GE Aviation - TTC

TARLA - Turkish Additive Research Lab

Onur Onder
Engineering Manager
GE Aviation

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Outline

Additive at GE Aviation
TTC Additive History
Lab capabilities
Projects & Ongoing Studies

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Turkey Technology Center

GE Aviation Engineering. A partnership between GE Aviation & GE’s joint venture company TEI. Employs 400+ engineers with sound technical depth. Attracts and hires Turkey's best engineering talents from highest rated engineering schools. Delivers timely and reliable solutions for **design**, **manufacturing**, **Digital** and **software** work scopes both for commercial and military engine lines.

Next to TUBITAK* Campus
Located at Free Trade Zone

Diverse Research Labs
$9M Development Hardware

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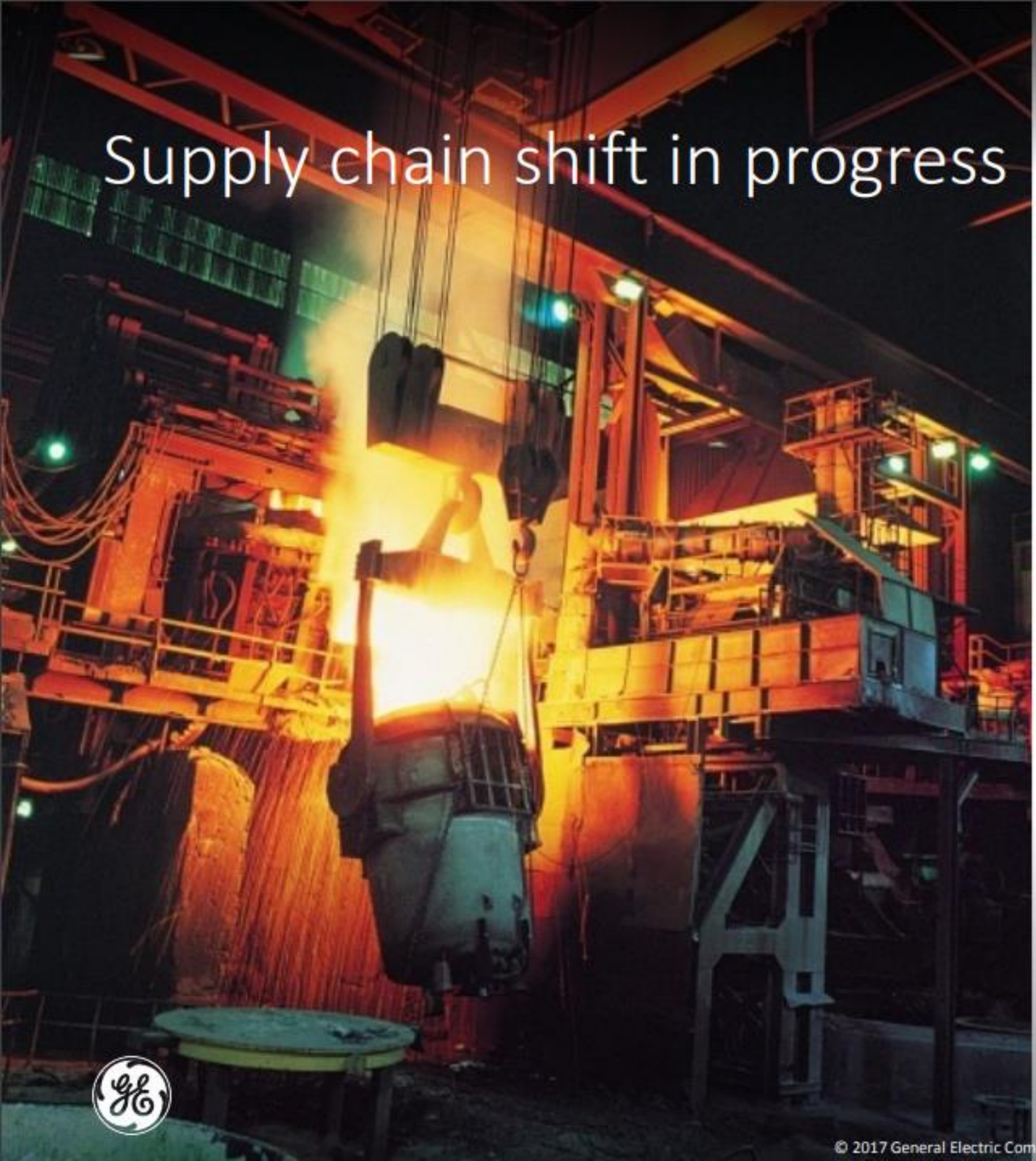
Supply chain shift in progress



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What is additive manufacturing?

