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Editorial

Special Issue on Metal Additive Manufacturing and Its Applications: From the Material to Components Service Life

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1. Introduction

These days, additive manufacturing processes have a large representation in current research and in the field of industrial applications. An overview of the current state of research for Wire and Arc Additive Manufacturing is provided in this Special Issue [1]. In addition to process and geometric aspects, material properties are also increasingly in focus, as well as modern materials, such as titanium aluminides, cobalt-based alloys [2], high entropy alloys [3], and nickel-based superalloys [4] are more and more qualified for additive manufacturing. Furthermore multi-material approaches are another focus of research [5,6]. The more the knowledge about additive manufacturing processes increases, the more these processes are used in industrial manufacturing. They are used in many industries, from aviation to energy technology, and ensure the continuous further development of technical equipment with appropriate post-processing, such as milling or heat treatment. In order to take this fact into account, this Special Issue was open to a wide range of topics and provides 13 submitted and 11 published papers (an acceptance rate of 85%), further providing a good overview of the current state of research.

2. Metal Additive Manufacturing in This Special Issue

The process steps in additive manufacturing range from the design of the component with the help of CAD programs to the path planning for the production to the determination of properties and service life prediction, i.e., as shown in [7]. An essential step in path planning is, among other things, the consideration of manufacturing-related distortion. To address this problem, Wacker et al. showed that in arc-based additive manufacturing (WAAM), deformation and distortion occur due to the high energy input and the resulting strains. They use an artificial neural network (ANN) to predict welding distortion and geometric accuracy for the multilayer WAAM structures created. For demonstrative purposes, the ANN creation process is presented on a smaller scale for multilayer weld bead-on-plate welds on a thin substrate sheet. The use of several approaches for the creation of ANNs and the development of a strategy to deal with the outliers developed led to the achievement of good results. In particular, good results were obtained by applying an extended ANN using the deformation and geometry of the previously deposited layer. However, further adaptations of this method are necessary for a prediction of additively welded structures, geometries, and shapes in defined segments. A conceivable method would be the use as a preliminary procedure for multi-segment structures as well as an application during the welding process to continuously adjust the parameters for a higher resulting component quality [8].

In order to improve the prediction of deformations, Hartmann et al. [9] have devoted themselves to the full-field strain determination for additively manufactured parts with the aid of radial basis functions. In particular, the rough, curved surfaces of additively manufactured parts are the focus of their investigations, so that the strain and surface deformation analysis of such parts can be carried out using digital image correlation (DIC) methods. Hartmann et al. address two essential questions: (1) How can DIC measurements and calculation results for such components be interpreted? (2) How can we deal with the discontinuities in the approach to DIC strain analysis based on triangulation or local tangent plane the main strain directions? For this purpose, they use globally formulated radial basis functions (RBF) for the first time. These functions have the advantage that all the quantities of interest can be evaluated at arbitrary points. Furthermore, they validate this approach on an experimental example [9].

The next step in additive manufacturing is the selection of a material that ensures the desired component properties. This is where Leicher et al.'s [10] research comes into play, as they have developed a new alloy development concept for wire and arc additive manufacturing. They postulated that the classic time-consuming and costly development of welding filler materials can be substituted by an alternative alloy concept. This is based on the thin-film coating of welding consumables by means of PVD coating. As a validation example, they have used an HSLA steel DIN EN ISO 14341-A G 50 7 M21—which was alloyed with the elements Al, Cr, Nb, Ni, and Ti by means of PVD thin-film coating—as the basis for a welding filler metal available on the market and compared the properties of components from the new alloy development concept and conventionally developed welding filler metals. As part of the qualification of the alloy development concept, they also investigated the influence of the process and material properties. The investigations showed that the thin-film coating on the surface of the filler metal influences the process properties in the form of a changed arc length. For the alloy development concept, the mechanical properties of the test components show that they match [10].

In addition to the mechanical properties of the components, the electrical and magnetic properties of additively manufactured components are also becoming increasingly important. Tiismus et al. [11] showed that samples of FeSi4 powder produced by selective laser melting (SLM) have excellent DC magnetic properties compared to commercial and other 3D-printed soft ferromagnetic materials in the literature at low magnetization (1 T). Furthermore, the empirical total core losses were divided into hysteresis, eddy current, and excess losses by subtracting the finite element method (FEM)-simulated eddy current losses and the hysteresis losses measured under quasi-static conditions and it was found that the hysteresis losses decrease from 3.65 to 0.95 W/kg (1 T, 50 Hz) after a subsidiary heat treatment [11].

In order to ensure the geometry of the additively manufactured component, knowledge of the relationships between process parameters and the resulting layer geometry is of decisive importance. Hoefer [12] addressed this aspect in his work on plasma- and powder-based additive manufacturing 3DPMD. This work showed that the powder mass flow only influences the layer thickness and not the wall thickness and is thus available as a process control variable. Overall, a comprehensive knowledge of the complex relationships between the control parameters and the component geometry in additive manufacturing using 3DPMD has been attained and forms the basis for further scientific work [12].

The use of neural networks in additive manufacturing is also currently increasing rapidly in order to fulfil a wide range of tasks. In this Special Issue, Izonin et al. [13] showed that neural networks are able to predict quality aspects of additively manufactured components [13]. Furthermore, Mbodj et al. [14] showed that neuronal networks can be used for geometric prediction in Wire and Laser Additive Manufacturing.

The last step in the additive manufacturing of components is the reworking of functional surfaces, which should have special surface requirements. In this Special Issue, Parvez et al. [15] demonstrated that integrated laser polishing can significantly reduce the surface roughness of additively manufactured components.

In summary, it can be said that this Special Issue provides a good overview of the current topics in research along the entire additive manufacturing process chain. This shows that the issues surrounding additive manufacturing are very topical and that a great deal of scientific work still needs to be performed in this area. One example—among many others—of such a work is the integration of sensor functions into the additively manufactured material [16], which is also included in this Special Issue.

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