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Editorial

Advanced Characterization and On-Line Process Monitoring of Additively Manufactured Materials and Components

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1. Introduction

Additive manufacturing (AM) techniques have risen to prominence in many industrial sectors. This rapid success of AM is due to the freeform design, which offers enormous possibilities to the engineer, and to the reduction of waste material, which has both environmental and economic advantages. Even safety-critical parts are now being produced using AM. This enthusiastic penetration of AM in our daily life is not yet paralleled by a thorough characterization and understanding of the microstructure of materials and of the internal stresses of parts. The same holds for the understanding of the formation of defects during manufacturing. While simulation efforts are sprouting and some experimental techniques for on-line monitoring are available, still little is known about the propagation of defects throughout the life of a component (from powder to operando/service conditions). This Issue was aimed at collecting contributions about the advanced characterization of AM materials and components (especially at large-scale experimental facilities such as Synchrotron and Neutron sources), as well as efforts to liaise on-line process monitoring to the final product, and even to the component during operation. The goal was to give an overview of advances in the understanding of the impacts of microstructure and defects on component performance and life at several length scales of both defects and parts.

2. Characterization and Process Monitoring

This Issue was born with a further precise scope: BAM funded in 2018 two large internal projects on characterization of materials and on-line process monitoring in additive manufacturing (AM) of metals (therefore including PBF, LMD and WAAM techniques). Therefore, we aimed to spark the debate on those two important aspects, starting from the output of such projects. In particular, we fostered a) the discussion about the influence of the microstructure and residual stress in AM of metals on the performance of materials and components and b) the investigation of possible ways to predict the appearance of defects in printed parts by on-line monitoring during manufacture. One particular aspect of point a) above was the use of advanced characterization techniques, especially based on large-scale facilities (synchrotron radiation and neutrons).

Indeed, many aspects of the generation, determination, and effects of residual stress (RS) in metallic AM materials and components are discussed in this Special Issue [1–3], whereby such stresses are determined by neutron or synchrotron X-ray diffraction. A review paper on the subject is also published in this Special Issue [4]. Moreover, advanced imaging techniques, in particular laboratory and synchrotron X-ray computed tomography, are used to disclose the defects generated by AM processes and some strategies for their mitigation [5–7].

Another axis of investigation in AM is the use of on-line monitoring techniques and their coupling with post-mortem microstructural analysis. This Special Issue contains a number of important contributions to the solution of the problems of how to extract defect distributions from temperature profiles in the manufactured parts during printing [8,9]. Not only are X-ray computed tomography data compared with infrared thermographic investigations, but also aspects of the calibration and registration of such techniques are thoroughly discussed [10,11].

Interestingly enough, authors contributed to demonstrating how more 'classic' non-destructive testing techniques can also well give invaluable insights into the problem of defect characterization [12], thereby complementing the high-end (but somehow expensive) characterization techniques.

Finally, the discussion is extended to component level, whereby defects [13] and residual stress [14] are determined in relevant industrial cases.

3. Conclusions

The Special Issue opens a few important points for discussion in the scientific community, such as the correlation between on-line measurements and defects in the final AM printed part, and the proper determination of residual stress in complex materials and components, such as additively manufactured metallic parts. It demonstrates that advanced and classic characterization techniques are both needed to solve the problems of defect and microstructure determination in the above-mentioned materials, together with on-line monitoring techniques and data fusion.

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