Дзюбенко Александр Андреевич – канд. техн. наук, доц., доц. кафедры автомобильной электроники Харьковского национального автомобильно-дорожного университета, Харьков, Украина, e-mail: sashastar82@mail.ru

Липинский Михаил Сергеевич – асистент кафедры двигателей внутреннего сгорания Харьковского национального автомобильно-дорожного университета, Харьков, Украина, e-mail: mehani_k@mail.ru

Кузьменко Анатолий Петрович – канд. техн. наук., ас. кафедры двигателей внутреннего сгорания Харьковского национального автомобильно-дорожного университета, Харьков, Украина, e-mail: kuzmatolja@mail.ru

Подлещук Сергей Олегович – аспирант кафедры двигателей внутреннего сгорания Харьковского национального автомобильно-дорожного университета, Харьков, Украина, e-mail: podluy23@rambler.ru

ВИЗНАЧЕННЯ ЦИКЛОВОЇ ПОДАЧІ ГАЗОВОГО ДВИГУНА З ЕЛЕКТРОННИМ КЕРУВАННЯМ ПАЛИВОПОДАЧІ

О.М. Врублевський, О.А. Дзюбенко, М.С. Липинський, А.П. Кузьменко, С.О. Подлещук

В роботі наведено методику визначення циклової подачі паливоподавальної апаратури з електронним керуванням, яка базується на використанні сигналів системи керування та термодинамічної теорії витікання газів. Точність розрахунку циклової подачі, що забезпечується використанням наведеної методики не перевищує 5 %.

DETERMINATION OF FLOW RATE IN GAS ENGINE WITH ELECTRONIC CONTROL OF FUEL DELIVERY SYSTEM

A. Vrublevskiy, A. Dzyubenko, M. Lipinskiy, A. Kuzmenko, S. Podleschuk

In this paper shows a method of determining the cyclic flow of fuel equipment with electronic control based on the use of the control system and the thermodynamic theory escape of gases. Ensures accuracy of determining the cyclic flow using the proposed method does not exceed 5%.

УДК 621.43.06:534.83

A. Marchenko, D. Samoilenko, Ali Adel Hamzah, Omar Adel Hamzah

WASTE HEAT RECOVERY SYSTEMS FOR INTERNAL COMBUSTION ENGINES: CLASSIFICATION AND BENEFITS

Recent trend about the best ways of using the deployable sources of energy in to useful work in order to reduce the rate of consumption of fossil fuel as well as pollution. Out of all the available sources, the internal combustion engines are the major consumer of fossil fuel around the globe. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems, resulting in to entropy rise and serious environmental pollution, so it is required to utilized waste heat into useful work. The recovery and utilization of waste heat not only conserves fuel, usually fossil fuel but also reduces the amount of waste heat and greenhouse gases damped to environment. It is imperative that serious and concrete effort should be launched for conserving this energy through exhaust heat recovery techniques. Such a waste heat recovery would ultimately reduce the overall energy requirement and also the impact on global warming.

Introduction

Presently, high fuel costs and concerns about foreign oil dependence have resulted in increasingly complex engine designs to decrease fuel consumption. For example, engine manufacturers have implemented techniques such as enhanced fuel-air mixing, turbocharging, and variable valve timing in order to increase thermal efficiency. However, around 60-70% of the fuel energy is still lost as waste heat through the coolant or the exhaust. On the other hand, legislation of exhaust emission levels has focused on carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM).

Energy conservation on engine is one of best ways to deal with these problems since it can improve the energy utilization efficiency of engine and reduces emissions [1] . Given the importance of increasing energy conversion efficiency for reducing both the fuel consumption and emissions of engine, scientists and engineers have done lots of successful research aimed to improve engine thermal efficiency, including supercharge, lean mixture combustion, etc.

However, in all the energy saving technologies studied. Engine exhaust heat recovery is considered to be one of the most effective. Many researchers recognize that Waste Heat Recovery from engine exhaust has the potential to decrease fuel consumption without increasing emissions, and recent technological advancements have made these systems viable and cost effective [2].

