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WeARE Research Area

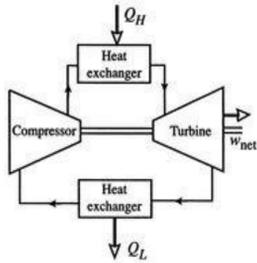
Brayton Power cycles based on supercritical carbon dioxide (sCO₂) as the working fluid have potential to yield higher thermal efficiencies at lower capital cost than steam-based power cycle. The sCO₂ is a highly efficient working fluid to generate power because it acts like a gas yet has the density of a liquid. The research area for this project falling under Raj will be to find an effective heat source for the cycle.

Motivation or Background

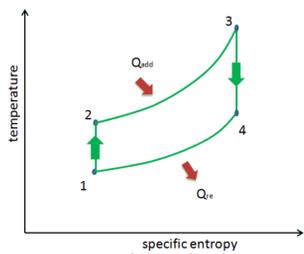
The sCO₂ Brayton cycles are promising alternatives for power generation. The fossil reserves are depleting rapidly due to rapid increase in demand, and this power cycle is also an improvement for environment from greenhouse gas reduction. The machinery size for same power output is also very small so smaller footprint.

Objectives

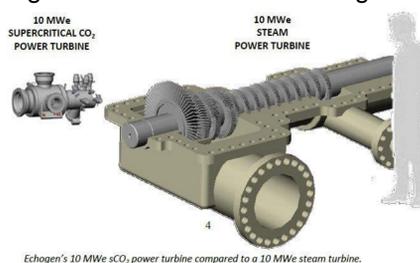
The Brayton cycles have four major stages and one of them is a heat source which is stage 2 to 3. Critical Heat Transfer calculations is main objective to address the heating needs. Accurate calculations for a compressible fluid heat transfer and making sure the flow is not choking is a primary objective.



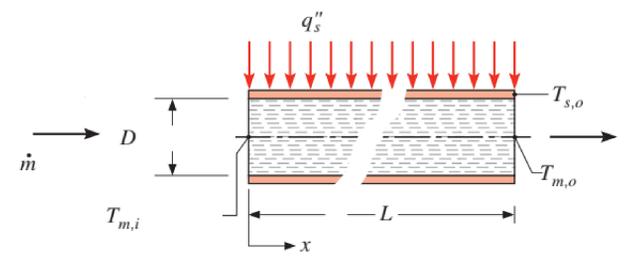
Basic Brayton Cycle
Bergman et al., 2017



T-S Diagram of an ideal Brayton Cycle
Bergman et al., 2017



Size comparison of Steam Turbine with that of sCO₂
Wright et al., 2017

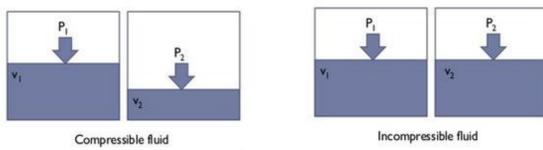


Heating Section - Concept
Bergman et al., 2017

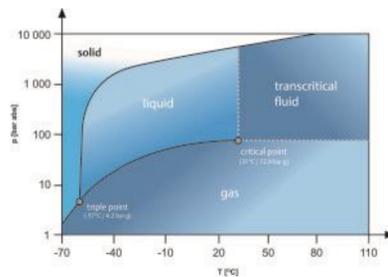
Methodology

In order to calculate the heat required to bring the sCO₂ (compressible fluid) to required temperature ideal gas assumption was not made because of high pressure and low pressures. Since it is a compressible fluid, the Rayleigh Flow and Fanno Flow analysis was conducted to see the Mach number inside the pipe in the heating section is not going beyond 1 as it will choke the flow. Lastly, heat flux calculation is for the Power Density comparison of the Heating Elements available to our requirements.

Compressible and Incompressible flows



Compressible Fluid vs. Incompressible Fluid
Siddique, 2015



Phase Diagram
Patenaude, 2015

$$h_1 + \frac{u_1^2}{2} + q = h_2 + \frac{u_2^2}{2}$$

Compressible Flow Heat Transfer Formula
Anderson, 2003

$$q = q''_s A = q''_s \pi DL$$

Heat Flux Calculation Formula
Bergman et al., 2017

Results

Results for the 2" OD Pipe for outlet Temperature of 200°C are below. Heat Flux calculated is very high, so Heat Tapes is not a viable option. The Fanno and Rayleigh Flow analysis determined that Flow won't be choking for any realistic length of Heating section.

m_dot = 0.25 kg/s						
Length (ft)	Length (in)	Heat Transfer (kW)	Heat Flux (kW/in ²)	Heat Flux (W/in ²)	Rayleigh Choke	Fanno + Rayleigh
1	12	48.8	0.647	647.0	No, M3 < 1	Mach number is
2	24	48.8	0.324	323.5	No, M3 < 1	very small to choke
4	48	48.8	0.162	161.8	No, M3 < 1	L = 27000 inches
6	72	48.8	0.108	107.8	No, M3 < 1	Solved on MATLAB
8	96	48.8	0.081	80.9	No, M3 < 1	
10	120	48.8	0.065	64.7	No, M3 < 1	

Results



Heat Tapes
Omega, 2020



Immersion Heater
Omega, 2020

Skills and Experience

I am skilled and experienced in budgeting and managing. I have strong skillset for CAD modeling. I am CSWA certified for SolidWorks. I have two internship experience in the manufacturing industry.

What I Learned

The whole process of formulation and moving from very basic calculations to complex calculations and validating them is a very critical part engineers working on any projects and that is what I have learned.

Future Plans

Short term goal is to achieve Master's Degree in Mechanical Engineering from UTSA. In long term my plan is to work in the development of the Aerospace Future plans as far as the project goes is to accomplish the fabrication phase of the project next year to achieve the objective of verifying the viability of the project.

Acknowledgments

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References

- "Brayton Cycle - PV - Ts Diagram." Nuclear Power. Accessed May 13, 2020. <https://www.nuclear-power.net/nuclear-engineering/thermodynamics/thermodynamic-cycles/brayton-cycle-gas-turbine-engine/brayton-cycle-pv-ts-diagram/>.