Turbomachinery Research Centre | UNIVERSITY OF BATH | HiETA technologies

Internally Cooled and Lightweight Radial Turbine Wheels for Gas Turbines

IGTC Conference

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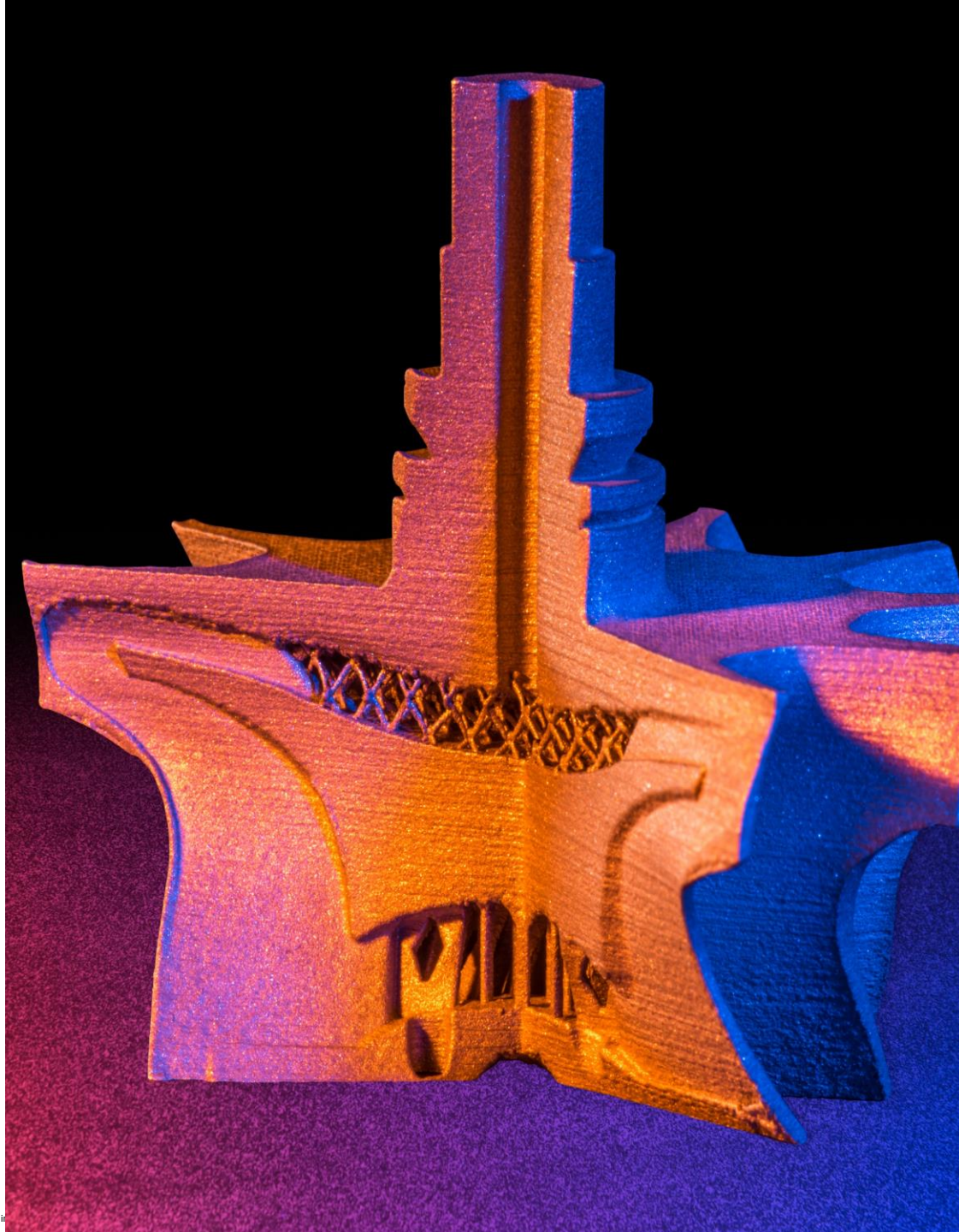
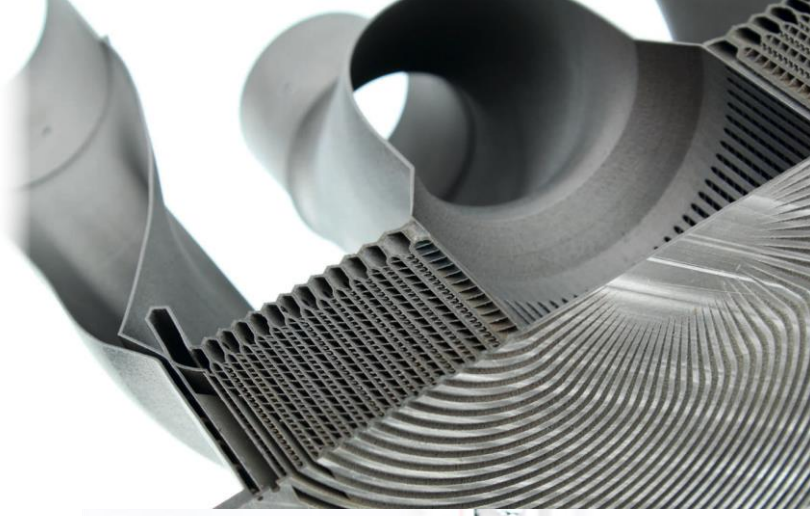


Company Profile



- Specialists in **thermal management** and **lightweighting** solutions enabled by Additive Manufacturing (AM)
- Established 7 years with approximately 55 staff, covering whole AM value chain
  - Design & Analysis
  - Applications, Data, Parameters and Materials
  - Manufacturing, Quality & Industrialisation
  - Test & Validation
- Running 11 Powder Bed AM Machines

HiETA Product Portfolio

COMPONENTS

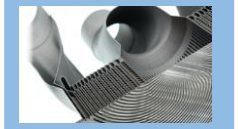
Low temp heat exchanger

Water cooled charge air coolers

Oil Coolers

Phase change fuel cell coolers

High temp heat exchanger



Annular recuperators

Cuboid recuperators

Phase change HXs

Turbo machinery

Cooled turbine wheels

Nozzle Guide Vanes

Shrouded compressors

Fuel & combustion

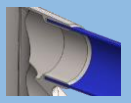
Fuel injectors

Porous injectors & filters

Legacy & Low Volume combustors

Multi-functional & Lightweight

Combined structural & cooling



Penetrating & double lap joining

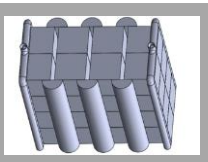
Hybrid truss & mass customisation

SYSTEMS

High efficiency integrated micro gas turbine

Inverted Brayton Cycle waste heat recovery

Modular heat exchanger



SERVICES

Design Engineering Services

1D Analysis
CFD, FEA & Topology Optimisation
Conceptual & detailed design

Additive Manufacturing Services

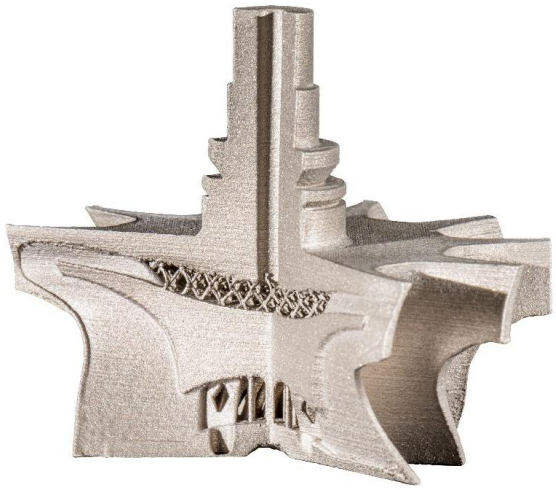
Renishaw AM250, AM500M & AM500Q machines
AlSi10Mg, Ti6Al4V, SS316L
Inc625, Inc718, CM247LC

