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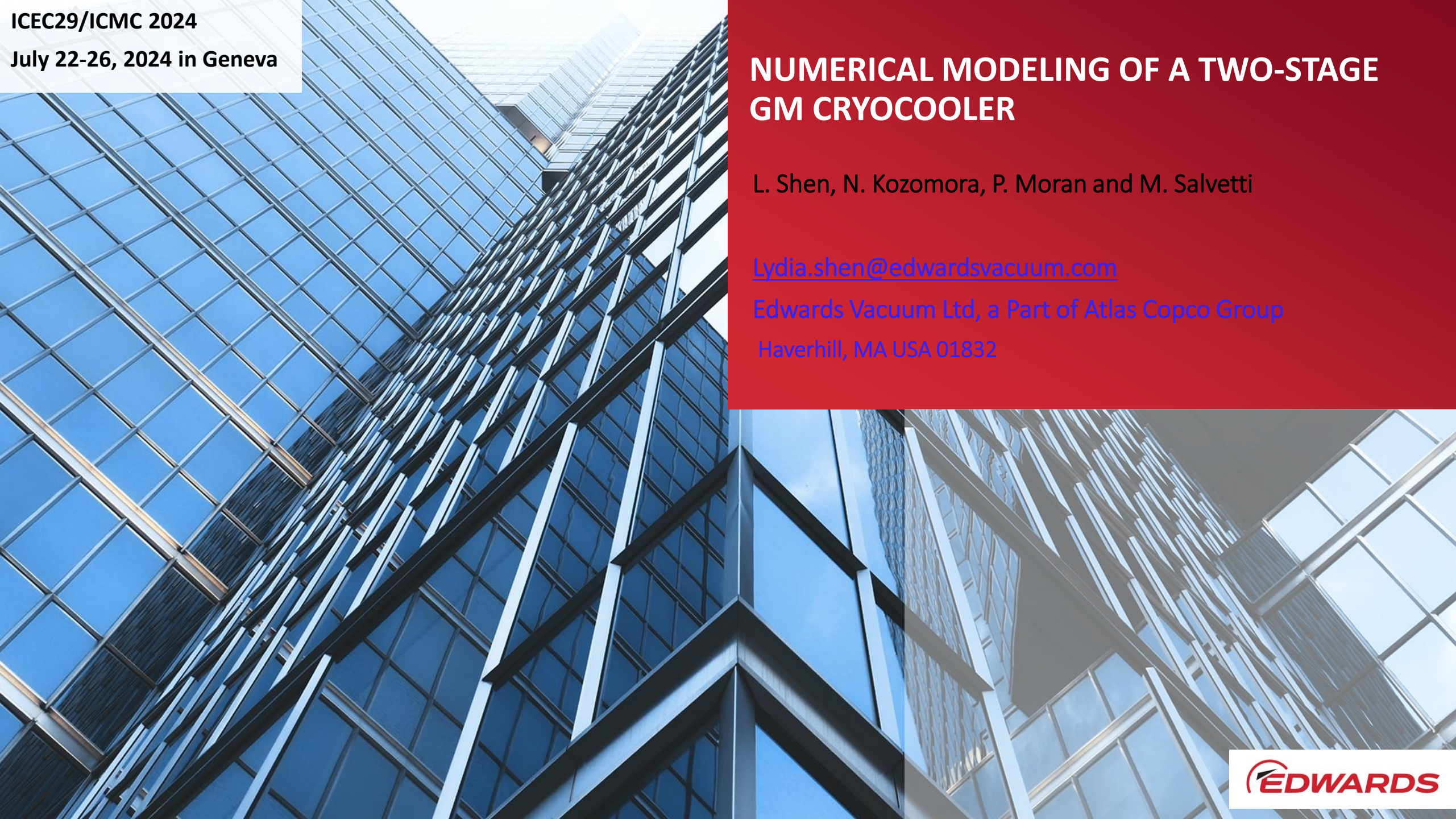
NUMERICAL MODELING OF A TWO-STAGE GM CRYOCOOLER

L. Shen, N. Kozomora, P. Moran and M. Salvetti

Lydia.shen@edwardsvacuum.com
Edwards Vacuum Ltd, a Part of Atlas Copco Group
Haverhill, MA USA 01832



