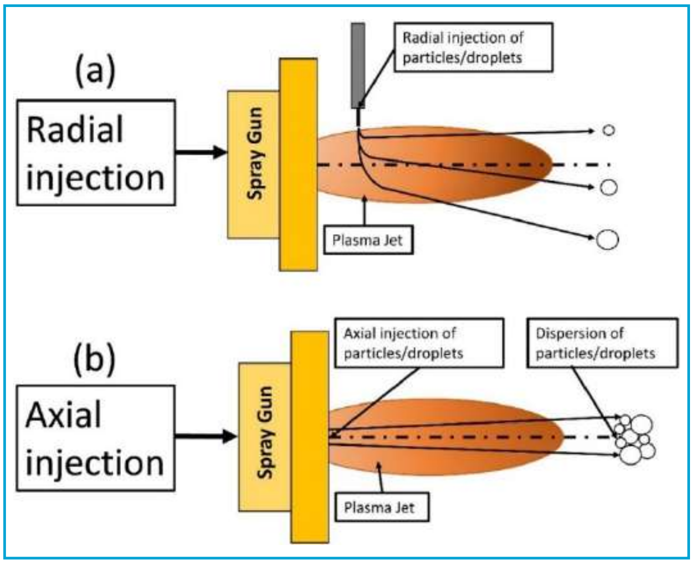


HVOF and even HVAF. From an implementation perspective, the implementation of liquid feedstock thermal spraying is extremely straightforward and only requires the powder feeder to be substituted by a liquid delivery system, different forms of which are commercially available today.

Axial Plasma Torches: Changing the Game for Liquid Feedstock

The way the feedstock enters the plasma has a decisive influence on the gas-particle or gas-droplet heat and momentum transfer that takes place and therefore, significantly affects the outcome of the spray process. In conventional plasma spray torches, the feedstock is introduced radially, perpendicular to the plasma plume. The problem with this approach is that much of the injected material never reaches the hottest part of the plasma: the finer particles with low momentum tend to bounce off the plasma plume due to the high gas viscosity under plasma conditions, while the particles with very high momentum travel right through the plume. In case of liquid feedstock, the former situation predominates and inhibits intimate gas-droplet heat transfer which is critical for optimum utilization of the thermal energy available in the plasma plume.

More recently, axial feed capable plasma torches capable of resolving the above problems associated with radial feeding have become commercially available. In axial systems, the feedstock is injected directly along the axis of the plasma jet. This ensures maximum residence time in the hottest zone and leads to more uniform heating. For suspensions, this means more consistent evaporation of solvent and melting of suspended particles. For solution precursors, axial injection is even more critical, since the droplets must undergo multiple steps outlined earlier (solvent evaporation, salt decomposition, gelation, particle nucleation, pyrolysis and melting in sequence), all within milliseconds.



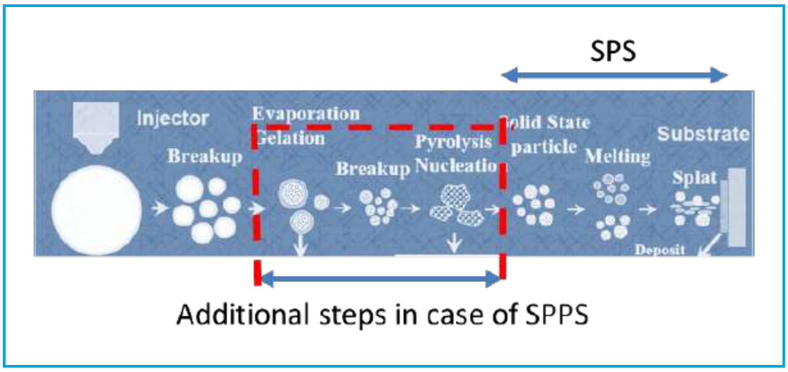
The benefits of axial injection that are readily discernible include higher deposition efficiency, better reproducibility and improved coating microstructures. It has also made it feasible to explore powder-liquid 'hybrid' feedstock processing where powders and liquids are injected either sequentially or in tandem, enabling layered or composite coatings with tailored properties. Axial plasma torches, therefore, not just afford incremental improvements but are also a key enabler for the entire field of liquid feedstock spraying.

How does Suspension Plasma Spray (SPS) work?

Suspension plasma spraying can be thought of as a stepwise transformation of liquid droplets containing entrained fine particles into a coating. A suspension is injected into the plasma and is atomized into fine droplets. Almost instantaneously, the solvent evaporates due to the rapid heat transfer from the high temperature plasma plume. The solid content remaining – comprising fine particles or their clusters - is then exposed directly to the plasma, where it melts and accelerates toward the substrate in a manner somewhat akin to that in conventional thermal spraying with powder feedstock. Upon impact with the substrate, these tiny molten or semi-molten particles form thin splats. Because of their small size, the splats are much finer than those produced in conventional powder spraying. By adjusting parameters such as the suspension concentration, the type of solvent used, the torch power, and the injection velocity, a wide range of microstructures can be produced. These range from dense, lamellar coatings to porous, sponge-like structures and even columnar architectures reminiscent of vapor-deposited coatings. The mechanism by which columnar microstructures unique to thermal spraying can be realized by SPS is now well-known and related to the very fine particles not having sufficiently high momentum deviating from their axial trajectory in the vicinity of the substrate surface due to aerodynamic drag forces and depositing preferentially on surface asperities.

