Effect of Preheated Pure Oxygen on IC Engine Performance using Heat Pipe Exhaust Heat Recovery Method

Manoj Modi, Ashish Khare, V.Patil

Abstract: ***Nowadays, the requirements and dependency of people on vehicles are increasing day by day which lead to high emission of flue gases and it results in the severe environment pollution. Many researchers have done research to improve the efficiency of IC engine. The main reason for less efficiency is the incomplete combustion of fuel in the IC engine. To improve the efficiency, we carried out the experiments with two stroke petrol engine by supplying preheated pure oxygen instead of air. The oxygen is preheated by the exhaust heat recovery system using heat pipe. In this research work, engine performance is analyzed in two ways primarily by using the pure oxygen and secondly by using the pre-heated pure oxygen through heat pipe. The output response in this work is brake thermal efficiency without heat pipe (without inlet-air-preheating) and with heat pipe (with inlet air preheating). The output response is calculated with the use of numerical formula. Exhaust gases energy is used to preheat the inlet pure oxygen supplied to petrol engine with the help of heat pipe. A heat pipe without bend is used here in which working fluid is water. Experimental results show that there is an increase in brake thermal efficiency with use of heat pipe.***

Keywords: ***Heat Pipe, Pure Oxygen, Two stroke petrol engine, efficiency etc.***

I. INTRODUCTION

Total energy is supplied to the engine in the form of heat energy from the fuel. A large amount of energy is expelled to environment through engine cooling system and exhausts gases. Increasing energy problem, economic development, and energy crises over the world have caused the automotive world researcher's attention on saving of IC engine exhaust gases energy. The effort is focused on improving overall vehicle energy efficiency. For waste energy can be converted in to useful work by various means. One way to use this energy is to supply the exhaust gas energy into inlet pure oxygen by means of heat pipe. This research work will make use of preheating of inlet pure oxygen using heat pipe .In the heat pipe one end is connected to exhaust gas (Higher temperature) i.e. evaporator heats up and vaporizes the heat pipe fluid, and then rises to the condenser where it is condensed and working fluid return to evaporator, condenser is attached to inlet air (Low temperature) take the heat and condense heat pipe fluid i.e. water [1]. Nowadays dependency on fossil fuels is increase due to increase in number of vehicles and their applications, this leads to increase in the consumption of fuel. Vehicles plays an important role in the daily life but it has some drawbacks such as incomplete combustion of fuel leads to increase in air pollution, increase in greenhouse effect and emits poisonous gases in our environment and to overcome from this there were many research are already done and it still continues to get higher amount of power from lower fuel consumption because we know that the efficiency of the internal combustion engine is very low which is not satisfactory.

Revised Manuscript Received on October 05, 2019.

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II. LITRATURE REVIEW

Mangi Naveen et al. [1] reported about the effect of oxygen in the 4 Stroke Petrol Engine. They did the small adjustment in the carburetor which results in changes in vehicle mileage. It is done by increasing the length of the fuel adjustment screw. The increase order of oxygen amount will cause changes in the performance parameters in the engine cylinder. In this view we made some changes in supplying of oxygen into the engine cylinder, by creating the vacuum chamber. Baskar et al. [2] used Enriched Oxygen in the air on a single cylinder, Four stroke diesel Engine in their research work and observe the performance characteristics of the engine. An increase in oxygen concentration increases the mixture ratio of specific heats, which in essence increases the potential to convert the mixtures thermal energy to work energy. There is about 4 to 8 percent increase in brake thermal efficiency throughout all levels of oxygen enrichment. The increase in exhaust gas temperature with increased load and oxygen concentration was due to increase in the reaction rate, flame velocity and increased heat release rate as compared to heat loss rate. The exhaust gas temperature for all oxygen concentrations were increased considerably. Waleed et al. [3] studied the effects of feeding more oxygen to the combustion mixture experimentally. It was found from tests applying on an engine that excess oxygen has positive results in decreasing concentration of both CO and HC's. CO concentration in the oxygen injection test is much less than that at without oxygen injection at the two cases: With load and without load tests and at nearly all engine speeds. Yan et al. [4] reported that the Oxygen-enriched combustion of internal combustion engine is one of the main ways of energy saving.

