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Design and Construction of a Prototype Engine for Generation of Power from Exhaust Gas of Gasoline Generator

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Abstract
The use of waste heat from exhaust gases of internal combustion engine such as gasoline generator for electricity generation is not new. However, reasonable quantity of energy associated with the waste heat such as the pressure energy is not utilized and more or less still wasted. In order to forestall this further wastage of energy a prototype engine was designed and constructed using pressure energy of the exhaust gas of gasoline generator to generate electricity in this research. Careful selection of quality materials, design calculations and fabrication of the component parts with the analysis of its performance against speed of turbine, power generated and efficiency of the prototype engine were adopted. On performance evaluation at gasoline generator speed of 5000rpm and output power of 2800W, the prototype engine was able to generate an average power of 90.2W at an average turbine speed of 640rpm.The average efficiency of the prototype engine was found to be 43.4%..

Keywords: *Blade, Prototype engine, Exhaust gas, Turbine, Power*

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1. Introduction

Reciprocating internal combustion engine is the prime mover of electricity generator fueled with either gasoline or diesel. All internal combustion engine generates 55-75% of its total fuel energy as waste heat (Cirincione, 2011) and the exhaust gases from an internal combustion engine carry away about 30% to 40% of the heat of combustion (Vijay *et al*, 2016). This waste heat has been used extensively to generate electricity by many researchers. Taguchi (2007) invented an exhaust gas-based thermoelectric power generator for an automobile use. In his invention, the exhaust gas in the pipe provides the heat source to the thermoelectric power generator, whereas the heat sink (cold side) is provided by circulation of cooling water. Kim *et al* (2011) as reported by Monga *et al* (2015) designed a thermoelectric generator system working in combination with heat pipes to produce electricity from a limited hot surface area. In the experiment they used exhaust gases as a heat source and the result of their study revealed that the amount of electricity generated from the modules is directly proportional to their heated area. Kumar *et al* (2011) demonstrated the potential of thermoelectric generation. They carried out a detailed experimental work to study the performance of thermoelectric generators under various engine operating conditions. Adavbiele (2013) investigated a typical total waste heat recovering technology, using thermoelectric generators (TEGs), coupled with a gasoline engine. The researcher presented a mathematical method for assessing and optimizing the performance of the application followed by the different configurations of the applications of TEGs in vehicles.

Orr *et al* (2017) stated that exhaust heat recovery systems are used to make use of otherwise wasted heat from a car engine. In view of this, they designed a system that utilizes thermoelectric generators (TEGs) and heat pipes and fitted to the exhaust of a car with a 3.0 L V6 engine. Anchal and Saikhedkar (2015) did an Experimental analysis of waste heat recovery using TEG for an internal combustion engine. They found that maximum amount of heat carried away by hot exhaust gases obtained at a speed of 1300 RPM and load of 20 Kg, was 2597.61 J/s. Bobba and Rajesh (2016) developed a Thermo Electric Generator of mater Bismuth Tellurium (Bi2Te3) of size 7X7 cm, using heat energy from exhaust gases of an automobile and used to charge the battery of a hybrid vehicle to improve its performance

Chavan *et al* 2017) evaluated the potentials of thermoelectric power generator for generating electricity using exhaust gas heat of an automobile. Their results showed that voltage, current, power developed and efficiency of the system increased with the increase in the automobile IC engine load, exhaust temperature & flow rate of cooling water. Tzer-Ming *et al* (2016) embarked on the design, manufacture and performance test of the thermoelectric generator system for waste heat recovery of engine exhaust. They successfully investigated the effects of the engine rotation speed and the mean velocity of external cooling air on the temperature and discharged quantity of engine exhaust gas. Kunt (2017) designed an air-cooled thermoelectric generator to recycle waste heat energy in exhaust systems of internal combustion engines. He evaluated the performance by measuring voltage, current, and power values under different thermal conditions which depended on the change in load resistance.

Concerted efforts have been made by the notable researchers and host of others on only the use of waste heat without recourse to the use of pressure energy associated with the waste heat of the exhaust gas to generate electricity. This gap has been identified in literature, hence the aim of this research is to design and fabricate a prototype engine that can utilize the pressure energy associated with the waste heat of exhaust gas of gasoline generator for electricity generation.

2. Materials and methods

2.1 Design theory and calculations of the prototype engine

The following main parts of the prototype engine were considered for the design: (1) The exhaust gas system, (2) Turbine and (3) Nozzles.