EDWARDS

Numerical Modeling of a Two-Stage GM Cryocooler

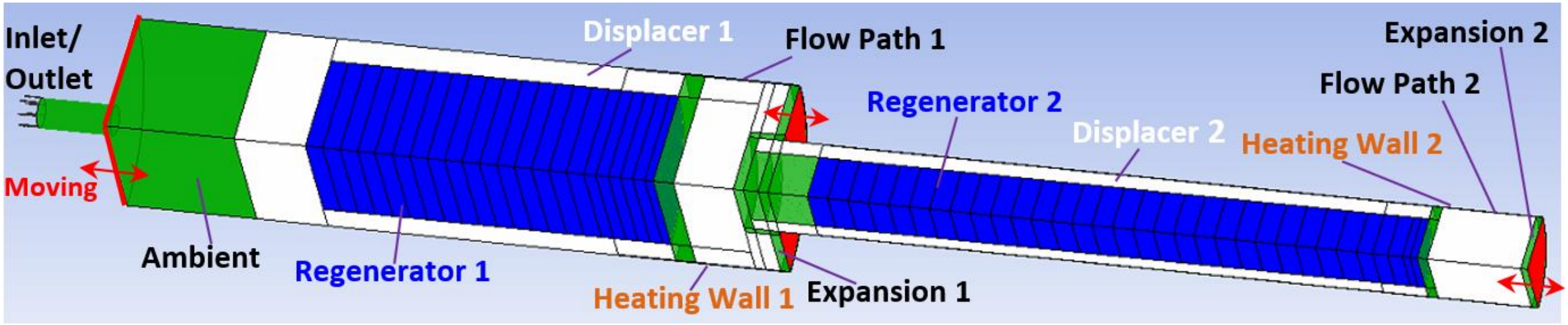
Challenges:

- Transient- Input and solution variables change with time
- Deformable mesh- Moving displacers → Ambient and Expansion volumes change in size with time
- Porous modeling- Porosity, loss coefficient, fluid-solid area density & heat transfer coefficient

Outlines

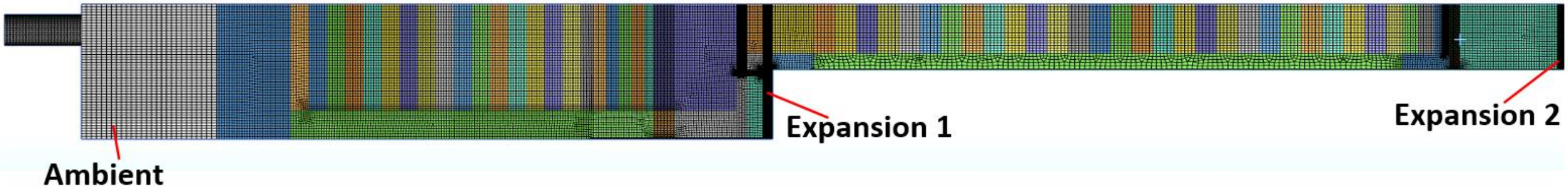
- Geometry simplification
- Meshing
- Model setup-BCs, turbulence and porous domain setup
- Solutions and comparison with testing
- Conclusions

The simplified geometry of a two-stage GM cryocooler



- Working fluid flows from Inlet/Outlet into Expansion 2 and reversely to complete a cycle
- Simplifications: eliminating dead volumes; minor features e.g. holes on Displacer 1 & 2;
  no cylinder and heaters
- A quarter of a refrigerator considered by approximating the geometry to be axisymmetric
- Moving boundary of Ambient, Expansion 1 & 2 (in **Red**) to approximate Displacers' movement

Ansys-CFX Meshing



- 1.4 million nodes
- 84% hexahedra elements
- Over 100 bodies in total, including 30 bodies in regenerators
- Global element size of 0.5mm for decent mesh transition
- Dense meshes for Expansion 1 & 2 when starting of a cycle