Testing Services

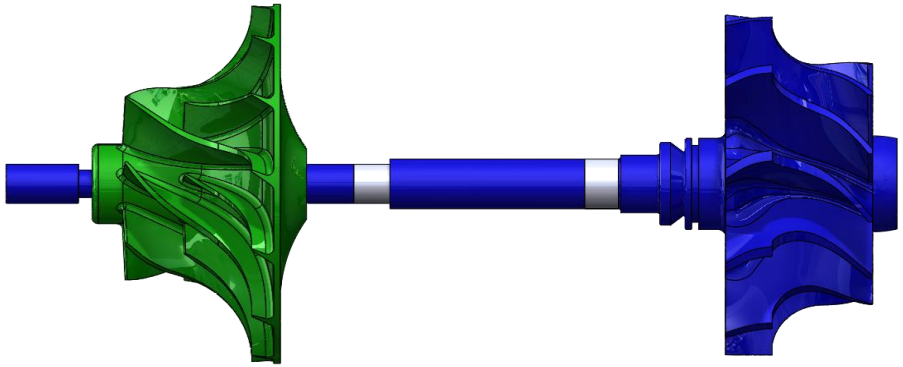
Heat transfer surface characterisation
Low temperature heat exchangers
Phase change heat exchangers
NDI/NDT services

Cooled Turbomachinery Project

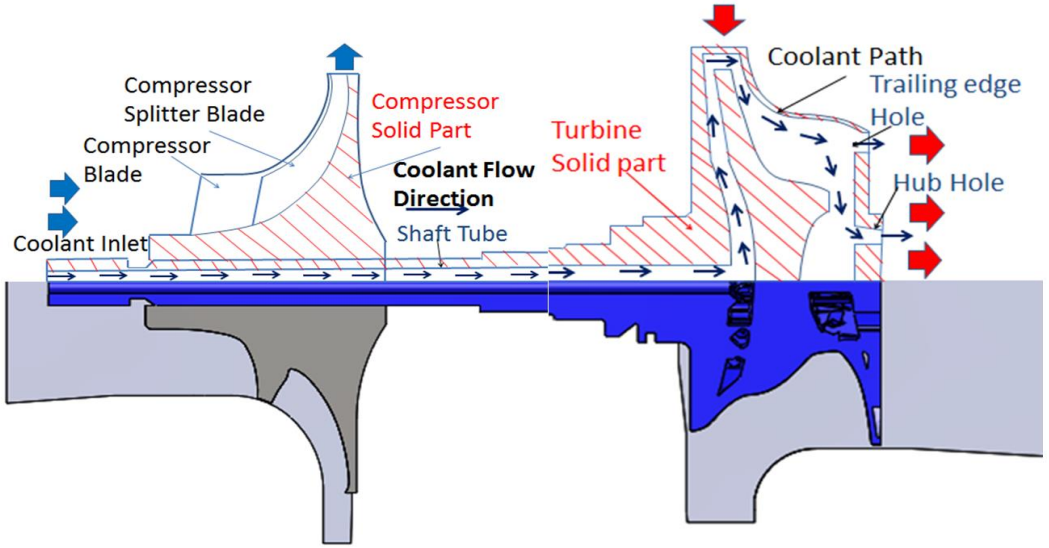
- 18m collaborative project with University of Bath
- Objective: prove technical feasibility of using Additive Manufacturing to create lightweight & internally cooled turbine wheel with:
  - Operating temperatures of 1050C+ TIT
  - 50% reduction in inertia
- Approach:
  - Utilise existing turbocharger – redesign
  - Development of high temperature material
  - Prove with physical test vs baseline solid wheel
  - Use test data to validate CFD