SPS has already demonstrated success in several key applications. Yttria-stabilized zirconia thermal barrier coatings with columnar microstructures, essential for next-generation turbine engines, can be produced by SPS at lower cost compared to electron beam physical vapor deposition. In the biomedical field, SPS enables deposition of hydroxyapatite coatings with fine porosity that enhances bone integration. For solid oxide fuel cells, SPS can produce porous electrodes that optimize ionic conductivity and catalytic activity. Apart from the above, extremely dense coatings have also been achieved using suspensions. Each of these examples underscores the flexibility of the SPS process. Gradually, various groups have managed to also increase the solid loading in suspensions to as high as 50-60% to effectively address practical concerns regarding throughputs for possible industrial implementation.

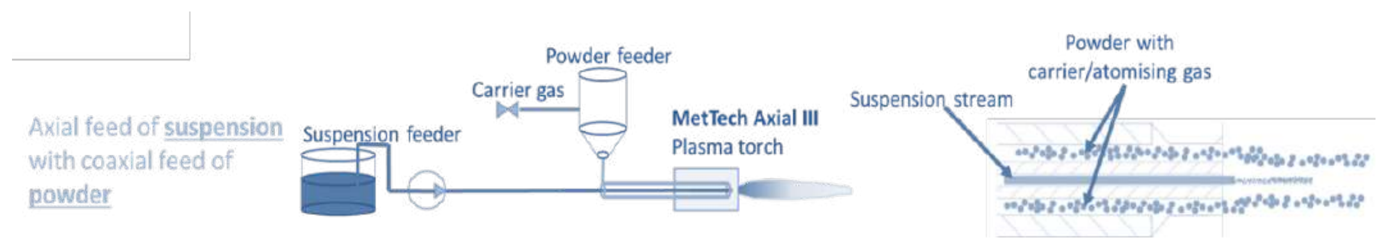
Solution Precursor Plasma Spray (SPPS): Coatings without using any powder!



Solution precursor plasma spraying, or SPPS, is more chemically complex but a very exciting avenue for obtaining coatings without using any powder whatsoever in the feedstock. The process begins with a droplet of precursor solution introduced into the plasma jet. The solvent evaporates within microseconds, leaving behind a concentrated solute that undergoes pyrolysis and/or decomposition. This results in the nucleation of new particles, which may subsequently melt and be deposited. What makes SPPS unique is that the particles are generated on the fly. Unlike SPS, where the solid material already exists in the suspension, SPPS creates new sold material during spraying. This means that metastable phases, novel compositions and controlled stoichiometries are possible. For example, materials such as yttria stabilized zirconia, lanthanum zirconate etc. and even complex high entropy oxides can be formed in situ and used as thermal barrier coatings. Alumina coatings with tailored phase composition have also been produced, as well as functional oxides such as cobalt ferrite for magnetic and catalytic applications. The advantages of SPPS include flexibility in chemistry and access to unique materials. However, the process is even more thermal energy intensive than SPS. Consequently, many past SPPS efforts have yielded academically interesting results and demonstrated potential to harness unique chemistry in a plasma plume but stopped short of being practically exciting for industrial implementation. The axial plasma spray systems bear promise to change this outlook. Recently, columnar YSZ coatings at throughputs comparable to SPS have been shown to be possible by axial SPPS.

Hybrid Powder–Liquid Feedstock Strategies

Following successful deployment of liquid feedstock and the clear promise that it has demonstrated, a related exciting development has involved exploring the use of a combination of powders and liquids in the form of a “hybrid” feedstock. With modern torches, it is possible to inject powders and suspensions or precursors simultaneously or sequentially. This opens entirely new possibilities in coating design, not only by enabling material combinations that are not readily available as commercial thermal spray feedstock but also by allowing coating build-up incorporating two very distinct building blocks ('splats') that differ by nearly two orders of magnitude.



One potential motivation for thermal spraying with 'hybrid' feedstock can be to build layered coatings, with distinct layer properties. For example, the top layer can provide a dense layer relatively impervious to oxidizing and/or corrosive species, while the lower layer can impart strain tolerance. Another interest in hybrid feedstock can be to form composite coatings, where fine or sub-micron splats/particles from the liquid feedstock are incorporated within a conventional powder matrix, creating multi-scale architectures with improved properties. Functionally graded coatings are also achievable, where the composition or porosity gradually changes from the substrate surface to the top of the coating, thereby reducing thermal stresses and improving performance.

Applications and Outlook

The impact of liquid feedstock thermal spraying is evident across several sectors. In aerospace and power generation, SPS-derived thermal barrier coatings with columnar structures have shown superior durability compared to conventional plasma-sprayed coatings. In energy technologies, SPS electrodes and electrolytes have enhanced the performance of solid oxide fuel cells. Biomedical implants have benefited from hydroxyapatite coatings applied by SPS, which improve bone integration and longevity. SPPS has expanded the materials palette further, allowing the creation of novel oxides for catalytic, electronic, and magnetic functions.

