Fundamental Study on Additive Manufacturing of Aluminium Alloys by Friction Surfacing

Junjun Shen[1, a)], Stefanie Hanke[2], A. Roos[1], Jorge F. dos Santos[1], Benjamin Klusemann[1,3,b)]

[1]*Helmholtz-Zentrum Geesthacht, Institute of Materials Research, Materials Mechanics, Solid-State Joining Processes (WMP), Max-Planck-Str. 1, 21502 Geesthacht, Germany*
[2]*University of Duisburg-Essen, Faculty of Engineering, Forsthausweg 2, 47057 Duisburg, Germany*
[3] *Institute of Product and Process Innovation, Leuphana University of Lüneburg, Universitätsallee 1, 21335 Lüneburg, Germany*

[(a)] *Corresponding author: junjun.shen@hzg.de*
[(b)] *benjamin.klusemann@hzg.de*

Abstract. Friction Surfacing is a friction-based process capable of depositing similar or dissimilar materials on a substrate surface. The process is based on the plastic deformation of a rotating metallic consumable rod, which is pressed against the substrate material under an applied axial load. Frictional heat is then generated at the interface between the rod and the substrate due to their relative motion, resulting in a layer of plasticized material, which forms a continuous deposit by the translation of the stud along the substrate. On top of this deposit, more layers can be realized to build up a multilayered wall in a solid-state fashion.

In this study, an Al alloy 5083 build was deposited on an AA2024 substrate, using studs of 20 mm in diameter. The custom-designed equipment allows recording process forces and torque through implemented sensors. The primary process parameters include the axial force (9 kN), the rotational speed (1500 rpm) and the translational speed (10 mm/s). During the build-up of multiple layers, all these parameters were kept constant. The developed microstructure and the layer interfaces were investigated by metallographic methods as well as SEM-based techniques including EBSD. Hardness mapping was used for examining local mechanical properties.

The deposit is 180 mm in length, 15 to 20 mm in width. It consists of 6 layers. Each layer is 0.84 to 1.2 mm in thickness. According to the process monitoring, the quality of the layers were reproducible. The remnant oxides on the surface of the previously deposited layer are broken up and dispersed in the material surrounding the interface between two neighboring layers. Oxides' dimension is usually sub-micron,. EBSD maps have shown that sound bonding has been achieved around the interface with its upper part showing recrystallized grains where the lower part consists of partially recrystallized grains due to the thermal and mechanical impact, while the HAZ changes little. Thus, all layers exhibit fine, equiaxed recrystallized grains. The size of these grains is typically 4-5 microns, and the variations in size of grains from different layers or various locations are limited. It indicates a very stable microstructure since the follow-up depositing process has no noticeable impact on the already deposited layers. For this, the multilayered deposit shows very homogenous local mechanical properties, i.e., microhardness.

In summary, Friction Surfacing has shown the feasibility and required flexibility for multilayer depositing. The dimensions of the deposited layers can be adjusted by changing process parameters and the stud diameter. The process may be an effective alternative to melting-based additive manufacturing methods for specific applications.