Rotor Waste Energy Recovery Device from I. C. Engine Exhaust

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Abstract: Due to the current globalization in the present world there is a need to utilize the waste energy and heat which is being exposed to atmosphere from the exhaust of automobiles, industries, power plants etc. The energy which is being wasted can be recovered by waste energy recovery systems. This may vary according to applications. Recovery systems largely depend upon exhaust gas temperatures. The Rotor Engine heat should be recovered so that it can be efficiently used, for other purposes. There is an element which can store the sensible heat and waste energy, and then recovered waste energy can be used for specific applications.

Rotary air-to-air energy recovery system (also called Rotor Engine) transfer heat between supply and exhaust airstreams in an I.C Engine waste, thermal power stations and other various applications. Heat is which is generated in a process by way of fuel combustion, and then "dumped" into the environment even if it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved.

Large quantities of hot flue gases are generated from Boilers, I.C.Engines, and thermal power station. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and loss minimized.

Key words: I.C engine exhaust energy, Waste energy recovery device and system, Performance of waste energy recovery device.

INTRODUCTION

The basic purpose of the project is to make use of energy of exhaust gases that are produce from the combustion of fuel in the engine. In an internal combustion engine fuel in the presence of air burns from which various gases produce. These gases are thrown out in the atmosphere from the engine through an exhaust pipe with a certain velocity. With the help of a proper arrangement at the exhaust pipe we can make use of these exhaust gases which can be used in many ways.

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LITERATURE SURVEY

In ICE, the chemical energy of the fuel is converted into heat energy through combustion [1]. Via the thermodynamic cycle, some heat energy is converted into effective work to drive the vehicle [2, 3]. The remaining energy is released into the environment in the form of waste heat generated from cooling water and exhaust gas. Except for the waste heat that has to be released into the environment, according to the second law of thermodynamics, the rest can theoretically be utilized. If the waste heat of ICE can be recovered, the engine efficiency will be improved [4].

WASTE HEAT RECOVERY SYSTEM

A **waste heat recovery unit** (WHRU) is an energy recovery heat exchanger that recovers heat from hot streams with potential high energy content, such as hot flue gases from a diesel generator or air from cooling towers or even waste water from different cooling processes such as in steel cooling [5, 6].

Exhaust gas turbocharger is a technology widely used for recovering the heat of exhaust gas. Due to the characteristics of energy transfer between the ICE and the turbocharger, there are constraints for the turbo-charged ICE which can cause inconvenience [7].

Besides the turbocharger, there are two additional processes to recover the waste heat of exhaust gas: electricity generation using the temperature difference of the waste heat [8], and the heating and absorption refrigeration using the waste heat [9, 10]. However, there are some disadvantages in these two processes. The energy conversion efficiency is very low with electricity generation technology. The heating device cannot be used when the engine is powered off, and there are special requirements for the heat exchange component when the heating device is used in a high cold region [11, 12]. As for the absorption refrigeration system using waste heat, there are additional disadvantages, such as: low refrigeration power of unit mass adsorbent, heavy system, low utilization efficiency of waste heat, and so on [13]. Considering the above-mentioned disadvantages, work production has become a new research hotspot in the field of waste heat recovery of ICE.

Possible Way of Using Heat Recovery System

The modern day vehicles run generally on IC engines, i.e. Internal Combustion engines. The majority of vehicles are still powered by either spark ignition (SI) or compression ignition (CI) engines [13]. Small air-cooled diesel engines up to 35 kW output are used for irrigation purpose, small agricultural tractors and construction machines whereas large farms employ tractors of up to 150 kW output. Water or air-cooled engines are used for a range of 35-150 kW and unless strictly air cooled engine is required, water-cooled engines are preferred for higher power ranges. Earth moving machinery uses engines with an output of up to 520 kW or even higher, up to 740 kW. Trucks and road engines usually use high speed diesel engines with 220 kW output or more [14].

Principle

The work area is the automobile engine which throws considerable amount of the waste/ flue gases in to the atmosphere. It is observed that the gases coming out of the engine from the exhaust pipe contain waste energy, and heat also, the gases posses K.E as they are thrown with certain velocity in environment; it is observed that the pressure exerted by the flue gases is about 2 bar. Thus by the law of conservation of energy, energy can be converted from one form to the other; hence this attempt has been made for waste exhaust energy of the gases be converted in to the useful work by fabricating a suitable system.

