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ScienceDirect

Procedia Engineering 146 (2016) 400 – 409

Procedia Engineering

www.elsevier.com/locate/procedia

8th International Cold Climate HVAC 2015 Conference, CCHVAC 2015

Modeling and optimization of a hybrid-power gas engine-driven heat pump

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Abstract

Based on the coaxial HPGHP system experiments, the mathematical model of the various components of the coaxial HPGHP system is established to research the matching relations between the drive system and the load demand of the compressor. This paper establishes the thermal efficiency of the engine model based on load rate, to maintain the thermal efficiency always be above 0.25, combined with the thermal efficiency map of the engine, the best economic zone of engine operation is determined. Finally, Torque optimization model of the coaxial HPGHP system was proposed, the transmission ratio of the HPGHP system was optimized and mode control strategy of the coaxial HPGHP system was determined. Simulation results show the thermal efficiency of the HPGHP system can be always been guaranteed above 0.25 and the transmission ratios are respectively 2.9, 1.8 and 1.4 in three different load demand range.

Peer-review under responsibility of the organizing committee of CCHVAC 2015

Keywords: Energy management, HPGHP, SOC, transmission ratio, torque limits, control strategy

1. Introduction

Since the beginning of the 21st century, energy and the environment has become a national strategic issues remaining to be resolved. Natural gas, which is considered as a clean energy, will occupy an important part in the future energy structure. Development of distributed energy systems on natural gas will be a major trend in the future

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Peer-review under responsibility of the organizing committee of CCHVAC 2015
doi:10.1016/j.proeng.2016.06.421

of energy development. So development of natural gas as a new energy driving air conditioning equipment will be particularly important. The GHP system is a kind of system which can realize the different heating and cooling load demands through changing the operating conditions of the engine [1-2]. However, the engine will depart from the economic zone in the low- load operation, which leads to a decline in the thermal efficiency. In this paper, air Conditioning and Refrigeration Laboratory of Southeast University proposes a kind of the HPGHP system, which combines hybrid power technology with gas engine heat pump [3-7]. Through the rational allocation of torque, speed and power of engine and the motor, the engine can be remained in the economic zone. Li Yinglin proved that the thermal efficiency is 27%~37% higher than the conventional gas heat pump system [8]. Wang Yanwei put forward a kind of energy control strategy which was based on the minimum gas consumption rate [9]. Wang Jieyue carried out the simulation and optimization of the HPGHP system [10].

However, in order to ensure the HPGHP system runs in the economic area all the time and minimize the gas consumption rate and emission levels, in this paper, through the establishment of the comprehensive charging/discharging efficiency model of the HPGHP system, Finally, the transmission ratio of the HPGHP system is optimized and control strategy mode of the coaxial HPGHP system was determined.

Nomenclature

η_f	the thermal efficiency of the gas engine
T_f	the torque of the gas engine[Nm]
ω_f	the speed of the gas engine[rpm]
T_d	the torque of the motor[Nm]
ω_d	the speed of the motor[rpm]
ηd	the thermal efficiency of the motor
η_{dc}	the motor charging efficiency
η_{df}	the motor discharging efficiency
η_b	transmission efficiency[%]
η_n	inverter efficiency[%]
$\overline{\eta}$	average comprehensive efficiency[%]
Q_h	the heating capacity[KW]
Qc	the cooling capacity[KW]
ω	the speed of the compressor [rpm]

Subscripts

η	efficiency [%]
T	the torque [Nm]
ω	the speed[rpm]

Abbreviations

GHP	gas engine heat pump
HPGHP	hybrid-power gas engine heat pump
SOC	the state of charge

2. Principle of the coaxial parallel-type HPGHP system

As is showed in Fig.1,a coaxial parallel-type HPGHP system has two power sources:the engine and the motor.Both the engine and the motor can be run separately or together to drive the heat pump system.The motor which can be used as a generator or a electric motor can work together with the engine throttle opening,which can adjust the engine