Possibility of heat recovery and availability from I.C. Engine

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then “dumped” into the environment even though it could still be reused for some useful and economic purpose. This heat depends in part on the temperature of the waste heat gases and mass flow rate of exhaust gas. Waste heat losses arise both from equipment inefficiencies and from thermodynamic limitations on equipment and processes. For example, consider internal combustion engine approximately 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems [3]. It means approximately 60 to 70% energy losses as a waste heat through exhaust (30% as engine cooling system and 30 to 40% as environment through exhaust gas). Total energy distributions from internal combustion engine is shown on Fig. 1

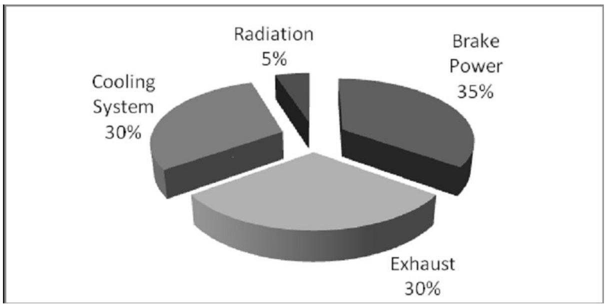

Fig. 1 Total energy distributions from internal combustion engine

Exhaust gases immediately leaving the engine can have temperatures as high as 450-600°C. Consequently, these gases have high heat content, carrying away as exhaust emission. Efforts can be made to design more energy efficient reverberatory engine with better heat transfer and lower exhaust temperatures; however, the laws of thermodynamics place a lower limit on the temperature of exhaust gases [4].

Benefits of 'waste heat recovery' can be broadly classified in two categories

1. Direct Benefits:

Recovery of waste heat has a direct effect on the combustion process efficiency. This is reflected by reduction in the utility consumption and process cost.

2. Indirect Benefits:

a) Reduction in pollution: A number of toxic combustible wastes such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM) etc, releasing to atmosphere. Recovering of heat reduces the environmental pollution levels.

b) Reduction in equipment sizes: Waste heat recovery reduces the fuel consumption, which leads to reduction in the flue gas produced. This results in reduction in equipment sizes.

c) Reduction in auxiliary energy consumption: Reduction in equipment sizes gives additional benefits in the form of reduction in auxiliary energy consumption [5].

Diesel engines

In general, diesel engines have an efficiency of about 35% and thus the rest of the input energy is wasted. Despite recent improvements of diesel engine efficiency, a considerable amount of energy is still expelled to the ambient with the exhaust gas. In a water-cooled engine about 35 kW and 30-40% of the input energy is wasted in the coolant and exhaust gases respectively.

The amount of such loss, recoverable at least partly, greatly depends on the engine load [6]. The wasted energy represents about two-thirds of the input energy and for the sake of a better fuel economy, exhaust gas from Internal Combustion engines can provide an important heat source that may be used in a number of ways to provide additional power and improve overall engine efficiency. These technical possibilities are currently under investigation by research institutes and engine manufacturers. For the heavy duty diesel engines, one of the most promising technical solutions for exhaust gas waste heat utilization appears to be the use of a useful work.

Availability of Waste Heat from I.C. Engine the quantity of waste heat contained in a exhaust gas is a function of both the temperature and the mass flow rate of the exhaust gas:

$$\dot{Q} = \dot{m} \times C_p \times \Delta T$$

Where, Q is the heat loss (kJ/min); m is the exhaust gas mass flow rate (kg/min); Cp is the specific heat of exhaust gas (kJ/kg°K); and ΔT is temperature gradient in °K. In order to enable heat transfer and recovery, it is necessary that the waste heat source temperature is higher than the heat sink temperature. Moreover, the magnitude of the temperature difference between the heat source and sink is an important determinant of waste heats utility or "quality".

The source and sink temperature difference influences the rate at which heat is transferred per unit surface area of recovery system, and the maximum theoretical efficiency of converting thermal from the heat source to another form of energy (i.e., mechanical or electrical). Finally, the temperature range has important function for the selection of waste heat recovery system designs [7-8].

Heat recovery sytem for engine

Large quantity of hot flue gases is generated from internal combustion engine etc. If same of this waste heat could be recovered, a considerable amount of primary fuel could be saved. It is depends upon mass flow rate of exhaust gas and temperature of exhaust gas. The internal combustion engine energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and losses be minimized by adopting certain measures. There are different methods of the exhaust gas heat recovery namely for space heating, refrigeration and power generation. The mass flow rate of exhaust gas is the function of the engine size and speed, hence larger the engine size and higher the speed the exhaust gas heat is larger. So heat recovery system will be beneficial to the large engines comparatively to smaller engines. The heat recovery from exhaust gas and conversion in to mechanical power is possible with the help of Rankine, Stirling and Brayton thermodynamic cycles, vapour absorption cycle.

These cycles are proved for low temperature heat conversion in to the useful power. Engine exhaust heat recovery is considered to be one of the most effective means and it has become a research hotspot recently.