Working principle

The gases possessing the kinetic energy and velocity enter the main nozzle as shown in the figure; system has been prepared such that rotor consists convergent nozzle in the system, by use of these nozzles total kinetic energy of the exiting gases from the exhaust pipe are converted in to the potential energy thus these gases with potential energy are distributed equally to the three tubes which are inclined to each other in circular manner in one plane as in the figure. The nozzles are tilted 60^0 to the horizontal for the maximum thrust (Fig 3). The gases finally are passed through the nozzles with potential energy which exist a thrust thus giving motion in the opposite direction, thus rotating the whole assembly. This rotational work can be coupled to any other system for usage of the work produced according to the standard conditions.

Applications

Waste energy recovery can substantially increase the mechanical efficiency associated with performance in following systems.

- In automobiles
- In generators
- Thermal power station
- Boilers

METHODOLOGY

The methodology of Rotor Engine is shown in Fig 1. A experimental setup is set up in which exhaust air at temperature T1 from the I.C. engine's exhaust is passed in the diffuser of Rotor Engine, the upper portion of the Rotor Engine is exposed to this exhaust air and absorbs Q1 amount of waste energy from it and the exhaust air with low heat content which is at temperature T2 is given out of the nozzles. As the rotor rotates the amount of waste energy is transmitted by it. This waste energy transmitted from the Rotor Engine is given out for useful purpose. Fig 2 shows the experimental setup of recovery device.

The Rotor which is mounted on the shaft is made up of cast iron and cast iron nozzles, which provide maximum power absorption from exhaust gas.

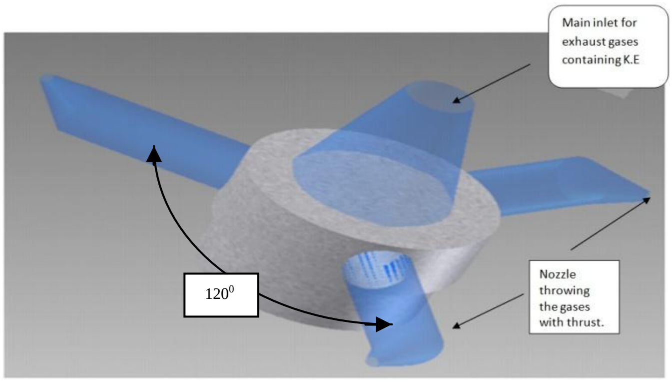
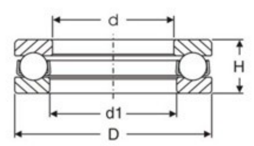
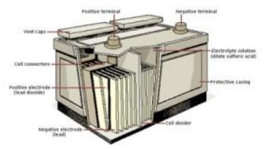
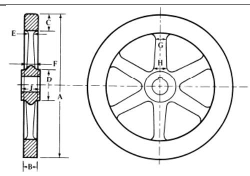


Fig 1: The figure shown shows Rotor Engine setup

The shaft on which rotor is mounted is connected to the motor through meshing gears to effectively control the rotation rates so as to get maximum output. The Rotor which is mounted on the shaft is made up of cast iron and cast iron nozzles. Specifications for experimental setup are given in Table 1.

Table 1: Experimental Setup Specifications

Sr No.	Component	Dimensions	Diagram
1.	Ball Bearing	d = 12 mm	
2.	Battery	6V Rechargeable	
3.	Generator (Dynamo/ Motor)	0.5 HP	
4.	Flywheel	123 mm × 20 mm	
5.	Gear (Driver)	123 mm	
6.	Gear (Driven)	24 mm	

Sr No.	Component	Dimensions	Diagram
7.	Rotor Pipe	L = 80 mm	

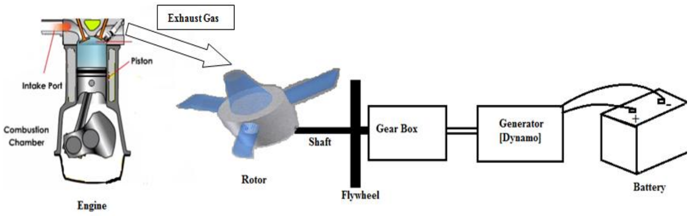


Fig 2: Experimental Setup

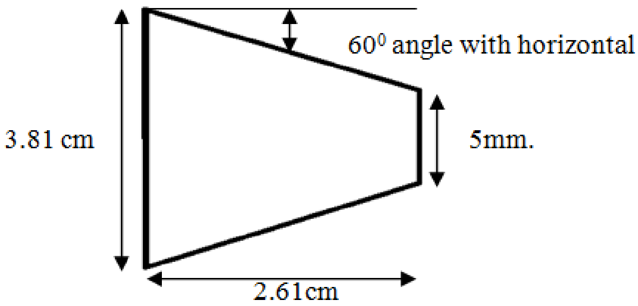


Fig 3: Rotor Nozzle Diagram

Experimental Setup Specifications

The other necessary specifications for motor (Dynamo) and flywheel are calculated as below.