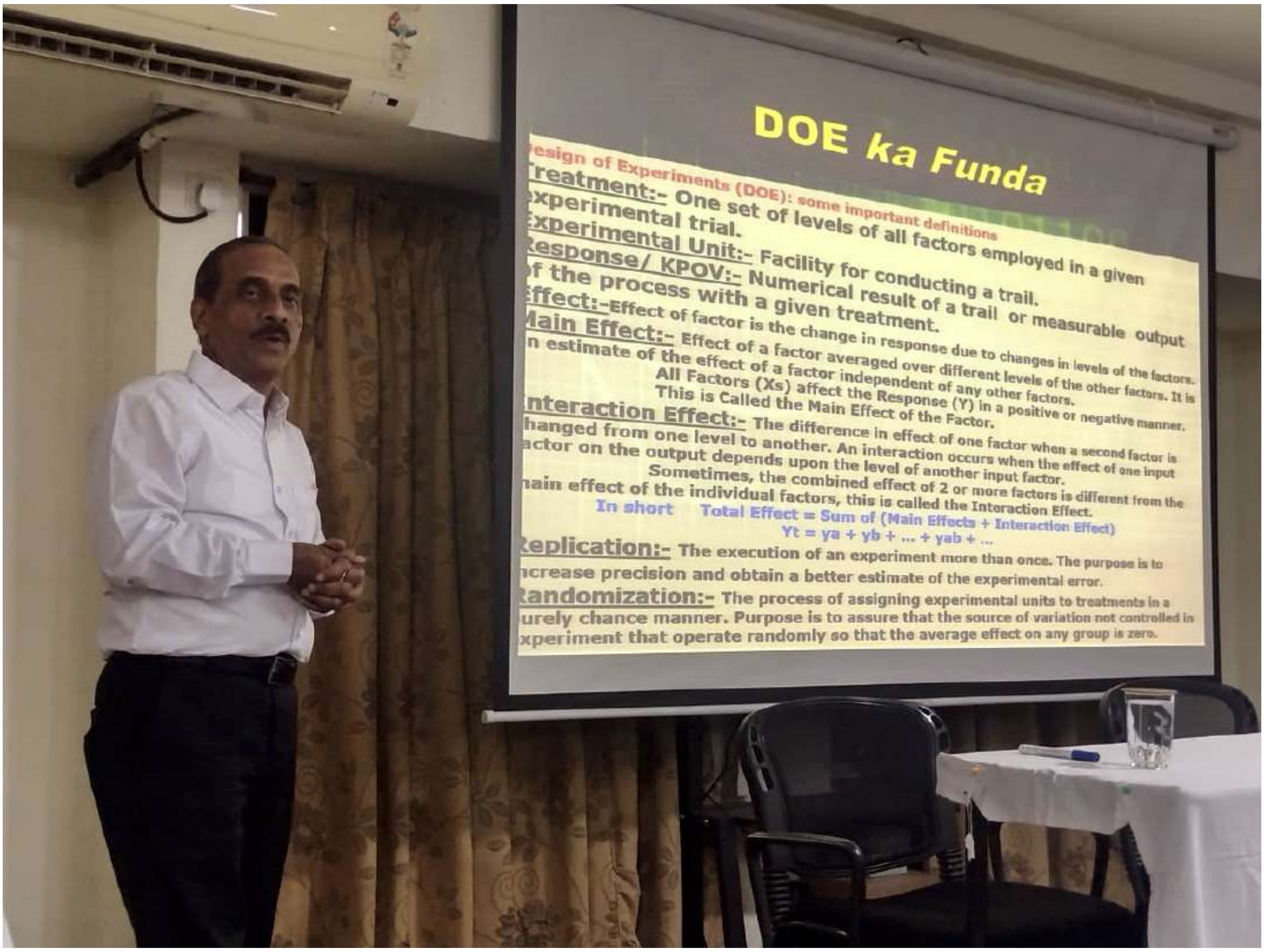
Despite its promise, liquid feedstock spraying is not without challenges. Feedstock preparation requires careful control of suspension stability and precursor concentration. Process reproducibility depends on precise control of injection parameters and plasma conditions. Nevertheless, the trajectory is clear. As axial torches become more widely adopted and as researchers deepen their understanding of process–structure–property relationships, liquid feedstock spraying is likely to become a mainstream technology. Its ability to bridge the gap between nanoscale control and industrial scalability positions it as one of the most transformative advances in modern coating science, capable of straddling demands of both conventional applications and demands for uniform, thin coatings (<15 microns) to meet niche demands.