Overview

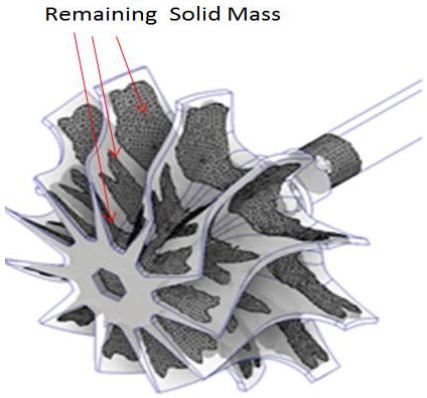


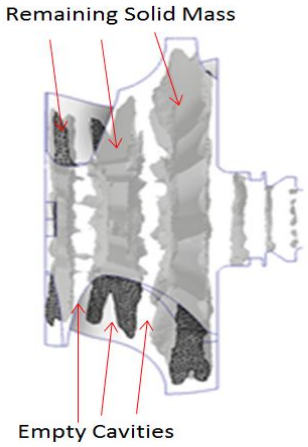
Conventional turbocharger baseline

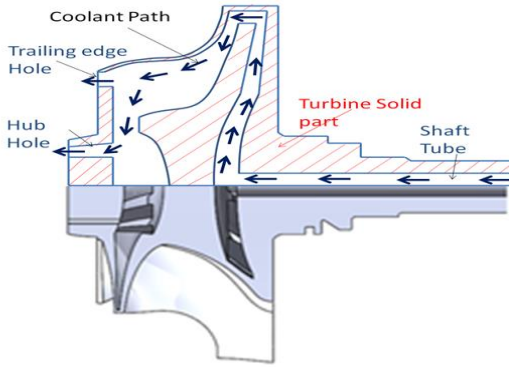


Cooled turbine prototype setup

Design

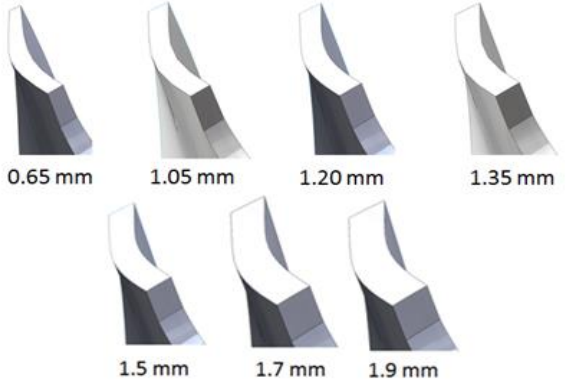


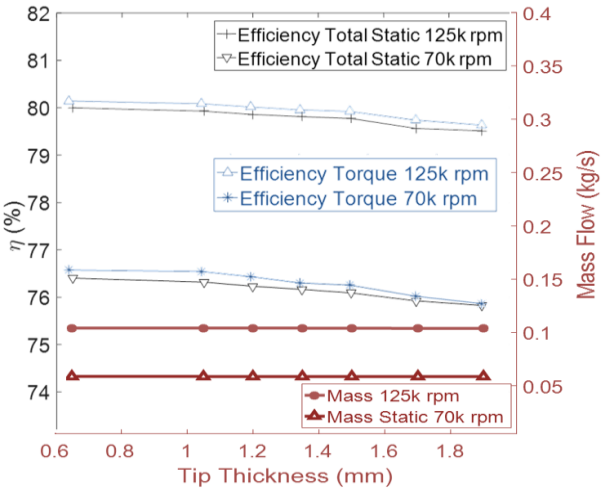




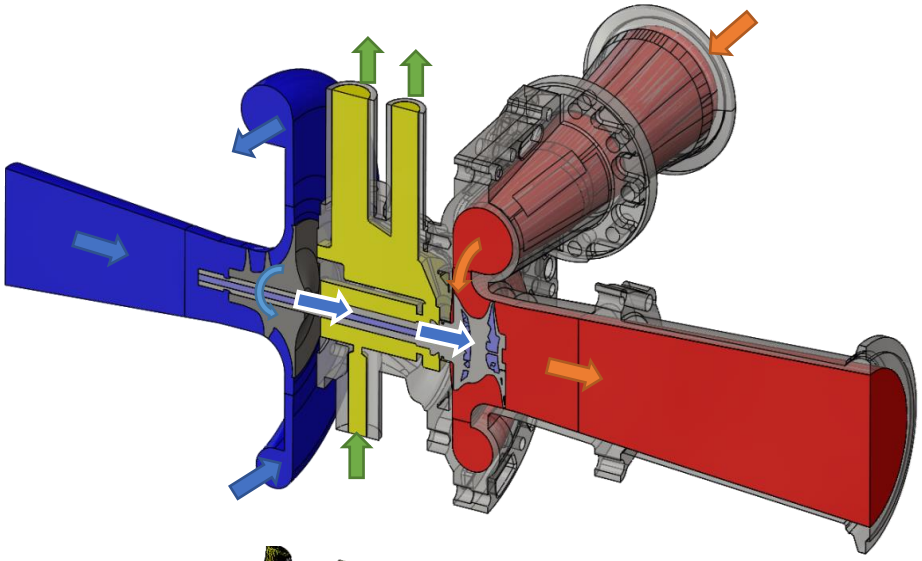
- Topology optimisation carried out
- Coolant system added

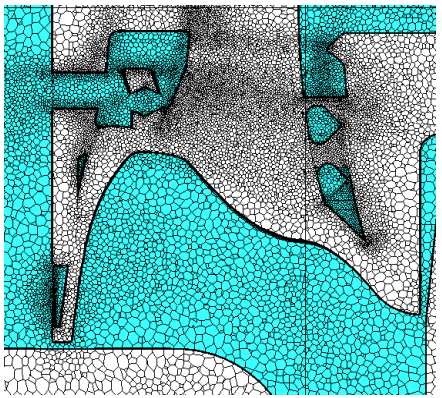
- Design for AM adaptations made
- Blade thickness sensitivity study carried out to assess impact – deemed minimal