Oxygen-enriched combustion can increase the fuel combustion in calorific value, heat efficiency and work capacity, comparing with ordinary air combustion with the same quality. At the same time, the theoretical calculation proved that the oxygen-enriched combustion can eliminate the generation of CH, CO and other pollutants. They conclude that the peak pressure and the peak temperature, oxygen concentration of 24%, can make the combustion pressure rise rate increase, and the heat release rate increase, at the same time, the lowest rate of combustion cycle change in the internal combustion engine, and got the maximum power capability of the internal combustion engine. Rahman et al. [5] worked on the Internal Combustion Engine Performance Characteristics. Single cylinder4-stroke SI engine was tested on an engine dynamometer at LSBU. Engine torque, fuel flow, airflow, and exhaust gas temperature were measured at 7 different engine speeds, all full-load. In this he calculated BP, Specific fuel consumption, Speed and drawn Energy balance Diagram, speed vs. torque graph etc. Blarigan et al. [6] worked on An Experimental Based Investigation of Oxy combustion in an SI Engine. Oxy combustion is the process in which nearly pure oxygen and fuel are burned in diluents of exhaust gas, which is re-circulated from the exhaust to the intake, referred to as exhaust gas recirculation (EGR). Experiments were carried out a single-cylinder, variable compression ratio CFR engine on which the intake and exhaust systems were Redesigned to include a large, steady-state EGR loop. Dry EGR has been found to have significantly higher knock resistance than air, allowing operation at higher compression ratios (CR) which can ultimately produce higher thermal efficiencies than air operation when combusting a low octane fuel. Khare et al. [7] evaluated the use of pure oxygen in engine will largely influence the performance of the engine. Oxygen enhances the performance of engine if it is used as the right level of replacement. Uses of oxygen increase the speed of engine which directly indicates that the efficiency of engine is increased. And that is only possible when the fuel is completely burn inside the cylinder. The use of oxygen increases the break-power, SFC and the break thermal efficiency.

A. Review Conclusion

The test is performed on the engine by varying the load from 2 to 8 kg with and without pre heated pure oxygen.

a. Spring load and net load in case of air.

b. Spring load and net load in case of pure oxygen.

c. Spring load and net load in case of pre heated pure oxygen.

The difference between the outside air dry bulb temperature and the wet bulb temperature is the key factor which decides the use of evaporative coolers. Larger the difference, usefulness of evaporative coolers is better. Various attempts have been made to study the effect of various parameters on the evaporative cooler performance. The pad material, and pad thickness are found have the major role for a given air flow rate. Studies have shown that excessive water circulation does not contribute in improving the performance. Considerable energy savings are possible by optimizing the pump operations.

III. HEAT PIPE

A heat pipe is sealed under vacuum with a small, prescribed amount of working fluid. During non-operation, the fluid is contained inside the wick structure that lines the inner diameter of the heat pipe. When a heat source, such as an electronic component, generates heat, the fluid vaporizes at what is known as the evaporator section. The fluid vapour quickly spreads to the other end of the heat pipe, using pressure generated by the temperature difference. At the opposite end, known as the condenser, the fluid gives up its latent heat, which is rejected to an external heat sink. The fluid then returns to liquid form, and the wick structure passively pumps the fluid back to the evaporator using capillary force. By utilizing liquid and vapor phases, the heat transport is extremely efficient. Because it’s a closed loop system, heat pipes operate continuously and passively, creating a very reliable component in your thermal management system.

