

Experimental Analysis of Thermoelectric Waste Heat Recovery System Retrofitted to Two Stroke Petrol Engine

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Abstract

The efficiency of the thermal power plants is only around 35% and the remaining 50 - 55% of energy is lost due to many losses. The major source of loss in the conversion process is the heat rejected to the surroundings due to the many inherent constraints. Also further losses of around 10-15% are associated with the transmission and distribution of electricity in the electrical grid. Therefore, the energy saving is one of the key issues, not only from the view point of fuel consumption but also for the protection of environment. So, it is imperative that significant efforts have been made for conserving the energy by recovering the heat dissipated to the atmosphere. The main objective of this paper is to study and analyse the feasibility of retrofitting the waste heat recovery system to a two stroke petrol engine. Finally, the potential of recovery of waste heat as a renewable energy source is assessed.

Keywords: Combined heat and power generation, petrol engines, waste heat recovery, retrofitting.

1. Introduction

Industrial waste heat refers to the energy that is generated in industrial processes without being used for the practical use. The sources of waste heat include hot combustion gases discharged to the atmosphere, heated products in exiting industrial processes, and heat transfer from hot equipment surfaces. It is estimated that

approximately 20 to 50% of heat as waste heat in the industrial process. While some waste heat losses from industrial processes are inevitable, facilities can reduce these losses by improving the equipment efficiency or installing waste heat recovery systems. The waste heat recovery entails capturing and reutilizing the waste heat in the industrial processes for heating and/or for generating mechanical or electrical work.

Many heat recovery technologies reduce the operating costs are already well developed and technically proven; however, there are numerous applications where heat is not recovered due to market and technical constraints. A comprehensive investigation of waste heat losses, recovery practices, and constraints is required in order to identify the heat recovery opportunities and technology needs.

Cogeneration is on-site generation and utilisation of energy in different forms simultaneously by utilising the fuel energy at optimum efficiency in a cost-effective and environmentally safe. There are many types of cogeneration systems and almost all the types primarily generate electricity along with making the use of heat. The most prevalent example of cogeneration is the generation of electric power and heat. The heat may be used for generating steam, hot water, or for cooling through absorption chillers.

It is very important to consider many aspects at the design stage of cogeneration system by the industry, to provide and maintain the optimum performance. The cogeneration system suitable to one industry may not be suitable for some other industry, though both would be manufacturing the same product. The selection of appropriate cogeneration technology would enhance the economic benefits of any industry and provide reliable energy and improve environmental performance. The feasibility study at conceptual stage is required for designing of a better cogeneration system. Typical sources of waste heat and recovery options are listed in Table 1.

A proper selection of a cogeneration system configuration, from a few basic system configurations described below, makes it feasible to produce electrical energy and/or thermal energy.

1. Steam turbine based cogeneration system
2. Gas turbine based cogeneration system
3. Combined steam/gas turbine based cogeneration system
4. Reciprocating engine based cogeneration system

Most widely used cogeneration systems in the chemical process plants are based on steam turbine, gas turbine or combined steam/gas turbine configurations with installations based on reciprocating engine configuration. These configurations are widely accepted by the industries due to their proven track record and easy commercial availability of required equipment.

The heat dissipated to the atmosphere, can either be "reused" within the same process or transferred to another process. There are many ways of reusing the heat within the process; for example the flue gases can be used to preheat the combustion air or feed water in industrial boilers. Alternately, the heat can be transferred to another process; for example, a heat exchanger could be used to transfer heat from combustion

exhaust gases to hot air needed for a drying oven. Such methods for recovering waste heat can help facilities significantly reduce the consumption of fossil fuel, as well as reduce operating costs and pollutant emissions.

Table 1: Examples of waste heat sources and end uses.

Waste Heat Sources	Uses for Waste Heat
Combustion Exhausts: <ul style="list-style-type: none"> • Glass melting furnace • Cement kiln Fume incinerator • Aluminum reverberatory furnace Boiler Process off gases: <ol style="list-style-type: none"> 1. Steel electric arc furnace and aluminum reverberatory furnace 2. Cooling water from: 3. Furnaces, air compressors, IC engines 4. Conductive, convective, and radiative losses from heated products: <ul style="list-style-type: none"> • Hot cokes and blast furnace slag 	Combustion air preheating Boiler feed water preheating Load preheating Power generation Steam generation for use in: <ol style="list-style-type: none"> 1. Power generation 2. Mechanical power 3. Process steam Space heating Water preheating Transfer to liquid or gaseous process streams

