Imperial College London

ME3 – Design, Make and Test 2020-2021

7C TURBOGENERATOR

Compressed Air Energy System (CAES)

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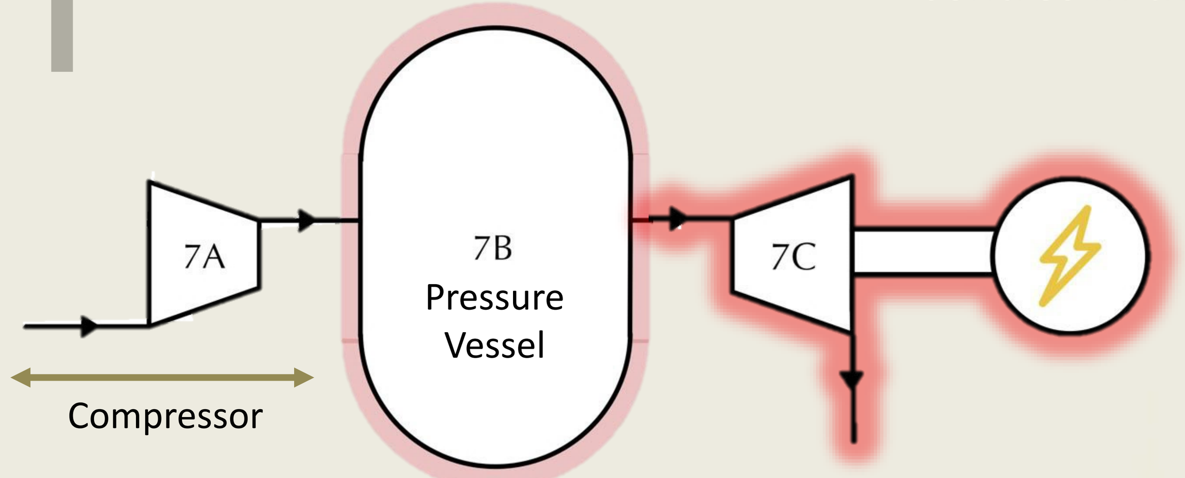
01 PROJECT OVERVIEW

CAES provides backup power to large data centres in the event of a power cut.

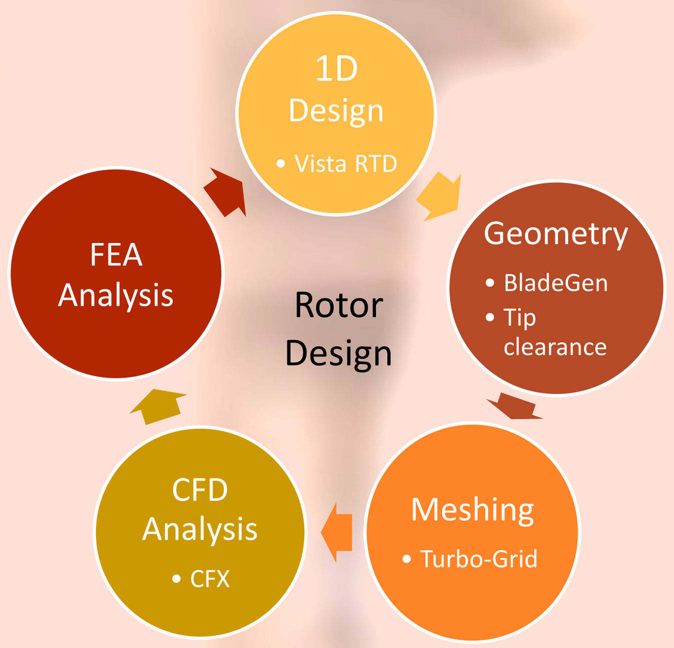


- 1-Stage Radial Inflow Turbine
- Technology Readiness Level 3 Proof of Concept
- Expands Compressed Air to generate Electricity

