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Section Information

Over the past 30 years, Additive Manufacturing has grown to be used in an ever-growing number of application areas. The "Additive Manufacturing Technologies" section is open to receive high-quality papers on new technologies, processes, methods, materials, systems, and applications in the field of additive manufacturing.

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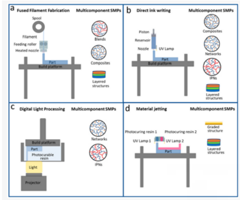
Section Additive Manufacturing Technologies

Featured Papers

DOI:0.3390/app12157880

4D Printing of Multicomponent Shape-Memory Polymer Formulations

Authors: Muhammad Yasar Razzaq, Joamin Gonzalez-Gutierrez, Gregory Mertz, David Ruch, Daniel F. Schmidt and Stephan Westermann

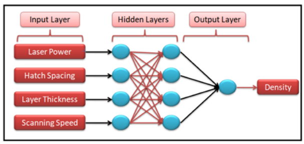


Abstract: Four-dimensional (4D) printing technology, as a next-generation additive manufacturing method, enables printed objects to further change their shapes, functionalities, or properties upon exposure to external stimuli. The 4D printing of programmable and deformable materials such as thermo-responsive shape-memory polymers (trSMPs), which possess the ability to change shape by exposure to heat, has attracted particular interest in recent years. Three-dimensional objects based on SMPs have been proposed for various potential applications in different fields, including soft robotics, smart actuators, biomedical and electronics. To enable the manufacturing of complex multifunctional 3D objects, SMPs are often coupled with other functional polymers or fillers during or before the 3D printing process. This review highlights the 4D printing of state-of-the-art multi-component SMP formulations. Commonly used 4D printing technologies such as material extrusion techniques including fused filament fabrication (FFF) and direct ink writing (DIW), as well as vat photopolymerization techniques such as stereolithography (SLA), digital light processing (DLP), and multi-photon polymerization (MPP), are discussed. Different multicomponent SMP systems, their actuation methods, and potential applications of the 3D printed objects are reviewed. Finally, current challenges and prospects for 4D printing technology are summarized.

DOI:10.3390/app12147271

Density Prediction in Powder Bed Fusion Additive Manufacturing: Machine Learning-Based Techniques

Authors: Meet Gor, Aashutosh Dobriyal, Vishal Wankhede, Pankaj Sahlot, Krzysztof Grzelak, Janusz Kluczyński and Jakub Łuszczek

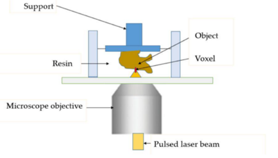


Abstract: Machine learning (ML) is one of the artificial intelligence tools which uses past data to learn the relationship between input and output and helps to predict future trends. Powder bed fusion additive manufacturing (PBF-AM) is extensively used for a wide range of applications in the industry. The AM process establishment for new material is a crucial task with trial-and-error approaches. In this work, ML techniques have been applied for the prediction of the density of PBF-AM. Density is the most vital property in evaluating the overall quality of the AM building part. The ML techniques, namely, artificial neural network (ANN), K-nearest neighbor (KNN), support vector machine (SVM), and linear regression (LR), are used to develop a model for predicting the density of the stainless steel (SS) 316L build part. These four methods are validated using R-squared values and different error functions to compare the predicted result. The ANN and SVM model performed well with the R-square value of 0.95 and 0.923, respectively, for the density prediction. The ML models would be beneficial for the prediction of the process parameters. Further, the developed ML model would also be helpful for the future application of ML in additive manufacturing.