Model Setup

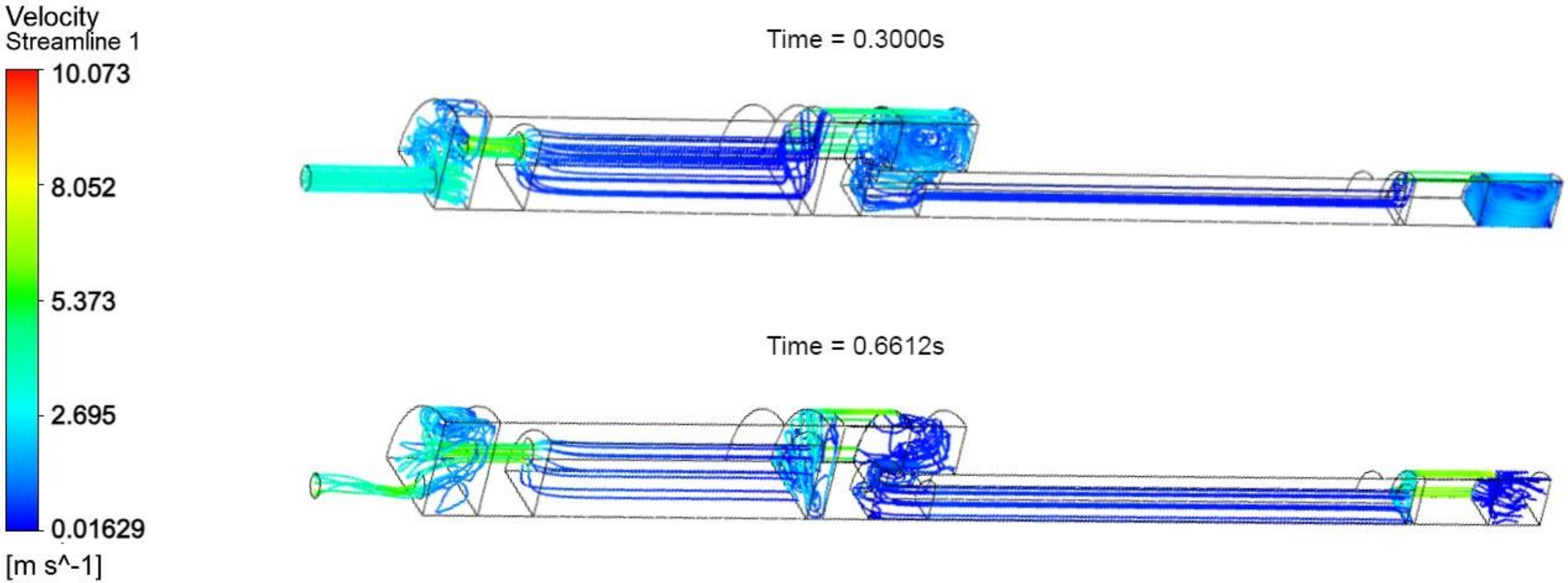
Item	Parameter	Option/Value
Boundary Conditions	T1 at Heating Wall 1	80 ~ 100 K
	T2 at Heating Wall 2	4 ~ 20 K
	Mass Flowrate at Inlet/Outlet	0.3 ~ 0.5 g/s
	Surrounding Wall Heat Transfer	Adiabatic
Displacer Movement	Frequency	0.5 ~ 1.7Hz
	Stroke	20 ~ 30 mm
Fluid Model	Turbulence	SST
Porous Domains	Porosity for Regenerator 1	0.55 ~ 0.65
	Porosity for Regenerator 2	0.26 ~ 0.4
	Heat Transfer Coefficient	Variable
	Loss Coefficient	Variable
	Interfacial Area Density	8000 ~ 29000 m^{-1}

Solver Control

- Convergence criterion: 10^{-4} RMS residual
- Max time step: 10^{-4} second
- **4** days for one simulation on a computer of 64 GB RAM and 36-core
- Initialize domains based on testing data
- One run for one cycle & continue next cycle w/ the last step of previous cycle as initial

Final converged solution → major solution variable, e.g. P or T for both starting and ending of a cycle meet error requirement (1 or 0.5 psi)

