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AN EXPERIMENTAL STUDY OF FORCED INDUCTION ON A FOUR STROKE ENGINE

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Abstract -
The personal transportation choices that people make will have a drastic impact on air quality. What the people commute with and how they commute will impact the environment. The air pollutants have an additional impact on human life as these particulate matter cause respiratory diseases with an elevated risk of cancer. To improve this dire situation, several steps have been adopted by automobile companies worldwide over the past 20 years. The emission and fuel consumption norms are becoming more stringent. Hence, the present work reports an experimental study to investigate the usefulness of the auxiliary unit that introduces compressed air into the intake manifold to improve the fuel economy and volumetric efficiency of the IC engine[1]. It is observed that the fuel economy and volumetric efficiency have been improved by introducing compressed air through the auxiliary unit.

Key Words: IC engine, power, air fuel, auxiliary unit, manifold, efficiency

1. INTRODUCTION

Fossil fuels (oil, diesel, natural gas and coal), which today represent the bulk of global energy demand, are rapidly depleting. Their combustion products pose global problems, such as the greenhouse effect, depletion of the ozone layer, acid rain and pollution, which pose a major threat to the environment and possibly to life. on the planet. These factors encourage automakers to develop alternative-fueled cars. Another possibility is the vehicle, whose energy efficiency can be increased by compressed air. It is well known that by varying the air-fuel mixture of an engine, it is possible to increase fuel economy or increase power [2].
IC engine is a heat engine wherein the high temperature and high pressure gasses produced by combustion produces power to provide drive to a vehicle.

Forced induction:

The displacement and efficiency of a naturally aspirated engine limits the amount of power it can produce. The engine cannot breathe as much air as the atmospheric force that pushes it into the engine. Higher compression engines have the advantage of maximizing the amount of usable energy developed per unit of fuel. Therefore, the thermal efficiency of the engine is enhanced according to the steam cycle analysis of the second principle of thermodynamics. The reason why not all engines have a higher compression is that the fuel explodes prematurely at a certain octane number at a compression ratio higher than normal. These are called pre-ignition, detonation or knock and can cause serious engine damage. A forced intake system overcomes the limits of atmospheric pressure by forcing more air into the cylinder. Therefore, the power of the engine depends on the thrust received. In addition, the selection of the boost pressure eliminates many deficiencies in the intake system and in the cylinder heads, which could affect the air flow and the volumetric efficiency of the engine; two systems, supercharging and turbo charging, are conventionally used [3]. They differ chiefly in how they generate boost. A turbocharger is spun by exhaust gasses whereas a supercharger is driven by a pulley via the crankshaft [4][5].

2. OBJECTIVES

- To supply compressed air to the air intake manifold by using a compressor.
- To find the optimal air flow rate that provides the best fuel economy without compromising on the power.
- To determine the brake power, indicated power, mechanical efficiency, brake thermal efficiency and indicated thermal efficiency of the engine with the installed auxiliary unit.
- To ascertain the viability of the auxiliary unit, the test results after the augmentation is compared with the test results prior to the augmentation.

3. METHODOLOGY

- In order to test the viability of the augmentation, a basis for comparison of the test results had to be formed. This was achieved by testing the engine under the required conditions to determine certain key factors such as:-

    1. Brake power
    2. Frictional power
    3. Indicated power
    4. Specific fuel consumption
    5. Mechanical efficiency
    6. Brake thermal efficiency
    7. Indicated thermal efficiency

- Certain modifications to the intake manifold to supply compressed air were performed.

- Determining the key factors of engine performance with the installed auxiliary unit.

- To ascertain the viability of the auxiliary unit, the test results after the augmentation is compared with the test results prior to the augmentation.

- The optimum air flow rate which provides the best fuel economy without compromising too much on the power is then determined through iterative method.