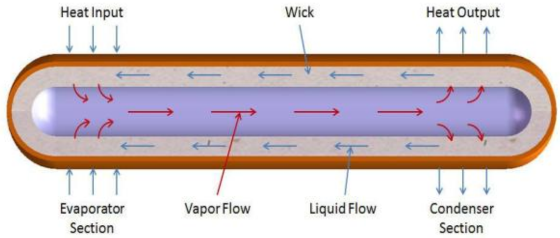

Fig. 1: Heat Pipe

IV. PROBLEM DEFINITION

Now a days, the dependency of human being on vehicle is increasing day by day and the incomplete combustion of fuel in engine emits some harmful gases that will adversely affect the life of human and cause several diseases. To improve this, many researches are done and that also improves the efficiency but still we don’t get the complete combustion of fuel. There are many ways to improve the efficiency but there are some losses that can’t be removed like frictional losses, thermal losses, transmission losses etc. But still there are few things that can improve the efficiency of engine. Are we replacing the air suck into the engine by pure oxygen then it will improve the efficiency of engine. As we all know that air consist of only 21% of air which is not sufficient to burn all the fuel inside the cylinder and that’s why the fuel is not completely burnt and this will reduce the efficiency of the engine. If we supply pure oxygen then all we supplying is 100% oxygen that means 5times of oxygen with respect to air which is sufficient to burn all the fuel present into the cylinder. The complete combustion of fuel improves the thermal efficiency of engine. If we supply preheated pure oxygen instead of only pure oxygen and air then it will lead to the better vaporization of fuel and in-cylinder combustion potentially reduces the CO and smoke emissions.

V. WORKING OF TWO STROKE PETROL ENGINE WITH FUEL AND AIR

a) In this experimental work the speed of engine, time taken for 10 ml of fuel consumption is noted.
b) Firstly, we run two stroke petrol engines with air and fuel without using heat pipes.
c) With the help of this, we calculated fuel consumption and rpm.
d) After this we calculated the specific fuel consumption (SFC) of two stroke petrol engine.

A. Working of two stroke Petrol Engine with fuel and pure oxygen

a) The experiments are carried out on two stroke petrol engines with fuel and pure oxygen without using heat pipe.
b) With the help of these experiments, we calculated fuel consumption and rpm.
c) After this we calculated the brake power, specific fuel consumption (SFC) and brake thermal efficiency of two stroke petrol engine using pure oxygen instead of air.

B. Working of two stroke Petrol Engine with fuel and pre heated pure oxygen using heat pipe

a) The experiments are carried out on two stroke petrol engine with fuel and pre heated pure oxygen by using heat pipe.
b) Here we connect inlet and exhaust of two stroke petrol engine by using heat pipe for heating pure oxygen at inlet by the heat of exhaust.
c) After this we calculate fuel consumption, rpm, brake thermal efficiency.
d) With the help of fuel consumption, we calculate specific fuel consumption.
e) After obtaining specific fuel consumption (SFC) we plot SFC vs rpm curve.
f) In this experimental work the speed of the engine, time taken for 10 ml of fuel consumption and Load on spring balance reading at various stages is taken.

C. The Experiment work

Step1. In the first stage, the oxygen cylinder is connected to the test rig of two stroke petrol engines and run the engine.
Step2. By varying the load, the Speed of the engine is noted.
Step3. At the various load condition, the time taken for 10 ml of fuel combustion is noted.
Step4. At this various load condition temperature of inlet water, water outlet calorimeter, gas inlet and gas outlet are taken.
Step5. Finally, the Brake power, Specific Fuel Consumption and Brake thermal efficiency is calculated at different load condition on the engine.

Table 1: Specification of the Engine

Items	Specification
Make	Bajaj
Stroke	66.7 mm
Bore	70 mm
Capacity	150 cc
Rated R.P.M	3000 rpm
Fuel	Petrol
Sp. Gr. of petrol	0.739
Calorific Value of petrol	47100 kJ/kg

Fig. 2: Experimental Setup

VI. LOAD CALCULATIONS

W_{net} = Net load = $[(S_1-S_2) + W_0] * 9.81$
Where,
S_1 = Weight on hanger 1
S_2 = Weight on hanger 2
W_0 = Dead weight = 1 Kg

The net load is calculated with the help of dead load and weight on hangers in Table 2 with air.