TECHNICAL LECTURES

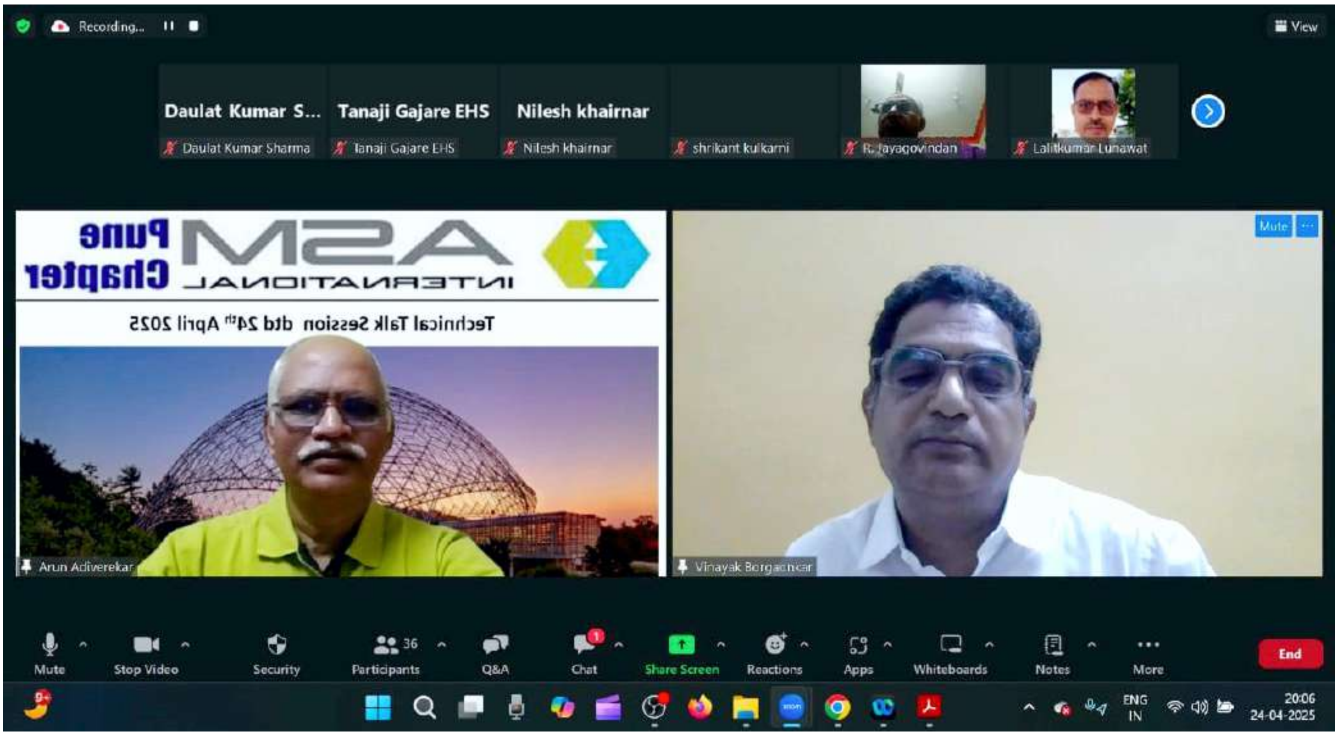
The ASM International Pune Chapter is arranging a technical lecture per month thanks to the efforts of Mr. Adiverekar. A brief of the lectures since March is given below:

The first lecture on " DOE - Sustainable Approach to Improve Yield on PQCD" was conducted in person by Mr. Ajay Tar on the 20th March who he delivered his talk and shared his practical experience on the implementation of DOE. Around 15 people amongst them EC members & Students from Cummins college Pune - Material Advantage Chapter, were present.

Mr. Ajay Tare is in the field of metals and metallurgy for the last 40 years and has a rich experience in portfolios of metallurgical engineering, research and development, operations, quality, manufacturing, NPD and business excellence. He is having extensive experience of processes, case hardening, carbonitriding, nitriding (liquid, gas and plasma), induction hardening, induction brazing, vacuum heat treatment, LPC processes, solution annealing and aging, sursulf, tufftriding, liquid cyaniding, friction welding, laser welding, fluidized bed furnace, shot Blasting and shot peening. He has also been a key team member for 4 patents (national and international) in the areas of shot peening and heat treatment for process and products.