EXPERIMENT AND THE SETUP

AUXILIARY UNIT

The auxiliary unit consists of two components:-

1. Modified intake manifold
2. Compressor

MODIFIED INTAKE MANIFOLD

The intake manifold was modified in such a way as to supply compressed air at the required angle to the intake of the engine[6]. The supply of the compressed air was provided after the carburettor to ensure constant supply of air even in no load condition[7][8]. The modified intake manifold is shown in Fig.1.

Fig 1: Modified intake manifold

COMPRESSOR

Fig 2 shows the compressor set up used for our study. The specifications are as follows:

- Power = 0.34 KW
- Maximum working time = 15 minutes
- Maximum decompression rate = 50 L/min
- Maximum compression rate = 32 L/min

Fig 2: Compressor

DETERMINATION OF BRAKE POWER

Experimental setup:

Fig 3 shows the Brake drum dynamometer petrol engine used for the study. The following are the details of the engine.

BHP: 2.5HP
No. of cylinders: 1
Compression ratio: 4.67:1
Bore: 70mm
Stroke: 66.7mm
Speed: 3000rpm
Loading radius: 0.1m

Fig 3: Brake drum experimental setup

From the previous experimental setup, some changes were made to accommodate the intake of compressed air as shown in Fig.4.

Fig 4: Experimental setup with the compressor and modified intake manifold

Experiment

The procedures followed before the implementation of the auxillary unit are as follows:

- The engine was started and the time taken for consumption of 25cc of fuel was noted down under no load condition.
- The brake drum was subsequently loaded with weights and the time taken for consumption of 25cc of fuel was noted.
- The speed of the engine was also determined with the help of a tachometer.
- This procedure was repeated for different loads until the engine was loaded 100%.
- The results were tabulated and graphs were plotted.

The procedures followed after implementation of the auxiliary unit are as follows

- The modified intake manifold was mounted to the engine and the outlet of the compressor was directed towards the open port in the intake manifold.
- The engine was started and the time taken for consumption of 25cc of fuel was noted down under no load condition.
- The flow of the compressed air was also simultaneously monitored.
- The brake drum was subsequently loaded with weights and the time taken for consumption of 25cc of fuel was noted.
- The speed of the engine was also determined with the help of a tachometer.
- This procedure was repeated for different loads until the engine was loaded 100%.
- The results were tabulated and graphs were plotted.
- This experiment was repeated for different air flow rates to determine the optimum air flow rate that gives the least specific fuel consumption without compromising on anti-knocking characteristic of the engine.

Formulae used for the calculations:

- **BP**$= \dfrac{2\pi NT}{60000}$**KW**
- $FP = V * I\ KW$
- $IP = BP + FP\ KW$
- $F_c = \dfrac{25 * SG * 3600}{1000 * t}$
- **SG = 0.739**
- $Q = \dfrac{C_v * F_c}{3600}$
- C_v **= 45,800 KJ/Kg**
- **Mechanical efficiency = BP/IP %**
- **Brake thermal efficiency = BP/Q %**
- **Indicated thermal efficiency = IP/Q %**
- **Full load** $= \dfrac{1.865 * 60 * 1000}{2 * \pi * 3000 * 0.1}$ **= 6 Kg**

RESULTS AND ANALYSIS

Determination friction power

The motor has a rated capacity of 1HP and has a rated speed of 3000rpm. From the motoring method, the voltage and current values obtained while running the engine at 2900 rpm are:

Voltage - 230V

Current - 0.45A

The power output obtained is FP = V*I = 0.51 KW

Determination brake power without the auxiliary unit

In this experiment the engine was run without the aid of compressed air.

