Advanced manufacturing technologies for nuclear applications

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In recent years, advanced manufacturing technologies have been widely developed for industrial applications. Nuclear industry is also evaluating these emerging technologies for its own needs. Additive manufacturing is considered for complex geometries, improved designs, innovative materials (gradient compositions, high entropy alloys…), reparation of components… Several types of processes have been developed according to different potential applications, such as laser powder spraying, wire melting, or laser melting or electron beam on powder bed. While progresses have been made on the understanding of processes and the production of materials, there are still many issues, both on the processes and on the materials: understanding of the physical phenomena, control of the stability of the fusion, specific metallurgical problems induced by the processes, process control or modeling and simulation.

Innovation in surface treatments make them also appear as a promising option to protect materials from solicitations (mechanical, environment…) in nuclear systems. Indeed, advanced thin film technologies allow physical vapor deposition with exceptional properties thanks to sources generating highly ionized metallic vapors. For example HiPIMS (High Power Impulse Magnetron Sputtering) allows the deposition of dense and adhesive layers with high homogeneity even on complex geometries. Recent developments on advanced tolerant fuels, involving a zirconium base alloy clad protected by a thin chromium layer deposited by PVD HiPIMS show extremely satisfying results under reproduced conditions of accidental loss of coolant. MAX phase coatings performed by PVD HiPIMS are also developed to increase the behaviour of clads under accidental conditions. Other technologies such as DLI MOCVD which are less mature but also extremely promising offer the possibility to protect the inner part of tubes.

In this paper, recent developments on laser additive manufacturing, mainly for GEN2&3 and GEN4 reactors, including issues and opportunities will be presented together with results on innovative surface treatments.