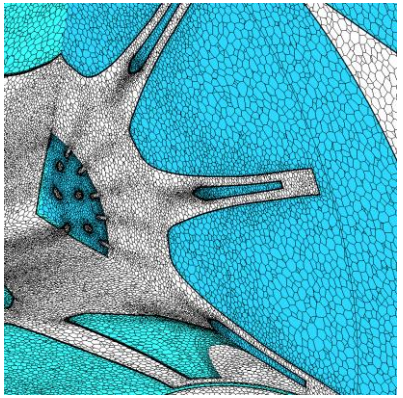


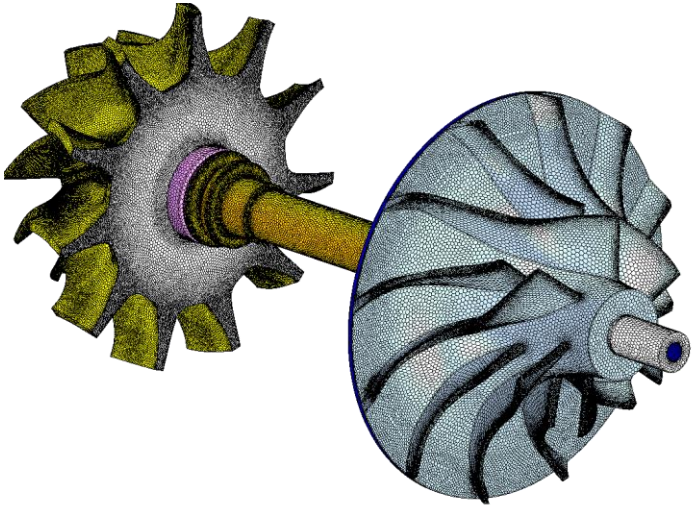


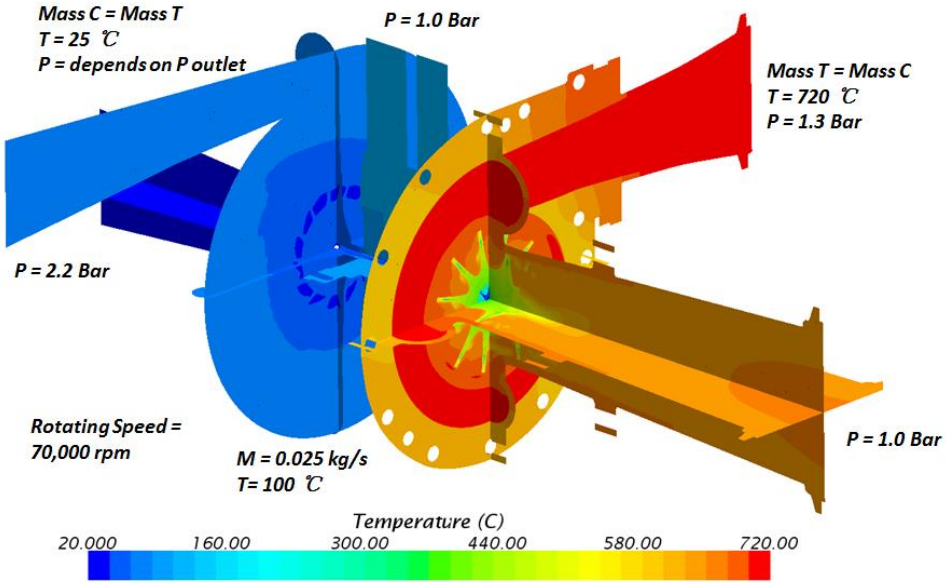
Analysis Setup



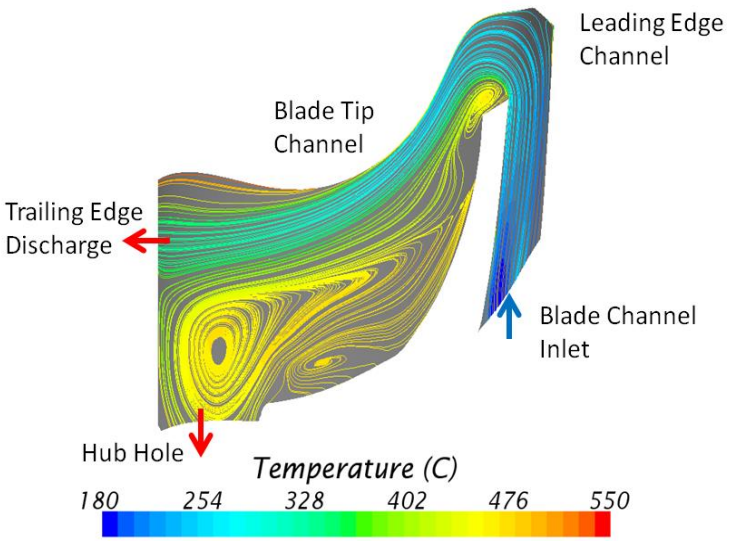




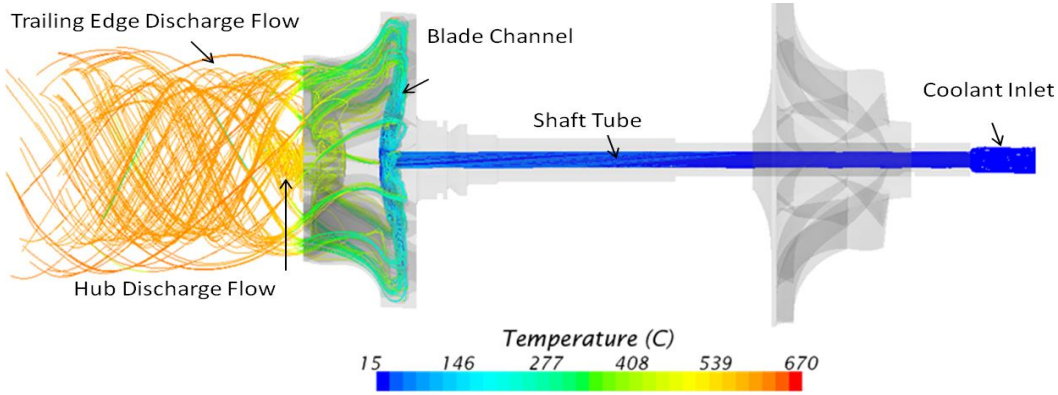




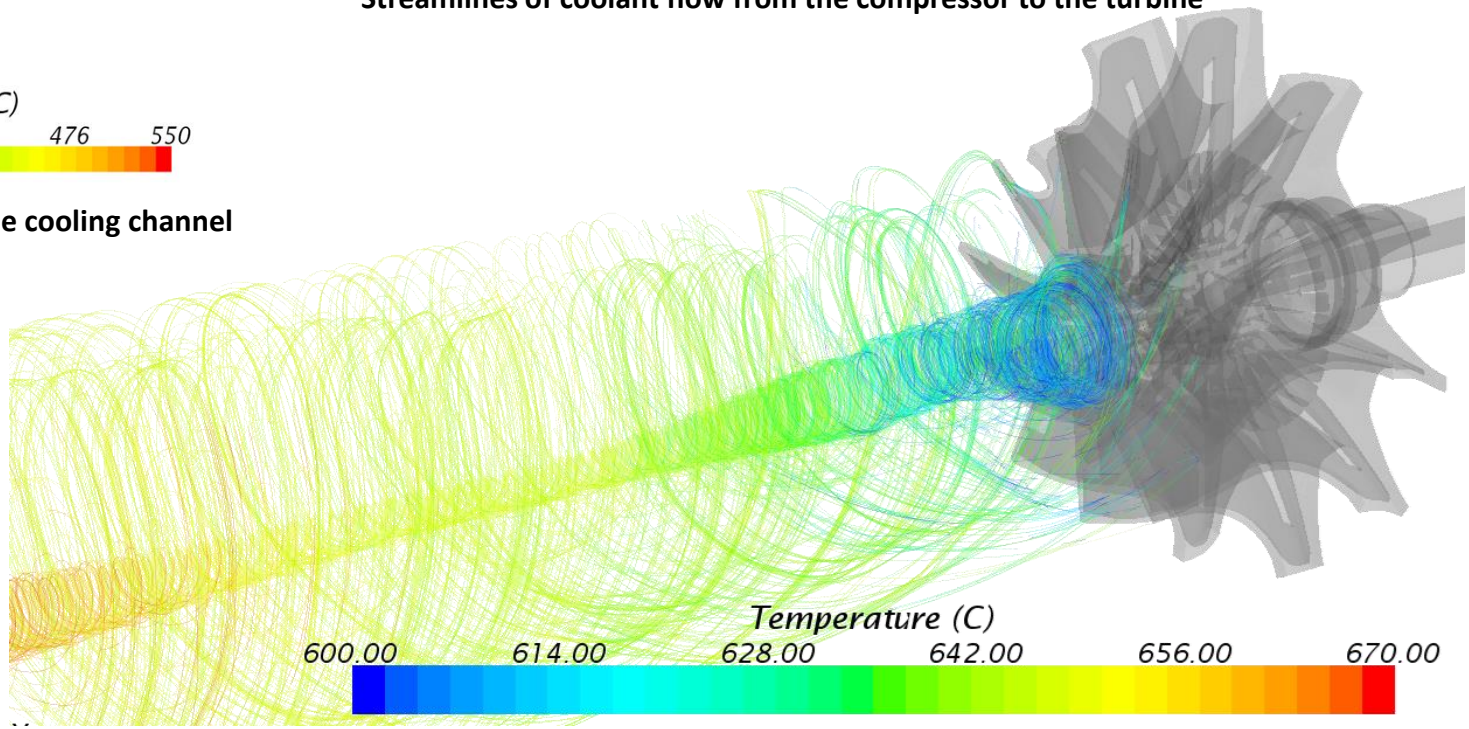
Analysis Results



Velocity streamlines in a blade cooling channel