2. Literature Survey

The utilization of waste heat energy from exhaust gas in IC engines is another novel application of electricity generation using thermoelectric power generators. Basel I et.al. (2009) have analysed the thermoelectric power generation with waste heat recovery system and concluded that such systems would be promising solution to the environmental issues with many advantages. Hou Xuejun and Xiao Peng (2012) have analyzed and evaluated the parameters such as diesel exhaust emission rates and diesel exhaust waste heat rates. J. S. Jadhao, D. G. Thombare (2013) have reviewed the technology of exhaust gas heat recovery for I.C. engine and concluded that such system would provide the opportunity to enhance the thermal efficiency of I.C. engines. Janak Rathavi et. al. (2012) have carried out the experimental study of waste heat recovery technique and observed that such systems increase the efficiency and reduce the emissions. S. R. Jumade, V. W. Khond (2012) have carried out a survey on waste heat recovery from internal combustion engine using thermoelectric technology and concluded that the use of copper for the support structure would provide better results. Marian, et. al. (2013) have investigated the possibility of using thermo-electric power to convert flue gas waste heat from a small-scale domestic pellet boiler and concluded that the heat lasses from the flue gases is reduced. Mohd.Izam Abd Jalil and Jahariah Sampe (2013) have carried out the experimental investigation of the thermoelectric generator modules with different techniques of cooling system and proposed that the water based cooling system would provide better performance. Saidur et. al. (2012) have studied the different technologies to recover the heat wasted

from the exhaust gas of IC engines and concluded that there is a huge potential for extracting the waste heat from the exhaust gas of IC engines.

3. Experimental Setup

The waste heat recovery system consists of (i) two stroke petrol engine, (ii) gas turbine, (iii) dynamo, (iv) battery, (v) inverter and (vi) thermoelectric generator.

3.1 Two stroke petrol engine

The specification of the two stroke petrol engine is shown in the Table 2.



Fig. 1: Experimental setup

Table 2: Specification of the two stroke petrol.

Engine Type	Two Stroke Petrol Engine
Bore/Stroke	50 × 50 mm
Piston Displacement and Compression Ratio	98.2 cm ³ and 6.6:1 respectively
Maximum Torque and Power	9.614 N-m at 5,500rpm and 7.5 ps at 5,800 rpm respectively

3.2 Batteries

In an isolated system, batteries are used for storage of excess energy converted into electrical energy. It is necessary that the overall system be optimized with respect to available energy and local demand pattern. Li-ion batteries are used in the system for energy storage.

3.3 Inverter

An inverter has been used to convert the DC power into AC power.

3.4 TE-Generator

TEGs are made from thermoelectric modules which are solid-state integrated circuits that employ three established thermoelectric effects known as the Peltier, Seebeck and Thomson effects. Their construction consists of pairs of p-type and n-type semiconductor materials forming a thermocouple. These thermocouples are then connected electrically forming an array of multiple thermocouples called as thermopile. They are then sandwiched between two thin ceramic wafers. When heat and cold are applied this device then generates electricity.

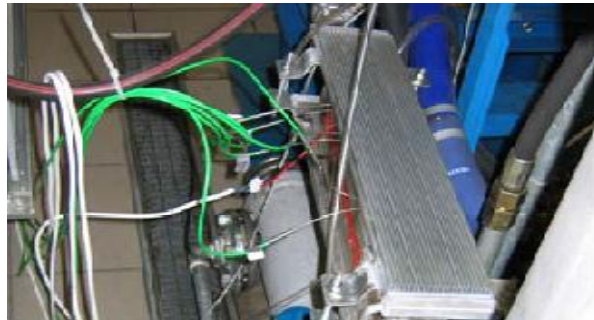


Fig. 2: Thermoelectric generator mounted on exhaust system.

4. results and Discussion

The waste heat recovery is done using the velocity and the temperature on the surface of the primary exhaust pipe. The power is generated instantaneously since the turbine and the generator are coupled together. In accordance with throttle input, the velocity of exhaust gases varies directly. This energy is used to run the turbine and the output is measured and tabulated in Table 3.

Table 3: Experimental Results.

S. No.	V (Volts)	I (Amps)	Power (Watts)	Speed rpm
1	0.80	0.47	0.376	46
2	1	0.5	0.5	50
3	0.16	0.68	1.09	315
4	3.5	0.7	2.45	435
5	3	0.8	2.4	470
6	4	0.9	3.6	700
7	4.6	1.1	4.76	900

5. Conclusion

The combined heat and power system offers additional benefits like reduction in the emission of carbon dioxide (CO₂), sulphur dioxide (SO₂) and oxides of nitrogen (NO_x) for the same power and heat generation. This is achieved by using the waste heat

recovery system and can be installed on any equipment which generates heat and needs heat dissipation to reduce the pollution during the operation of machines in addition to the auxiliary power generation. This auxiliary power can be utilized for the operation of main mechanism. The efficiency of the equipment increases considerably since the waste heat is being utilized for the useful work. This system reduces the cost of operation by reducing the consumption of fuel. The size of all the flue gas handling equipment such as fans, stacks, ducts, burners, etc., is reduced. The consumption of auxiliary power is also reduced since the reduction in size of all the auxiliary equipment.

The experimental performance testing has shown that the overall efficiency of two stroke petrol engine installed with and without the waste heat recovery system is 29.67% and 29.2% respectively when the power extraction was 90W. It is also observed that the consumption of fuel decreased by 4%. This experimental study has revealed that the use of waste heat recovery system is more efficient for extracting the energy wasted in various process industries.

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