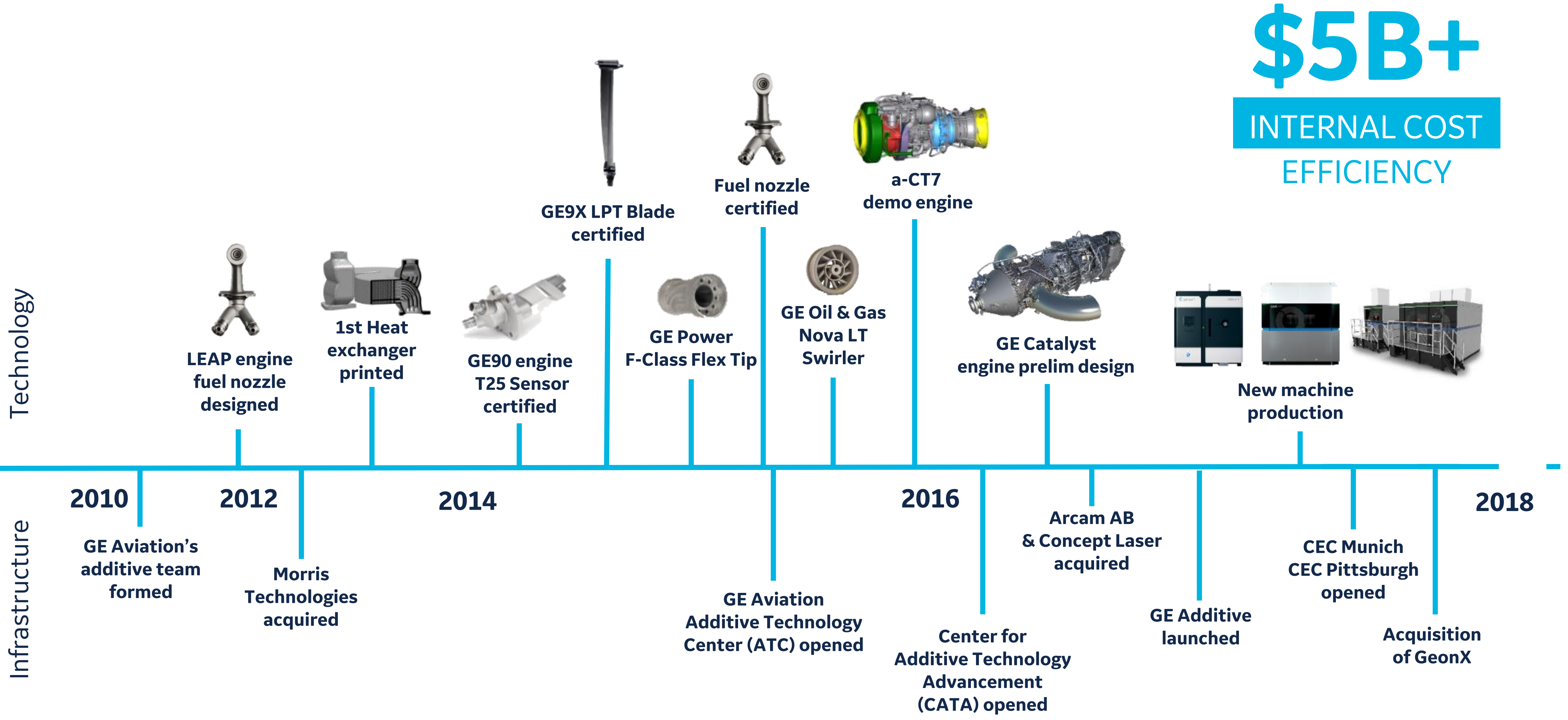
3D PRINTING

Additive manufacturing, also knows as 3D printing, is a process that creates a physical object from a digital design file.