Table 1: Tabulated results of the experiment to determine brake power without auxiliary unit

LOAD		Time (s)	Speed (rpm)	F_c (Kg/hr)	Q	T Nm	BP KW	FP KW	IP KW	Mechanical efficiency (%)	BTE (%)	ITE (%)
Kg	N											
0	0	73.47	2940	0.905	11.513	0	0	0.51	0.51	-	-	-
1	9.81	68.9	2900	0.965	12.276	0.981	0.297	0.51	0.807	36.80	2.41	6.57
2	19.62	64.72	2890	1.027	13.065	1.962	0.593	0.51	1.103	53.76	4.53	8.44
3	29.43	59.89	2870	1.11	14.121	2.943	0.884	0.51	1.394	63.41	6.26	9.87
4	39.24	56.47	2860	1.177	14.974	3.924	1.175	0.51	1.685	69.73	7.84	11.25
5	49.05	53.85	2840	1.235	15.711	4.905	1.458	0.51	1.968	74.08	9.28	12.52
6	58.86	50.53	2800	1.316	16.742	5.886	1.725	0.51	2.235	77.18	10.30	13.34

Determination of optimum air flow rate

In order to obtain maximum fuel efficiency without affecting the anti-knock characteristics of the engine, the engine was run by introducing compressed air at different air flow rates. Hence, an optimum air flow rate was obtained that could satisfy the objective of the present work. The engine was tested for the following values of air flow rate – 0.4 L/s, 0.5L/s, 0.6 L/s, 0.65 L/s and 0.7 L/s.

Table 2: Fuel efficiency and speed determinants for 0.4 L/s,0.5L/s, 0.6 L/s, 0.65 L/s and 0.7 L/s volume flow rate of air

		0.4 L/s volume flow rate of air		0.5 L/s volume flow rate of air		0.6 L/s volume flow rate of air		0.65 L/s volume flow rate of air		0.7 L/s volume flow rate of air	
LOAD		Time (s)	Speed (rpm)	Time (s)	Speed (rpm)	Time (s)	Speed (rpm)	Time (s)	Speed (rpm)	Time (s)	Speed (rpm)
Kg	N										
0	0	73	2940	73.58	2940	75.56	2940	76.06	2950	76.65	2960
1	9.81	69	2900	69.85	2910	70.35	2900	71.12	2900	71.0	2920
2	19.62	64.69	2890	65.2	2880	65.88	2860	66.63	2850	66.43	2830
3	29.43	59.89	2870	60.23	2860	60.3	2860	60.48	2860	61.48	2860
4	39.24	56.5	2860	56.7	2850	57.89	2800	58.42	2790	59.42	2790
5	49.05	54.1	2840	54.69	2830	54.69	2790	55.89	2730	54.89	2730
6	58.86	50.8	2800	52.1	2800	52.67	2770	53.42	2660	53.42	2680

Fuel efficiency and speed determinants for 0.4 L/s,0.5L/s, 0.6 L/s, 0.65 L/s and 0.7 L/s volume flow rate of air are shown in Table 2. The engine exhibited severe knocking which resulted in the rate of fuel consumption to be erratic when the air flow rate was raised to 0.7 L/s. Hence, the optimum air flow rate is 0.65 L/s in which the engine exhibited best characteristics.

Determination of brake power with the auxiliary unit

In this experiment, the engine was tested with the auxiliary unit which supplied compressed air at the rate of 0.65 L/s to determine various parameters.

Table 3: Tabulated results of the experiment to determine brake power with auxiliary unit

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LOAD		Time (s)	Speed (rpm)	F_c (Kg/hr)	Q	T Nm	BP KW	FP KW	IP KW	Mechanical efficiency (%)	BTE (%)	ITE (%
Kg	N											
0	0	76.06	2950	0.874	11.119	0	0	0.51	0.51	-	-	-
1	9.81	71.12	2900	0.935	11.895	0.981	0.297	0.51	0.807	36.80	2.49	6.7
2	19.62	66.63	2850	0.998	12.696	1.962	0.585	0.51	1.095	53.42	4.60	8.6
3	29.43	60.48	2860	1.099	13.981	2.943	0.881	0.51	1.391	63.33	6.30	9.9
4	39.24	58.42	2790	1.138	14.477	3.924	1.146	0.51	1.656	69.20	7.91	11.4
5	49.05	55.89	2730	1.190	15.139	4.905	1.402	0.51	1.912	73.32	9.26	12.6
6	58.86	53.42	2660	1.245	15.839	5.886	1.639	0.51	2.149	76.26	10.34	13.5