Table 2: Spring load and net load in case of air

S. No.	S_1 (kg)	S_2 (kg)	W_{net} (N)
1	2	1	19.62
2	4	2.2	27.468
3	6	3.8	31.392
4	8	4.8	41.202

The net load is calculated with the help of dead load and weight on hangers in Table 3 with pure oxygen.

Table 3: Spring load and net load in case of pure oxygen

S. No.	S_1 (kg)	S_2 (kg)	W_{net} (N)
1	2	.5	24.525
2	4	1.5	34.335
3	6	2.2	47.088
4	8	3.4	54.936

The net load is calculated with the help of dead load and weight on hangers in Table 4 with preheated pure oxygen.

Table 4: Spring load and net load in case of preheated pure oxygen

S. No.	S_1 (kg)	S_2 (kg)	W_{net} (N)
1	2	.2	27.468
2	4	1	39.24
3	6	1.6	52.974
4	8	2.4	64.746

A. Speed, Torque and Brake Power

Torque is calculated with the help of load and speed of the engine in Table 5 with air.

Table 5: Speed and Torque in case of air

S. No.	Speed (rpm)	Torque (N. m)	BP (kW)
1	140	19.24	0.281
2	131	26.946	0.369
3	115	30.795	0.370
4	98	40.414	0.414

Torque is calculated with the help of load and speed of the engine in Table 6 with pure oxygen.

Table 6: Speed and Torque in case of pure oxygen

S. No.	Speed (rpm)	Torque (N.m)	BP (kW)
1	180	24.059	0.453
2	150	33.682	0.528
3	125	46.193	0.604
4	112	53.89	0.631

Torque is calculated with the help of load and speed of the engine in Table 7 with preheated pure oxygen.

Table 7: Speed and Torque in case of pre heated pure oxygen

S. No.	Speed (rpm)	Torque (N.m)	BP (kW)
1	210	26.946	0.592
2	198	38.494	0.797
3	190	51.967	1.033
4	179	63.518	1.190

The Fig. 3 shows that the Torque is increased in case of pure oxygen compared to the air with respect to applied load (S_1).

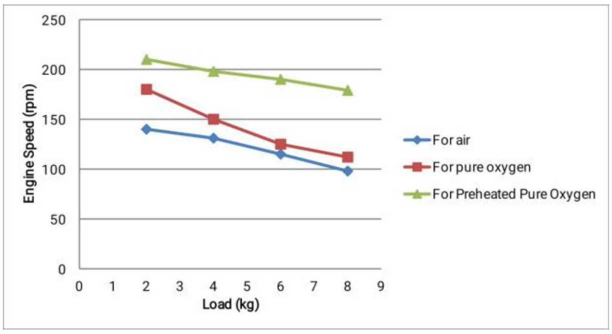

Fig. 3: Load Vs Engine speed for air and pure oxygen

In the Fig. 4 shows that the Torque is increased in case of pure oxygen compared to the air with respect to applied load (S_1).

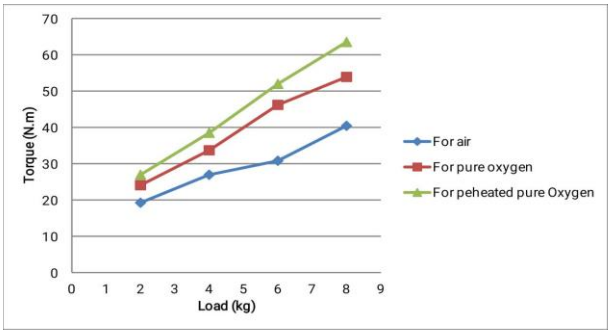

Fig. 4: Load Vs Torque for air and pure oxygen

The Fig. 5 shows that the Brake Power is increased in case of pure oxygen compared to the air with respect to applied load (S_1).