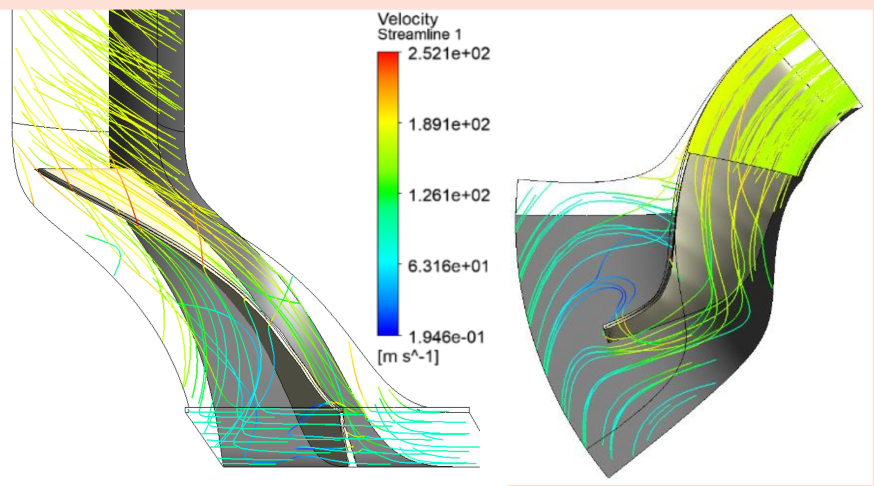
02 ROTOR DESIGN

Rotor designed for testing with key design parameters:

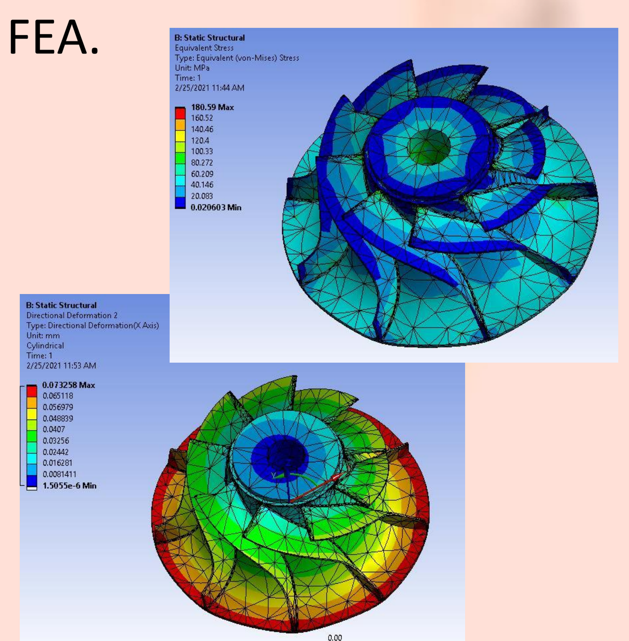
Pressure Ratio	Rotational speed	Inlet Temperature	Speed Ratio
3	70 krpm	77°C	0.63



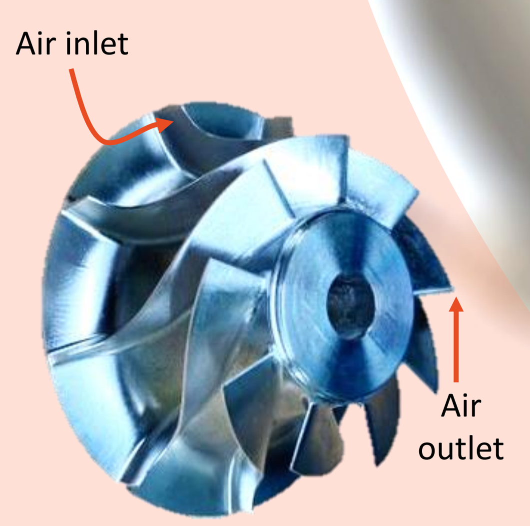
- Design refined and assessed aerodynamically using CFD.
- Structural integrity appraised using FEA.



Forward velocity streamlines from inlet blade passage. Left: side view. Right: top view.



Finite Element Analysis results.