Characteristic curves of four stroke petrol engine

With reference to Table 1 and Table 3, the graph of Brake Power (BP) vs Fuel Consumption (FC), graph of Indicated power (IP) vs Brake Power (BP), the graph of Brake Power (BP) vs Mechanical Efficiency, the graph of Brake Power (BP) vs Brake Thermal Efficiency (BTE) and the graph of Brake Power (BP) vs Indicated Thermal Efficiency (ITE) are shown in Fig 5, Fig 6, Fig 7, Fig 8 and Fig 9 respectively.

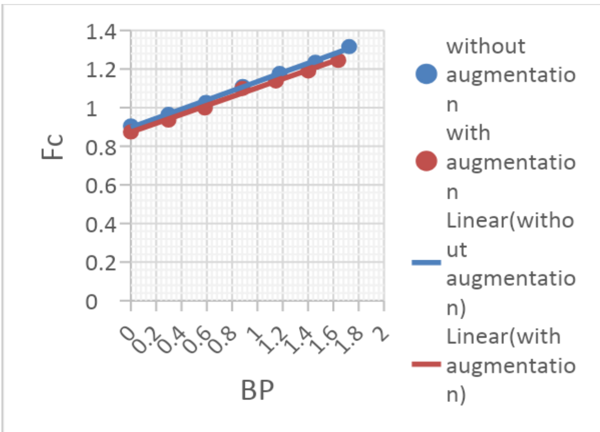

Fig: 5 Graph of BP vs F_c

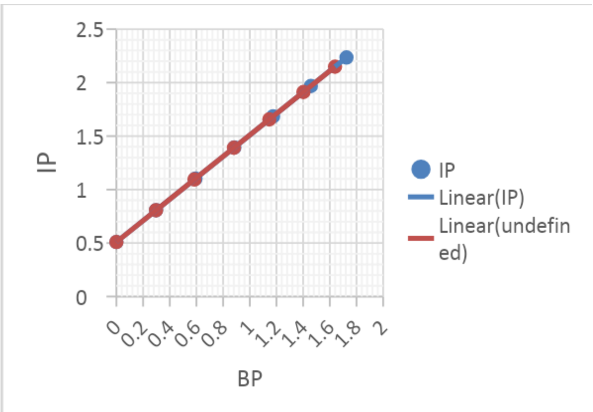

Fig: 6 Graph of BP vs IP

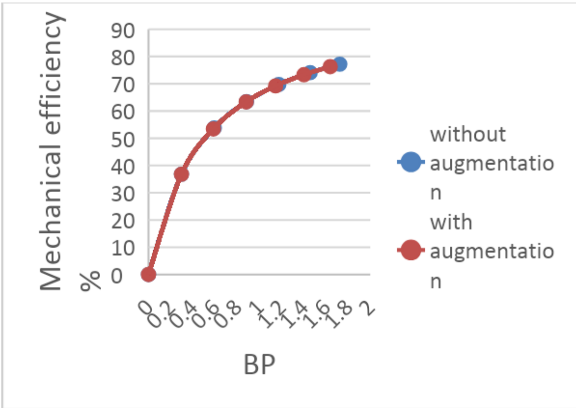

Fig: 7 Graph of BP vs Mechanical efficiency

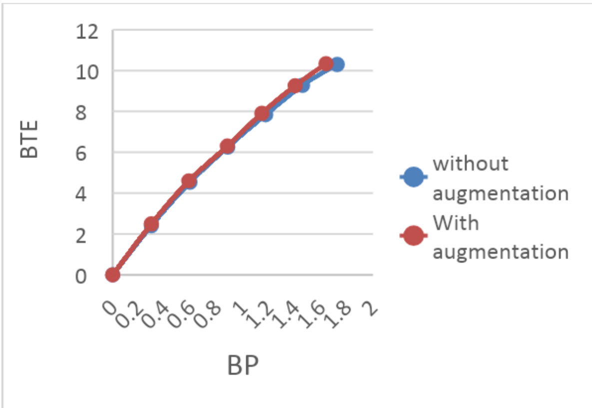

Fig: 8 Graph of BP vs BTE

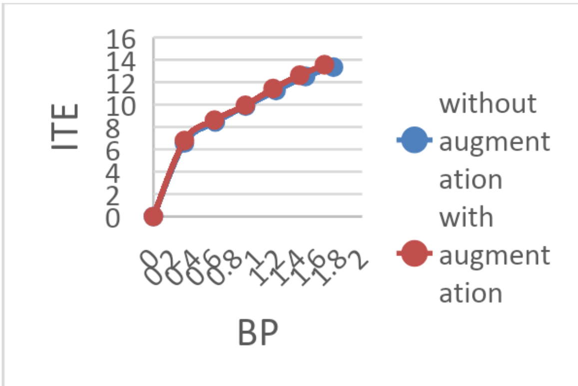

Fig: 9 Graph of BP vs ITE

ANALYSIS OF THE RESULTS

From the graphs it is evident that there is a significant improvement in the specific fuel consumption when the engine was run with the auxiliary unit. The average specific fuel consumption of the engine without the auxiliary unit is 1.105 Kg/hr whereas the average specific fuel consumption of the engine with the auxiliary unit is 1.045 Kg/hr. Therefore, the specific fuel consumption has improved by 5.43%.

On the comparing the Indicated power of the engine when it was run with the auxiliary unit and with the one without the auxiliary unit, it is found that the indicated power has dropped by only 1.87%. Hence, it is suffice to say that the performance of the engine is not significantly affected.

There have been significant improvements in the brake thermal efficiency and indicated thermal efficiency. In other words, the fuel is burning much better with the introduction of the auxiliary unit. This will ensure the longevity of the engine performance and health. Since the fuel is burning better, there are less carbon deposits on the cylinder head and more importantly, the emission of the harmful gases have reduced.

SUGGESTIONS AND DISCUSSIONS

From the present work, with the introduction of the auxiliary unit, the specific fuel consumption was improved with negligible change in the power output of the engine. This implies that the engine is able to burn the fuel much better without compromising on the performance.