Two-stage solutions---streamlines



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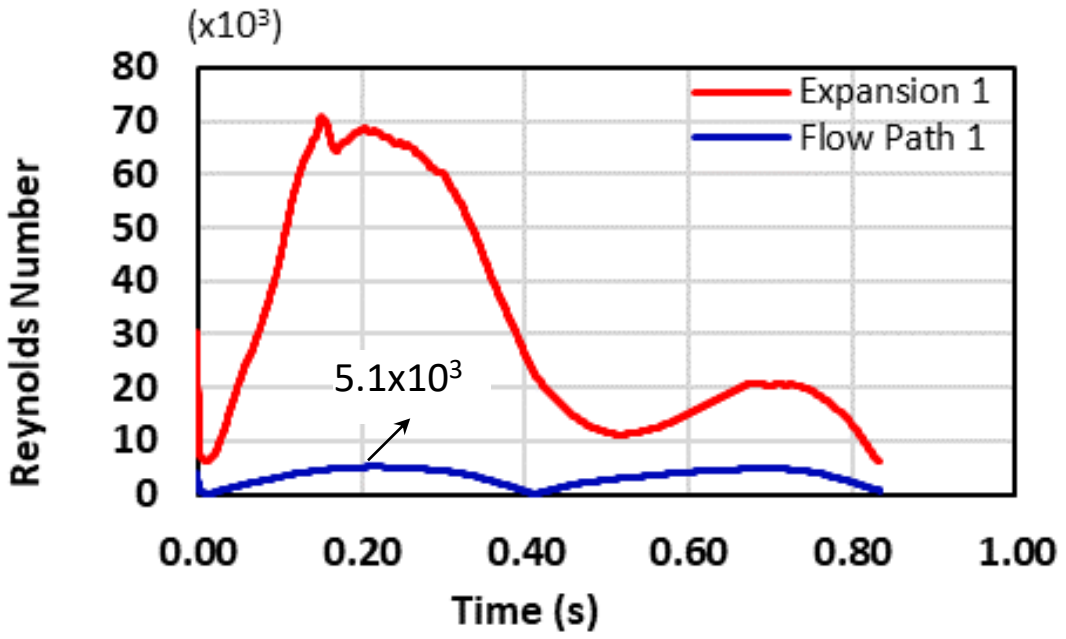
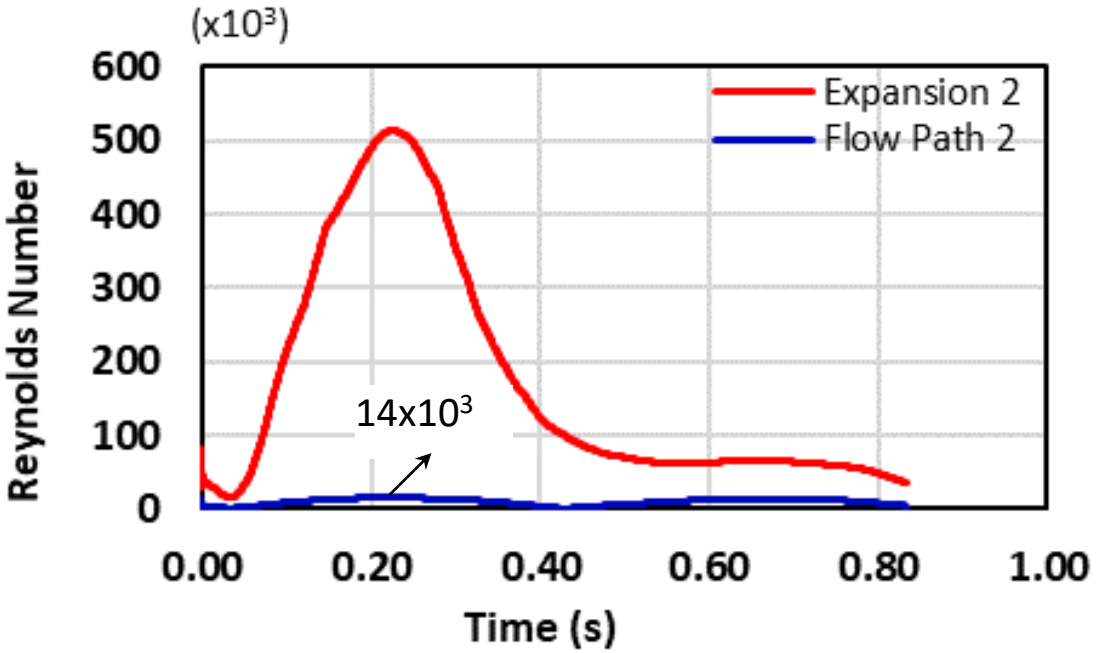
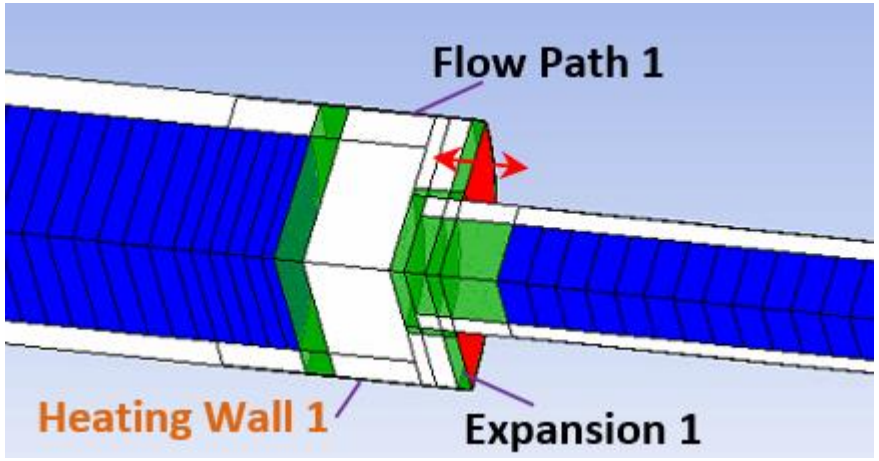
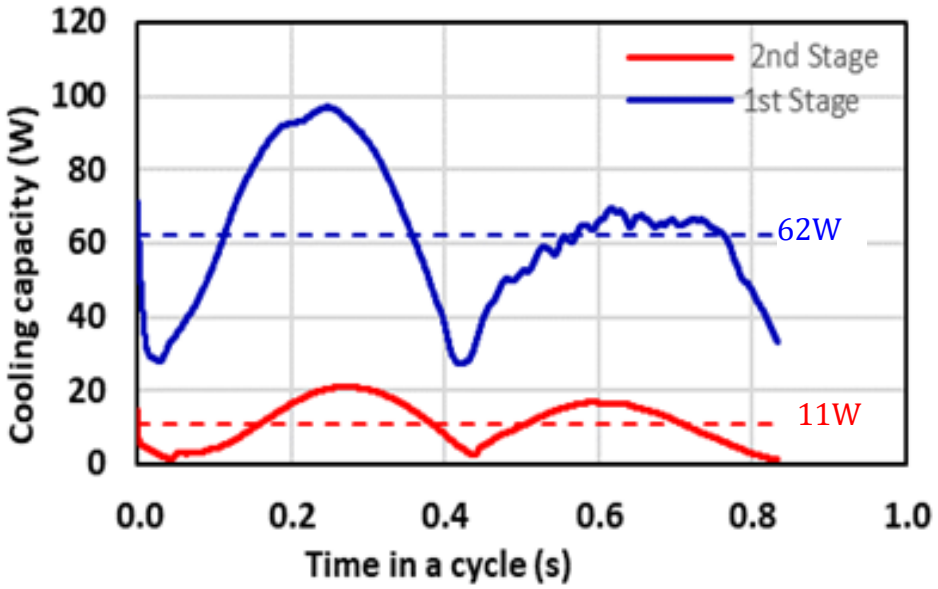
Reynolds numbers changing with time in a cycle