For example, Doyle and Patel [9] have designed a device for recovering exhaust gas heat based on Rankine cycle on a truck engine. The commissioning experiment of 450 kilometers showed that this device could save fuel consumption by 12,5%. Cummins Company has also done some research on waste heat recovery on truck engines, and the results showed that engine thermal efficiency could improve by 5,4% through exhaust heat recovery. James C. Conklin and James P. Szybist [10] have designed a six-stroke internal combustion engine cycle with water injection for in-cylinder exhaust heat recovery which has the potential to significantly improve the engine efficiency and fuel economy. R. Saidur et al [11] Rankine bottoming cycle technique to maximize energy efficiency, reduce fuel consumption and green house gas emissions.

Recovering engine waste heat can be achieved via numerous methods. The heat can either be reused within the same process or transferred to another thermal, electrical, or mechanical process.

Waste heat can be utilized for some useful works and it is reduces pollution. The diesel engine exhaust gas waste heat recovery rate increase with increasing diesel engine exhaust gas emission rate.

The increasing fuel costs and diminishing petroleum supplies are forcing governments and industries to increase the power efficiency of engines. A cursory look at the internal combustion engine heat balance indicates that the input energy is divided into roughly three equal parts: energy converted to useful work, energy transferred to coolant and energy lost with the exhaust gases. There are several technologies for recovering this energy on a internal combustion engine, where as the dominating ones are: Waste heat can utilized for heating purpose, power generation purpose, refrigeration purpose, etc.

A Using of exhaust gas. Heating Purpose

Waste heat can be utilized for the heating purpose like space heating, Preheating intake air and fuel, dryer etc. Typical examples of use would be preheating of combustion air, space heating, or pre-heating boiler feed water or process water etc. waste heat recovery system can utilized for pre heating intake air and intake fuel [12].

Heat energy is recovered from the exhaust gases, which causes lower heat addition, thus improving engine thermal efficiency. Low grade fuel, such as, kerosene can be used in diesel engine by blending with conventional diesel fuel. Using the air preheating system and 10% kerosene blend as fuel, the thermal efficiency is improved and exhaust emissions (NOx and CO) is reduced as compared to neat diesel fuel without using air preheating system [13]. The general view of heat recovery system is shown on Fig.2.

Waste heat recovery is useful for preheating alternative fuel so reduce viscosity of fuel, better fuel atomization and low volatility of fuel.

B Using of exhaust gas. Power Generation Purpose

Waste heat can also be utilized indirectly for the power generation using rankine cycle. Bryton cycle, Stirling cycle and directly used for thermoelectric generator etc

Generating power from waste heat typically involves waste heat utilization from internal combustion engine to generate mechanical energy that drives an electric generator. Electricity generation is directly from heat source such as thermoelectric and piezoelectric generator. A factor that affects on power generation is thermodynamic limitations for different temperature range.. The efficiency of power generation is heavily depended on the temperature of the waste heat gas and mass flow rate of exhaust gas.

Thermoelectric generation

The exhaust pipe contains a block with thermo electric materials that generates a direct current, thus providing for at least some of the electric power requirements. In which two different semiconductors are subjected to a heat source and heat sink. A voltage is created between two conductors. It is based on the seeback effect. The Cooling and Heating is done by applying electricity. It is low efficiency approximately (2 to 5%) and high cost.

Thermoelectric generator and its components. Thermoelectric devices may potentially produce twice the efficiency as compared to other technologies in the current market [14]. Thermo Electric Generator is used to convert thermal energy from different temperature gradients existing between hot and cold ends of a semiconductor into electric energy. This phenomenon was discovered by Thomas Johann Seebeck in1821and called the „Seebeckeffect".

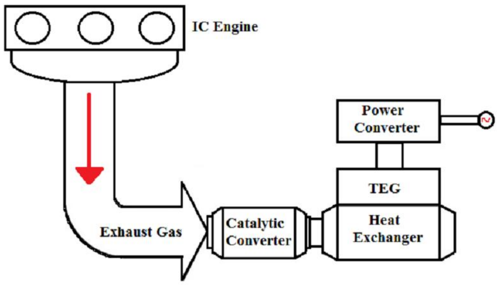

Fig. 2 Thermoelectric Generator

The device offers the conversion of thermal energy into electric current in a simple and reliable way. Advantages of Thermo Electric Generator include free maintenance, silent operation, high reliability and involving no moving and complex mechanical parts. Recycling and reusing waste exhaust gas can not only enhance fuel energy use efficiency, but also reduce air pollution [15].