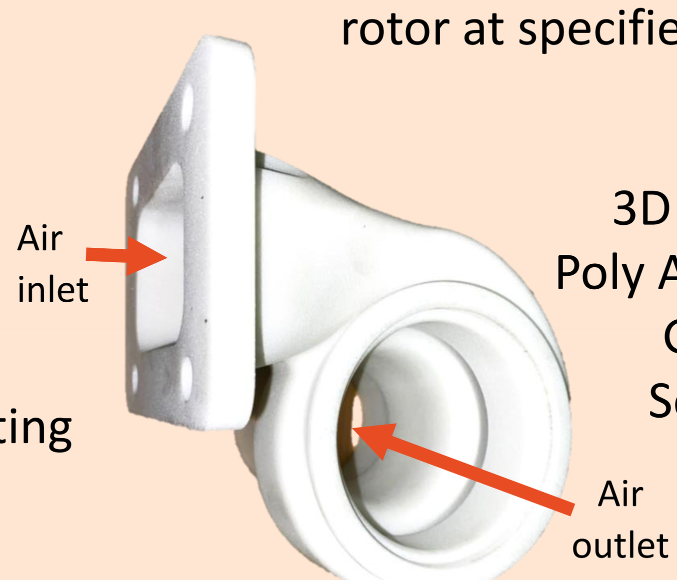


Manufactured from Aluminium (Al6061-T6) using 5-axis CNC machining

03 VOLUTE DESIGN

Volute redistributes the inlet air around the annulus of the rotor at specified conditions.

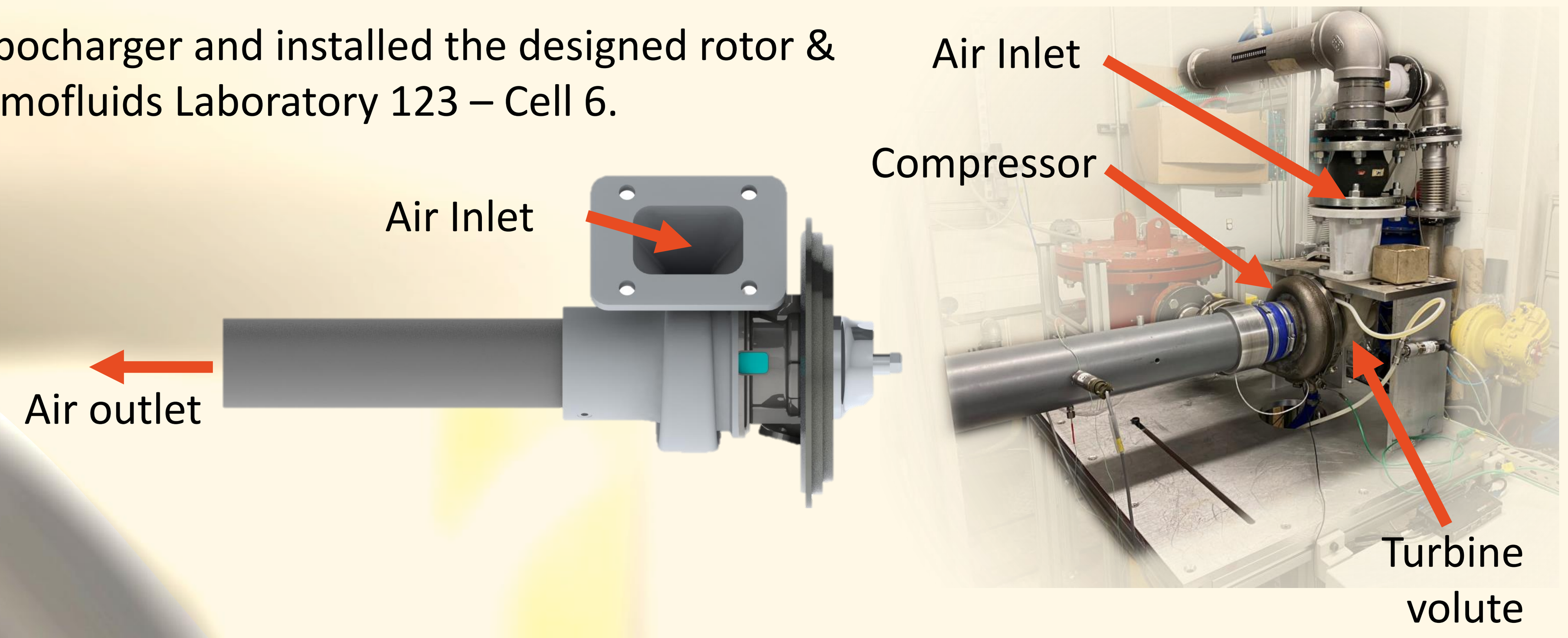
- Designed to provide an optimum flow angle of 78.2° into the rotor using a linearly decreasing A/R ratio
- Trapezoidal cross section chosen
- Flange and side profiles designed to match testing rig
- 8mm thickness to ensure structural integrity