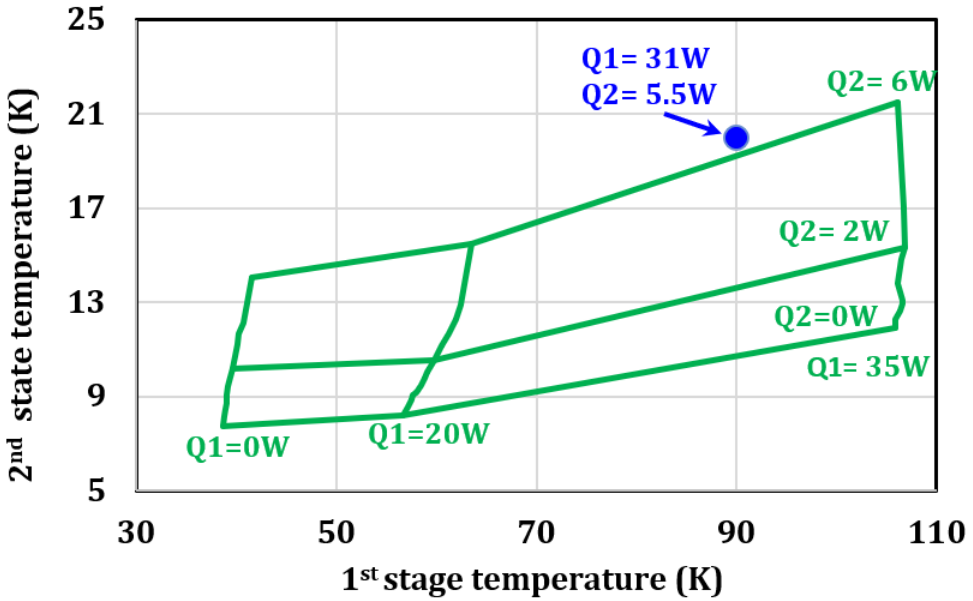






Cooling capacity compared with testing





Conclusions

- Numerical modeling of a two-stage GM cryocooler conducted by using Ansys-CFX
- A robust 3D model created by taking a quarter of the axisymmetric refrigerator
- 84% of hex elements in 1.4 million nodes of mesh as required mainly by deformable mesh
- 4 days computing for 1 cycle w/ 10^4 time steps on a workstation of 64GB ram & 36-cores
- Max. cooling, Q1=62W & Q2=11W with no thermal resistance from fluid to heaters
- Simulation results subtracted all heat losses, fairly match Edwards' testing data
- More advanced two-stage model including heaters, cylinders and major flow paths to be created
- More studies on all heat losses to follow.

Thank you for your patience!

lydia.shen@edwardsvacuum.com

Edwards Vacuum Ltd, a Part of Atlas Copco Group
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