2.1.1 Design of the muffler of the prototype engine

Muffler is a part of exhaust system of internal combustion engines and its primary role is to aid the reduction of engine noise or sound. According to Reddy and Prakash (2016), the chamber length of the muffler is in the range of $10d_e \text{ to } 16\, d_e$. In this case, the length of the chamber is taken as:

$$L_{ch} = 12d_e \tag{1}$$

where L_{ch} is the length of the chamber and d_e is the diameter of the exhaust exit of the gasoline generator which was measured with vernier caliper to be 18mm

The chamber diameter is given according to Reddy and Prakash (2016) as:

$$D_{ch} = 3d_e \tag{2}$$

where D_{ch} is the chamber diameter

2.1.2 Determination of Diameter of holes in the element of the muffler

Perforated cylindrical pipe forms the acoustic element of muffler, the diameter of the hole or perforations on the pipe was taken to be 2.34mm as used by Huang *et al* 2018) and the number of perforated holes was taken to be 342 (Pratap *et al.*, 2015)

2.1.3 Determination of exhaust system length, location of the muffler and turbine

The displacement of the engine is equal to the volume of the exhaust pipe

$$V_d = \left(\frac{\pi {d_e}^2}{4} + \frac{\pi {d_{ch}}^2}{4}\right) \times L_e \tag{3}$$

where V_d is the displacement of the engine of the selected gasoline generator = 200cc (0.0002m^3). Volume of silencer or exhaust pipe must be at least 12 to 25 times the volume considered (Shah *et al.*, 2010). So, the volume of the exhaust pipe is taken as 15 × 0.0002 = 0.003m^3. According to Prasad (1980) stated by Oke *et al* (2014), the length of exhaust pipe = 2.52 × length of exhaust pipe before fitting the muffler.

2.1.4 Determination of Exhaust gas flow rate

The exhaust gases flow through the nozzle that is fitted to the exhaust pipe of the generator and impinges on the turbine blade. The volumetric flow rate of the exhaust gas can evaluated using the equation stated as:

$$Q_f = AV = \frac{\pi {d_1}^2 v}{4} \tag{4}$$

where Q_f is the volumetric exhaust gas flow rate, A is the exhaust gas pipe cross-sectional area, V is the exhaust gas flow velocity which is taken as 22.9m/s as measured by anemometer and d_1 is the exhaust gas pipe diameter which is taken as 18mm. The mass flow rate of the exhaust gas is given as

$$\dot{m} = \rho Q_f \tag{5}$$

where $\dot{m}$ is the mass flow rate of the exhaust gas, ρ is the density of the exhaust gas which is taken as 0.592kg/m^3 (Pipeflow calculation, 2020) at measured average temperature of exhaust gas of 327^{0}C by Paul *et al*. (2013)

2. 1.5 Determination of Nozzle Dimensions

Convergent nozzle is designed to be fitted to the exhaust pipe of the gasoline generator for the creation of the jet of the exhaust gas from the generator. The schematic diagram of the nozzle is shown in Fig. 1.

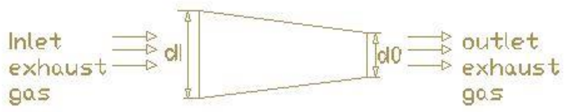


Fig. 1: Schematic diagram of the nozzle

According to Mahajan *et al*, (2016), the length of the nozzle = 8d$_i$6. Where d$_i$ the inlet diameter of the nozzle, was taken to be the same as the diameter of the exhaust pipe =18mm. According to Mahajan *et al*, (2016), design of nozzle is done by employing critical pressure ratio. That is ratio of pressure at the inlet of the nozzle to that at the throat of the nozzle is equated to critical pressure ratio to obtain nozzle dimensions. According to Mahajan *et al.* (2016).

$$\frac{p_c}{p_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}} \tag{6}$$

And $p_c = p_2$

According to Venkatesh (2006), p$_2$ = 1.3bar. Where p_1 s the inlet pressure, p_2 is the pressure at the throat, p_c is the critical pressure and n the polytropic index of the exhaust gas which is taken between 1.32 and 1.4 (Luo *et al*, 2014). In this case it is taken to be 1.36. The mass flow rate of the exhaust gas through the nozzle where the minimum pressure equals critical pressure can be expressed according to Mahajan *et al*. (2016) as:

$$\dot{m} = A_2\sqrt{np_1\,\rho_1 \times \left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}}} \tag{7}$$

where $\dot{m}$ is the mass flowrate and A_2 is the throat or outlet area of the nozzle.

2.1.6 Determination of nozzle exit parameters (temperature, density and velocity)

The temperature of the exhaust gas at the nozzle outlet can be found assuming adiabatic process in line with Mahajan *et al.* (2016) using the relation given as

$$T_2 = T_1\left(\frac{P_1}{P_2}\right)^{\frac{1-\gamma}{\gamma}} \tag{8}$$

where T_2 is the temperature of the exhaust gases at the nozzle outlet, T_1 =327, P_1 = 2.43bar, P_2 = 1.3bar. The density of exhaust gas at the nozzle exit can be found using the relation for the volumetric expansion of exhaust gas. Thus,

$$\rho_2 = \frac{\rho_1}{1+\beta(T_2-T_1)} \tag{9}$$

where β is the cubic expansivity of the exhaust gas, ρ_1 and $\rho_{2,}T_1$ and T_2 are the initial and final density and temperature of the exhaust gas. The nozzle exhaust gas velocity can be obtained using continuity equation stated as:

$$V_2 = \frac{\dot{m}}{\rho_2 A_2} \tag{10}$$

2.1.7 Evaluation of power of jet of exhaust gas through the nozzle

The power in the jet of the exhaust gas which drives the turbine can be evaluated by using the relation given by Dineshkumar et al (2019) as:

$$P_i = \frac{C_p\rho_2 A_2 {V_2}^3}{2} \tag{11}$$

where Pi is the power of the exhaust gas and C_p is a constant = 0.5 (Dineshkumar et al., 2019)