Thermal power technology such as the Thermo Electric Generator arises, therefore, significant attention worldwide. Thermo Electric Generator is a technology for directly converting thermal energy into electrical energy. It has no moving parts, is compact, quiet, highly reliable and environmentally friendly. Because of these merits, it is presently becoming a noticeable research direction. The mathematical model of a Thermoelectric Generator device using the exhaust gas of vehicles as heat source, and preliminary analysis of the impact of relevant factors on the output power and efficiency of Thermo Electric Generator

1.2 Piezoelectric Generation

It is used for low temperature range of 100 to 150 C. Piezoelectric devices convert mechanical energy in the form of ambient vibration to electric energy. This is thin film membrane can take advantage of oscillatory gas expansion to create a voltage output.

Conclusion

It has been identified that there are large potentials of energy savings through the use of waste heat recovery technologies. Waste heat recovery defines capturing and reusing the waste heat from internal combustion engine for heating, generating mechanical or electrical work and refrigeration system.

The waste heat recovery from exhaust gas and conversion in to mechanical power is possible with the help of Rankine, Stirling and Brayton thermodynamic cycles, vapour absorption. For waste heat recovery thermoelectric generator is use low heat, which has low efficiency. It is helpful for the same amount of increases in thermal efficiency and reduction in emission.

New regulations and standards for noise emission increasingly make the automotive improvements about decreasing the engine noise. Considering the cost and the volume of the muffler in the vehicle, the aim is to develop smaller and more compact designs without any loss from the back pressure in muffler. Proposed new designs should be analyzed with respect to both acoustics and back pressure. In this study, a new design reactive perforated muffler is investigated. The present new design muffler was analyzed to obtain minimal back pressure affects for the engine. Back pressure values from numerical analysis were calculated. It was established that new design muffler has less back pressure effect for the engine. The difference between total pressure drops is 686 Pa which is essential. Next step for investigation should include simulation of acoustic effects and temperature fields in the muffler units for new design muffler.

Bibliography:

1. Nantha Gopal K. Thermodynamic analysis of a diesel engine integrated with a PCM based energy storage system / K. Nantha Gopal, Rayapati Subbarao, V. Pandiyarajan, R. // Velraj International Journal of Thermodynamics. – 2010. – №13 (1). P. 15-21. 2. Hakan Özcan Thermal balance of a LPG fuelled, four stroke SI engine with water addition / Hakan Özcan, M.S. Söylemez // Energy Conversion and Management. – 2006. – № 47 (5). –570-581. 3. Sathiamurthi P. Design and Development of Waste Heat Recovery System for air Conditioning / P. Sathiamurthi // Unit European Journal of Scientific Research. – 2011. – Vol.54 No.1. – P.102-110. 4. Karellasa S. Energetic And Exergetic Analysis Of Waste Heat Recovery Systems In The Cement Industry / S. Karellasa, A.-D. Leontaritisa, G. Panousisa , E. Bellos A, E. Kakaras // Proceedings of ECOS 2012 - The 25th International Conference On Efficiency, Cost, Optimization, Simulation And Environmental Impact Of Energy Systems: June 26-29: Perugia, Italy, 2012. 5. Teng H. Waste Heat Recovery of Heavy-Duty Diesel Engines by Organic Rankine Cycle Part I: Hybrid Energy System of Diesel and Rankine Engines / H. Teng, G. Regner, C. Cowland // SAE Int. Publication. 2007. –№ 2007-01-0537. 6. Hatazawa M. Performance of a thermo acoustic sound wave generator driven with waste heat of automobile gasoline engine / M. Hatazawa // Transactions of the Japan Society of Mechanical Engineers. – 2004. –№ 70 (689). Part B. – P. 292–299. 7. Heywood John B. Internal Combustion Engine Fundamental / John B. Heywood // Tata McGraw Hill Education Private Limited, Edition. – 2011. – P. 249-250. 8. Ganeshan V. Internal Combustion Engine / V Ganeshan // Tata McGraw Hill Publishing Company Limited, Second Edition. – pp 35. – P. 606-670. 9. Doyle E.F. Compounding the truck diesel engine with an organic rankine cycle system / E.F. Doyle, P.S. Patel // Society of Automotive Engineers (SAE). – 1976. –№760343. 10. Conklin C. James. A highly efficient six-stroke internal combustion engine cycle with water injection for in-cylinder exhaust heat recovery / C. James Conklin, P. James Szybist // Energy. – 2010. – № 35 (4). – P. 1658-1664. 11. Saidur R. Technologies to recover exhaust heat from internal combustion en-

