Supercritical CO_2 Power Cycles Symposium

Theoretical study on windage loss characteristics of supercritical carbon dioxide in a rotating annular gap

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Introduction

Background:

In the realm of Supercritical Carbon Dioxide (S-CO2) rotary machinery, a shaft-type clearance is formed between the rotating rotor and stationary casing—a phenomenon prevalent in electric motors, compressors, and turbines. Due to its high density, the rotational flow of S-CO2 within such clearances results in significant windage loss, exerting a substantial impact on the performance of rotary machinery.

Objective:

This paper employs numerical simulation to theoretically investigate the aerodynamic drag characteristics induced by high-speed rotation of S-CO2 within shaft-type clearances. The flow field characteristics and influencing factors related to wind friction loss are analyzed.

Model and validation process

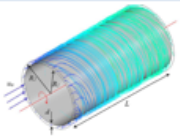


Fig. 1 Geometric model of TCP flow

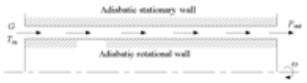


Fig. 2 Numerical simulation computing domain

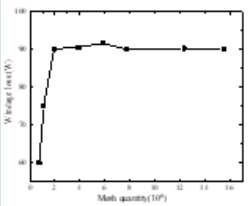


Fig. 3 Grid independence verification

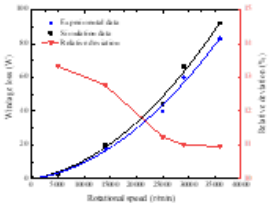


Fig. 4 Comparison between simulation results and experimental data

Results & Discussion

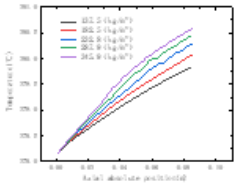


Fig.5 The temperature of the working fluid varies along the axial position at different densities

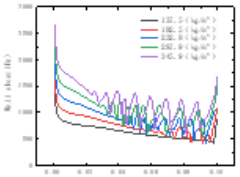


Fig.6 The wall shear varies along the axial position at different densities

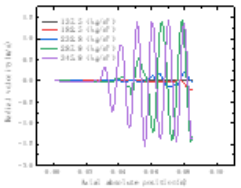


Fig.7 The radial velocity varies along the axial position at different densities

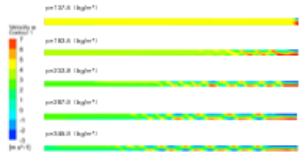


Fig.8 Axial velocity contour of an axial cross-section

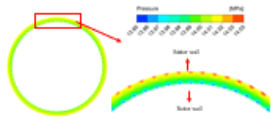
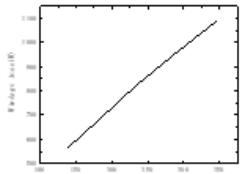
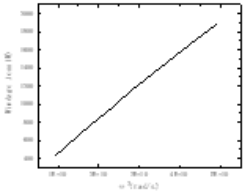


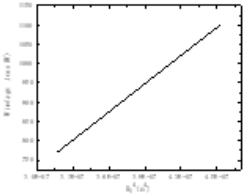
Fig.9 Pressure distribution in the tangential profile



(a) The effect of ρ on the windage loss



(b) The effect of ω^3 on the windage loss



(c) The effect of R_1^4 on the windage loss

Fig.10 Verification diagram of the applicability of the windage loss correlation formula

Main Conclusions

In summary, an increase in S-CO2 density results in increased wall shear force, leading to a rise in temperature. As density increases, the starting point of the radial velocity fluctuation is closer to the inlet position, aligning closely with the transition point of Taylor vortices. The basic correlation equation for windage loss is also applicable to TCP flow, though further research is needed to develop a more accurate empirical correlation for the friction coefficient.

Acknowledgements

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