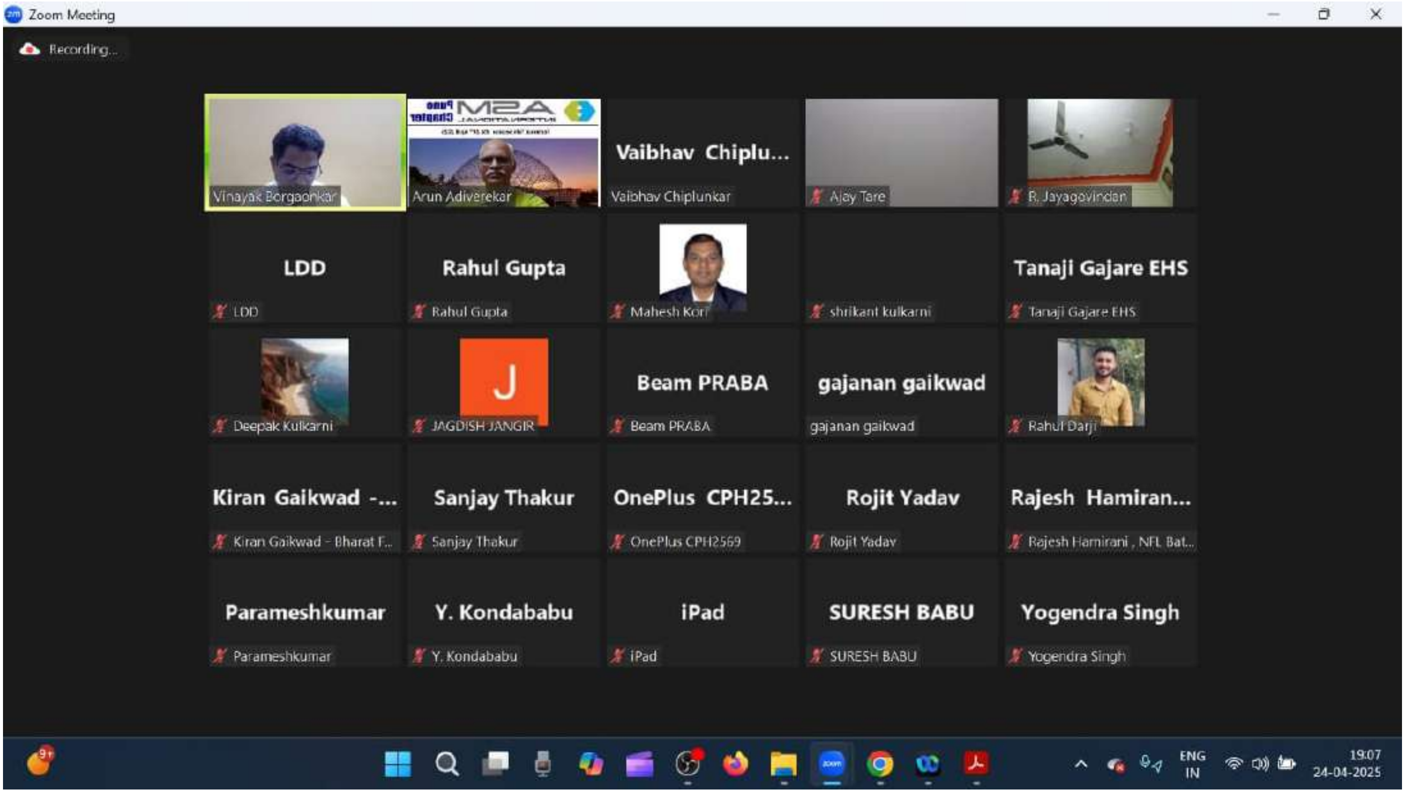


The next technical Talk on "Safety in Heat Treatment Shop and Foundry-Casting Industry" with Mr. Vinayak Borgaonkar on 24th April 2025 was held online. Mr Borgaonkar, a dynamic professional with



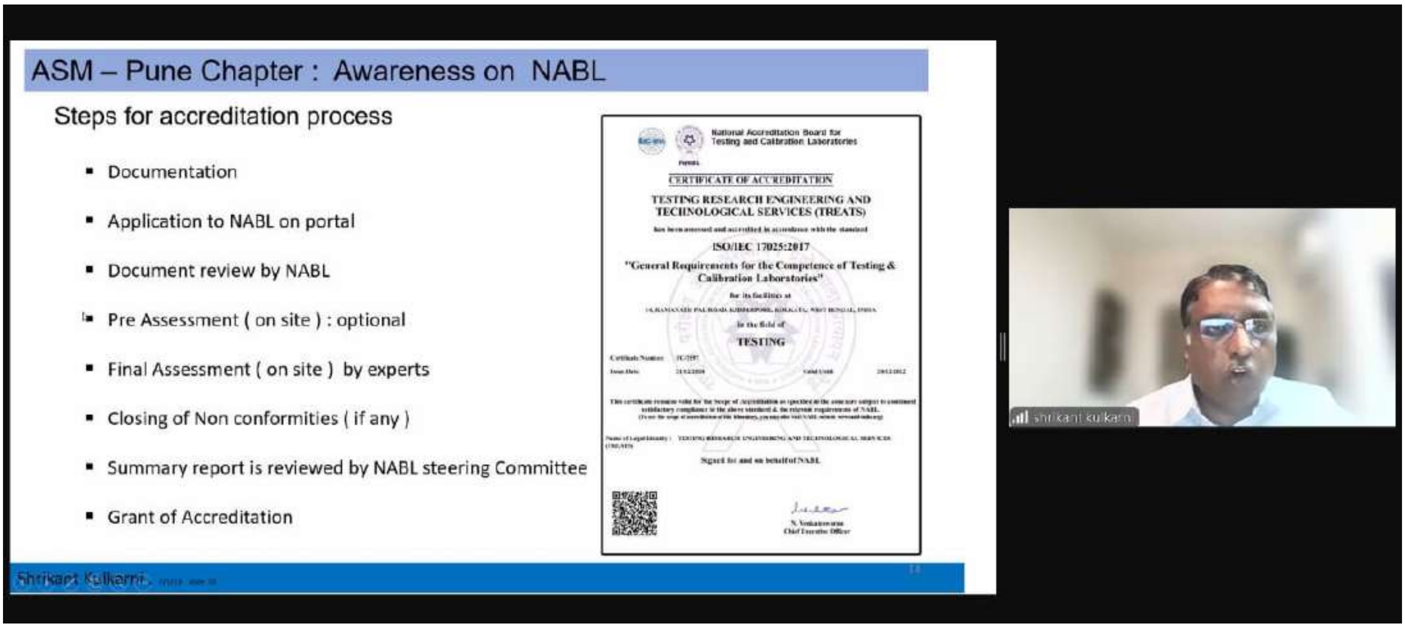
over 35 years of hard-core experience in maintenance, projects and safety in the automotive and precision engineering sector. He has handled the management of green field and brown field projects ensuring safety at all steps. The talk covered basics of heat treatment, its types and the hazards associated with it as well as the safety measures needed to counter these risks.