Streamlines of coolant flow from the compressor to the turbine



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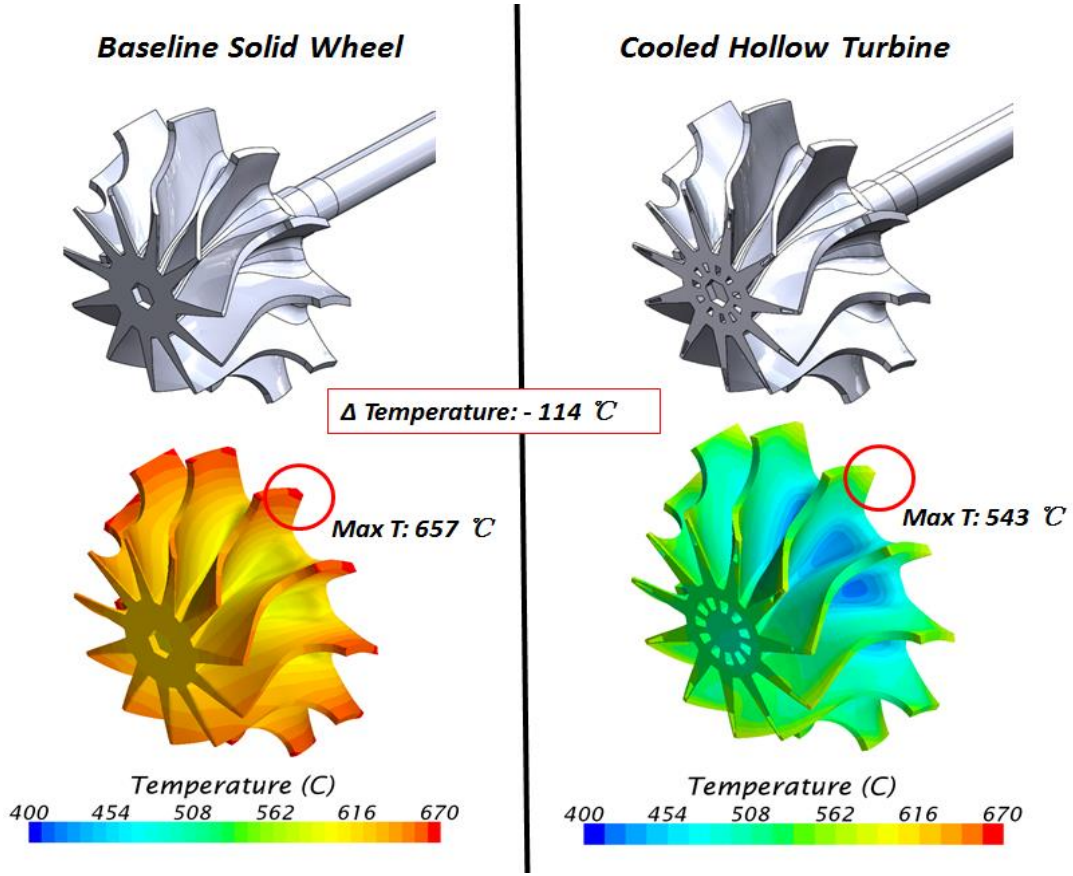
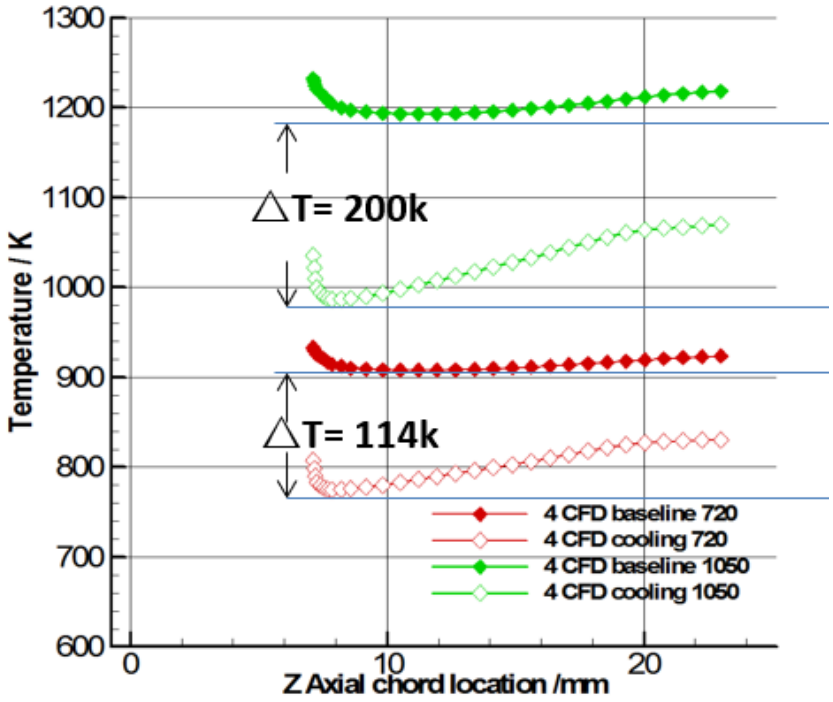
Analysis Results



At 720C TIT (gas stand limit)

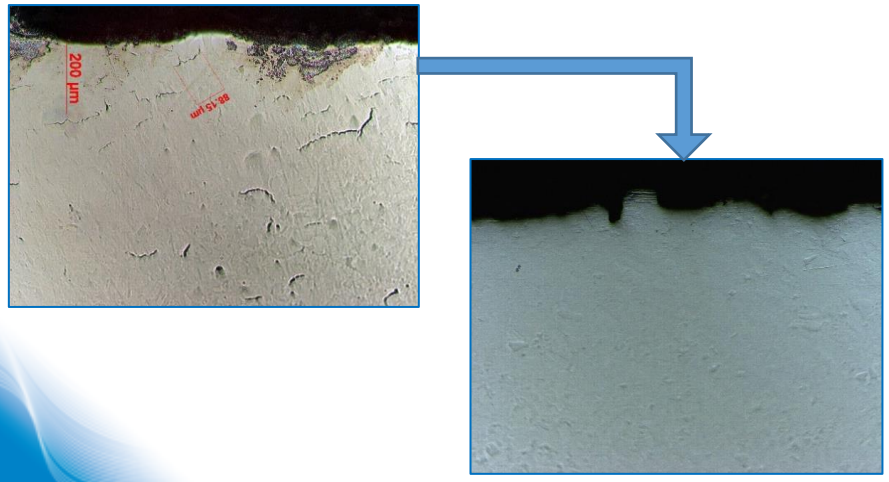


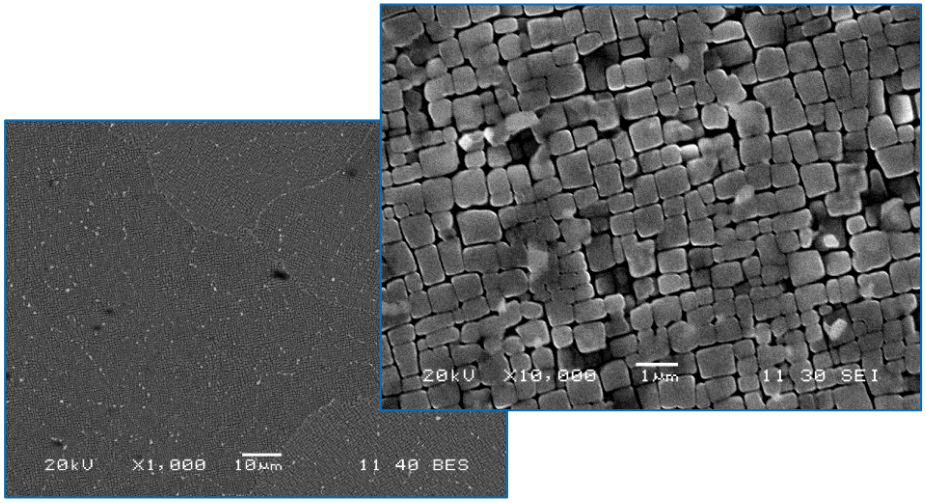
Predicting temp reduction of ~100C at 720C TIT, ~200C at 1050C TIT