gines / R. Saidur, M.Rezaei, W.K.Muzammil, M.H.Hassan, S.Paria, M.Hasanuzzaman // Renewable and Sustainable Energy Reviews. – 2012. – №16. –P. 5649–5659. 12. Mhia Md. Zaglul Shahadat. Diesel Nox Reduction By Preheating Inlet Air / Mhia Md. Zaglul Shahadat, Md. Nurun Nabi And Md. Shamim Akhter // Proceedings Of The International Conference On Mechanical Engineering, 2005. 13. Karaosmanoglu F.Vegetable oil fuels: a review / F. Karaosmanoglu // Energy Sources. – 1999. – №21. P. 221–231. 14. Zhang X. An automotive thermoelectric–photovoltaic hybrid energy system using maximum power point tracking / X. Zhang // Energy Conversion and Management. – 2011. – 52(1). P. 641–7. 15. Vazquez J. State of the art of thermoelectric generators based on heat recovered from the exhaust gases of automobiles / J. Vazquez, Bobi M. Sanz-, R.Palacios // In: Proceedings of the seventh European workshop on thermoelectrics, 2002.

Поступила в редакцию 21.07.2014

Марченко Андрей Петрович – доктор техн. наук, профессор, заведующий кафедрой двигателей внутреннего сгорания Национального технического университета “Харьковский политехнический институт”, Харьков, Украина, e-mail: dvs@kpi.kharkov.ua

Али Адель Хамза - аспирант кафедры двигателей внутреннего сгорания Национального технического университета “Харьковский политехнический институт”, Харьков, Украина, e-mail: dvs@kpi.kharkov.ua

Омар Адель Хамза - аспирант кафедры двигателей внутреннего сгорания Национального технического университета “Харьковский политехнический институт”, Харьков, Украина, e-mail: dvs@kpi.kharkov.ua

Самойленко Дмитрий Евгеньевич – канд. техн. наук, старший научный сотрудник кафедры двигателей внутреннего сгорания Национального технического университета “Харьковский политехнический институт”, Харьков, Украина, e-mail: dvs@kpi.kharkov.ua

СИСТЕМИ УТИЛІЗАЦІЇ ЕНЕРГІЇ ВІДПРАЦЬОВАНИХ ГАЗІВ ДВС: КЛАСИФІКАЦІЯ І ПЕРЕВАГИ

А.П. Марченко, Д.Є. Самойленко, Алі Адель Хамза, Омар Адель Хамза

Серед енергетичних установок, представлених у світі, ДВЗ є основним споживачем викопних палив. Теплота і енергія відпрацьованих газів ДВЗ, а також теплота, відведена з охолоджувальною рідиною призводять до зростання ентропії і забруднень навколишнього середовища. Використання цієї теплоти для отримання корисної роботи - один із шляхів зниження навантаження на навколишнє середовище. Розглянуто основні методи утилізації вторинної теплоти ДВЗ. Виконана їх класифікація та оцінка ефективності.

СИСТЕМЫ УТИЛИЗАЦИИ ЭНЕРГИИ ОТРАБОТАВШИХ ГАЗОВ ДВС: КЛАССИФИКАЦИЯ И ПРЕИМУЩЕСТВА

А.П. Марченко, Д.Е. Самойленко, Али Адель Хамза, Омар Адель Хамза

Среди энергетических установок, представленных в мире, ДВС является основным потребителем ископаемых топлив. Теплота и энергия отработавших газов ДВС, а также теплота, отводимая с охлаждающей жидкостью приводят к росту энтропии и загрязнениям окружающей среды. Использование этой теплоты для получения полезной работы – один из путей снижения нагрузки на окружающую среду. Рассмотрены основные методы утилизации вторичной теплоты ДВС. Выполнена их классификация и оценка эффективности.

УДК 621.43

Д.В. Мешков

ВЫБОР ИСХОДНЫХ ДАННЫХ ПРИ РАСЧЕТЕ ПОГРЕШНОСТИ ИНДИЦИРОВАНИЯ ДВС

Рассмотрен выбор и обоснования исходных данных при расчете термодинамической погрешности при индицировании ДВС исследовательскими комплексами с использованием пьезокерамического датчика давления. Даны рекомендации относительно выбора значений, предложены пути совершенствования метода расчета термодинамической погрешности.

Введение

При индицировании ДВС современными исследовательскими комплексами с пьезокерамическим датчиком давления необходимо учитывать термодинамическую погрешность. Методика расчета погрешности подробно рассмотрена в [1, 2]. Анализ показывает, что существуют различные точки зрения на методику учета данной погрешности, которые отличаются методом выбора исходных данных и глубиной усреднения итоговой индикаторной диаграммы.

Формулирование проблемы

Методика расчета термодинамической погрешности представлена в [1, 2]. В соответствии с данной методикой исходными данными являются: P_{1mess}, P_{2mess} – измеренное давление; $V_{1,2}$ – объем