Fast thermal cycling during laser welding of AA6061 alloy with dynamic beam shaping in the MHz regime to control solidification cracking

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Among aluminium alloys, the 6xxx series stands out for its strength, formability and recycling characteristics. While the 6xxx series offers excellent properties, laser welding of these alloys presents challenges related to solidification cracking. The state-of-the-art uses lasers in conjunction with filler wires to alter the freezing range and hence reduce the crack susceptibility. Although this process allows achieving up to 80% joint efficiency, it necessitates a close contact to the material. This negates the key advantages of on-the-fly laser welding. To give manufacturers the tools they demand, advancements in dynamic beam shaping has the potential to revolutionise the welding process by offering free-shape beam shaping technologies, modulated at speeds up to tens of MHz. The introduction of such fast modulation in time and space can be used to influence the melt pool dynamics and the microstructure. Although this is a very attractive proposition, there is a lack of methodologies and fundamental knowledge on how the material responds to such fast thermal cycling in time and space. This talk will present an in-process thermal imaging system consisting of an IR camera and a multi-physical macro-scale model for heat transfer and fluid flow. The CIVAN OPA6 laser system was employed to generate a group of eight non-axisymmetric static beam shapes at different frequencies (from a few kHz to several MHz). Results revealed distinct signatures in the thermal cycling that correlate with the formation of solidification cracking. Among the eight beam shapes, the “forward triangle” shape led to reduced thermal strains and ultimately less crack sensitivity. The result of this research holds great potential to transition from the state-of-the-art wire-fed laser welding to a fully autogenous and non-contact laser welding. This versatility will have a significant impact on the sustainability of products and the resilience of production processes.