Material Development

- CM247LC chosen
  - High Gamma Prime nickel superalloy
  - High strength at temperature, but deemed "unweldable"!
- Process parameters & heat treatment developed
  - DoE & Machine Learning utilised
- Material Properties generated

HIP cycle used to close up micro-cracking

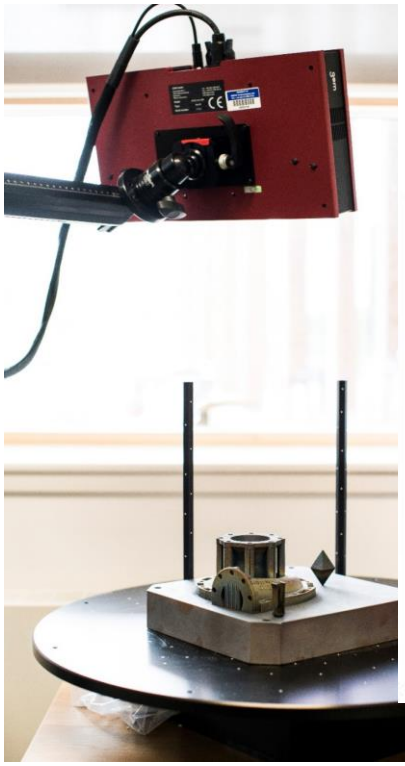




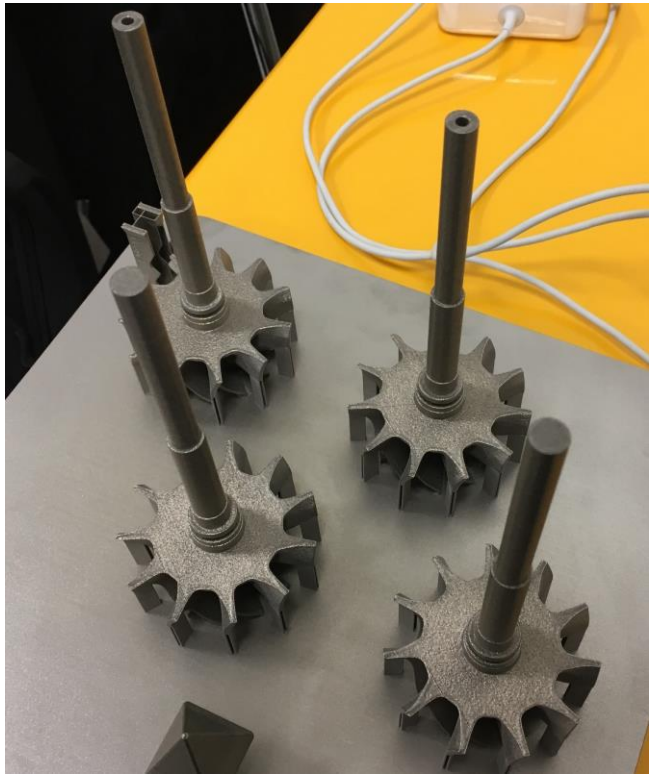
Solution treat & Age used to improve microstructure

Manufacture

- Wheels manufactured with shaft as one piece
- QA & HT & EDM
- Post machining & balancing carried out
- Thermal history paint applied



Build Direction



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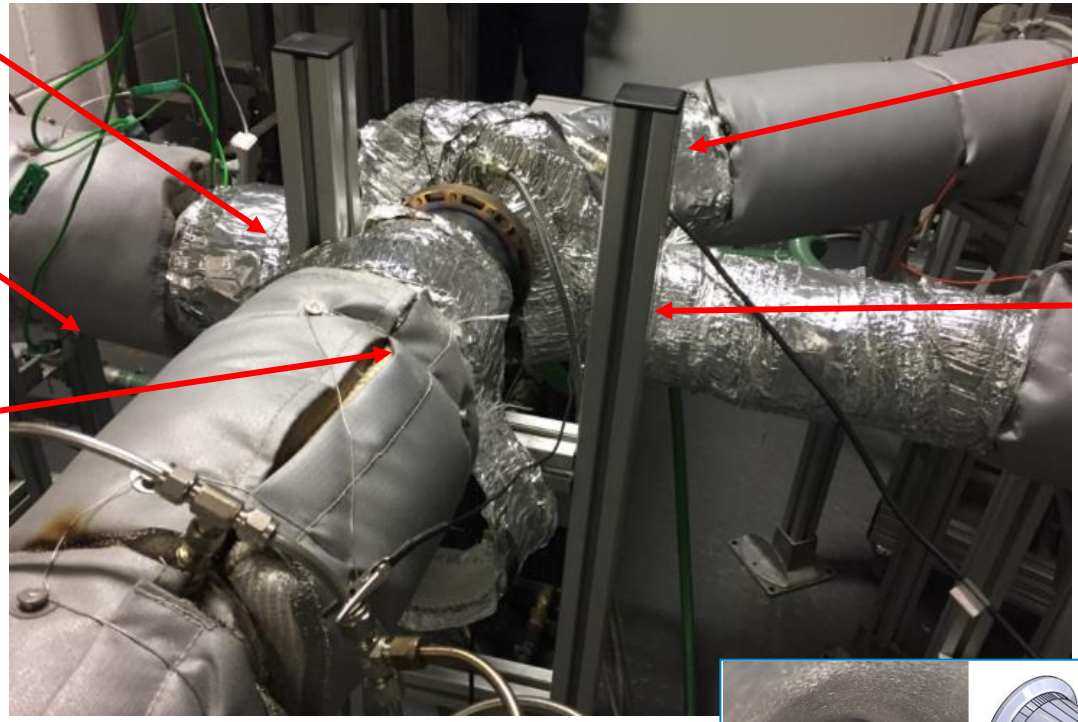
Test

Turbine Inlet
(Temperature/Pressure)

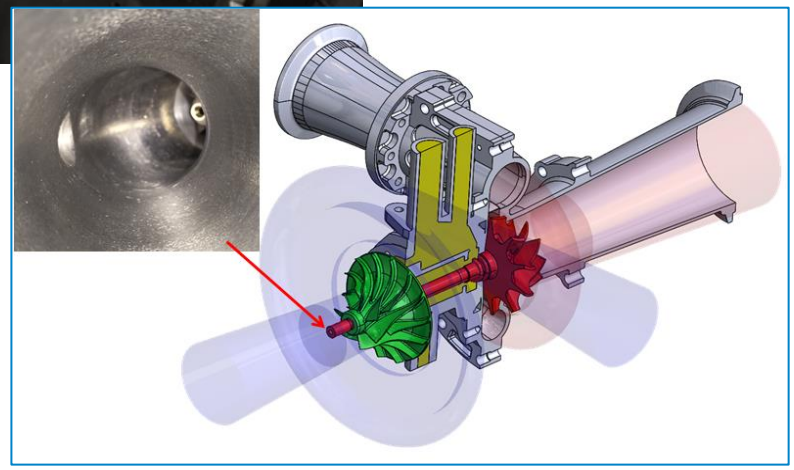
Measure Turbine/Compressor
RPM, Mass flow

