Newsletter #2
Release 1 |

Funded by the European Union

GEAR-UP: Advancing Circular Manufacturing in Europe

GEAR-UP is moving from concept to practice, showing how circular manufacturing can work in real industrial settings. The project combines recycled metals, polymers, and advanced digital tools with additive manufacturing to reduce waste, extend product lifetimes, and make manufacturing more sustainable.

This newsletter issue is released in two parts. In this first one, GEAR-UP focuses on metals: from recycled powders and wires to the simulation and design tools that help make them reliable for industrial production. We highlight the latest developments from the project's partners and their progress towards practical applications of more circular manufacturing solutions.

Partners

Partners

3D Production · aerobase · AkerSolutions · CelluCircle · CELFEED · DigiProd Pass · eit Manufacturing · eurecat · FLOWPHYS · Fraunhofer · SINTEF · TECHNOVATIVE SOLUTIONS · Welding Alloys

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101178484

Recycled Metals in Additive Manufacturing

SINTEF's Role in Demonstrating Industrial Feasibility

SINTEF continues to play a key role in showing how recycled metals can be used reliably in laser-based additive manufacturing, including **Powder Bed Fusion using a laser (PBF-LB)**, where a laser melts layers of metal powder to build a component, and **Directed Energy Deposition using a laser (DED-LB),** where metal material is deposited and melted by a laser to build or repair a component.

Alongside 3D printing, SINTEF functions as the project's primary additive manufacturing partner for metallic materials, assessing the quality of the manufactured parts and solutions through a wide range of **in-situ and ex-situ characterisation**, meaning checks carried out both **during the manufacturing process and on the finished parts.** The results are compared with the quality and performance requirements defined by the use-case partners and relevant standards.

This work directly supports two industrial use cases:

- A **robotic gripper** for 3D Production, manufactured with recycled AlSi10Mg (a widely used aluminium alloy for metal 3D printing) via **PBF-LB (Powder Bed Fusion with a laser),** a 3D-printing process that uses a laser to melt layers of metal powder.
- **Pelton turbine** components for Aker Solutions, repaired or manufactured using **DED-LB (Directed Energy Deposition with a laser)**, a process in which metal material is deposited and melted by a laser to build or repair components, helping to extend component lifetimes and reduce material consumption.

Robotic gripper, latest developments:

The development of this use case has presented several challenges. **One of the main challenges** is **the production of the metal powder required for 3D printing.**

Centrifugal atomisation is the process used by Eurecat to produce the recycled AlSi10Mg powder, which generally produces particles that are larger than those typically used in PBF-LB (see Figure 1).

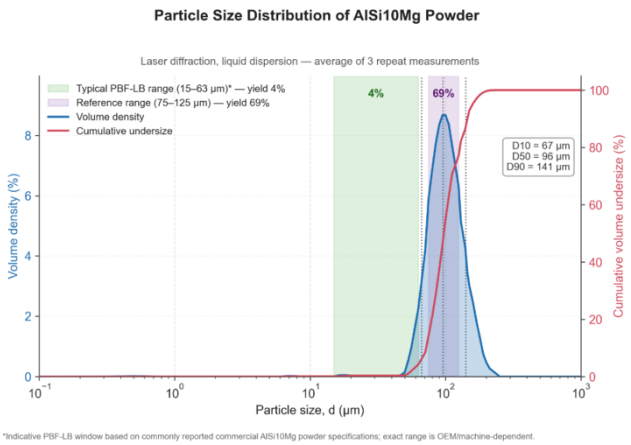

Figure 1: Particle size distribution (PSD) of particle sizes generated through centrifugal atomisation at Eurecat. This plot shows volume density of different AlSi10Mg particle sizes.

As demonstrated by Figure 1, **centrifugal atomisation results in a yield of only 4% within the particle size range required for the selected commercial process parameters.**

The particle size distribution is particularly important because only a specific range of powder particle sizes is suitable for the selected commercial PBF-LB process parameters. With the current powder production process, **only around 4% of the material falls within the applicable particle size range,** resulting in a very low yield.

To address this challenge, SINTEF is carrying out a feasibility study on using **larger particles in the 75–125 µm range,** building on its previous experience with AlSi10Mg. This approach could increase the usable powder yield by approximately **17 times compared** with the current approach.