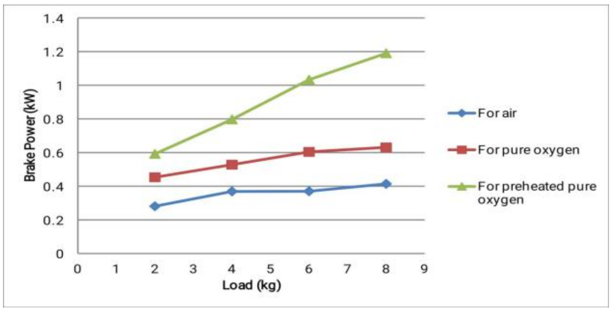

Fig. 5: Graph shows the relation between BP and Load (S1) for air and pure oxygen

VII. BRAKE THERMAL EFFICIENCY

The calculation of Fuel consumption, Specific fuel consumption, Engine heat and Brake thermal efficiency with the help of time period for fuel consumption, brake power is displayed in Table 8 with air.

Table 8: Engine Heat and Brake Thermal Efficiency for air

S. No.	Time Period for Fuel Consumption t_f (Sec)	Fuel Consumption (kg/hr)	Specific Fuel Consumption (kg/kWh)	Engine Heat (kW)	η_{BT} (%)
1	75	0.354	.793	4.703	6.06
2	77	0.345	1.069	4.581	8.17
3	78	0.341	1.085	4.522	8.29
4	81	0.328	1.262	4.355	9.64

The calculation of Fuel consumption, Specific fuel consumption, Engine heat and Brake thermal efficiency with the help of time period for fuel consumption, brake power is displayed in Table 9 with pure oxygen

Table 9: Engine Heat and Brake Thermal Efficiency for pure oxygen

S. No.	Time Period for Fuel Consumption t_f (Sec)	Fuel Consumption (kg/hr)	Specific Fuel Consumption (kg/kWh)	Engine Heat (kW)	η_{BT} (%)
1	80	0.332	1.364	4.409	10.40
2	84	0.316	1.670	4.199	12.77
3	93	0.286	2.111	3.793	16.14
4	101	0.263	2.399	3.429	18.33

The calculation of Fuel consumption, Specific fuel consumption, Engine heat and Brake thermal efficiency with the help of time period for fuel consumption, brake power is displayed in Table 10 with preheated pure oxygen.

Retrieval Number: L28771081219/2019©BEIESP
*DOI: 10.35940/ijitee.*L2877.*1081219*

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Table 10: Engine Heat and Brake Thermal Efficiency for preheated pure oxygen

S. No.	Time Period for Fuel Consumption t_f (Sec)	Fuel Consumption (kg/hr)	Specific Fuel Consumption (kg/kWh)	Engine Heat (kW)	η_{BT} (%)
1	100	0.266	2.25	3.527	17.01
2	103	0.258	3.089	3.424	23.61
3	108	0.246	4.199	3.266	32.09
4	114	0.233	5.107	3.094	39.03

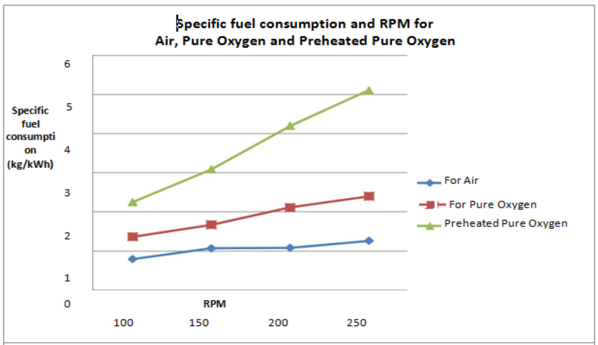

Figure 6 Graph shows the specific fuel consumption of the engine for air, pure oxygen and preheated pure oxygen

Fig. 6 shows that the specific fuel consumption is increased in case of preheated pure oxygen compared to the air with respect to applied load (S_1). This means that the heat supplied by fuel is reduced in case of pure oxygen.