Turbine Exit
(Temperature/Pressure)



Compressor Inlet
(Temperature/Pressure)

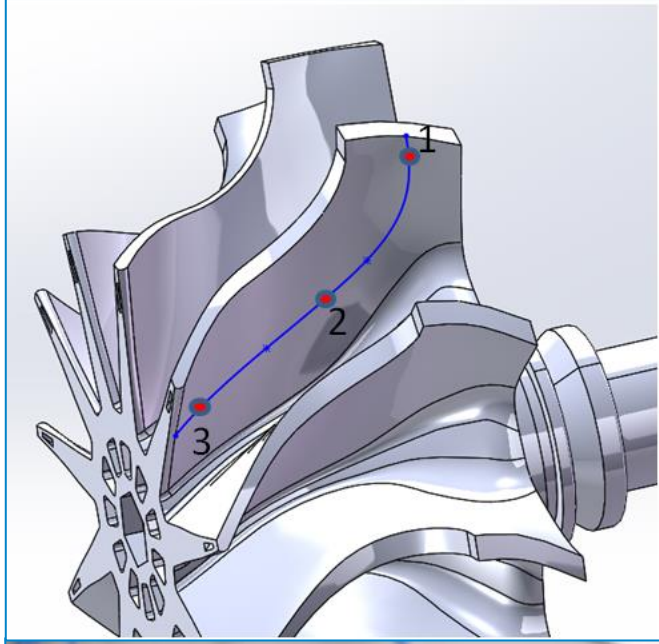
Compressor Exit
(Temperature/Pressure)



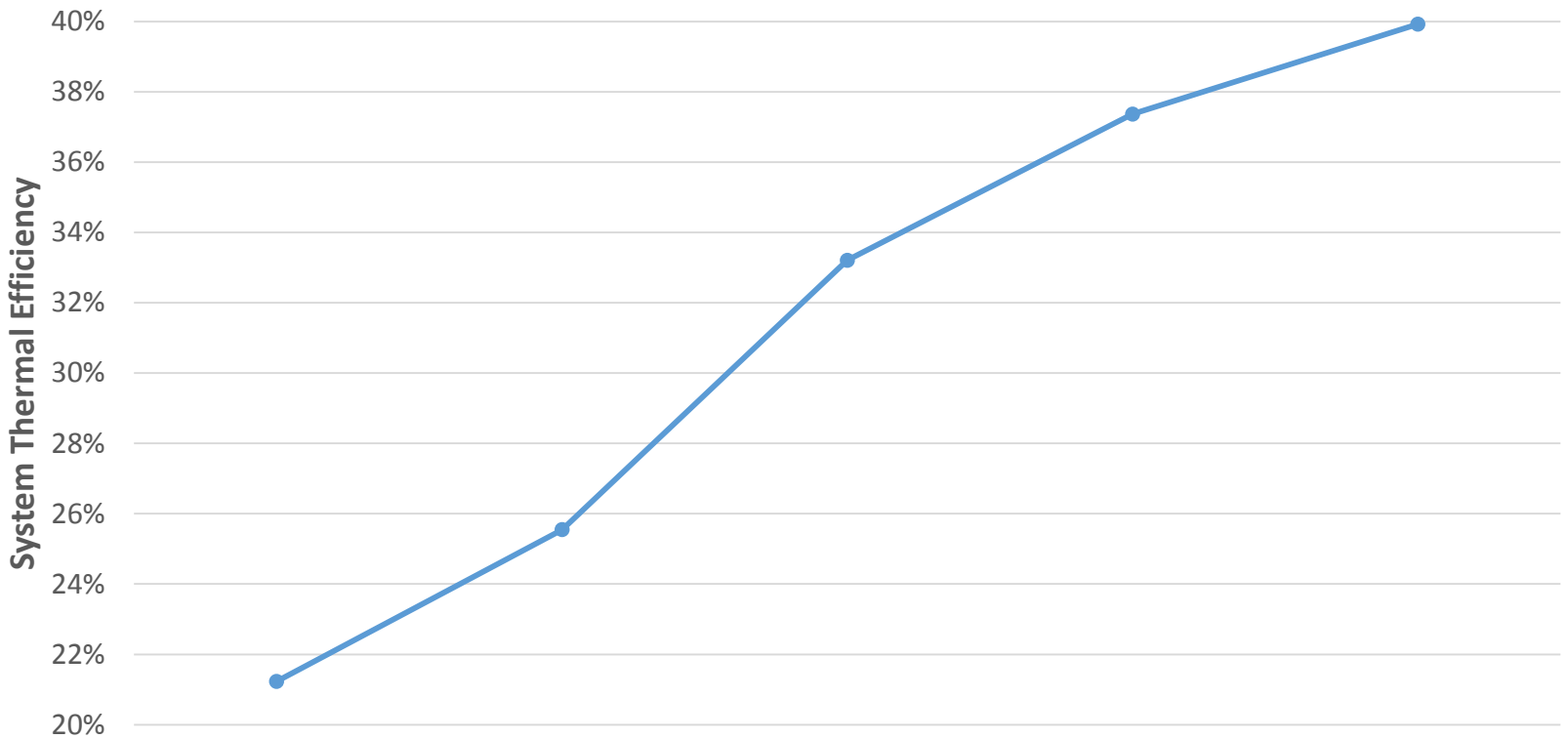
- Measure maximum metal Temperature
- Compare solid vs cooled wheels
- Monitor impact on efficiency

Results

		Position 1	Position 2	Position 3
Test @ 720C TIT	Solid wheel	609	582	581
	Cooled wheel	548	503	505
	Difference	61	79	76
CFD @ 720C TIT	Solid wheel	650	627	625
	Cooled wheel	537	502	526
	Difference	113	125	99
CFD prediction @ 1050C TIT	Solid wheel	945	920	950
	Cooled wheel	750	740	790
	Difference	195	180	160
CFD prediction @ 1200C TIT	Solid wheel	1100	1035	1090
	Cooled wheel	885	810	880
	Difference	200	220	200