2.2 Design theory and calculations on turbine parameters

The turbine consists of a wheel with attached blades and it extracts the pressure energy in the exhaust gases via the nozzle and converts it into useful work. That is when the kinetic energy of exhaust gas acts on the blades, rotational energy imparts to the rotor.

2.2.1 Estimation of the dimensions of the blade

The dimensions of the blade are estimated in line with the works of Rajput (2008b), Shaikh et al. (2017) and Mahajan et al. (2016) as follows:

Axial width of the blade

The axial width of the blade is given as:

$$B_w = 3.5\,C_C\,d_o \tag{12}$$

where B_w is the axial width of the blade, C_C is the coefficient of contraction of the exhaust gas which is taken as 0.611(Lienhard and lienhard, 1984; Katopodes, 2018).

Length of the blade

The length of the blade is given as:

$$B_1 = 2.8\, C_C\, d_o \quad (13)$$

where B_1 is the length of the blade

2.2.2 Determination of number of blades

Rajput (2008b) and Nasir (2013) stated that the number of blade on the runner or wheel is given as:

$$Z = 15 + \frac{D}{2d_j} \quad (14)$$

where Z is the number of blades, D is the turbine wheel or runner diameter = 60mm (Nonthakarn et al., 2019) and d_j is the jet diameter.

Since $D_j = C_c \times d_o$ (15)

2.2.3 Determination of the turbine wheel (runner) speed

The speed of the turbine wheel as a result of the impart of the exhaust gas on the blades will be determined using the equation stated as:

$$N = \frac{60V_b}{\pi D} \quad (16)$$

where N is the speed of the turbine wheel and V_b is blade speed which is 0.44-0.46 × velocity of the jet (Mahajan et al, 2016). In this case,

$$V_b = 0.46 \times V_j \quad (17)$$

Where Vj is the velocity of the jet of the exhaust gases.

$$V_j = C_v \times V_2 \quad (18)$$

where C_v is the coefficient of velocity which is taken as 0.97

2.2.4 Determination of power developed by the turbine

The power developed by the turbine is given according to Nonthakarn et al (2019) as:

$$N_t = G_s \times l_o \times \eta_t \quad (19)$$

where N_t is the power developed by the turbine, G_s is the intensity of exhaust gas flow = $\dot{m}$ = 0.00345 kg/s , η_t is the isentropic efficiency of the turbine which is typically between 70-90% (Nuclear power for everybody, 2021) and l_o is the theoretical work by energy per mass of exhaust gas which is expressed according to Nonthakarn et al. (2019) as:

$$l_o = \frac{K_1}{K_{1-1}} \times R_{sp} \times (T_{S'} - T_S) \quad (20)$$

where K_1 is the value of adiabatic exhaust gases = 1.36, R_{sp} is the constant value of the exhaust gases relative to the gas constant to the molecular weight of the exhaust gas = 0.287KJ/kgk, T_s is the temperature of exhaust gases flowing into the turbine = 327^{0}C and $T_{S'}$ is the temperature of exhaust gases flowing out from the turbine and it is assumed to be 286^{0}C

2.2.5 Determination of turbine shaft diameter

The design torque on the shaft is given as:

$$T_d = \frac{60P}{2\pi N} \quad (21)$$

where P = power received = N_t = 110W. The tangential force acting on the turbine wheel is given as:

$$F_T = \frac{T_d}{r} \quad (22)$$

where F_T is the tangential force and r = radius of the wheel = $\frac{D}{2}$ = $\frac{0.06}{2}$ = 0.03m. The schematic diagram of the turbine wheel mounted on the shaft is shown in Fig. 2.

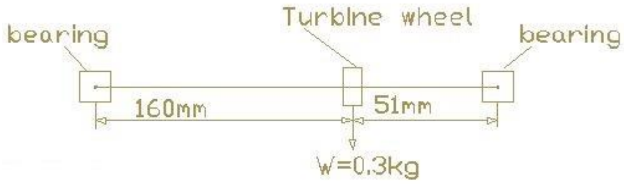


Fig. 2: Schematic diagram of the turbine wheel mounted on the shaft

2. 3 Design of belt drive for power transmission from the turbine to the alternator

According to Khurmi and Gupta (2005), for efficient transmission of power, the belt speed of 20 to 22.5m/s may be used. In this case, belt speed of 21m/s was used. The power developed by the turbine to be transmitted to the alternator is 110W. The schematic diagram of the belt drive is shown in Fig. 3.