Fig. 7 shows that the Brake thermal efficiency is increased in case of preheated pure oxygen compared to the air with respect to applied load (S_1). This means that the heat supplied by fuel is reduced in case of pure oxygen.

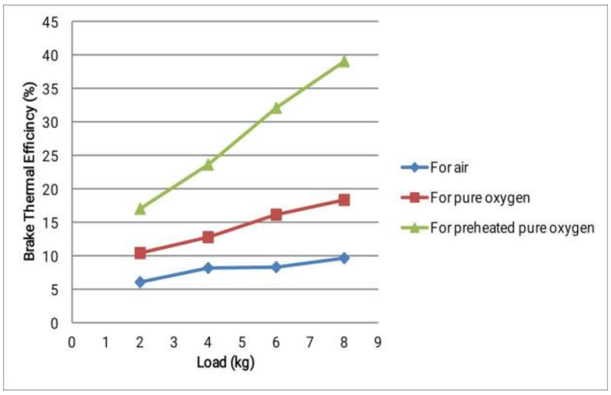

Fig. 7 Graph shows the Brake Thermal Efficiency of the engine for air, pure oxygen and preheated pure oxygen

A. CALCULATIONS

Given,
Pressure = 1 bar
Fuel = petrol
Wnet = [(S1－S2)＋W0] 9.81

$$\text{Break power} = \frac{2\pi NT}{60\times1000}\ \text{kW}$$

$$\text{Torque} = (S1\text{-}S2)\times 9.81\times .1\ \text{Nm}$$

$$\text{Fuel Consumption} = \frac{10\times3600\times.739}{t\times1000}\ \text{kg/h}$$

$$\text{Specific fuel consumption} = \frac{Fc}{BP}\ \text{kg/kWh}$$

$$\text{Efficiency} = \frac{BP\times3600}{Fc\times47100}$$

$$\text{Engine Heat} = \frac{352.77}{T}\ KW$$

B. CALCULATION FOR AIR

Given, W_0=1, Cv = 47100, S1=2, S2=1
We have, Load (S1-S2) =1, Time = 75sec, rpm = 140
Wnet = [(S1-S2) + W0] 9.81 = [(1-2) + 1] 9.81=19.62 N
Torque (T) =Wnet × 9.81 × 0.1 = 19.62×9.81×0.1=19.24 Nm

$$\text{Break Power (BP)} = \frac{2\times3.14\times140\times19.24}{60\times1000} = 0.281\ \text{kW}$$

$$\text{Fuel Consumption (Fc)} = \frac{10\times3600\times0.739}{t\times1000} = \frac{10\times3600\times0.739}{75\times1000} = 0.354\ \text{kg/h}$$

$$\text{Specific Fuel Consumption (SFC)} = \frac{BP}{FC} = \frac{0.281}{0.354} = 0.793\ \text{kg/kWh}$$

$$\text{Engine Heat (EH)} = \frac{352.77}{t} = \frac{352.77}{75} = 4.703\ \text{kW}$$

$$\text{Efficiency} = \frac{0.281\times3600}{mf\times cv} = \frac{0.281\times3600}{0.354\times47100} = 6.06\%$$

Now, similarly all the values of Break power, torque, Specific fuel, consumption, Wnet, fuel consumption, engine heat, and Efficiency are obtained by above formulas, similarly for 4kg ,6kg ,8kg are obtained see it in observation tables.

