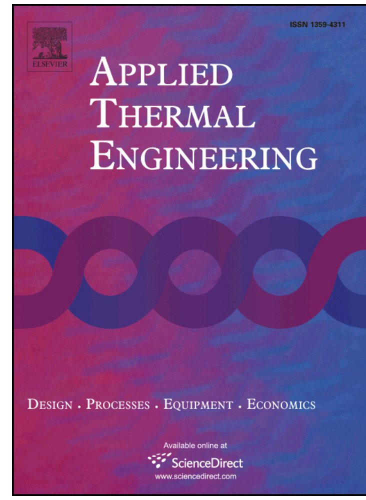
Accepted Manuscript



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PII: S1359-4311(16)32319-5
DOI: http://dx.doi.org/10.1016/j.applthermaleng.2016.10.062
Reference: ATE 9264

To appear in: *Applied Thermal Engineering*

Received Date: 30 March 2016
Revised Date: 30 September 2016
Accepted Date: 10 October 2016

Please cite this article as: B. Flannery, R. Lattin, O. Finckh, H. Berresheim, R.F.D. Monaghan, Development and experimental testing of a hybrid Stirling engine-adsorption chiller auxiliary power unit for heavy trucks, *Applied Thermal Engineering* (2016), doi: http://dx.doi.org/10.1016/j.applthermaleng.2016.10.062

Development and experimental testing of a hybrid Stirling engine-adsorption chiller auxiliary power unit for heavy trucks

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HIGHLIGHTS

- Free-piston Stirling engine for truck APU
- Waste heat driven adsorption chiller for cab air conditioning
- Reduced-order model comparing proposed system to existing technology
- Experimental test data from prototype test rig

ABSTRACT

This paper identifies the key technical requirements for a heavy truck auxiliary power unit (APU) and explores a potential alternative technology for use in a next-generation APU which could eliminate key problems related to emissions, noise and maintenance experienced today by conventional diesel engine-vapour compression APUs. The potential performance of a novel hybrid Stirling engine-adsorption chiller concept is investigated and benchmarked against the incumbent technology using a reduced-order model based on experimental data.

Experimental results from a Stirling-adsorption system (SAS) prototype test rig are also presented which highlight system integration dynamics and overall performance. The adsorption chiller achieved an average COP of 0.42±0.06 and 2.3±0.1 kW_t of cooling capacity at the baseline test condition. The prototype SAS test rig demonstrates that there appear to be no major technology barriers remaining that would prevent adoption of the SAS concept in a next-generation APU. Such a system could offer a reduction of exhaust emissions, greenhouse gases (GHG), ozone-depleting substances, noise, low maintenance and the potential for fuel flexibility and higher reliability. Preliminary modelling results indicate that the proposed system could offer superior overall electrical and cooling efficiencies compared to incumbent APUs and demonstrate a payback period of 4.6 years.

1. Introduction

It is estimated that 3.2% of global energy was consumed by heavy trucks in 2010 [1]. During mandated driver rest periods in the United States, truck drivers idle the main truck engine on average for 1860 hours per year, to provide for “hotel loads” [2]. Typically, the hotel load consists of a space heating load, cab air conditioning load and electrical power load for appliances such as refrigerators, cookers and electronic devices.

In many US states, idling has been heavily restricted through legislation because it is highly fuel inefficient, polluting and adds significant unnecessary wear to the main truck engine [3]. To avoid idling the main engine, a smaller, more suitably sized diesel engine and vapour compression (DEVC) air conditioning system is used instead. Such systems are collectively known as an auxiliary power units (APU). However, these systems face difficulties of their own.

Diesel engine combustion is intrinsically noisy and produces relatively high levels of unwanted emissions such as diesel particulates, carbon monoxide (CO) and oxides of nitrogen (NO_x). Government bodies, such as the California Air Resources Board, regulates these emissions and requires that all diesel engine APUs incorporate expensive exhaust after-treatment systems such as diesel particulate filters [4]. The cost of these aftermarket components is significant and can be up to 30% of the total APU cost DEVC APUs also use environmentally damaging hydrofluorocarbons (HFCs) such as R-134a as refrigerants in the air conditioning subsystem. The long-term viability