Additive manufacturing enables engineers to design parts, systems and shapes once thought impossible to make.

Additive manufacturing allows for complex design geometries, making products that are lighter, stronger and more efficient, revolutionizing products in many industries.

GE's additive journey ... so far



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It started with 1 part … the CFM LEAP fuel nozzle

Capabilities of full production
35,000 – 40,000 per year

10,000+
PARTS SHIPPED

20 → 1
PARTS

95%
INVENTORY
REDUCTION

25%
WEIGHT
REDUCTION

30%
COST EFFICIENCY
IMPROVEMENT

5x MORE
DURABLE

LEAP is a trademark of CFM International, a 50/50 JV between GE and Safran Aircraft Engines

Source: GE Aviation

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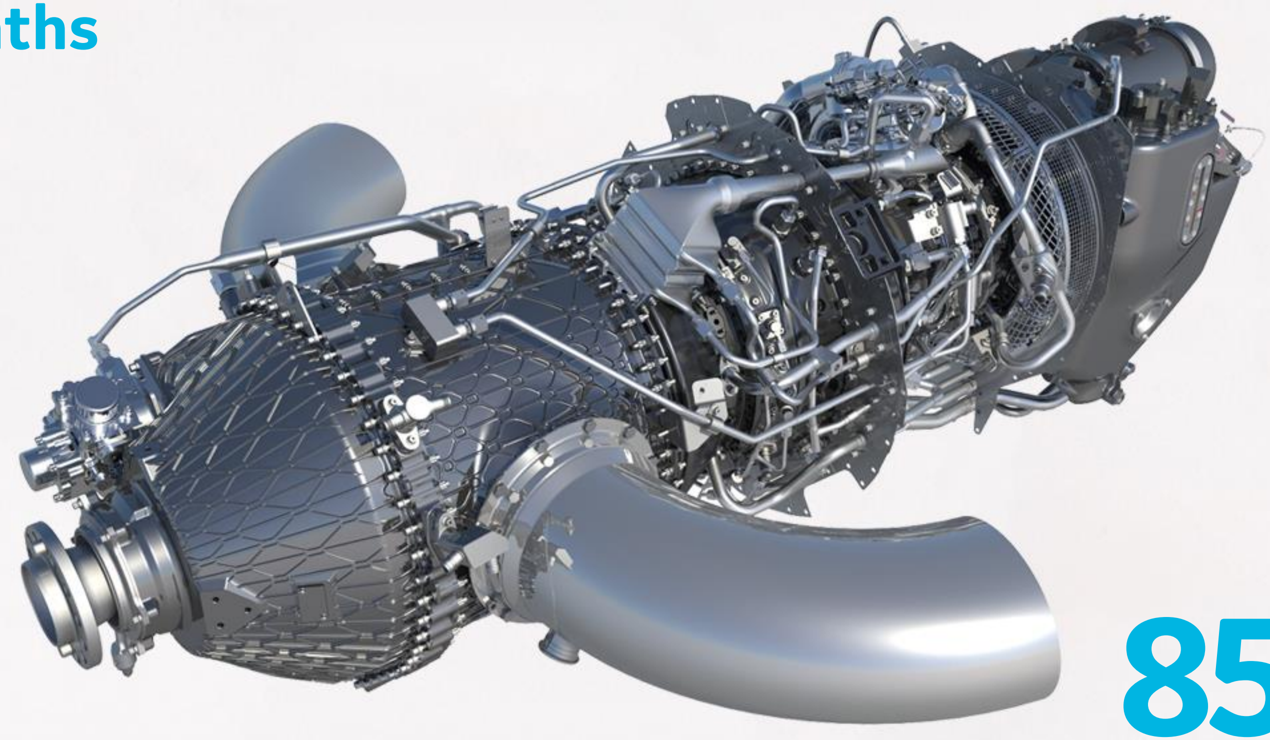
Then a system … Advanced Turboprop