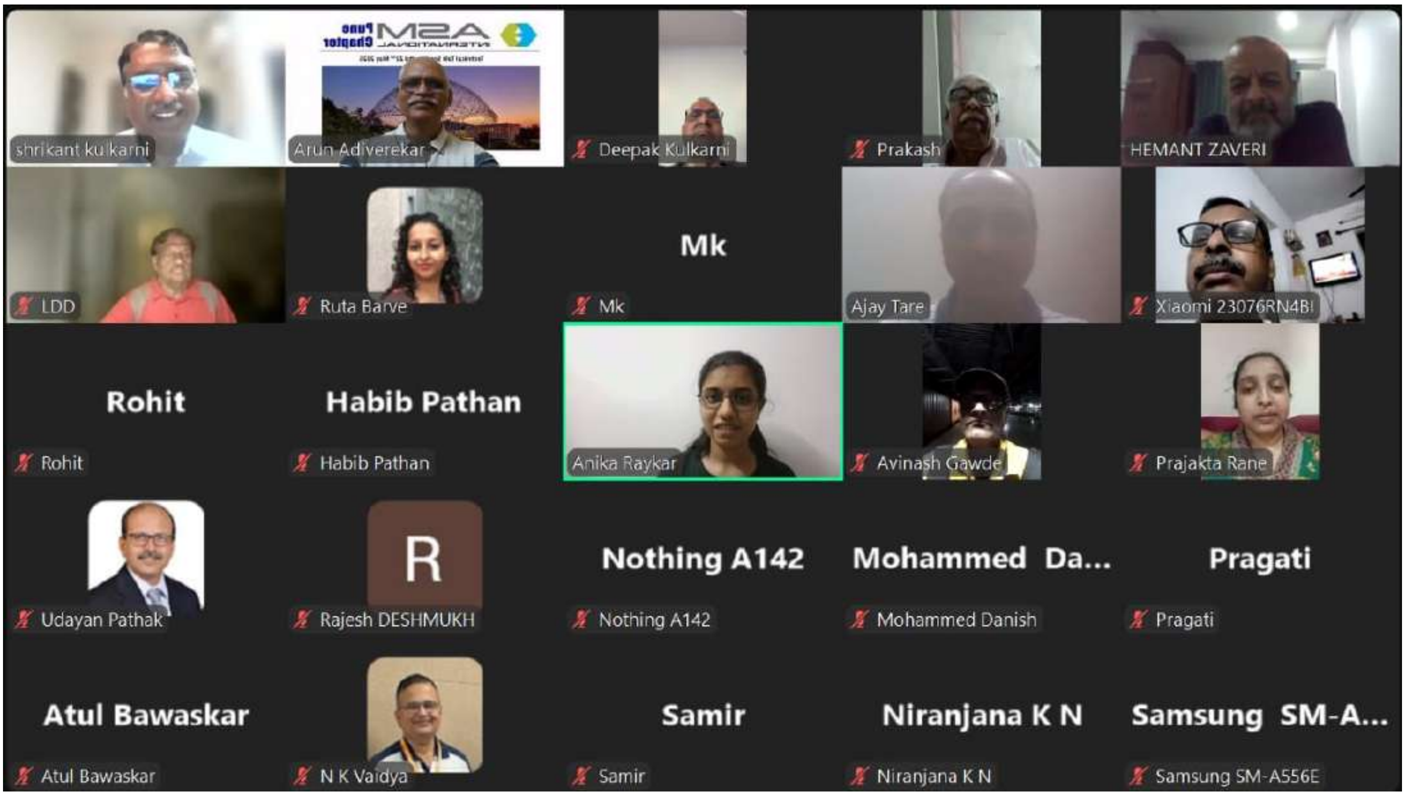
A total of forty-four members including EC members, tech committee members, students from the GIT College of Engineering, Belgaon as well as PVG college of Engineering Pune (Material Advantage Chapter) and also members from various industries were present during this Tech Talk Session. The session was very interactive and ended with questions and answers. The vote of thanks was given by Miss Pragati Demji, a student from GIT College.



