अनुसंधान एवं विकास तथा औद्योगिक अनुप्रयोगों के लिए स्वदेशी लेसर योजक विनिर्माण में अग्रणी

Pioneering Indigenous Laser Additive Manufacturing for R&D and Industrial Applications

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Laser Additive Manufacturing Activity at RRCAT

Additive Manufacturing (AM) is shaping the future of production by offering unprecedented design flexibility, faster product development cycles, localized manufacturing, and improved resource efficiency. Around the world, industries and research institutions are investing in AM to overcome the limitations of traditional manufacturing and advancing sustainable industrial growth.

In India, RRCAT has taken a leadership role in developing indigenous Laser Additive Manufacturing (LAM) systems, establishing itself as a national pioneer in additive technology. The centre has successfully designed and deployed Laser Directed Energy Deposition (LAM-DED) and Laser Powder Bed Fusion (LAM-PBF) systems, complemented by Wire-Arc Additive Manufacturing (WAAM) and Wire-Laser Additive Manufacturing (W-LAM) platforms to cater to a range of component sizes and material types.

These state-of-the-art systems are employed in cutting-edge research across the Department of Atomic Energy (DAE) laboratories and through collaborations with leading academic institutions and industries. Applications span complex functional structures, graded materials, and multi-metal interfaces that are otherwise unachievable through conventional manufacturing. Through its technology development and technology translation initiatives, RRCAT has strengthened India's additive manufacturing ecosystem—directly contributing to the vision of Atmanirbhar Bharat and the national mission of technological self-reliance.

Collaborations with Materials Group at BARC

A major success story of RRCAT's innovation is its long-term collaboration with the Materials Group, BARC, for developing advanced materials vital to nuclear and aerospace technologies. Under the collaborative work with Dr. R. Tewari, Director, Materials Group, BARC, the teams have developed novel material systems and joining methods using the LAM-DED process.

One of our remarkable achievements is the creation of functionally graded transition joints between titanium and steel—a critical innovation for high-performance applications that demand both low weight and high strength. Traditional welding or brazing methods often form brittle intermetallic layers between these metals due to large differences in thermal and physical properties. To overcome this challenge, the RRCAT–BARC team engineered a graded transition zone using vanadium (V) and chromium (Cr) interlayers using LAM-DED technology. The LAM-DED process offered the spatial control necessary to sequentially deposit these interlayers, ensuring gradual compositional transitions from stainless steel to titanium without disrupting metallurgical continuity. Comprehensive microstructural and phase-evolution studies were carried out under the guidance of Dr. Tewari using advanced scanning and transmission electron microscopy (SEM/TEM). These investigations revealed diffusion-controlled solid-solution formation with minimal intermetallic precipitation. The developed joint at optimized process parameter is found to have excellent mechanical strength developed with functionally graded approach.

This collaborative research not only provided a fundamental understanding of solidification dynamics, diffusion phenomena, and phase transformations in multicomponent alloy systems but also showcased the potential of laser additive manufacturing for designing site-specific materials architectures. The results have significant implications for fabricating dissimilar metal joints in nuclear reactors, aerospace propulsion systems, and high-temperature structural components. The success of this effort underscores the importance of cross-institutional cooperation that integrates laser processing technology with materials characterisation.

Indigenous Development of Laser Powder Bed Fusion System for MG, BARC

In a further step toward technology localization, RRCAT has developed a compact LAM-PBF system for MG, BARC, featuring a 500W fiber laser with a build volume of

Fig.1: Indigenously developed LAM-PBF System.

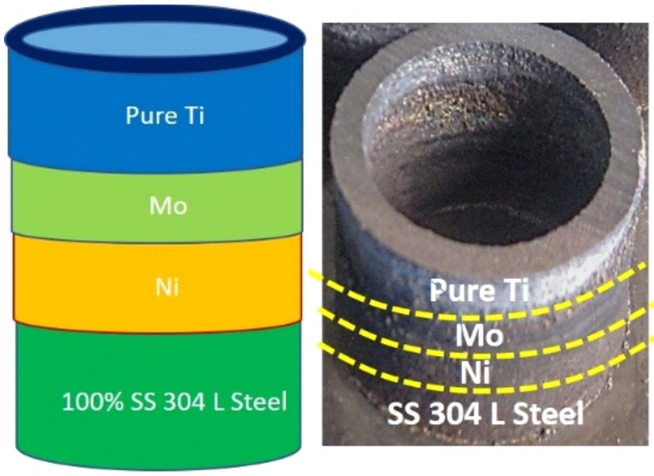

Fig.2: LAM built SS-Ti Transition Joint.

150mm×150mm×150mm to accelerate the development and qualification of advanced materials for future nuclear technologies. The system is designed for controlled experimentation with advanced materials, providing high process reproducibility while minimizing powder handling.

Such a platform provides an ideal balance between laboratory-scale throughput and process control, enabling fabrication of representative test coupons, graded specimens and parameter matrices while minimizing powder inventory and radiological handling footprint. The developed system is presently under trial testing, marking a significant step toward deploying this advanced manufacturing technology for nuclear material development and related applications.

Perspective and Outlook

The growing convergence of laser additive manufacturing and advanced materials characterization is reshaping how materials are designed, processed, and applied. The collaborative efforts with Dr R. Tewari illustrate this synergy, where deep insights into phase transformations, diffusion mechanisms, and microstructural control enable the creation of tailor-made materials with superior properties.

Looking ahead, future research is expected to focus on developing different materials using LAM-DED and LAM-PBF technologies with enhanced properties for various applications. There is also growing interest in exploring multi-material printing, functionally graded coatings, and repair of high-value components for critical sectors.

The sustained collaboration between RRCAT and BARC stands as a model of multidisciplinary synergy—bridging laser technology, metallurgy, and materials characterization. This partnership continues to inspire innovations that address challenges in nuclear materials development, aerospace structures, and advanced manufacturing contributing to India's advancement in strategic materials research.