Performance Study of Air Driven Engine Being Modified From Conventional Four Stroke Engine without Cam Modification

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ABSTRACT: *This research presents a novel mechanism to convert a conventional100-cc four stroke driven engine into a 2 stroke compressed air driven engine without doing any modifications in the cam shaft. This allows for a faster valve operation & also helping the existing engines to be converted into air driven engines with removal of intake and exhaust manifold and also provides a platform to curb the growing menace of air pollution by using the existing old engines to be used as air driven engine. Also, cycle of operation of the Air Engine has been representedon P-V diagram and theoretical efficiency has been calculated which is a function of pressure ratio and temperature, and comes out to be around 80 percent (@ Prr. Ratio of 10& Temp of 550K). Variation of rpm with percentage valve opening is seen at different pressure ratios and the maximum speed of the engine (after doing said modifications and running through compressed air)is observed to be 1573 rpm at a pressure of 9 bar with the developed mechanism for the existing 4 stroke maestro engine.*

I. INTRODUCTION

As the world is hard pressed with the energy and fuel crises, compounded by pollution of all kinds, any technologies that bring out the solutions to this problem is considered as a bounty.At first glance the idea of running an engine on air seems to be too good to be true. But in one of such new technologies, is the development of a new engine called as compressed air engine which does not require any of the known fuels like diesel, petrol, CNG, LPG, hydrogen etc. and requires only compressed air as an aid for running the engine [1-2]. This replaces all types of up-to-date known fuels and also permanently solves the problems of pollution as its exhaust is clean and cool measured practically as low as 5ºC[3]. This low temperature air can be used in the air conditioning system of the vehicle directly or by using heat exchanger[4-5]. In present experimental setup at normal pressure, atmospheric temperature of air before compression was 35ºC and after expansion in the cylinder a dip of 3- 4ºC was observed in the discharge side. Since this engine runs only on high pressure compressed air, the exhaust of which is undoubtedly only air (which is all around us and will never runs out), making it a zero pollution engine[6]. No heat is generated because there is no combustion of fuel, hence this engine needs no cooling system and it result in reduced cost, weight, volume and vibration[7].It requires lighter metal only since it does not have to withstand elevated temperatures. An Air Driven Engine makes use of Compressed Air Technology for its operation[8].

Compressed Air Technology is now widely preferred for research by different industries for developing different drives for different purposes[9]. The Compressed Air Technology is quite simple in principle too. If we compress normal air into a cylinder the air would hold some energy within it. This energy can be utilized for useful purposes. When this compressed air expands, the energy is released to do work.So this energy in compressed air can also be utilized to displace a piston. This is the basic working principle of the Air Driven Engine[10-11]. It uses the expansion of compressed air to drive the pistons of the engine. So an Air Driven Engine is basically a pneumatic actuator that creates useful work by expanding compressed air[12]. This work provided by the air is utilized to supply power to the crankshaft of the engine

NOMENCLATURE

T_1 = Atmospheric Air Temperature

T_3 = Air temperature before entering cylinder

Q_{add} = Represents energy inlet to Cylinder (in form of compressed air)

Q_{re} = Represents energy outlet from Cylinder (in form of compressed air)

η = Efficiency

r_p = Pressure Ratio

C_p = Heat Capacity at constant volume

γ = Heat Capacity ratio at constant pressure and volume

Q_S = Heat Supplied

Q_R = Heat Rejected

R = Universal Gas Constant

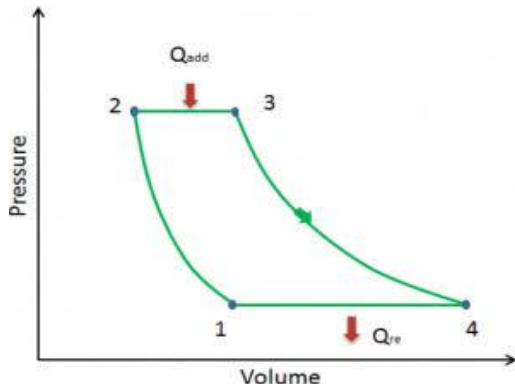## II. THEORETICAL P-V REPRESENTATION& EFFICIENCY CALCULATION

Fig. 1   Theoretical P-V Cycle For CAE

Process 1-2 : Isothermal compression

Process 2-3 : Expansion at constant pressure

Process 3-4 : Isentropic expansion inside the engine

Process 4-1 : Air discharge at constant pressure from the engine

$\eta = W.D/Q_S = Q_S - Q_R/Q_S$

$\eta = 1 - Q_R/Q_S$

$\eta = 1 - [mR \ln(P_2/P_1) + mC_p(T_3 - T_2)] / [mC_p(T_4 - T_1)]$

$\eta = 1 - [mR \ \ln(P_2/P_1)] / [mC_p(T_4 - T_1)] - [mC_p(T_3 - T_2)] / [mC_p(T_4 - T_1)]$