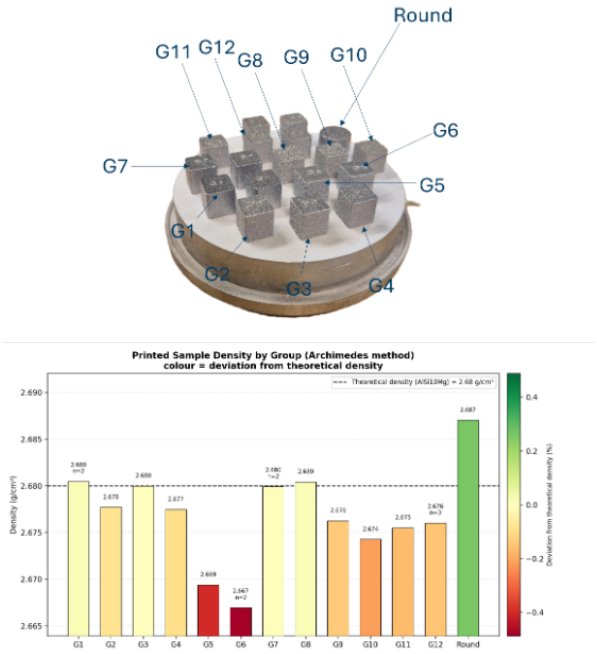

Figure 2: Display of samples produced with powder particles 75– 125 µm and their densities. Multiple instances of the same process parameters have been averaged.

Initial screening shows successful results for a range of parameter sets, with samples visualised in Figure 2 all possessing exceptional density. The most promising parameter sets will be used to print tensile bars in the coming weeks.

While SINTEF is investigating the use of larger particles, 3DP is producing test coupons (small samples used to evaluate the printing process and material properties) using the particle size range required for commercial process parameters. However, only a small amount of powder is available in this range due to the low yield of the current production process. To make the most efficient use of the available material, the team has designed a GEAR-UP dedicated build plate, a customised platform for the 3D printer that enables the production of taller samples. This allows more material to be tested in each build while making better use of the limited amount of available powder.

Pelton turbine — latest developments:

For the Pelton turbine component use case, the team is continuously optimising the process parameters to ensure stable and consistent material deposition during DED-LB (Directed Energy Deposition with a laser). The aim is to reliably manufacture or repair turbine components while extending their service life and reducing material consumption.

This is the first time we use cored wire, a type of metal wire used as the material feedstock for the printing process, with the **Meltio system**, a laser-based metal 3D-printing system that uses wire to build or repair components. Initial trials showed some challenges with **wire feeding**, as the wire occasionally slipped during deposition. This affected the regularity of the material deposition and

resulted in **lack of fusion (LoF)** in some areas, meaning that the deposited material did not fully fuse with the material underneath, as shown in Figure 3.

Figure 3: Slipping of the wire in the Meltio system caused LoF, a defect that should be avoided.

To address this issue, the team manufactured **knurled rollers** — rollers with a textured surface designed to improve the grip on the wire — using PBF-LB. The rollers have been successfully integrated into the system, improving wire feeding and allowing further optimisation of the printing process.

Currently, the most promising process parameters identified so far (see Figure 4) are being used to produce **samples for tensile and compression testing** at Eurecat, to further assess the material's mechanical properties. Tests carried out at different temperatures and **strain rates** (the speed at which the material is deformed) will provide data to Aerobase to calibrate **material models** and **digital twins** of the manufacturing process.

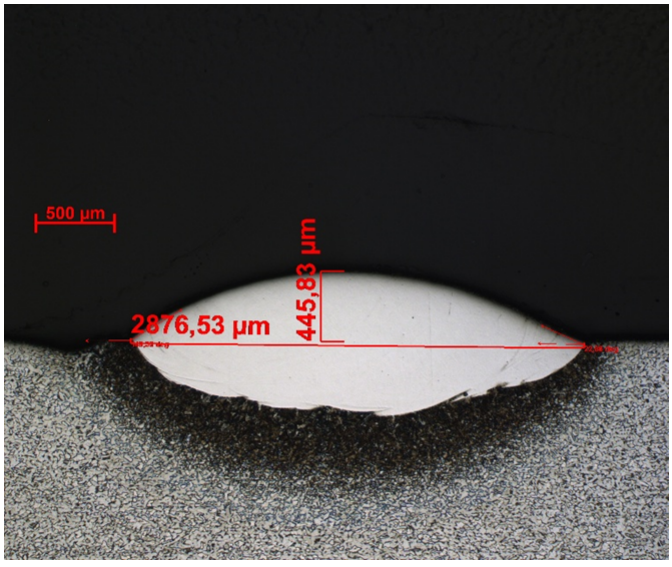

Figure 4: Promising process parameter set for DED-LB.

SINTEF

"The problems we couldn't plan for are the ones that produce some of the solutions industry can use."

— Sander Grønnerød, SINTEF

Developing Recycled Feedstocks

Eurecat and Welding Alloys' Contribution

A critical step in circular additive manufacturing is producing suitable recycled feedstocks, the materials used to manufacture new components through 3D printing. Eurecat and Welding Alloys are **developing metal powders and metal-cored wires**, respectively, using recycled machining waste as the source material. These recycled feedstocks are designed to provide suitable materials for additive manufacturing while supporting the reuse of industrial waste. SINTEF uses these materials to compare mechanical performance, process stability, and defect behaviour against conventional references.