DOI:10.3390/app13116844

Light–Matter Complex Interactions in Stereolithographies

Authors: Thomas Doualle, Laurent Gallais and Jean-Claude André

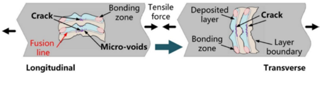


Abstract: Since its inception in 1984, 3D printing has revolutionized manufacturing by leveraging the additivity principle and simple material–energy coupling. Stereolithography, as the pioneering technology, introduced the concept of photopolymerization with a single photon. This groundbreaking approach not only established the essential criteria for additive processes employing diverse localized energies and materials, including solid, pasty, powdery, organic, and mineral substances, but also underscored the significance of light–matter interactions in the spatial and temporal domains, impacting various critical aspects of stereolithography's performance. This review article primarily focuses on exploring the intricate relationship between light and matter in stereolithography, aiming to elucidate operational control strategies for fabrication processes, encompassing voxel size manipulation. Furthermore, advancements in light excitation modes, transitioning from one-photon to two-photon mechanisms, have unlocked new material and creative possibilities. Notable advantages include the elimination of layering (true 3D printing) and the ability to fabricate objects using silica glass. Although these volumetric 3D printing methods deviate from conventional additive manufacturing concepts and possess narrower application scopes, they offer reduced manufacturing and design timeframes along with enhanced spatial resolution in select cases. These complex light–matter interactions form the cornerstone of this comprehensive review, shedding light on operational control strategies and considerations in stereolithography. By comprehensively analyzing the impact of light–matter interactions, including the novel two-photon excitation, this review highlights the transformative potential of stereolithography for rapid and precise fabrication. While these techniques may occupy a smaller niche within the broader spectrum of 3D printing technologies, they serve as valuable additions to the array of 3D devices available in the market.

DOI:10.3390/app13042720

Differences in Properties between Hybrid Wire Arc Additive-Milling Subtractive Manufactured Aluminum and Magnesium Alloys

Authors: Shuai Zhang, Mengcheng Gong, Ling Cen, Yang Lu and Ming Gao

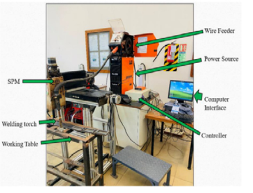


Abstract: Hybrid wire arc additive-milling subtractive manufacturing (HWMM) is an effective way to improve the quality of complex metal components, but the difference in the properties of the aluminum alloy and magnesium alloy fabricated by HWMM has been not addressed. In the paper, the differences in deposition accuracy and tensile anisotropy between the Al5Si Al and AZ31B Mg alloys were studied by using the HWMM method. Under the optimal parameters, the minimum surface roughness of the AZ31B sample was 146.1 μm, which was 90% higher than for the Al5Si sample. The differences in the tensile strength and elongation of the AZ31B sample were 32% and 56%, respectively, being 6 and 3.3 times higher than those of the Al5Si samples. According to the fracture behavior of the samples, the tensile anisotropy of both alloys was mainly attributed to defects such as incomplete fusion and porosity in the fusion line. However, there was obvious structural inhomogeneity in AZ31B samples, where the grain size difference between adjacent areas reached 40%. This led to the easier fracture of AZ31B samples. These results contribute to our understanding of the HWMM of light alloys.

DOI:10.3390/app12105060

Optimization of Bead Morphology for GMAW-Based Wire-Arc Additive Manufacturing of 2.25 Cr-1.0 Mo Steel Using Metal-Cored Wires

Authors: Jay Vora, Nipun Parikh, Rakesh Chaudhari, Vivek K. Patel, Heet Paramar, Danil Yurievich Pimenov and Khaled Giasin



Abstract: The fabrication of components involves the deposition of multiple beads in multiple layers for wire-arc additive manufacturing (WAAM). WAAM performed using gas metal arc welding (GMAW) allows for the manufacturing of parts through multiple-bead multi-layer deposition, which depends on the process variables. Thus, the selection of process parameters along with their required levels is mandatory to deposit multiple layers for WAAM. To obtain the desired levels of parameters, bead-on-plate trials were taken on the base plate of low alloy steel by following an experimental matrix produced through the Box–Behnken design (BBD) on GMAW-based WAAM. Wire feed speed, travel speed, and voltage were chosen as the input parameters and bead width and bead height were chosen as the output parameters. Furthermore, the robustness and adequacy of the obtained regression equations were analyzed by using analysis of variance (ANOVA). For both responses of BW and BH, values of R^2 and adj. R^2 were found to be near unity, which has shown the fitness of the model. Teaching–learning-based optimization (TLBO) technique was then employed for optimization. Within the selected range of process variables, the single-objective optimization result showed a maximum bead height (BH) of 7.81 mm, and a minimum bead width (BW) of 4.73 mm. To tackle the contradicting nature of responses, Pareto fronts were also generated, which provides a unique non-dominated solution. Validation trials were also conducted to reveal the ability and suitability of the TLBO algorithm. The discrepancy between the anticipated and measured values was observed to be negligible, with a deviation of less than 5% for all the validation trials. This demonstrates the success of the established model and TLBO algorithm. The optimum feasible settings for multi-layer metal deposition were determined after further tuning. A multi-layer structure free from any disbonding was successfully manufactured at the optimized variables. The authors suggest that the optimum parametric settings would be beneficial for the deposition of layer-by-layer weld beads for additive manufacturing of components.

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