Metal additive manufacturing for the railway industry: recycled materials and geometric solutions for the supply of mechanical components with optimized resources efficiency

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Abstract

The integration of metal additive manufacturing (AM) in rail infrastructure can present an opportunity and a transformative approach towards sustainability and efficiency. More specifically, the work carried out in this study has led to more efficient use of material resources for Laser Powder Bed Fusion (LPBF) process. To achieve this, two complementary approaches are implemented: a first approach is based on a Design for Additive Manufacturing (DFAM) method, enabling optimum use of material resources to meet mechanical specifications. A second approach is based on the implementation of a recycling chain for the supply of raw materials for LPBF process. These two approaches are dealt with in two separate rail infrastructure case studies: the rail yard and the railway catenary.

In the rail yards, railway switches can be operated by mechanical levers acting via a wire connection. This system may require motorization for some of these levers. Motorization involves several elements, the main one being the support element which holds the motor and part of the gear mechanism. This support element was originally designed for conventional manufacturing, involving the machining and assembly of eight parts, all in 316L steel, with additional time required to carry out the assembly operations with the required precision. The rail switch assembly support can be geometrically optimized

using DfAM methods that is a specific area of design including generative design. Generative design method starts with geometries to be preserved and obstacle geometries. This defined design space is iteratively filled with the minimal amount of material needed to withstand the loads. The work carried out in this study allowed the initial support assembly of eight parts to be replaced by a single 316L monoblock component. The material saving with this new design is 78%. Even without considering the material potentially lost during machining of the initial assembly, this first approach offers substantial material savings.

The second approach of this study is applied to a case study of a railway catenary. In this structure that carries electricity to the train, certain mechanical parts make the junction between the poles and the electrical cables. Some of these parts are made of bronze-aluminium alloy, due to its interesting properties in terms of mechanical strength, corrosion resistance and electrical conductivity. Reduced maintenance lead times, the need to replace small series parts with small series, the need to reduce stocks, and the geometric complexity of certain parts make them good candidates for a production by LPBF process. The replacement of parts during maintenance also enables the recovery of obsolete parts. In this second part of the work, a recycled powder by gaseous atomization was produced from obsolete bronze-aluminium parts. The next step was to produce a recycled material from the recycled powder in LPBF process. Firstly, the material's manufacturability and homogeneity are assessed. Mechanical properties are then evaluated by tensile tests and compared with the material obtained by casting. This second part of the study demonstrated the possibility of manufacturing a material that meets the catenary's mechanical specifications from a recycling chain.

In conclusion, two approaches have been presented in this study, applied to two case studies in the railway sector. These are two functional levers for saving material resources. The first lever enables substantial material savings through the optimized use of materials in relation to mechanical loads. The second is a functional circular economy process based on additive manufacturing using fully recycled powder.