Although the desired results were obtained, this setup is not viable to be commercialized because of the bulky nature of the compressor. This drawback can be eliminated by storing compressed air in pressurized air cylinders that can be mounted onto the chassis. But this system poses yet another drawback i.e., the short life of the compressed air in the cylinder. To improve the fuel economy, there has to be a constant supply of air to the engine. This may result in the pressure to drop quite rapidly inside the cylinder. Hence, this setup may also prove impractical.

However, there is a system that can be adopted which can supply air at a constant rate. This system should have a reservoir which is connected to a portable compressor which is powered by the standard 12V battery. This system can hence ensure constant supply of air at the required rate and at the same time eliminate the drawbacks of the former two systems.

3. CONCLUSIONS

Experiments have been conducted to check the viability of an engine which can be run by an auxiliary unit which supplies pressurised air into the intake manifold. The brake power of the system was determined by utilising the brake drum setup whereas the frictional power of the system was determined by the motoring method. Various parameters which are critical to the engine performance were determined. The rate at which the compressed air had to be sent was determined through an iterative method. The air flow rate which gave the best performance characteristics was adopted. The results of the experiment without the auxiliary unit and the experiment with the auxiliary unit were compared to check the viability of the auxiliary unit.

Following are the conclusions:

- From the present work, with the introduction of the auxiliary unit, the specific fuel consumption was improved with negligible change in the power output of the engine.
- The brake thermal efficiency and indicated thermal efficiency have been improved. In other words, the combustion of the fuel is much better with the introduction of the auxiliary unit. This will ensure the longevity of the engine performance and health. Since the fuel is burning better, there is less carbon deposits on the cylinder head and more importantly, the emission of the harmful gases have reduced.

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