Arconic WDED Additive Manufacturing and the Ampliforge™ Process

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Arconic Business Segments

Three strong, customer-focused groups

**EP&S**
Engineered Products and Solutions
- Arconic Engineered Structures
- Arconic Engines
- Arconic Fastening Systems

$5.9B 2017 revenue

**GRP**
Global Rolled Products
- Aerospace and Automotive Products
- Brazing, Commercial Transportation and Industrial Solutions

$5.0B 2017 revenue

**TCS**
Transportation and Construction Solutions
- Arconic Wheel and Transportation Products
- Building and Construction Systems

$2.0B 2017 revenue
AES is vertically integrated with a global presence
Range of Arconic AM equipment and processes

Combining materials and manufacturing knowledge to optimize the right process for the right application

- Characterize the material & process relationship
- Develop tailored feedstock
- Optimize process parameters by application
- Industrialize

EOS & Renishaw (Powder Bed)
- Laser
- Dual Laser
- Powder Feedstock

SLM (Powder Bed)
- Quad Laser
- Electron Beam

EOS (Powder Bed)
- Arcam (Powder Bed)

OPTOMEC (Powder Fed)
- Laser

Sciaky
- Electron Beam

Wire Feedstock

Net Shape

Decreasing Resolution / Increasing build envelope

Near Net Shape
Electron Beam Additive Manufacturing
High Deposition Rate (HDR) Additive Layer Manufacturing

High deposition rate additive typically refers to directed energy deposition methods (DED), especially wirefeed.

**Opportunity:** Deposit material quickly to produce a near-net preform that reduces the buy-to-fly for the customer. The objective is to reduce the cost of Ti-6Al-4V components.
- Arconic proprietary parameter set produces consistent, accurate, and dense parts.
- Properties exceed minimums in relevant specifications.

**Considerations:**
- Post machining operations still required.
- Additional wire cost and AM processing cost need to be balanced against the ability to reduce material input of plate or forged products.

Ti-6Al-4V Fitting:
- AM Preform: 5.5 kg (12.1 lbs)
- Conventional Plate: 14.8 kg (32.6 lbs)
Data from seemingly simple builds are essential to establishing reliable properties for design.
Arconic WDED ALM Fatigue Performance

Arconic DED parts over range of thicknesses (0.5-2.5 in.) meet fatigue results of conventional products.
Ampliforge™ - A Hybrid AM Technology for Forging

Arconic’s Ampliforge™ Process
A new, proprietary technique that combines additive and advanced forging technologies for enhanced properties of 3D printed parts.

3D part design → 3D print part to near net shape → Forging for enhanced properties → Finished part

An opportunity to reduce the cost of forged components
Ampliforge™ process reduces the cost of conventional forgings using an AM produced preform.

- Custom AM preform reduces input stock and eliminates waste / flash
- Eliminate multiple forging operations – single hit to finish
- Eliminates non-recurring cost of blocker tooling and dies

Target is to meet AMS 4928 for Ti-6Al-4V forgings with the Ampliforge™ process
Ampliforge™ Successful Trial Work

Rib Trials – 50k Ton Hydraulic Press
- Two iterations - 2016 and 2017
- Using existing dies and final part design
- Properties comparable to conventional forging with optimized parameters

Disc trial – Screw Press
- Single Trial in 2016
- Using existing dies and final part design
- Machined preform surface
- Tensile properties met customer specifications
Success requires the Ampliforge™ preform, when forged, to achieve the desired finish geometry with the target strain throughout the forging without forging defects.

Arconic forging models, material property data, simulation tools, and experience enable the 3D-printed Ampliforge™ preform to be designed.

Strain maps illustrating multiple iterations of the Ampliforge™ spar preform design. Process considers preform design and forging conditions to achieve the desired final geometry and material characteristics.
Initial rib trials showed a linear discontinuity along the length of the forging. Through detailed simulation of the forging process, the fold was determined to be a product of preform geometry and die design.

A second iteration of preform design reduced the presence of folds by geometric control, minimizing material used.

In future Ampliforge™ parts, the process can be improved further by dedicated die design, which will reduce risk of surface issues and maximize strain targets.
Ampliforge™ Strain Development

To further understand the effects of forging, plant trials were conducted using a series WDED blocks.

Blocks were forged on an open-die press to different thicknesses in order to see the property effects over a range of processing conditions.

This sample testing is being used to confirm the effectiveness of Arconic WDED preforms and optimize the Ampliforge™ process.
Improvement of Mechanical Properties with Strain

With a targeted amount of strain achieved, Ampliforge™ parts are able to meet industry forging specifications.