Motor Diameter = 2.4 cm

Flywheel Diameter = 12.3 cm

$$\text{Motor RPM} = \frac{\text{Flywheel Diameter}}{\text{Motor Diameter}} \times \text{Flywheel RPM}$$

$$\text{Motor RPM} = \frac{12.3}{2.1} \times \text{Flywheel RPM}$$

Motor RPM = 5.125 × Flywheel RPM

Gear ratio = 5.125

Specifications of engine tested are given in Table 2.

Table 2: Engine specifications

Items	Values
Engine Displacement	796cc
Make	Maruti Suzuki make
Bore diameter	68.5 mm
Stroke length	72.0 mm
Exhaust temperature idling	380 ⁰C
Power	47 PS (6,200 rpm)

OBSERVATIONS AND CALCULATIONS

Table 3: Observations and Calculations

Sr. no	Pressure [Bar]	Exhaust inlet temp. T1(°C)	Exhaust Outlet temp. T2(°C)	Flywheel RPM	Motor RPM
1	4	380	380	268	1271
2	5	380	380	511	2619
3	6	380	380	833	4270
4	7	380	380	1194	6120
5	8	380	380	1306	6694
6	9	380	380	1365	6996
7	10	380	380	1440	7380

From the above given table, we can observe that as the RPM of the rotor engine goes on increasing the pressure goes on increasing.

$$\text{Motor RPM} = \frac{\text{Flywheel Diameter}}{\text{Motor Diameter}} \times \text{Flywheel RPM}$$

$$\text{Motor RPM} = \frac{12.3}{2.1} \times \text{Flywheel RPM}$$

Motor RPM = 5.125 × Flywheel RPM

To check the performance of the experimental setup, air compressor is used and following readings are obtained to check efficiency of the setup.

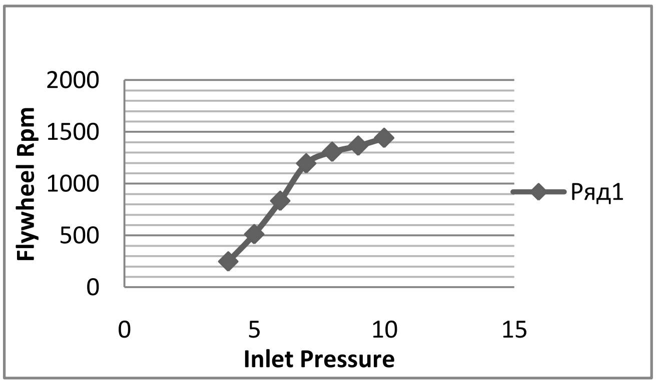
Table 4: Compressor Specifications

Items	Values
Volts	230 V
Make	Local Made
Motor Phase(s)	Single
Stage:	Two
HP:	5
Amps:	21 A
Max. PSI:	175
Tank Type:	Vertical
Air Outlet Size (in.):	0.5
Dimensions L×W×H (in.):	29 x 21 x 64

Reciprocating air compressors are used to compress air as efficiency and lower operating costs of experimental setup and producing more compressed air at a lower horsepower. Specifications shown in Table 4.

RESULT AND DISCUSSION

Here Rotor Engine system has been fabricated as a waste heat recovery device. An efficient transient system was developed so as to measure the power recovered from the exhaust gases of three cylinders, Maruti Suzuki Make computerized, I.C Engine Test Rig. And it was useful in successfully generating power from the intake air of I.C engine. And following results were observed.



Graph 1: Flywheel RPM Vs Pressure

In the graph 1 we can observe that as there is an increase in Pressure [X-axis], there is an increase in RPM [Y- Axis].

CONCLUSIONS

Installing waste energy recovery systems to three cylinders computerized, Maruti Suzuki Make, S. I. Engine tail pipe substantially reduces the cost and use of energy in laboratories. Selecting an appropriate waste energy recovery technology, properly designing the system, meeting the applicable codes, and commissioning the system are all important. When a waste energy recovery system is designed, installed and operated correctly it will provide significant energy and environmental benefits.