Now,

$C_P = \gamma R/\gamma - 1$

So,

$\eta = 1 - [mR \ln(P_2/P_1)] / [m(\gamma R/\gamma - 1)(T_4 - T_1)] - [mC_p T_2 (T_3/T_2 - 1)] / [mC_p T_1 (T_4/T_1 - 1)]$

Also,

$T_2/T_1 = (P_2/P_1)^{(\gamma - 1/\gamma)} = r_p^{(\gamma - 1/\gamma)}$

And,

$T_3/T_4 = r_p^{(\gamma - 1/\gamma)}$

So,

$T_2/T_1 = T_3/T_4$

Or,

$T_4/T_1 = T_3/T_2$

Therefore,

$\eta = 1 - [\ln(P_2/P_1)] / [(\gamma/\gamma - 1)(T_4 - T_1)] - [T_2/T_1]$

$\eta = 1 - T_1 [\ln(r_p)] / [(\gamma/\gamma - 1)(T_3 - T_1)] - [r_p^{(\gamma - 1/\gamma)}]$
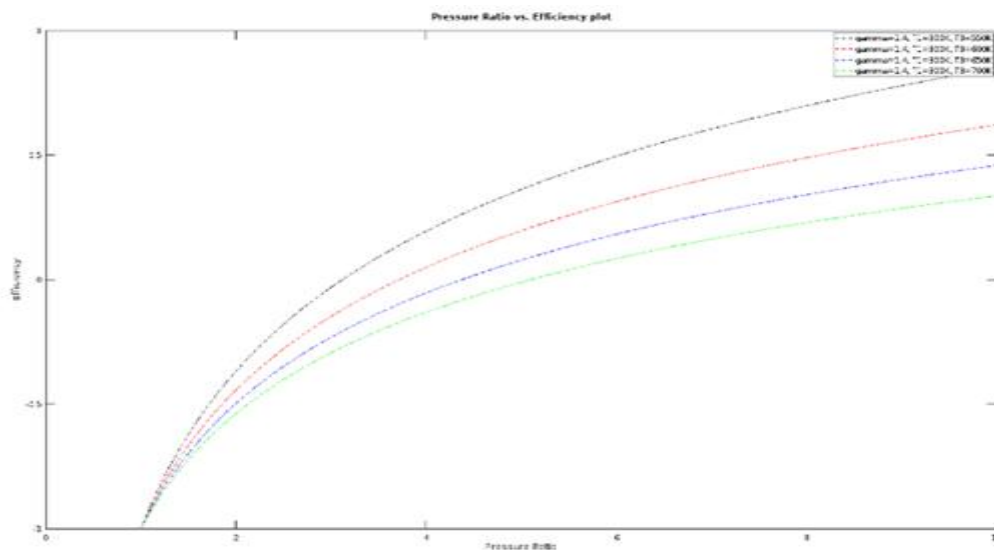

Fig.2 Pressure Ratio versus efficiency plot at different temperature
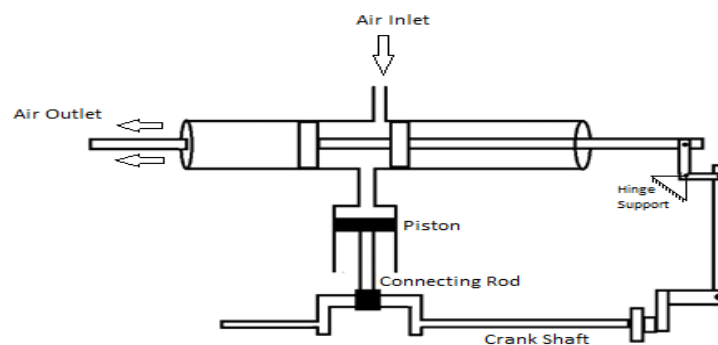
III. EXPERIMENTAL SETUP

