EVALUATION OF SOME THERMAL POWER CYCLES FOR USE IN SPACE

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ABSTRACT Production of power in space for terrestrial use is of great interest in view of the rapidly rising power demand and its environmental impacts. Space also offers a very low temperature, making it a perfect heat sink for power plants, thus offering much higher efficiencies. This paper focuses on the evaluation and analysis of thermal Brayton, Ericsson and Rankine power cycles operating at space conditions on several appropriate working fluids. 1. Under the examined conditions, the thermal efficiency of Brayton cycles reaches 63%, Ericsson 74%, and Rankine 85%. These efficiencies are significantly higher than those for the computed or real terrestrial cycles: by up to 45% for the Brayton, and 17% for the Ericsson; remarkably 44% for the Rankine cycle even when compared with the best terrestrial combined cycles. From the considered working fluids, the diatomic gases (N_2 and H_2) produce somewhat better efficiencies than the monatomic ones in the Brayton and Rankine cycles, and somewhat lower efficiencies in the Ericsson cycle. The Rankine cycles require radiator areas that are larger by up to two orders of magnitude than those required for the Brayton and Ericsson cycles. The results of the analysis of the sensitivity of the cycle performance parameters to major parameters such as turbine inlet temperature and pressure ratio are presented, and the effects of the working fluid properties on cycle efficiency and on the power production per unit radiator area were explored to allow decisions on the optimal choice of working fluids.

Keywords: Power cycles, Space power, Space, Brayton cycle, Ericsson cycle, Rankine cycle

Nomenclature

A	Area [m^2]
a	Exergy [kJ/kg]
c	Speed of sound [m/s]
G	Mass flow rate [kg/s]
h_c	Convective heat transfer coefficient [W/m^2·K]
h_r	Radiative heat transfer coefficient [W/m^2·K]
k	Thermal conductivity constant [W/m·K]
Nu	Nusselt number
p	Pressure [bar]
Pr	Prandtl number
Q	Heat duty [kW]
Re	Reynolds number
R_t	Total thermal resistance [K/W]
s	Specific entropy [kJ/kg·K]
t	Radiator wall thickness [m]
T	Temperature [K]
TIT	Turbine inlet temperature [K]
U	Overall heat transfer coefficient [W/m^2·K]
W	Power output [kW]
w	Specific power output [kJ/kg]
Greek	
δ	Radiator flow gap [m]
ΔT_{lm}	Log mean temperature difference [K]
ϵ	Emittance
ε	Exergy efficiency
η_I	Thermal efficiency
π	Pressure ratio
σ_{sb}	Stefan-Boltzmann constant [5.67(10^8)

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	W/kg·K^4]
Ψ	Power produced per unit radiator area [kW/m^2]

Subscripts

in	Inlet
out	Outlet
H	High
L	Low
rad	Radiator
s	Space
t	Total
1..10	States on the cycle flow sheet