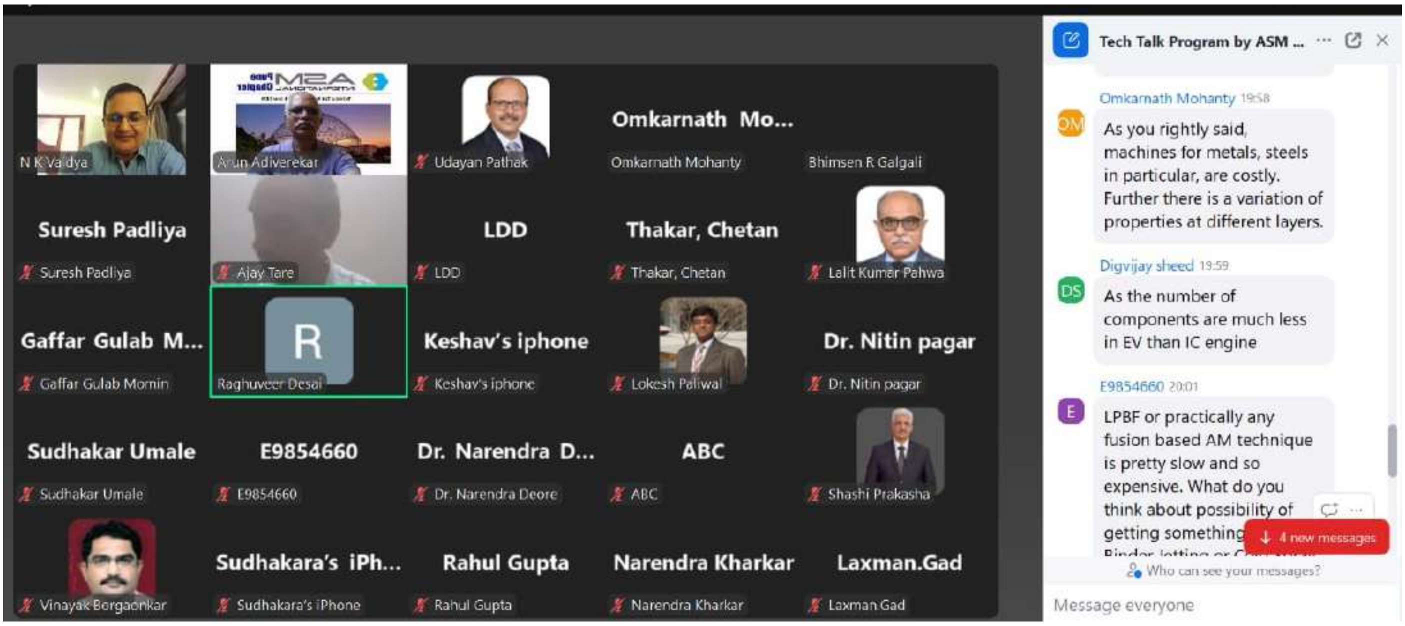
Another Technical Talk on "Understanding of NABL requirements based on ISO 17025" with Mr. Shrikant Kulkarni on Thursday, 22nd May 2025. Mr. Kulkarni graduated from IIT Kanpur in 1986 with a degree in metallurgical engineering. He has over 35 years of Industrial experience in firms like Bosch, Mahindra and Greaves and hands-on experience in areas of heat treatment, surface treatment (Diamond coatings, phosphating, etc), failure analysis and steel developments. He is also associated with the National Accreditation Board of Laboratories (NABL) – Quality Council of India, Ministry of Commerce, since over 15 years, as expert for technical assessments of Labs as per ISO 17025 and has completed over 500 audits with NABL as Technical/Lead Auditor.

The lecture covered the needs and benefits of accreditation, an overview of ISO 17025, a brief background of NABL, the stepwise process and specific requirements of testing and the support of the Government.