Fig. 3 Mechanism For Converting Four Stroke Engine into Two Stroke Engine

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For running a compressed air engine, we require two strokes (one power stroke and the other exhaust stroke). So we require to modify a four stroke engine into a two stroke engine. The modification can be carried out by change in cam profile and gear ratio. But changing the cam profile to desired accuracy is difficult. So the alternate route was developed by working out a mechanism to convert four stroke engine to two stroke. As shown in the figure 3 an offset has been provided to the crank which is further connected with the bell crank lever in order to transmit the rotational movement of the crankshaft into the linear movement of directional control valve to regulate the supply line.
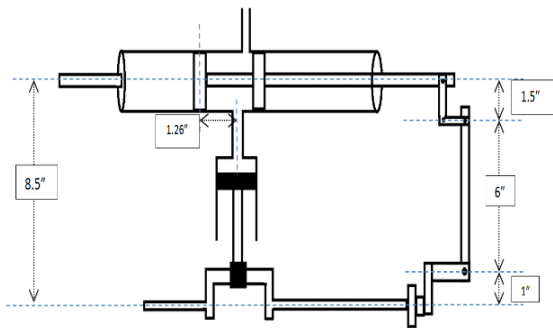

Fig.4 Final optimized dimensions of the engine

Using kinematic and dynamic motion study followed by practical optimization, the final dimensions have been calculated for the mastero four stroke 100cc engine, shown in the figure 4. In this way, by limiting the distance between the direction control valve pistons and their distance from the piston bore center, we can ensure that the inlet/outlet port will be open to compressed air when piston is at TDC and will be open to exhaust pipe when piston is at BDC which will provide us with 2 stroke functioning of engine.

Fig.5 Fabricated engine with modified Mechanism

Fig.6 Used Compressor with attached buffer tank

IV. RESULTS

After doing the said modifications in the engine as shown in Fig 5, it was connected to the air storage (buffer) tank as shown in Fig 6 through a ball valve. In the buffer cum storage tank, air was filled from a centrifugal compressor (mounted overhead) having an operating pressure of 100 psi as shown in Fig 6. The tank has a capacity of 25 litre and got fully charged in approximately 6 minutes and discharged in approximately half minute as shown in Fig 7.
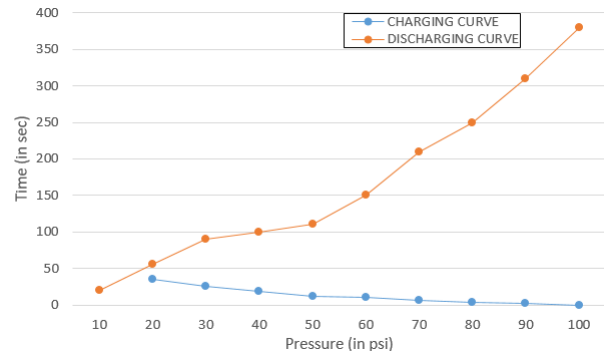

Fig.7 Variation of Charging & Discharging Time with Pressure in Buffer Tank

Time required for rise/fall of pressure in the tank is less at the beginning and increases at the last because of the fact that initially the difference between inside and outside pressure is more, so the air flow rate is more and hence takes less time when compared with the last stage where the differential pressure with the surrounding becomes very less and hence the flow rate becomes very slow.
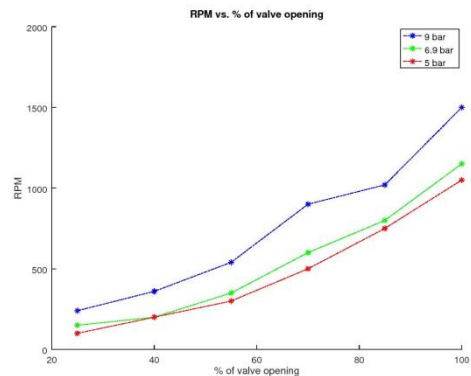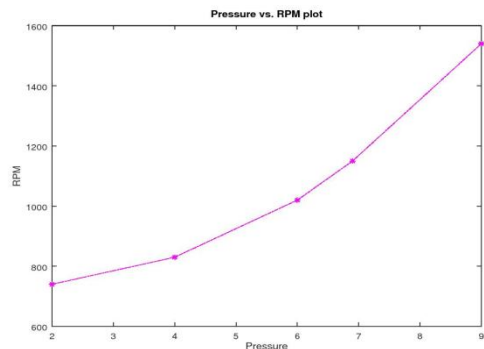