Combustor test schedule reduced from
12 months to **6 months**



5%
WEIGHT
REDUCTION

20%
LOWER
FUEL BURN

855 ▸ 12
PARTS

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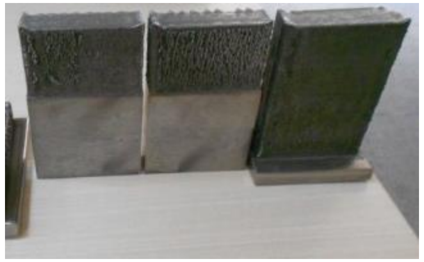
TTC's additive journey ... so far

2007

Laser Powder Deposition (DED) Studies



2011

Metal Leading Edge Demo

2013

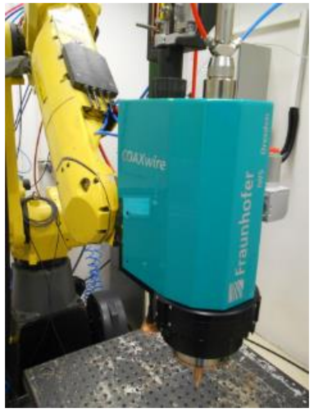
CMT DED Studies

2015

Hybrid DED AM Demo

2016

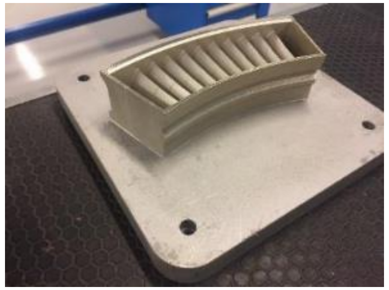
Coax Wire DED Studies

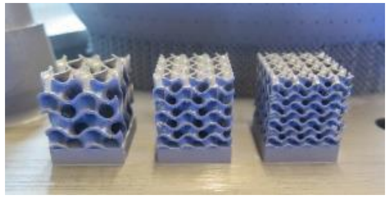


2017

TUBITAK 1515 Program Launch

2018





Turkish Additive Research Lab Opening

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Capabilities

Additive Capabilities at TTC

Design

Topology Optimization

Cost Modeling

Design for Additive

Ansys / Optistruct / Magics

Process

2 x Concept Laser M2

DED Powder

DED Wire

WAAM

Polyjet

Post Process

Vac Furnace

Powder Evac

Bluelight

Machining / EDM

Characterization & Test

Metal Lab

SEM

Tensile / Compression

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Available metal additive options

	Process		Form	Heat Source	Speed	Precis	Size
Powder Bed	DMLM Direct Metal Laser Melting	L	Powder Bed	Laser			
	EBM Electron Beam Melting	EB	Powder Bed	Electron Beam			
Deposition	LPF Laser Powder Forming	L	Powder Deposition	Laser			
	Cold Spray		Powder Deposition	Momentum			
	EBFF Electron Beam Free Form	EB	Wire	Electron Beam			
	Hot Wire	TIG/L	Wire	TIG/ Laser			
Consolidation	MIM/SNS HIP Metal Injection Molding		Binder Injection	Consolidation			
	Binder Jet		Binder Jet	Consolidation			