The graph between Flywheel (RPM) and Pressure (bar). From the graph we have concluded that for 160 rpm, there is the change in the heat content of the 1.8KJ/sec.

REFERENCES

[1] Shekh Nisar Hossain, Saiful Bari, "Waste heat recovery from the exhaust of a diesel generator using Rankine Cycle," *Energy Conversion and Management*, vol. 75,pp 141–151, June *2013*.

[2] Pratik Sapre, "Thermoelectric Exhaust Energy Recovery for I.C.Engine Review," *IJETR*, vol 2, Issue-12, pp. 81-85, Dec. 2014.

[3] R. Saidur, M.Rezaei, W.K.Muzammil, M.H.Hassan, S.Paria, M.Hasanuzzaman, "Technologies to recover exhaust heat from internal combustion engines," *Renewable and Sustainable Energy Reviews*, vol. 10, no. 5, pp. 5649–5659, May 2012.

[4] R. A. Scholtz, "Review on Exhaust Gas Heat Recovery for I.C. Engine," *IJEIT*, vol 2, Issue-12, pp. 93-100, June. 2013

[5] N. Espinosa, L. Tilman, V. Lemort, S. Quoilin, B. Lombard, "Rankine cycle for waste heat recovery on commercial trucks approach, constraints and modelling," in *Proc. Diesel International Conference and Exhibition, France*, May-2010, pp. 1-10.

[6] M Talbai, B Agnew, "Energy recovery from diesel engine exhaust gases for performance enhancement and air conditioning," *Applied Thermal Engineering*, Volume 22, Issue 6, Pages 693–702, April 2002

[7] S. C. Walawade,B.R Barve, P. R. Kulkarni, "Design and Development of Waste Heat Recovery System for Domestic Refrigerator", IOSR Journal of Mechanical and Civil Engineering, ISSN: 2278-1684, pp. 28-32

[8] Lokhande, S. B., and S. B. Barve, "Design &Analysis of Waste Heat Recovery System for Domestic Refrigerator," *IJMER*, Vol. 4, Issue. 5, pp. 61-72, May. 2014.

[9] He, Maogang, et al, "A combined thermodynamic cycle used for waste heat recovery of internal combustion engine." *Energy*, Volume 36, Issue 12, pp. 6821-6829, Dec 2011.

[10] Hussain, Q., Brigham, D., and Maranville, C, "Thermoelectric exhaust heat recovery for hybrid vehicles", SAE *Int. J. Engines*, pp. 1132-1142, 2009.

[11] Iyer RC, "Development of a vapor compression air conditioning system utilizing the waste heat potential of exhaust gases in automobiles", *SAE Technical Paper* , 2005.

[12] Lambert MA, Jones BJ, "Automotive adsorption air conditioner powered by exhaust heat", *Proceedings of the Institution of Mechanical Engineers Part D e Journal of Automobile Engineering 220(D7)*, pp. 959-89, Sep 2006.

[13] Jotava, D. J., D. J. Parmar, and Jay V. Shah, "Experimental Investigation of Heat Recovery from Engine Exhausts Gas and Its Application in Electrolux Refrigeration System: A Review." *International Journal of Engineering Research and Technology*, Vol. 3, Issue 1, January 2014.

[14] Mittal, Atishey, Devesh Shukla, and Karan Chauhan, "A refrigeration system for an automobile based on vapor absorption refrigeration cycle using waste heat energy from the engine", *International journal of engineering sciences & research technology*, pp.591-598, April 2014.

[15] Arnaud, L., Ludovic, G., Mouad, D., Hamid, Z., & Vincent L, "Comparison and impact of waste heat recovery technologies on passenger car fuel consumption in a normalized driving cycle", *Energies*, *7*(8), pp 5273-5290, 2014.

[16] Condle, Jasdeep S, "Analysis of a novel waste heat recovery mechanism for an IC engine." M.S Thesis, Dept Mech Eng, Michigan Technological University , 2012.

[17] Shu, Gequn, et al. "A review of waste heat recovery on two-stroke IC engine aboard ships." *Renewable and Sustainable Energy Reviews* 19, pp. 385-401, 2013

[18] Nadaf, S. L., and P. B. Gangavati. "A review on waste heat recovery and utilization from diesel engines." *Int J Adv Engg Tech*, Vol. V, Issue 4, pp. 31-39, Dec 2014.