Computational Analysis of Supercritical Carbon Dioxide Turbine

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1. Introduction

This study aims to design and evaluate performance of the turbine for the supercritical carbon dioxide (SCO_2) Brayton cycle power conversion system through the application of computational fluid dynamic analysis. For the SCO_2 energy conversion the efficiency of the turbomachinery is considered one of the most decisive parameters. In the absence of either practical experience or design data to help guide the design of the SCO_2 turbomachinery operated with the Brayton cycle, it is necessary to establish a methodology for the design and performance analysis of the turbomachinery before the detailed design and manufacturing stage [1-3].

2. Computational Analysis

Computational analysis of SCO_2 flow around a turbine was performed utilizing CFX® to check on the potential efficiency of turbine which determines such basic design values as the rotor and stator types, blade height, and radii of the hub and the tip.

2.1 Turbine Modeling

For the analysis of a SCO_2 Brayton cycle power conversion system, Table I presents the basic design parameters of the Advanced Burner Test Reactor being developed by the Argonne National Laboratory (ANL). A three-dimensional (3D) modeling was performed as demonstrated in Fig. 1 based on the data in Table I. A modeling was performed by ANSYS BladeGen™.

Table I: Design Parameter for SCO_2 Turbine

Power	156.4 MW
Number of stage	6
Rotational speed	3600 rpm
Length (stages)	1.02 m
Length (diffuser)	1.64 m
Length (total)	2.67 m
Max diameter	0.87 m
Hub radius	27.0 ~ 34.1 cm
Tip radius	41.4 ~ 43.5 cm
Blade height	7.3 ~ 16.5 cm
Blade chord	7.4 ~ 11.0 cm

Fig 1. 3D modeling for SCO_2 turbine.

2.2 Grid

Table II gives the gird data. To optimize the turbine it was necessary to vary cases. The 3D grid was created using CFX® TurboGrid.

Table II: Grid for Turbine

Number of Elements	579,520
Topology Definition	H/J/C/L-Grid
Distribution ratio between hub and shroud	200
O-type grid Distribution	50 (ratio)
O-type first grid length ratio	0.3

2.3 Boundary Conditions

The boundary conditions in Table III are based on the Advanced Burner Test Reactor Preconceptual Design Report.

Table III:. Boundary Condition for Turbine

Mass flow	137.593kg/s
Inlet absolute pressure	19.743MPa
Inlet temperature	471.715℃

outlet absolute pressure	7.731MPa
Outlet temperature	362.255℃
turbulence model	shear stress transport

2.4 Result

The efficiency of the turbine is calculated as 87.66% using

$$\frac{\dot{m}c_p(T_{in}-T_{out})}{\dot{m}c_p(T_{in}-T_{out,s})}=\frac{h_{in}-h_{out}}{h_{in}-h_{out,s}} \quad (1)$$

It is then considered that the turbine blade shape has yet to be optimized. The computed static enthalpy and absolute pressure are given in Figs. 2 and 3, respectively.

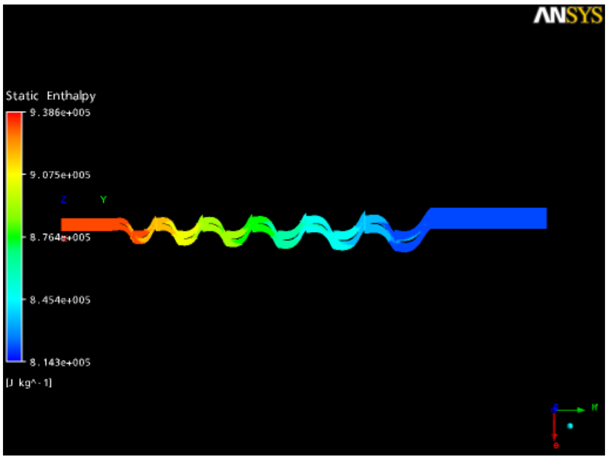

Fig. 2. Static enthalpy for SCO_2 turbine.

3. Conclusions

This study has designed and evaluated performance of the turbine for the SCO_2 Brayton cycle power conversion system through computational fluid dynamic analysis. For the SCO_2 energy conversion the efficiency of the turbomachinery has proved to require further study.

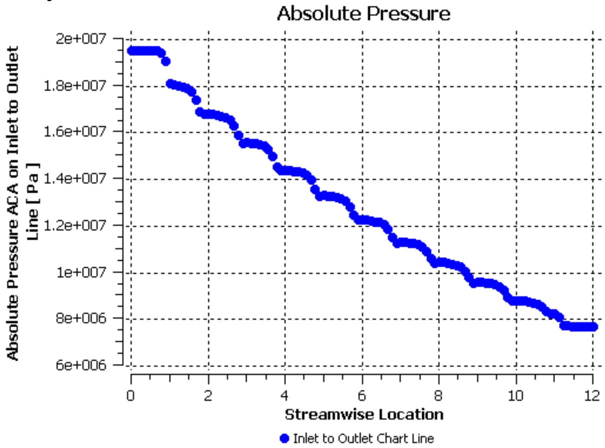

Fig 3. Absolute pressure for SCO_2 turbine.

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