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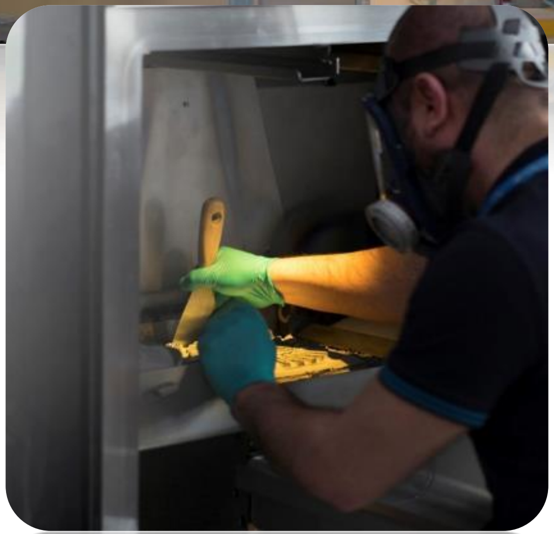
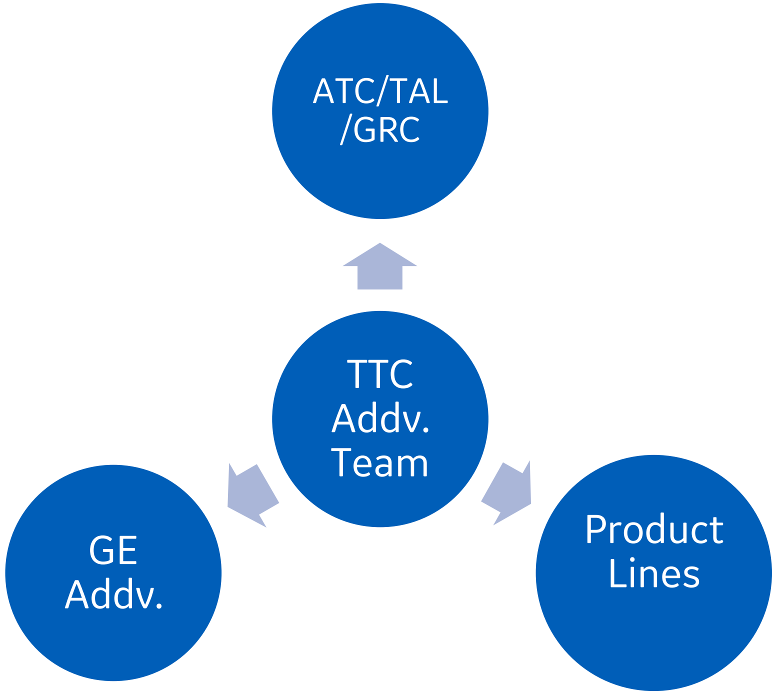
Projects and Activities

TTC Additive Research Lab - TARLA

LAB



WORK MODEL



Identify > Design & Optimize > Build & Test

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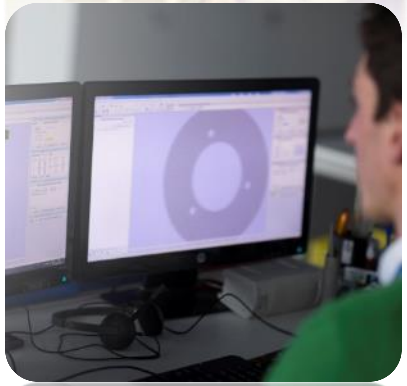
Turkish Additive Research Laboratory Projects

Proof of Concept Studies

Geometry and Technology Development Activities for Characteristic and Part Architectures

Research and Development of Material Feed Additive Manufacturing Technologies

Research and Development of Powder Bed Fusion Additive Manufacturing Technologies and Additive Manufacturing Materials



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High level additive design process

Requirements
What are your deliverables? What are the limits?

Conceptual Design
Start with the limits of your product and design the shape from there

Process Selection
Choose the additive process that will enable your concept

Design for Productibility
Refine the design to take full advantage of the process

FastWorks
Design, test, learn … iterate… to meet or exceed requirements

- Complex castings/geometries
- High labor parts
- Fabricated assemblies
- Part Consolidations
- Integrated systems
- Durability Improvements
- Weight reductions
- Performance improvements

Cost should be influencing your decisions throughout the process

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Additive part selection – drive to a common metric

Selection criteria

- Machine capacity and material
- Cost and weight
- Durability
- Performance
- Packaging

Limits on part integration

- Assembly
- Maintainability
- Material incompatibilities
- Repair

What it takes to succeed

- Clear business case
- Monetized metrics (derivatives)
- Real benefits the customer will pay for
- Strong, representative life cycle cost analysis

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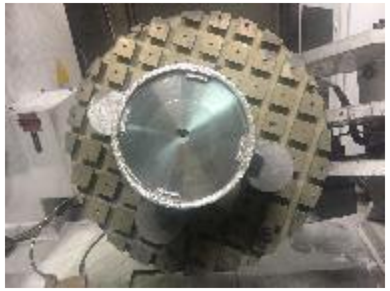
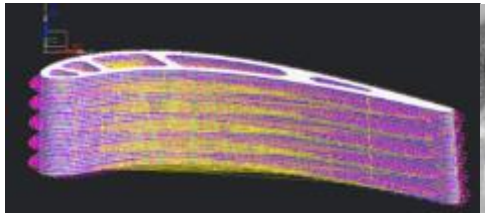
Directed Energy Deposition