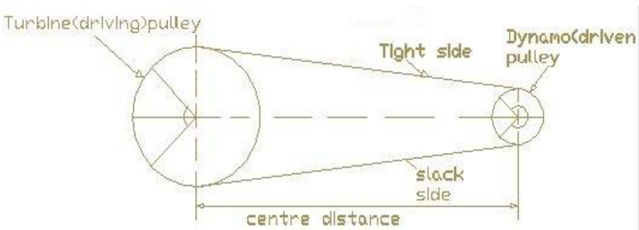


Fig. 3: Schematic diagram of the belt drive

2.3.1 Determination of the length of the belt

The belt is an open drive type so the length of the belt is given as:

$$L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x} \quad (23)$$

where L is the length of the belt.

2.3.2 Determination of the angular speed of the driving and driven pulley

The velocity of the belt is given by Khurmi and Gupta (2005) as:

$$v_0 = \frac{\pi d_1 N_1}{60} \quad (24)$$

The velocity ratio of the belt drive is given as:

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \quad (25)$$

2.3.3 Determination of tensions on the belt

The relation between the tight side and slack side tensions of the v- belt in terms of coefficient of friction and the angle of contact is given as:

$$2.3\log\left(\frac{T_1}{T_2}\right) = \mu\theta\operatorname{cosec}\beta \quad (26)$$

where μ is the coefficient of friction between the belt and the pulley, which is taken to be 0.5 (CHIORINO, 2021), β is the half angle of the groove which is taken to be 15^0 and θ is the angle of contact or lap. The angle of lap or contact between the belt and pulley is given as:

$$\theta = (180 - 2\alpha)\frac{\pi}{180} \text{ radian} \quad (27)$$

$$\sin\alpha = \frac{d_1 - d_2}{2x} \quad (28)$$

$$\alpha = \sin^{-1}\left(\frac{d_1 - d_2}{2x}\right) \quad (29)$$

$$T_1 = 269.15\, T_2 \quad (30)$$

The power transmitted by the belt drive is given as:

$$P_T = (T_1 - T_2)v_0 \quad (31)$$

where P_T = is the power transmitted = 110W

2.3.4 Determination of actual power transmitted by V-belt drive system to the alternator

The usual efficiency for V-belts is in the range of 90% to 98% (Bayne, 2006). In this case the efficiency is assumed to be 93% and the efficiency is expressed as:

$$\eta = \frac{Output\ power}{Input\ power} \times 100 \quad (32)$$

2.3.5 Estimation of generated electric power by the alternator

According to Algrain (2014), the efficiency of AC generator is typically in the range of 80 to 95 percent. In this case the efficiency of AC generator or alternator is taken as 90%. So, the efficiency of the AC generator is given as:

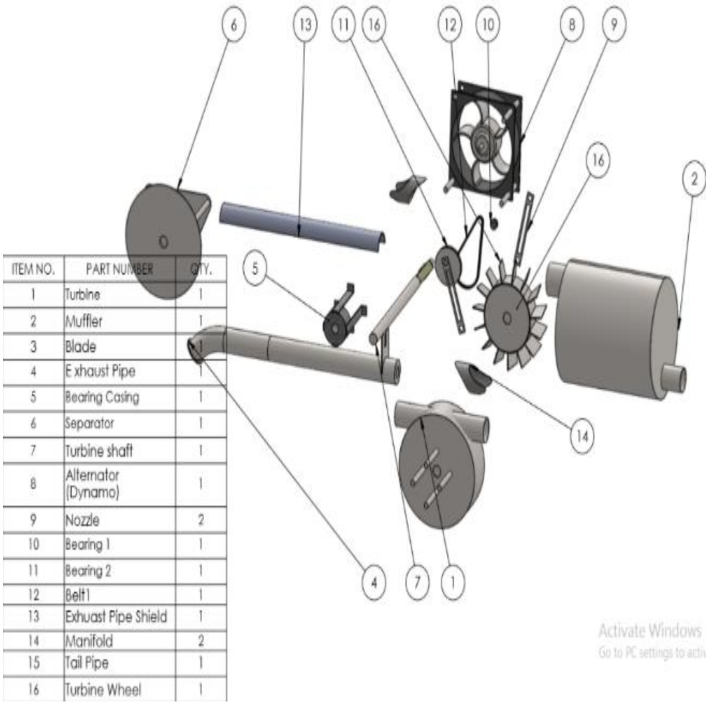
$$\eta_{gen} = \frac{Outputpower}{Inputpower} \times 100$$

The input power is the output power from the belt drive system = 102.3W

$$95\% = \frac{Outputpower}{102.3} \times 100$$

The output power = 0.95 × 102.3 = 97.2W.