3D Printed using Poly Amide 12 40% Glass Filled by Selective Laser Sintering

04 ASSEMBLY

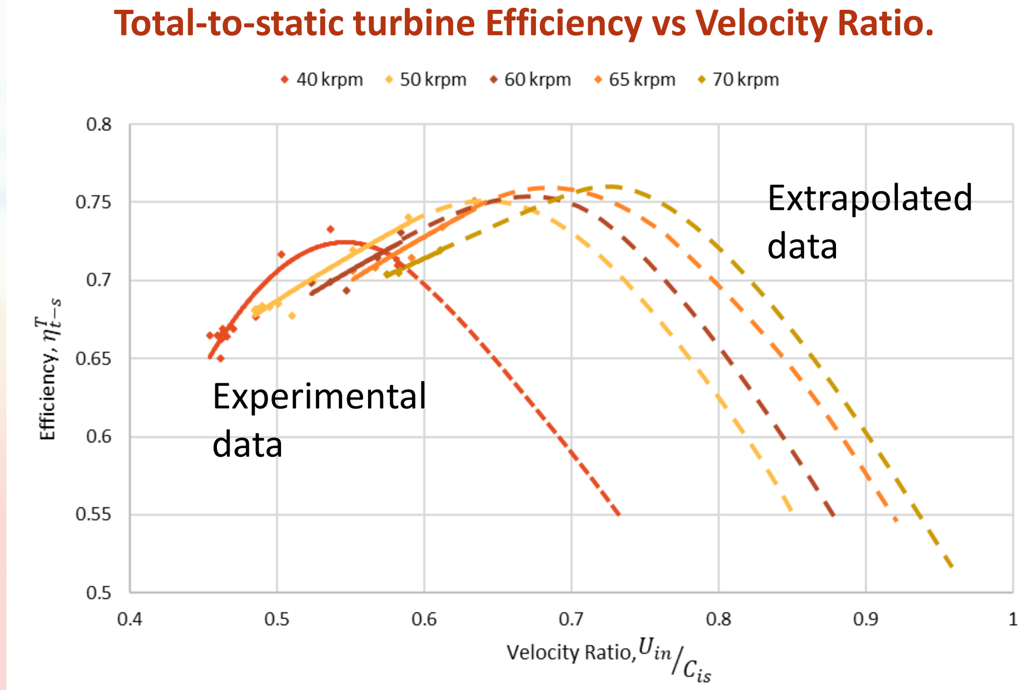
- Repurposed a turbocharger and installed the designed rotor & volute in the Thermofluids Laboratory 123 – Cell 6.