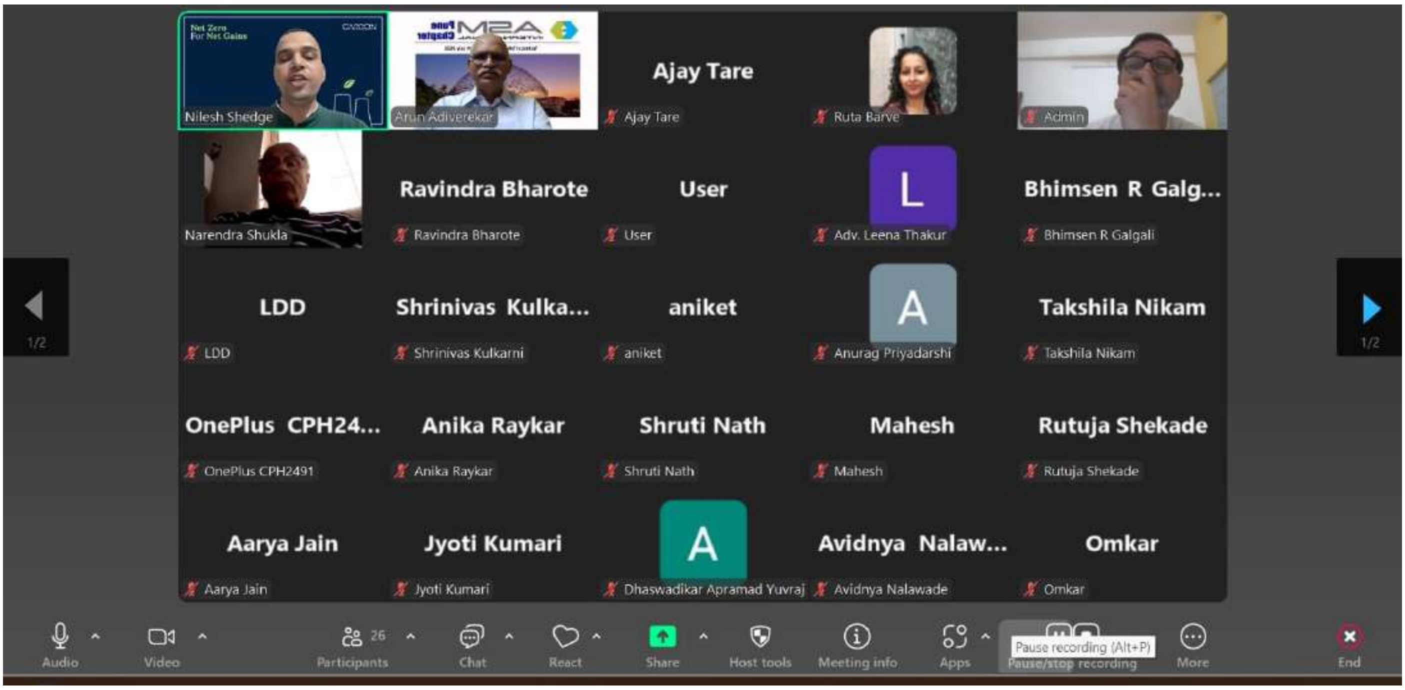
An online Tech talk - Proliferation of AM (Additive Manufactured) parts in Automotive vehicles - was given by Mr N. K. Vaidya on Thursday, 26th June 2025. Mr N K Vaidya shared his experience about the evolution of AM Technology, the current status of AM parts in a passenger car in domestic market Vs one of the largest car manufacturers in the world, the potential for AM parts in automotive vehicles, its challenges and enablers against the constraints. Around forty-eight participants were present during this Tech Talk session. The vote of thanks was given by Ms Pragati Demji, a student from the ASM MA Chapter of GIT College of Engineering, Belagavi.



The last ASM Tech Talk session was successfully held on Zoom platform on the evening of 24th July. The speaker was Mr Nilesh Shedge (CTO- Energy of CarbonMinus). He delivered a talk on "Smart Foundry: Energy resource analysis and sustainability management through IOT based platforms".

The speaker shared his experience about sustainability, energy management requirements in the foundry sector, the required national and international compliances for foundry, challenges in the foundry sector, solutions through implementation of Industry 4.0 and monitoring through IOT platform and their tangible benefits. He also shared the success story of the IOT platform implementation through a video of MSME foundries.

Twenty-five participants attended this Tech Talk Session. The vote of thanks was given by Ms Shruti Nath, a student from the MA Chapter of PVG College of Engineering, Pune.



TRAINING PROGRAMS

A two-day exclusive training program about 'Basic and Advanced Heat Treatment' was conducted on the 11th and 12th of March for the management of the Mahabal group of industries, Miraj and their staff. Rahul Gupta, D G Chivate and Udayan Pathak were Faculty.

STUDENTS OUTREACH

A Students Materials Camp was held in Government Polytechnic Pune starting on the 28th Feb 2025 and continuing till the 2nd of March 2025. Several industry experts gave lectures and provided hands-on technical knowledge.

The camp was conducted with the objective of teaching diploma students new skills in a safe and metallurgical environment. Its duration was 3 days. Around 45 students participated in different activities.

The following topics were taught

1. NDT Techniques
2. Welding Techniques
3. Corrosion Phenomenon
4. Metallography Techniques
5. Material Characterization
6. Heat treatment of metals, Hardenability, hardness measurements
7. Aluminium moulding and melting and pouring in die mould


शासकीय तंत्रनिकेतन,पुणे
ASM INTERNATIONAL
PUNE CHAPTER
30 YEARS

INDUSTRIAL VISIT

ASM Pune Chapter organized the awareness Programme "Know your Metallurgical Industries". The hospitality and the support by various units is highly appreciable. The Students were divided into six groups and visit the local units where they know about the Heat Treatment units, Foundries, Metallurgical Laboratories

VISIT TO POLYTECHNICS

There was also a visit to Bharatesh Polytechnic by the ASM team.

THANK YOU!

Be it during the planning stage, or when the camp was in progress, the wholehearted efforts of all the volunteers involved is what made the Conducting of the Students Materials Camp a success. We are especially grateful to the following volunteers: Teaching Staff of Government Polytechnic Metallurgy department Pune and our Industrial professionals' owners for financial support.

D G Chivate
Vice Chairman, Student Outreach Committee

NEW MEMBERS

Kapil	Rokade		Schlumberger
Anil	Ganapule	MD (CEO)	Mattest Laboratory
Shrikant Shridhar	Kulkarni	General Manager	Swajit Engineerin Ptv. Ltd.
Sandeep	Deshmukh		Sinhgad College of Engineering