So, the designed power rating of the AC generator or Alternator is 97.2W. The exploded, isometric and orthographic views of the prototype engine are shown in figures 4, 5 and 6 respectively.



ITEM NO.	PART NUMBER	QTY.
1	Turbine	1
2	Muffler	1
3	Blade	
4	Exhaust Pipe	1
5	Bearing Casing	1
6	Separator	1
7	Turbine shaft	1
8	Alternator (Dynamo)	1
9	Nozzle	2
10	Bearing 1	1
11	Bearing 2	1
12	Belt1	1
13	Exhuast Pipe Shield	1
14	Manifold	2
15	Tail Pipe	1
16	Turbine Wheel	1

Fig. 4: The exploded views of the prototype engine

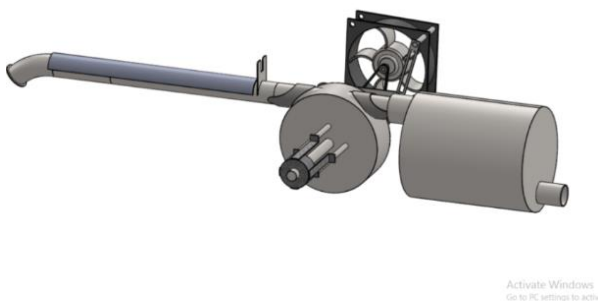


Fig. 5: The isometric view of the prototype engine

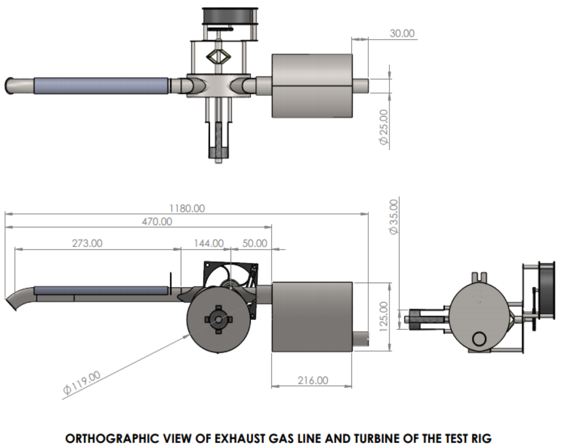


Fig. 6: The orthographic view of the prototype engine

Fig. 7: Picture of the prototype engine

Fig. 8: Picture of the complete system set up

2.3.6 Selection of storage battery

In order to store the electrical energy for future use, The AC generator is connected to a rectifier which converts the AC to DC and store the energy in the form of D.C. in the battery. So, a 12V battery was considered. Based on the design theory and calculations, the prototype engine was produced.

2.4 Performance Evaluation

The exhaust system of an Elepaq gasoline generator of power rating of 2800W and maximum speed of 5000rpm was removed and replaced with the developed prototype engine. The gasoline generator of the prototype engine was run at its maximum speed and output power or load of 2800W. The exhaust gas temperatures were measured by Type-k thermocouples. This was achieved by inserting one thermocouple probe into the exhaust pipe before the turbine to obtain initial temperature of the exhaust gas and second thermocouple probe was inserted into the exhaust pipe after the turbine and the third thermocouple was inserted in the tail pipe of the exhaust to measure the outlet temperature of the exhaust gas. The speed of the turbine of the prototype engine was measured with Tachometer and the current and voltage generated were measured with Multimeter and the product of measured current and voltage were evaluated to get the generated power by the prototype engine. All the measurements were carried for five minutes for a period of thirty minutes. The efficiency of the prototype engine was evaluated using the relation stated by Xu et al. (2021) as:

$$\eta_{PE} = \frac{P_e+P_t+P_g}{M_e H_u}$$

where P_e is the effective power of the generator (Elepaq generator) (W), P_t is the output power of the turbine(W), P_g is the output power of the alternator (Dynamo) (W), M_e is the mass of fuel consumed in unit time (kg/s) and H_u is the calorific value of gasoline used (J/kg).

3. Results and discussion

Table 1 shows results as obtained from the design calculations of components of the prototype engine. In this design, the turbine has to be fitted before the muffler. So the distance between the turbine outlet and muffler inlet was taken to be 0.05m. From the turbine shaft diameter of 0.03m, it was established that the normal load acting on the wheel was 1.19N. The variation of the turbine speed of the prototype engine with the time taken to run the prototype engine is shown in Fig. 9.

