Supercritical CO_2 axial turbine design for CSP applications.

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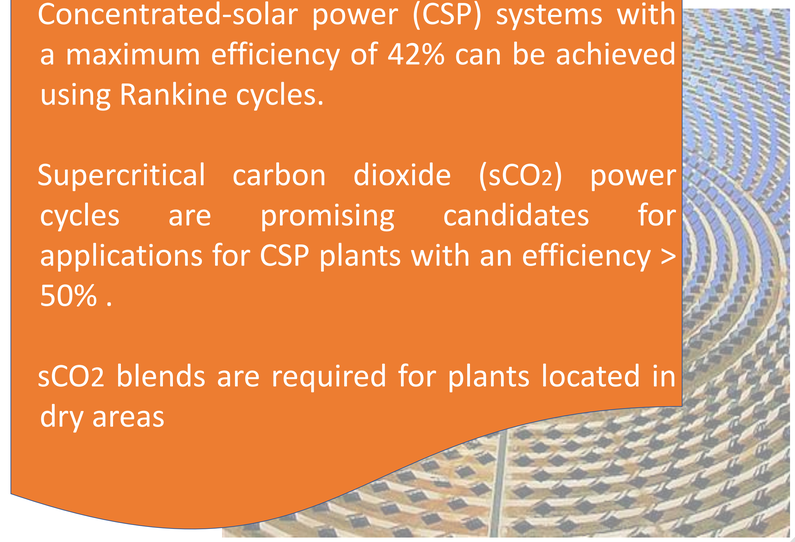
Background

Concentrated-solar power (CSP) systems with a maximum efficiency of 42% can be achieved using Rankine cycles.

Supercritical carbon dioxide (sCO_2) power cycles are promising candidates for applications for CSP plants with an efficiency > 50% .

sCO_2 blends are required for plants located in dry areas



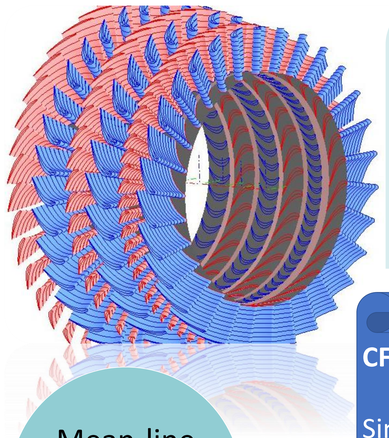
Objectives

To establish a design methodology for supercritical axial turbine design for sCO_2 working fluid blends.

To evaluate the validity of the existing loss models for the sCO_2 turbomachines using computational fluid dynamics (CFD) simulations.

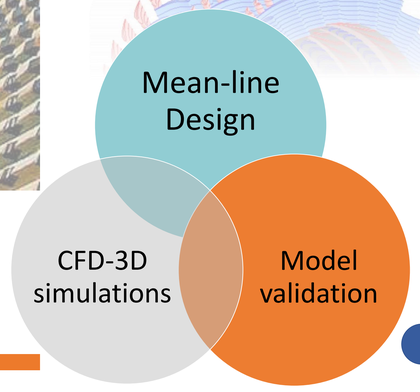
To examine the off-design performance of sCO_2 turbomachines under CSP system operating conditions.

Methodology



Mean-line Design

- 1D mean-line design integrated with suitable loss models.
- sCO2 properties : The Peng–Robinson Equation of State.



CFD Simulations

Single flow passage.

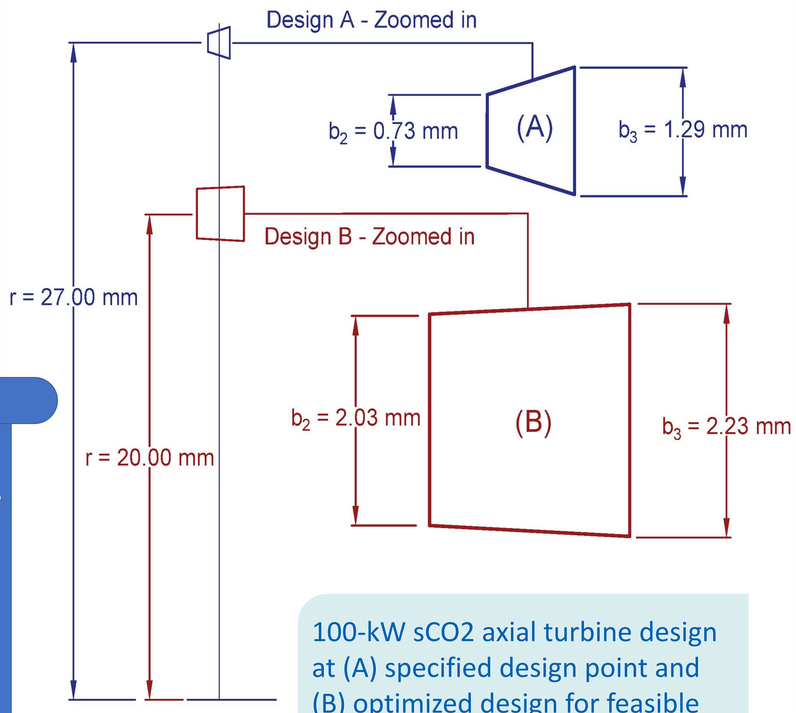
Steady mixing-plane conditions for the interface between the rotor and the stator.

Verification

Lack of sCO_2 turbines' prototypes.

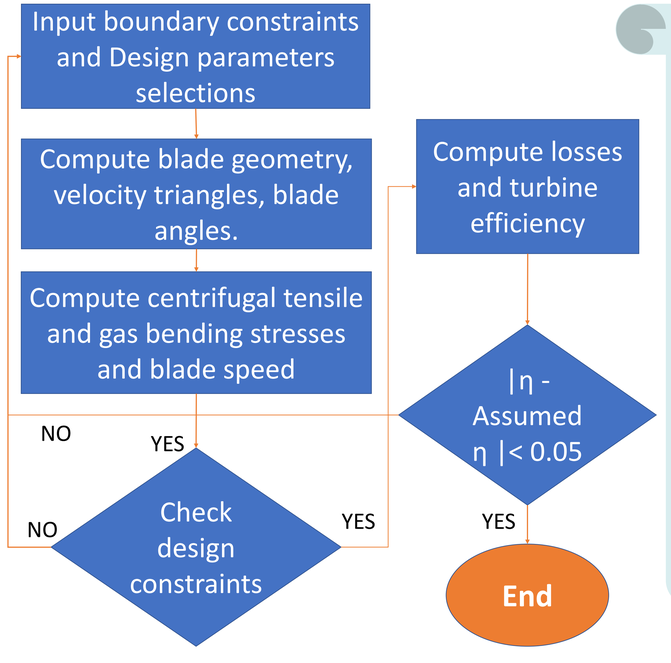
Challenging design validation.

100 MW sCO_2 axial turbine design has been used to verify the design model.



100-kW sCO2 axial turbine design at (A) specified design point and (B) optimized design for feasible micro turbine dimensions.

Mean-line Design



Design Parameters:
Flow coefficient φ,
Loading coefficient ψ,
Degree of reaction Λ,
Isentropic efficiency η,
Nozzle loss coefficient,
rotational speed N.

Design Constraints:
Mean blade speed.
Allowable stress limit.

Loss Models:
Soderberg and Craig and cox

Conclusions

100 kW small-scale turbine design has been developed for the design of small scale axial sCO_2 turbines.

Next steps :

- Extend the mean-line model to 100 MW design.
- Conduct 3D CFD simulations to further verify the model.
- Conduct off-design performance analysis for CSP applications

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