Advanced monitoring tools developed within the project help researchers understand heat flow, melt pool dynamics (the behaviour of the small pool of molten metal created by the laser), and defect formation during printing, enabling more efficient process optimisation.

Latest results:

As part of the GEAR-UP project, Eurecat is developing aluminium powder optimised for PBF-LB (Powder Bed Fusion with a laser) that can be produced from **end-of-life aluminium scrap,** helping to give discarded material a new use in additive manufacturing.

The team studied how common **impurities and additional elements present in recycled aluminium** can affect the conventional **AlSi10Mg alloy**, a widely used aluminium alloy for metal 3D printing. A total of 36 different impurity levels were tested at laboratory scale, assessing key properties that influence how the powder can be processed, including **flowability** (how easily the powder flows and spreads) and **wettability** (how well the molten material interacts with and spreads over a surface).

The study found a positive correlation between alloy flowability and the average size of the powder particles produced. This could help increase the amount of powder suitable for **metal 3D printing**, reducing material losses and improving production yield.

Powder from the three selected compositions has already been produced by Eurecat and test specimens are currently being printed. Testing these specimens will reveal how increased impurity levels affect final part properties and help establish where recycled aluminium powder can be successfully used in real components.

Welding Alloys has successfully manufactured multiple metal cored wires with elevated trace elements to replicate the chemistry of the recycled swarf (metal chips and shavings left over from machining) from the machining of Pelton turbines produced by Aker Solutions. These wires will be deposited via DED-LB by SINTEF to assess the impact of trace elements on additive manufacturing and repair applications for the Pelton turbine Use Case.

If these recycled feedstocks reach the same quality as virgin materials, the main benefit for manufacturers would be the ability to reduce reliance on virgin raw materials without compromising process performance or component quality. Making recycled metal feedstocks stable, predictable and scalable could have a major impact on resource efficiency, material costs and the wider adoption of circular additive manufacturing.

"Basic material properties, such as alloy flowability, can help identify the optimal composition for producing recycled aluminium powder suitable for 3D printing."

Manel da Silva, Eurecat

"It is vital that the impact of trace element contamination from recycled sources used to manufacture recycled feedstock is considered and understood. Trace elements that are not part of the original chemical composition or are out of tolerance from a material specification can affect the microstructure, weldability, and resultant mechanical and tribochemical properties."

Junny Lai, Welding Alloys

Simulating the Process, Before It Happens

Aerobase: Process Models for Recycled Metals

Predicting how recycled metals behave during printing, before committing material and machine time, is key to making circular additive manufacturing cost-effective. Aerobase, a Swedish small and medium-sized enterprise specialising in material models and finite element simulation, leads GEAR-UP's work on materials and process modelling.

Recycled steel and aluminium can contain different levels of trace elements from one batch to another. Aerobase builds **process models that start from this chemistry**: they follow the build's thermal history and predict the resulting microstructure, defects, residual stresses, and distortion in PBF-LB and DED-LB.

These models help predict what can happen to a material during 3D printing before a component is actually produced. The models run in commercial finite element software through Aerobase's Phases and SafeLight libraries, support process-parameter selection for robotic gripper and Pelton turbine use cases, and are validated against SINTEF's melt pool monitoring and Eurecat's material testing.

The same approach is also being extended to recycled fibre-reinforced polymers printed by material extrusion, where Aerobase's VisCoR model captures anisotropy, crystallisation and residual stress. **In this case, the model helps predict how these materials behave during printing, including changes in their internal structure and the stresses that can affect the final part.**

What these simulations help manufacturers avoid: every physical trial costs feedstock, machine time, and a round of testing, and each new batch of recycled feedstock can restart that cycle. With a calibrated model, a batch that would otherwise be rejected can have its process parameters adjusted in simulation first, which means fewer trial builds, less scrap, and components designed to the strength the material actually has.

aerobase

"A batch of recycled powder with slightly too much copper is usually a batch you reject. With a calibrated model, it becomes a batch you print with adjusted parameters and can still qualify."

Bijish Babu, Aerobase

Designing Parts That Tolerate Variability

Flowphys and Topology Optimisation

Recycled materials do not always deliver identical properties, and a lighter design is only useful if it still lasts. Flowphys, a Norwegian SME specialising in multi-physics simulation software, leads GEAR-UP's work on sustainable product design.

Using the Flowphys software suite, the team is developing **new topology optimisation methods** that account for variation in material properties and build quality, fatigue life and total cost. The aim is to find the best balance between using less material, keeping the component strong enough and controlling production costs.

Rather than only minimising weight, the aim is the lowest-cost design that still reaches the required service life. To keep large components computationally manageable, fine 3D-printed infill structures are represented by macro-scale elements whose properties come from data-efficient Kriging metamodels with uncertainty quantification. The optimised designs are demonstrated on the project's use cases and validated through component testing.

In the next release: recycled polymers and textiles, digital technologies for data and traceability, and the skills needed for circular manufacturing.