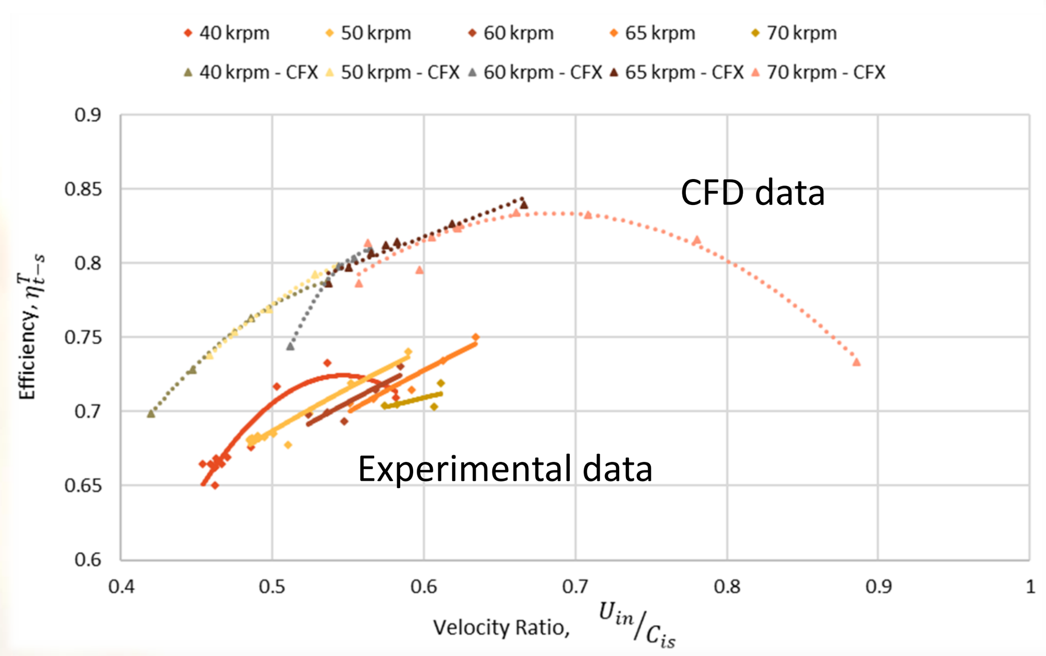
05 TESTING

- Design successfully tested at 40-70 krpm without any issues encountered
- Predicted isentropic efficiency of 0.75 is close to state-of-the-art in turbomachinery
- Experimental plots showed lower efficiency against CFD simulations
- Difference was around 5 to 10 efficiency points
- This was due to the reduced modelling domain (blade passage only) and neglected turbulent and friction effects

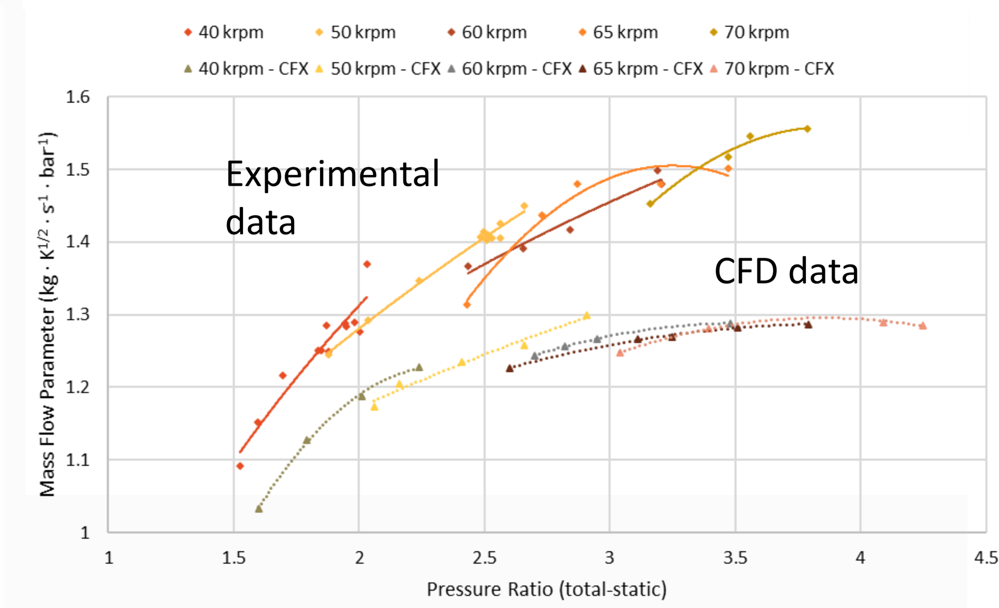
Total-to-static turbine Efficiency vs Velocity Ratio.



Total-to-static turbine Efficiency vs Velocity Ratio including CFX simulation results.



Mass Flow Parameter vs Total-to-static Pressure Ratio including both experimental and CFX simulation results.



06 CONCLUSIONS

- Over 70% efficiency obtained on each 40-70 krpm speed line
- TRL 3 achieved

NEXT STEPS

- Scale turbine and test with discharging pressure vessel
- Improve CFD model to include volute system

Acknowledgements

- **Chris Noon** for his resilience and perfectionism in testing our manufactured parts.
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References

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