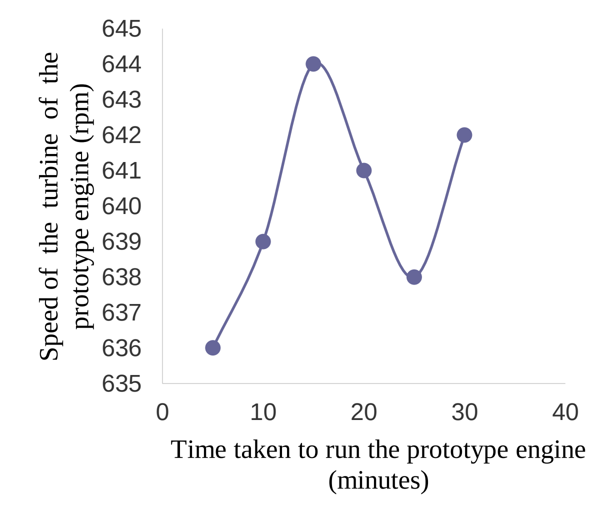


Fig. 9: Variation of speed of turbine of the prototype engine with time taken to run the prototype engine

It can be seen from Fig. 9 that the speed of the turbine fluctuated with the time taken to run the prototype engine. After five minutes, the turbine speed increased from 636rpm to 644rpm and declined to 638rpm after twenty-five minutes. The speed of the turbine increased steadily to 642 rpm after thirty minutes. The average turbine speed for the period of operation of the prototype engine was found to 640rpm. The variation of power generated by the prototype engine with the time taken to run the prototype engine is shown in Fig. 10.

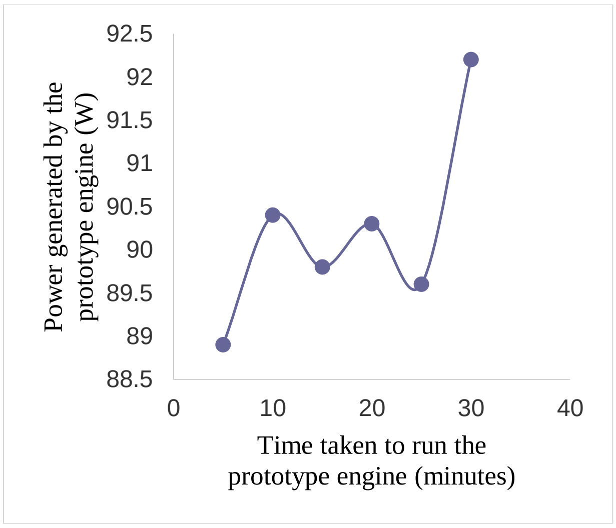


Fig. 10: Variation of power generated by the prototype engine with time taken to run the prototype engine

Table 1: Results obtained from design calculations of components

Component/Material Parameter	Value
Muffler	
Length of Chamber	216mm
Diameter of Chamber	54mm
Diameter of perforation	2.34mm
No. of perforation	342
Location of the muffler	0. 47m from the inlet of the exhaust pipe.
Length of the exhaust pipe	1.18m
Displacement of the engine	200cc (0.0002m^3)
Exhaust Flow rate	0.00345kg/s
Nozzle	
Length	144mm
Inlet area	2.55 x 10^{-4} m^2
Inlet pressure	2.43bar
Pressure at the throat	1.3bar
Critical pressure	1.3bar
Inlet temperature of the exhaust gases	327^{0}C
Outlet temperature of the gases	273.5^{0}C
Initial density of the exhaust gas	0.592kg/m^3
Final density of the exhaust gas	0.736kg/m^3
Exhaust gas velocity	207m/s
Power of the exhaust gas	37W
Turbine	

Axial width of the blade	0.02m
Length of the blade	0.017m
Number of blades	20
Blade speed	92.4m/s
Speed of the turbine wheel	29412rpm
Theoretical work by energy per mass of exhaust gas	-44.45KJ/kg
Power developed by the turbine	110W
Design torque on the shaft	0.0357Nm
Tangential force	1.19 N
Shaft diameter	0.005m
Belt	
Length of belt	383mm or 0.383m
Velocity of the belt	21m/s
Tension in the tight side of the belt	5.383N
Tension in the slack side of the belt	0.020N
Driving pulley Angular speed	6684rpm
Driven pulley Angular speed	13368rpm
Output Power	102.3W

It is evident in Fig. 10 that the power generated by the prototype engine increased and decreased steadily with the time taken to run the prototype engine. The prototype engine generated the least power of 88.9W after five minutes of operation and maximum power of 92.2W after thirty minutes of operation. The average power generated was found to be 90.2W. The variation of the efficiency of the prototype engine with the time taken to run the prototype engine is shown in Fig. 11.