Slicing and Toolpath Programming Software

Blade Repair

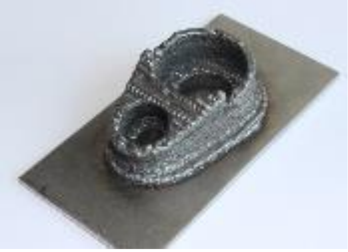
- Huffman System
- Slicing and Toolpath Programming





Hybrid AM Demo: T700 TMF

- In718



Metal Leading Edge

- In718 & Ti-6-4
- Robotic Laser Powder Deposition System
- Full Size 42" MLE, Build Parameters, Metallographic Analysis

42" Ti64 MLE built at TTC under IMPALA program

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Hybrid AM Demo: Deposition of main body and flanges

Turbine Mid-Frame

Hot Wire Shell

Near Finished Component with 1.5:1 Buy to Fly vs. Up to 10:1

Laser Powder Deposition Fine Features

Finished Shell (Turning)

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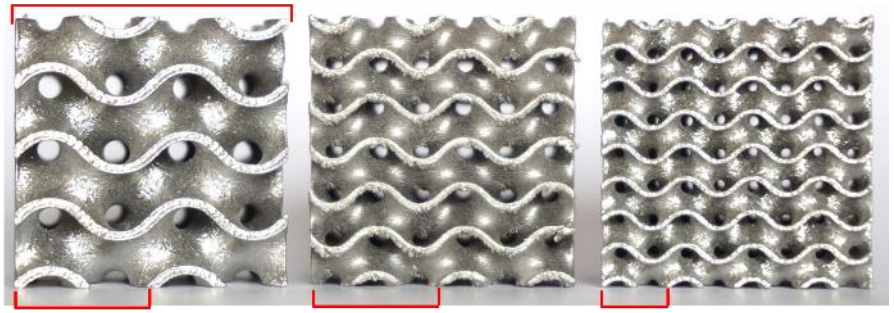
Double Gyroid Lattice Structure Compressive Testing and Characterization

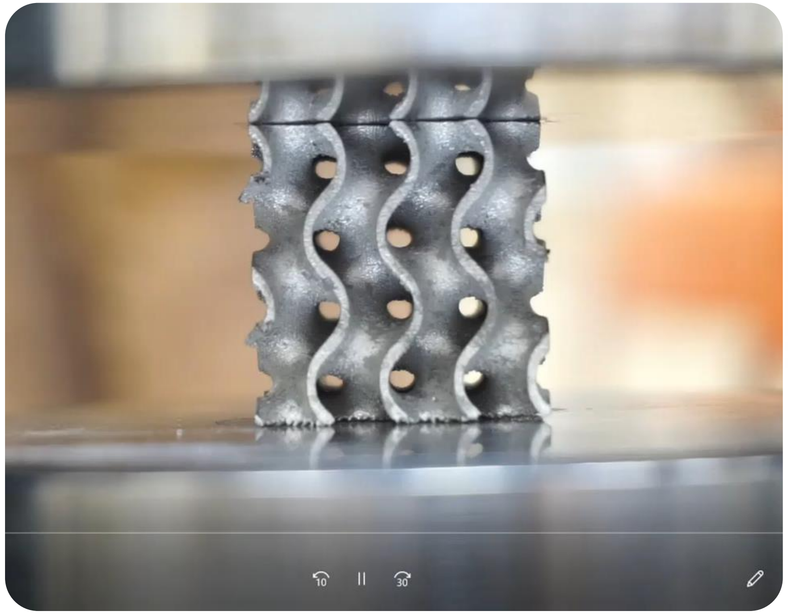
Barış Kavas, Dr. Şeref Sönmez, Dr. Evren Yasa

