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Energetic and Exergetic Investigation of a N_2O Ejector Expansion Transcritical Refrigeration Cycle

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Abstract

Thermodynamic analysis of a transcritical N_2O ejector expansion refrigeration cycle is analysed. A two phase ejector, as an expansion device, is used in place of a conventional expansion valve. Effect of three performance parameters for cycle, namely COP, refrigerating effect, compressor work and two performance parameters of ejectors namely entrainment ratio and pressure recovery ratio are evaluated for various motive nozzle inlet conditions and evaporator temperatures. Further, both energetic and exergetic comparison of the proposed cycle is presented with respect to conventional CO_2 ejector expansion refrigeration cycle. The N_2O ejector expansion system is found to have higher COP, lower compressor discharge pressure and higher entrainment ratio but have disadvantage of lower volumetric cooling capacity. Maximum COP of N_2O ejector cycle is found to be about 10 % higher than maximum COP of CO_2 ejector cycle. Exergetic output of N_2O ejector cycle is higher whereas losses occurred due to irreversibility during expansion is lower.

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*Keywords:*COP; ejector; transcritical; refrigeration; N_2O; CO_2

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Nomenclature

amb	= ambient	c	= compressor
COP	= coefficient of performance	d	= diffuser
h	= specific enthalpy(kJ/kg)	eje	= ejector
I	= specific exergy (kJ/kg)	evap	= evaporator
P	= pressure	exp	= control valve
Q	= specific heat transfer rate (kJ/kg)	gc	= gas cooler
S	= specific entropy (kJ/kgK)	gco	= gas cooler outlet
T	= temperature	gen	= generation
U	= entrainment ratio	m	= motive nozzle
x	= vapour quality	mix	= mixing chamber
η	= efficiency (%)	ref	= refrigerated object
V	= velocity (m/sec)	rec	= recovery
VCC	= volumetric cooling capacity (kJ/m^3)	rev	= reversible
W	= specific work (kJ/kg)	s	= isentropic
Subscripts		suc	= suction
0	= reference environment	t	= total
1, 2, 3...	= cycle locations		

1. Introduction

A number of natural refrigerants are available for use in refrigeration and air conditioning applications. Advantage of natural refrigerants such as air, water, ammonia, carbon dioxide, nitrous oxide, isobutene, propane etc. are their zero ODP and low GWP and cost. CO_2 based systems have already gained reasonably good compliance in refrigeration applications in colder countries. Potentials of N_2O is yet to be fully explored. N_2O has similar properties as CO_2 in terms of molecular weight and critical temperature & pressure [1]. However, it is less favourable in terms of GWP compared to CO_2. Table 1 shows comparison of important properties of N_2O and CO_2 and inference about N_2O.

Table 1 Properties of Carbon dioxide and nitrous oxide and comparative inferences.

Properties	CO_2	N_2O	Inference about N_2O
Critical pressure (MPa)	7.377	7.245	Lower heat rejection pressure operation
Critical temperature (°C)	31.1	36.4	Moderately warm weather operation
Boiling point (°C)	-78.4	-88.47	Ensures single phase at evaporator exit.
Triple point temperature (°C)	-56.55	-90.82	Lower evaporator temperature operation
Toxicity (ppm)	5000	1000	Low toxicity
Molecular weight (kg/kmol)	44.01	44.013	-
GWP	1	240	Higher GWP
ODP	0	0	-
Latent heat of vaporization (kJ/kg)	574	374.28	Higher mass of refrigerant in evaporator

Sarkar and bhattacharya [2] presented a comparative study of transcritical N_2O refrigeration/heat pump cycle with transcritical CO_2 cycle. They concluded that N_2O cycles perform better and have lower high side pressure compared to CO_2 cycle. Further, Sarkar [3] proposed a transcritical N_2O refrigeration cycle with an internal heat exchanger and compared it with CO_2 transcritical cycle having same configuration. It was reported that use of IHX is comparatively less effective in N_2O cycle. The paper also attempted to optimize the high side pressure for N_2O transcritical cycle having IHX. Agrawal et. al. [4], introduced a novel two stage transcritical N_2O cycle and compared it with similar cycle configuration of CO_2. It was demonstrated that a two stage transcritical N_2O cycle exhibits higher performance and lower optimum compressor discharge pressure compared to a two stage CO_2