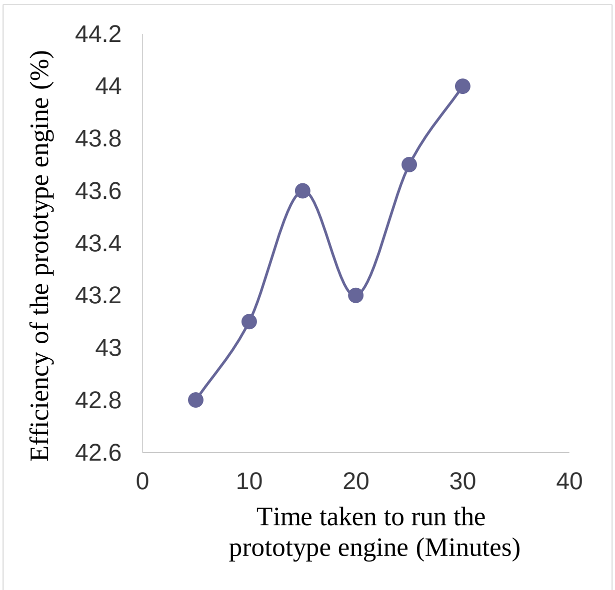


Fig. 11: Variation of efficiency of the prototype engine with the time taken to run the prototype engine

The efficiency of the prototype engine varied with time of running the prototype engine as seen in Fig. 11. It increased from 42.8% to 43.6% after five and fifteen minutes of operation respectively. The efficiency however dropped to 43.2% after twenty minutes and increased to 44% after thirty minutes of operation. The average efficiency of the prototype engine was found to be 43.4%. The power generated by the prototype engine and the prototype engine efficiency increase with increase in exhaust gas velocity and temperature, turbine speed, emissions CO_2 and decrease in backpressure of the exhaust gas and emissions of CO and HC. When scaled up, the efficiency could be doubled or increased greatly.

4. Conclusion

From the study, it has been identified that there are large potentials of energy savings through the use of pressure energy recovery technologies. Waste pressure energy recovery entails capturing and reusing the waste pressure energy from internal combustion engine and using it for electricity generation. This research has contributed immensely to the knowledge of the use of the waste energy in generating electricity. This use assists greatly in solving the emission problems associated with the use of sole gasoline generator since reduced emissions was observed in the use of prototype engine. On the basis of the overall result and in line with the stated objectives of this research, the following conclusions can be made. This research was embarked upon because of the quest for conserving and utilizing waste pressure energy associated with waste heat of exhaust gas of internal combustion engine, with focus on gasoline generator to generate electricity. Based on the findings and in line with the stated aim of the research, it can be concluded that a prototype engine developed, with appropriate technology, using pressure energy of exhaust gases from 2800W generator can generate additional power of about 100W-.

References

Adavbiele, A.S. (2013) Generation of electricity from gasoline engine waste heat. Journal of Energy Technologies and Policy, 3(5):16-32.

Algrain, M. (2014) Do DC Generators offer Fuel Economy Advantages over AC Generators? Answers for the Telecom Industry. Retrieved on the 10th of April, 2021 from http://s7d2.scene7.com/is/content/Caterpillar/C10282439#:~:text=By%20and%20large%2C%20the%20efficiency,160%20to%20190%20percent%20efficient.

Anchal, D and Saikhedkar, N.K. (2015) Experimental analysis of Waste heat recovery using TEG for an internal combustion Engine. IJISET, 2(6):711-720.

Bayne, D. (2006). Cost vs. Efficiency in Belt Drives. Retrieved on the 21st of February 2021 from https://www.mromagazine.com/features/cost-vs-efficiency-in-belt-drives/

Bobba, S and Rajesh, P (2016) Heat Energy Recovery System from Internal Combustion Engineby Using Thermo Electric Generator. International Journal of Mechanical and Industrial Technology, 3(2):23-32.

Chavan, S.V., Kale, S.S and Sonage, B.K. (2017) Exhaust waste heat recovery of I. C. engine by thermoelectric generator. International Journal of Innovations in Engineering and Technology, 8(2): 163-16.

CHIORINO UK (2021) Conveyor and power transmission belt. Retrieved on the 24th of February, 2021from https://www.chiorino.com/public/files/Chiorino_Conveyor_transmission_belts_general_catalogue-EN.pdf

Cirincione, N. (2011) Design, construction and commissioning of an organic rankine cycle waste heat recovery system with a tesla-hybrid turbine expander.M.Sc Thesis, Colorado State University.

Dineshkumar, C., Roshan D., Jeyakumar, P.D., Tamilarasan, T.R. and Deepan, V. (2019) Generation of electrical energy for charging of a attery by using exhaust gas energy. International Journal of Innovative Technology and Exploring Engineering, 8(10):2159-2163.

Huang, H., Ji, Z. and Li, Z. (2018) Influence of perforation and sound-absorbing material filling on acoustic attenuation performance of three-pass perforated mufflers. Advances in Mechanical Engineering, 10(1):1-11.

Katopodes, N.D. (2018) Free-surface flow. Environmental fluid mechanics. Kidlington, Oxford: Butterworth-Heinemann.

Khurmi, R.S. and Gupta, J.K. (2005) A Textbook on Machine Design (S.I Units). Updated Edition. New Delhi India, Eurasia Publishing House.

Kim, S.K., Won, B.C., Rhi, S.H., Kim, S.H., Yoo, J.H. and Jang, J.C. (2011) Thermoelectric power generation system for future hybrid vehicles using hot exhaust gas. Journal of electronic materials, 40(5):778-783.