C. Calculation for Pure Oxygen

Given, W0=1, Cv = 47100, S1= 2, S2 = 0.5
We have, Load (S1-S2) = 1.5, Time = 80sec, rpm=180
Wnet = [(S1-S2) + W0] 9.81 = [(2-0.5) +1] 9.81=24.525 N
Torque (T) =Wnet × 9.81× 0.1 = 24.525×9.81×0.1=24.059Nm

$$\text{Break Power (BP)} = \frac{2\times3.14\times180\times24.059}{60\times1000} = 0.453\ \text{kW}$$

$$\text{Fuel Consumption (Fc)} = \frac{10\times3600\times0.739}{t\times1000} = \frac{10\times3600\times0.739}{80\times1000} = 0.332\ \text{kg/h}$$

$$\text{Specific Fuel Consumption (SFC)} = \frac{BP}{FC} = \frac{0.453}{0.332} = 1.364\ \text{kg/kWh}$$

$$\text{Engine Heat (EH)} = \frac{352.77}{t} = \frac{352.77}{80} = 4.409\ \text{kW}$$

$$\text{Efficiency} = \frac{0.281\times3600}{mf\times cv} = \frac{0.453\times3600}{0.332\times47100} = 10.40\%$$

Now, Similarly all the values of Break power, torque, Specific fuel, consumption, Wnet, fuel consumption, engine heat, and Efficiency are obtained by above formulas, similarly for 4kg ,6kg ,8kg are obtained see it in observation tables.

D. Calculation for Pre Heated Pure Oxygen

Given, W0 = 1, Cv = 47100, S1=2, S2=0.2

We have, Load (S1-S2) =1.8, Time=100 sec, rpm=210

Wnet = [(S1-S2) + W0]9.81 = [(2-0.2)+1]9.81]=27.468 N

Torque (T) =Wnet×9.81×0.1 = 27.468×9.81×0.1=26.946Nm

$$\text{Break Power (BP)} = \frac{2\times3.14\times210\times26.946}{60\times1000} = 0.592 \text{ kW}$$

$$\text{Fuel Consumption (Fc)} = \frac{10\times3600\times0.739}{t\times1000} = \frac{10\times3600\times0.739}{100\times1000} = 0.266 \text{kg/h}$$

$$\text{Specific Fuel Consumption (SFC)} = \frac{BP}{FC} = \frac{0.592}{0.266} = 2.225 \text{ kg/kWh}$$

$$\text{Engine Heat (EH)} = \frac{352.77}{t} = \frac{352.77}{100} = 3.527\text{kW}$$

$$\text{Efficiency} = \frac{0.281\times3600}{mf\times cv} = \frac{0.592\times3600}{0.266\times47100} = 17.01\%$$

Now, similarly all the values of Break power, torque, Specific fuel, consumption, Wnet, fuel consumption, engine heat, and Efficiency are obtained by above formulas, similarly for 4kg ,6kg ,8kg are obtained see it in observation tables.

VIII. RESULTS AND DISSCUSSION

In this research work, engine performance is analyzed in two ways primarily by using the pure oxygen and secondly by using the pre-heated pure oxygen through heat pipe.

In this experimental work, we did experimental analysis on the two stroke IC engine to calculate its efficiency by two ways, primarily by using the pure oxygen and secondly by using the pre-heated pure oxygen through heat pipe. The break power of IC engine in case of air is less as compared to pure oxygen and it will further increase by the use of preheated pure oxygen through heat pipe.

The fuel consumption of IC engine in case of air is less as compared to pure oxygen and it is further less by the use of reheated pure oxygen through heat pipe. The specific fuel consumption of IC engine is continuously increasing when we supply pure oxygen instead of air and it will further increase if we supply preheated pure oxygen instead of pure oxygen. The efficiency of engine is tremendously increase when we supply preheated pure oxygen instead of air.

IX. CONCLUSIONS

The following conclusions could be drawn on the basis of results and discussion:

a) The quality of oxygen largely influenced the performance of the engine. It is evident from experimental results that pre heated oxygen could enhance the performance of the engine if used at the right level.

b) The experimental results also showed that the consumption of fuel is also decreased. The preheated supply of oxygen increases the speed of the engine to great extent. The brake power and thermal efficiency are also increased to the significance level.

Finally, we concluded that the replacement of air from pre heated pure oxygen is one of the best methods to increase the efficiency of the engine and also reduce the amount of the fuel as compared to conventional method.

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