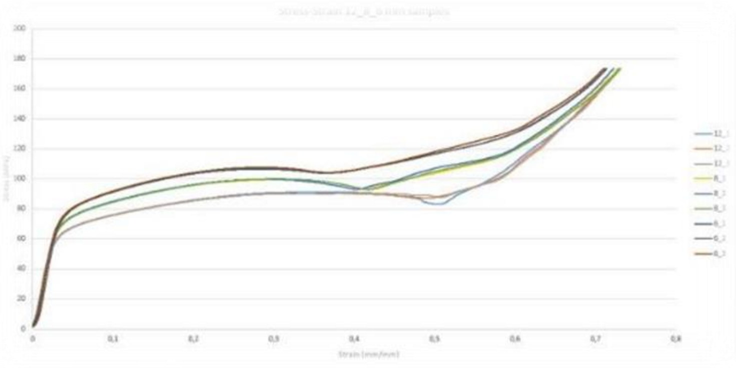
- ✓ Manufacturing of the structure is lately enabled with varying design parameters by developing additive manufacturing technologies.
- ✓ Surface is periodic and fully continuous in all directions: Idially, no excessive kt is generated through the structure
- ✓ isotropic: beneficial where the loading conditions & directions are uncertain
- ✓ Proven to have better specific strength against other popular lattice structures

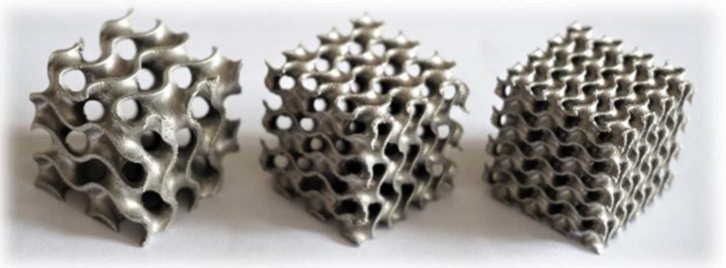
Sample size: 24 mm



Unitcell size: 12 mm Unitcell size: 8 mm Unitcell size: 6 mm







Effect of the unitcell size as well as the manufacturing process on the mechanical properties under compressive loading conditions are documented.

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Vibration characteristics of double gyroid lattice structures

Uğur Şimşek, Barış Kavas, Dr. Polat Şendur

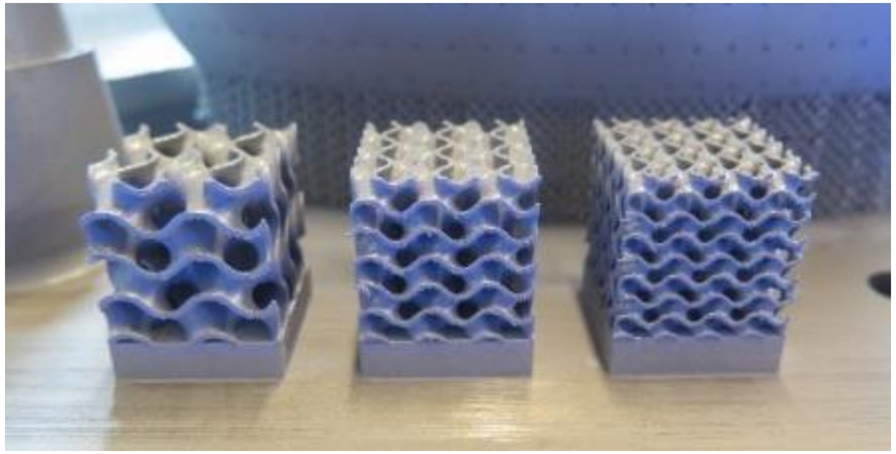
Aim: This paper is aimed at evaluating the dynamic performance of gyroid structures made of HS188 produced by direct metal laser melting (DMLM).

Method:

Frequency response prediction of a finite element-based model of the gyroid sandwich structure is first validated against the modal testing using Dewesoft software in terms of natural frequencies, mode shapes and damping characteristics.

Subsequently, four gyroid structures with different shell thickness are analyzed to understand the effect of shell thickness on the dynamic characteristics of gyroids.

The geometry, which provides the best dynamic performance, was printed to validate the findings from the parametric study. In addition, the performance of the optimum structure is compared to the bulk structure with same mass.