Kumar, C.R., Sonthalia, A and Rahu, l. (2011) Experimental Study on waste heat recovery from an Internal combustion engine using thermoelectric technology. Thermal Science, 15(4):1011-1022.

Kunt, M.A. (2017) An experimental investigation of exhaust waste heat recycling by thermoelectric generators under different thermal conditions for internal combustion engines. Journal of Automobile Engineering, 232(12):1648-1653.

Lienhard, J.H. and Lienhard, J.H. (1984) Velocity Coefficients for free jets from sharp-edged orifices. Journal of Fluids Engineering, 106 (1):13–17.

Mahajan, P., Nema, A. and Anantharama, P. (2016) Design and analysis of pelton turbine for organic rankine cycle application. International Research Journal of Engineering and Technology 3(8):1974-1980.

Luo, Q., Sun, B and Tian, H. (2014) The characteristics of polytropic coefficient of compression stroke in H2 internal combustion engine. International Journal of Hydrogen Energy 39(2014):13787-13792.

Monga, D., Baradia, G., Nangia, S.,Mishra, R., Chawla, Y and Chadha, T. (2015) Energy harvesting system using thermoelectric generators and heat pipes: A Review.

International Journal of Advance Research and Innovation, 5(2):258-263.

Nasir, B.A. (2013) Design of high efficiency pelton turbine for microhydropower plant. International Journal of Electrical Engineering & Technology, 4(1):171-183.

Nonthakarn, P., Ekpanyapong, M., Nontakaew, U. and Bohez, E. (2019) Design and optimization of an integrated turbo-generator and thermoelectric generator for vehicle exhaust. Electrical Energy Recovery Energies, 12(16):1-24.

Oke, P.K., Kareem, B. and Apalowo, R.K. (2014) Exhaust system optimization of the domestic electric generating plant. World Journal of Engineering and Physical Sciences, 2(2):25-35.

Orr, B., Singh, B., Tan, L and Akbarzadeh, A. (2014) Electricity generation from an exhaust heat recovery system utilising thermoelectric cells and heat pipes, Applied Thermal Engineering, 73(1):586-595.

Paul, J., Hossain, M.A., Das, S.K and Rahman, R. (2013) Studies of performance and emission characteristics of compressed natural gas fuelled S. I Engine and developing CNG conversion kit. IOSR Journal of Mechanical and Civil Engineering, 9(4):23-29.

Pipeflow calculation (2020) Flue gas properties table. Retrieved on December 15, 2020 from https://www.pipeflowcalculations.com/tables/flue-gas.xhtml

Prasad, M (1980) Acoustical modeling of automotive exhaust system. PhD Thesis, Purdue University.

Pratap, A., Kalita, U. and Kumar, S. (2015) Optimization of transmission loss of perforated tube muffler by using CAE Tool Ansys. SSRG International Journal of Mechanical Engineering (SSRG – IJME), 2(5):1-4.

Rajput, R.K. (2008 b) A textbook of fluid mechanics and hydraulic machines in SI units. Sixth edition, New Delhi, S. Chand and Company Ltd.

Reddy, G.G. and Prakash, N. (2016) Design and Fabrication of Reactive Muffler. International Journal of Chemical Sciences, 14(2):1069-1076.

Shah, S., Saisankaranarayana, K., Kalyankumar S.H and Thombare, D.G (2010) A Practical Approach towards Muffler Design, Development and Prototype Validation. SAE International Journal of Engines, 32:1-16

Shaikh, M.A.,Shaikh, S.A., Shaikh N.N., Pathan U.F.O and Pathan F.A. (2017) Utilization of exhaust gas of vehicle for electricity generation. International Research Journal of Engineering and Technology, 4(3):1809-1816.

Taguchi, T. (2007) Exhaust heat recovery power generation device and automobile equipped therewith, US Patent- US20070193617.

Tzer-Ming, J., Sheg, C.T., Bo-Jun, Y. and Yi-Chun, L. (2016) Design, manufacture and performance test of the thermoelectric generator system for waste heat recovery of engine exhaust (MDPI) Invention, 2016,1-2.

Venkatesh, G. (2006) Power production technique using exhaust gas from present automobiles via convergent-divergent nozzle. *2006* IEEE Conference on Electric and Hybrid Vehicles, Pune, 2006, pp. 1-9.

Vijay, V.S, AravindaB. K, Sachin, S., Gurudatta N.V. and Russell, S. (2016) Design and fabrication of heat exchanger for waste heat recovery from exhaust gas of diesel engine. Journal of Mechanical Engineering and Automation, 6(5A):131-137.

Xu, Y., Cui, Y., Wang, Y. and Wang, P. (2021) Simulation study of on exhaust turbine power generation for waste heat recovery from exhaust of a diesel engine. Energy Reports, 7(2021): 8378-8389.