Design of radial turbomachinery for supercritical CO₂ systems using theoretical and numerical CFD methodologies


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Windsor, 20/04/2017
I-ThERM Project aim is to…

Investigate, design, build and demonstrate innovative plug and play waste heat recovery solutions to facilitate optimum utilisation of energy in selected applications with high replicability and energy recovery potential in the temperature range 70 ℃ – 1000 ℃.

1000 ℃

500 ℃

200 ℃

70 ℃

flat heat pipes

condensing and not condensing heat pipes

sCO₂

TFC

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Outline

• Reference thermodynamic cycle
• Preliminary turbomachinery design
• CAD
• Simulation CFD
• Turbine Design
• Results and discussion
Thermodynamic cycle
$R = \frac{h_5 - h_6}{h_5 - h_{2\text{MAX}}}$
Specific speed and diameter

- Balje’s charts available for air and water turbo machines
- Loss correlations available for air
- Need of coupling CFD tools with thermo-physical properties of CO₂ (dll libraries or look-up tables)
- Need of importing thermomechanical properties in FEA tools if custom materials are employed
Balje Equations

\[ N_s = \frac{N \cdot Q_3^{1/2}}{H_{ad}^{3/4}} \]

\[ D_s = \frac{D \cdot H_{ad}^{1/4}}{Q_3^{1/2}} \]

- \( N \) = Rotational Speed (rpm)
- \( Q_3 \) = Rotor Flow Rate (ft\(^3\)/sec)
- \( H_{ad} \) = Adiabatic Head (ft)
- \( D \) = Diameter (ft)

Velocity Diagram
Computer Aided Design

Compressor

Turbine
CFD simulations setup

- **Flow type**
  - 3D Steady Compressible Flow

- **Solver**
  - coupled flow

- **Turbulence model**
  - RANS, K-Epsilon, All Wally+

- **Equation state**
  - Peng-Robinson
Turbine CFD – boundary conditions

Geometry

Pressure outlet
Stagnation Inlet
Mixing plane interface

2 domains: 1 considered Stationary (Volute+Nozzel)
1 considered in Rotation (Wheel)
Turbine CFD - Results

Streamlines

Pressure Field

Velocity field

Isentropic efficiency: 70%
Compressor CFD – boundary conditions

Geometry

- Mass flow inlet
- Pressure outlet
- Mixing plane interface

2 domains: 1 considered Stationary (Volute+Nozzle)
1 considered in Rotation (Wheel)
Compressor CFD - Results

Streamlines

Pressure Field

Velocity field

Isentropic efficiency: 76%
Rotordynamic analysis

Results

Max
Min

Diagramme de Campbell de l'arbre
CGT assembly
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