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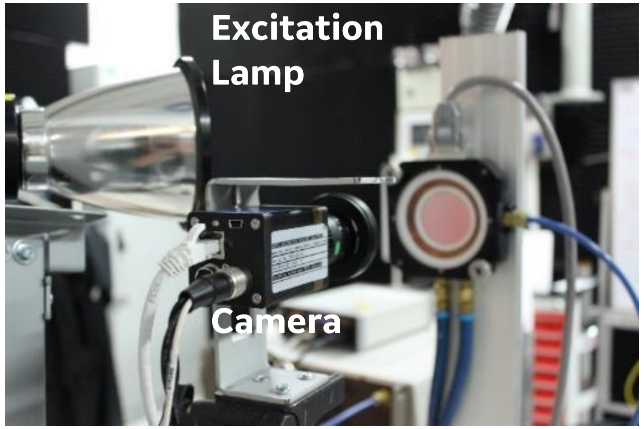
Additive DMLM Film Cooling Holes Cooling Efficiency

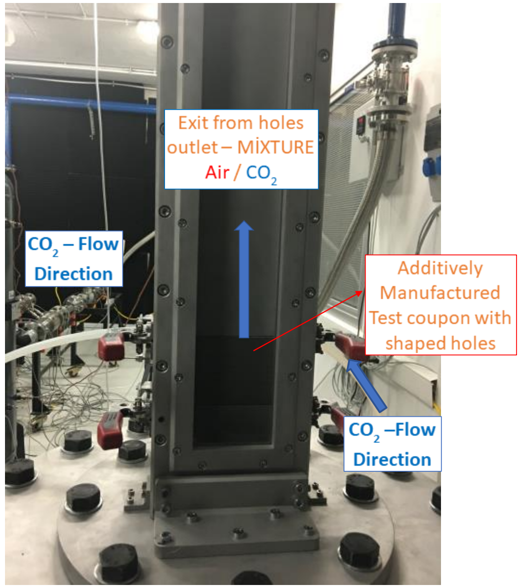
Ezgi Balkas, Dr. Nuri Solak, Alican Çelik

Objective and Test Setup

Pressure Sensitive Paint imaging application for film cooling efficiency on flat plates.

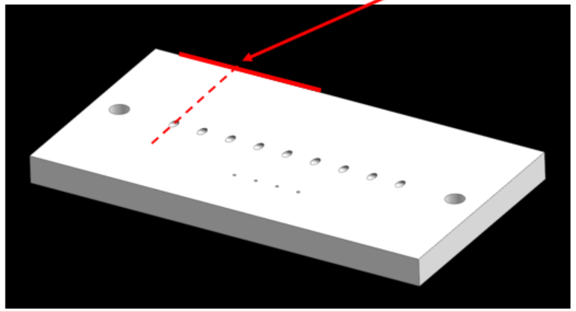
Additive Manufacturing & EDM will be compared to evaluate relation between surface roughness & film cooling efficiency.

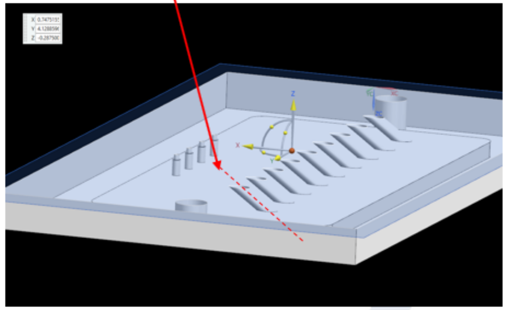


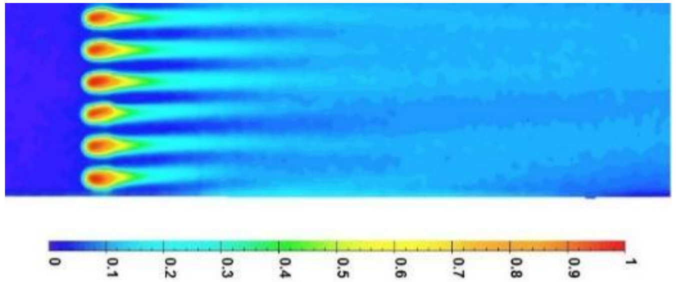


Test Outcome

Coupon Name	Diameter	Material	Injection Angle	Angle of Hole	Manufacturing Method	Build Direction
1X - CoCr - EDM	0.1 inch	CoCr	90°	35°	EDM	N/A
1X - CoCr - V - DMLM	0.1 inch	CoCr	90°	35°	DMLM	90° wrt Built Plate
1X - CoCr - A - DMLM	0.1 inch	CoCr	90°	35°	DMLM	35° wrt Built Plate







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