Fig.8 RPM versus % Valve Opening Variation

Fig.9 RPM versus Pressure Variation

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RPM of the crankshaft is found to be a direct function of pressure and valve opening with some parabolic relation as shown inFig 8&9. With increase of pressure, for a given rpm, efficiency also increases because of the increase of the force over the piston. The curve shown in Fig 10 is plotted using the dynamometer at different loads. When we change the load, rpm of the crankshaft changes, and hence the efficiency of the engine. When we change the load, the torque changes and hence the rpm of the crankshaft which is measured using the tachometer. From the graph shown in Fig 10, it can be seen that the maximum torque is approximately 20 N-m and occurs at 500 rpm and shows a decreasing trend after that. The decrease of torque with rpm can be attributed to the fact that the power available is constant. So if one variable increases other must decrease but the decrease is not hyperbolic because of the heat liberated due to friction.
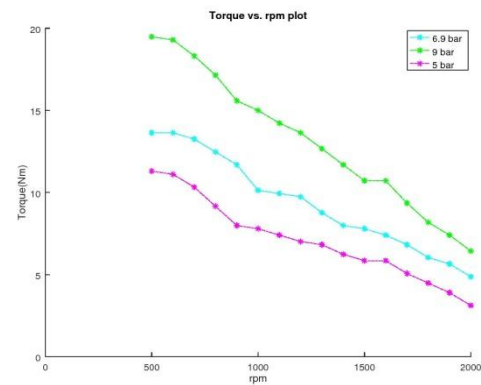

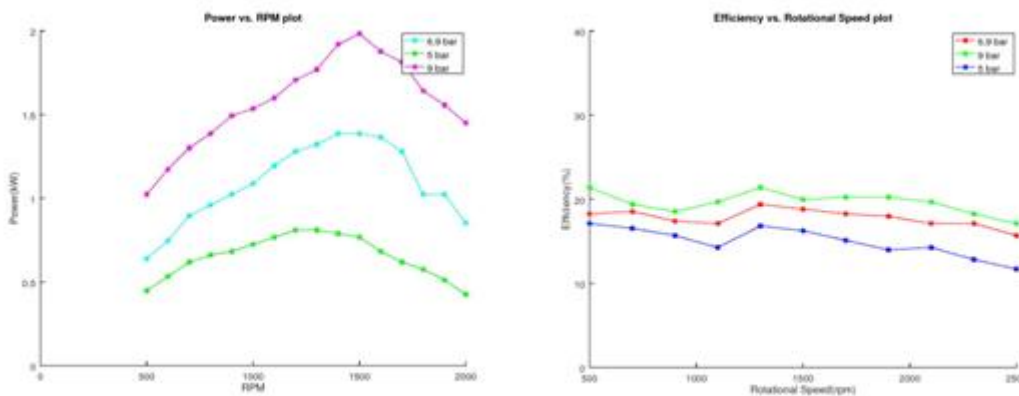**Fig.10 Torque versus rpm Variation**

Fig.11Variation of efficiency and power with RPM

Fig 11 showing variation of Power and efficiency with rpm is analytic in nature and is plotted experimentally using the setup. As seen in the curve, power is minimum at the starting and end and rises to a maxima in between.So the importance of this curve is that we will find the rpm corresponding to which the power is maximum and will operate the engine at the same rpm so that we get maximum power output by minimizing the losses.Among the readings taken, we can see that the power is maximum at approximately 1000 rpm when operated at 100 psi. Also the maxima shifts towards left side when the pressure is decreased.

V. CONCLUSION

In this study, theoretical cycle analysis of air engine on P-V Diagram and successful test run have been carried out by modifying a conventional four stroke 100cc engine(without changing cam profile). Thus proving the way for using I.C. Engines as Compressed Air driven Engine on the same assembly line by removing cooling jackets, spark plugs, cylinder head, complex fuel injection systems, silencer and many other parts. With present modifications, a maximum RPM of 1527 was observed at a pressure of 9 Bar. Similarly, the variation of torque and efficiency have also been plotted as a function of rpm and pressure ratio. Overall efficiency of the engine is although not very high because of high inertia forces of the parts designed to operate conventional I.C. Engines, but it can be improved by using light weight material since the load requirements are not high.RPM is found to be a direct function of pressure, but going beyond a pressure limit poses its own problem, hence restricting the maximum speed of the engine.The exhaust from the engine is comparatively at a dip of upto 3ºC with respect to atmosphere because of expansion and can be used in air conditioning system also, thus helping in further improve the efficiency. These types of engine can be used for LMV's and for higher speed and performance, hybrid can prove to be a viableoption specially with gaseous fuels for utilizing the pressure energy in driving the air engine and chemical energy for conventional working .

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AUTHOR PROFILE

Mr. Amit is presently working as a Scientific Officer in the Department of Atomic Energy. He is a BARC Training school pass out having an orientation course in Mechanical Engineering with specialization in Design, Operation and maintenance of Nuclear Facilities. He holds an M. Tech in Thermal engineering from Delhi Technological University (Formerly DCE) and has worked on Air Driven Vehicles for his Thesisdefense. His team has represented the college at University level and has won the second price for the same. He is presently working on re-startup of Heavy Water Production facility using Ammonia-Hydrogen Exchange and is also involved in commissioning of Solvent Production Plant for production of vital Solvents to be used in front end and back end of Nuclear Power Plant.