The Bigger Picture…



Baseline

900C TET
73% η_c
78% η_t
90% $\varepsilon_{recuperator}$

High efficiency turbomachinery

76% η_c
78% η_t

Increased TET

1200C TET

Innovation package

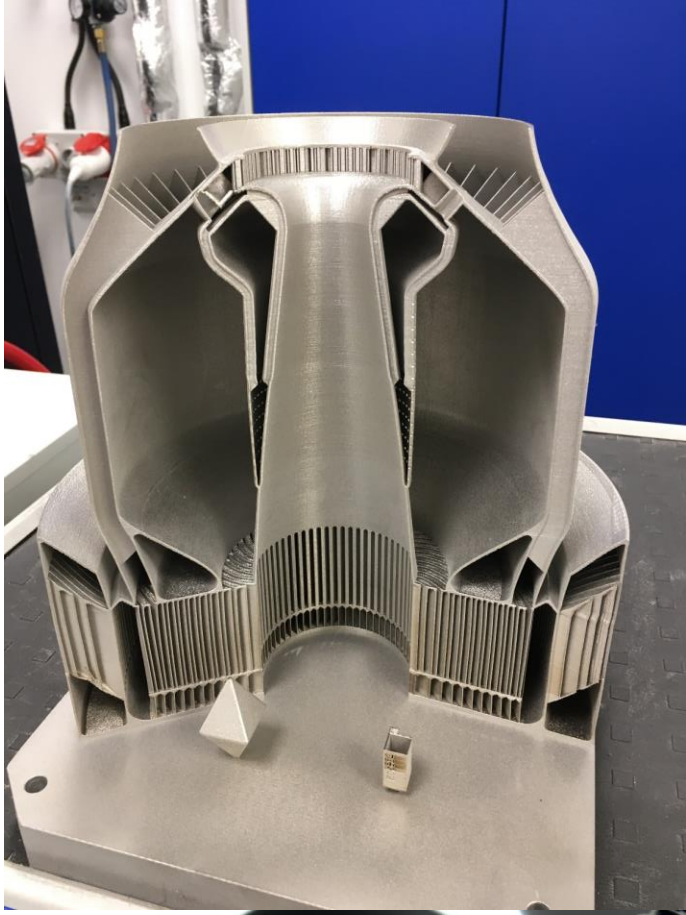
78% η_c
82% η_t
92% $\varepsilon_{recuperator}$

Integration

Lower pressure losses
93% $\varepsilon_{recuperator}$

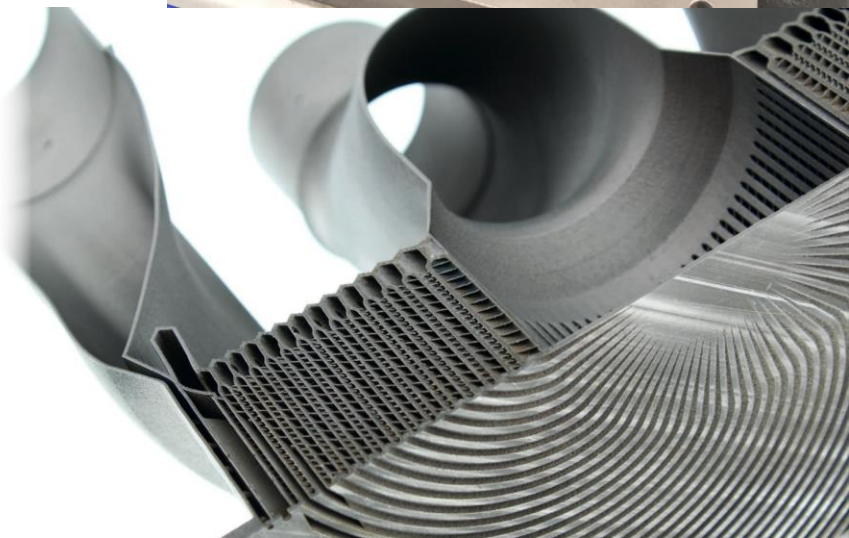
Conclusions

- Shown 1200C TIT technically feasible
- Up to 40% (1-50kWe) MGT are possible & are coming…

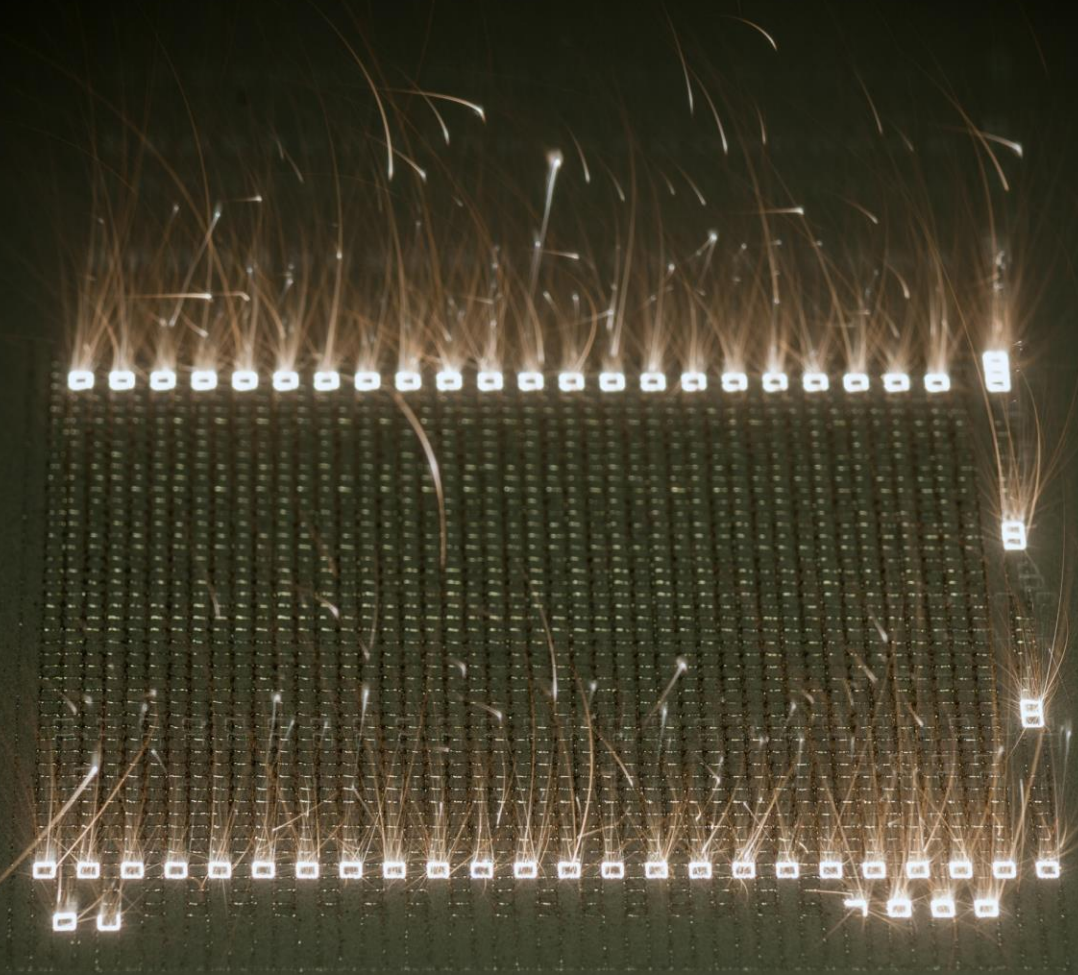


What Next:

- Currently applying technology commercially
- Looking for development partners…



Thank you!



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