Phenomena of brake specific fuel consumption and volumetric efficiency in CI engine by modified intake runner length

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Abstract: In this paper, we experimentally reported to improve the volumetric efficiency and brake specific fuel consumption of naturally aspirated conventional CI engine by modified intake pipe length by variable load. In order to increase the volumetric efficiency more amount of air aspirates by intake, and optimum for this case done by choosing 1.6 m length pipe based on the calculation of Chrysler’s ram theory and Helmholtz resonator theory for an inertia air charging. The volumetric efficiency improves with optimum length was found maximum increase of 6% and brake specific fuel consumption was found decreases maximum of 11% at full load conditions.

Keywords: Brake specific fuel consumption; volumetric efficiency; Intake runner length

1. Introduction

Modifying the intake pipe length improves the air charging method in internal combustion engines and leads to increase the volumetric efficiency and to reduce the brake specific fuel consumption. Number of research have been done on keeping load as constant by varying speed with multi cylinder turbo charged engines. This present work done by keeping speed as constant and varying load in single cylinder naturally aspirated CI engine. To find the length of pipe and frequency travelled by the wave generated by the incoming air while closing the inlet valve, based on Chrysler’s ram theory and Helmholtz resonator theory.

M.A. Ceviz [1] conducted an experiment, in spark ignition (SI) engine with different plenum volume by varying the speed it gives better engine performance upto 2600 rpm after that plenum volume should decrease to optimize the engine performance. He concluded relative air ratio increased to maintain homogeneity of mixture upto 2600 rpm after that combustion done by lean mixture, it leads to reduce hydrocarbon and carbon monoxide emissions. Mariucci, V [2] conducted an experiment in Single cylinder SI engine with different taper length \(L_t\) of inlet pipe found 11% increase of volumetric efficiency at 26.45 cm, further increasing the \(L_t\) deteriorate the volumetric efficiency due to frequency ahead during inlet valve closing for that careful length has to choose by Chrysler’s ram theory and its order. M.A. Ceviz et al.,[3] conducted an experiment in SI engine performance parameter of an engine gives favourable effects by variable length intake manifold...
plenum at high load and low engine speeds and thermal efficiency increased 3.5% against the baseline reading at 1500 rpm from this he inferred variable intake plenum is suitable for urban driving conditions.

Vaughan, A et al., [4] conducted test on four cylinder SI engine with varying intake runner length results 22% relative power improvement and 5% torque output gain compared to baseline. Taylor, J. et al.,[5] done an experiment on four cylinder SI engine with varying the length of intake manifold by positive tuning pressure wave reached during inlet valve closing this helps to increase the cylinder mass to boost the pressure for next intake, it gains the low speed torque this condition is favourable for naturally aspirated (NA) engine. Samuel, J. et al.,[6] analysed performance on single cylinder compression ignition NA engine by varying intake runner length results cylinder charge gives good supercharging effect at lower speeds. Brake specific fuel consumption (bsfc) reduced throughout an experiment for producing power by proper combustion of fuel with right amount of air quantity supplied by intake runner designed by Helmholtz resonator model. Malkhede D et al.,[7] investigated volumetric efficiency ($\eta_{vol}$) in single cylinder SI engine and $\eta_{vol}$ is depend on engine speed and intake length and observed 10% improvement at lower speed compared to fixed intake length. Giovanni Vichi et al.,[8] inferred by his experiment, innovative variable length duct has gain performance parameter of single cylinder SI engine. Singh, S et al., [9] developed intake runner and improved brake thermal efficiency of 2.42% and reduction of bsfc is 0.045 kg/kWh at low and mid loads. Alves, L et al., [10] developed an algorithm for better runner length at different speed with different runner length by using GT-Power engine simulation software with Helmholtz resonator theory, based on the literature inferred modifying intake pipe length will give effective results on brake specific fuel consumption and $\eta_{vol}$ pipe length 1.6m has to be calculated by familiar model of Helmholtz resonator theory and Chrysler’s ram theory and modified from existing length.

2. Length Calculation by using empirical relationships

Crank angle of Inlet valve open during intake (4.5°+180°+35.5°) = 220°
Crank angle of Inlet valve closed during one power cycle (720° - 220°) = 500°
Engine speed (N) in revolution per second = 1500 rpm / 60 = 25 rps
Crank angle for one complete rotation corresponding speed (360° X 25) = 9000° per second
Time (t) for inlet valve closing one power cycle (500° / 9000°) = 0.0555 Seconds
Pressure wave travelled at speed of sound (C) = $\sqrt{\gamma RT}$ = 347.188 m/s
Total length (L) of inlet pipe needed for ram induction = C * t =19.268 m

In practical 19.268 m length of the pipe is not possible to install by a valve bouncing ram theory calculation need to reduce the length. Pressure wave has to travel back during the inlet valve closes and again has to come back when it opens to cover the distance of 19.268 m, which means 9.634 m wave travels back when inlet valve closes and again return to 9.634 m to reach when inlet valve opens. Wave bounce order 6, we need to choose for reducing the pipe length further 0.0555 seconds inlet pipe will be closed and the pressure wave travels at a speed of 347.18 m/s, from the total time to cover the distance of 19.268 m during 6th bounce only the wave reached to attain ram induction, so 9.634 divide by 6 we will get a length of 1.6 m for effective intake.

### Table 1. Pressure wave bounce table

| Time (seconds) | Wave Bounce (order) |
|----------------|---------------------|
| 0.00921        | 1                   |
3. Experimental setup and Procedure
The test was conducted on four stroke, single cylinder water cooled diesel engine loaded with eddy current dynamometer. The Specification of engine setup mentioned in Table 3, and figure 1, shows the layout of the experimental setup. After supply of fuel engine was started and waited for few minutes to reach constant speed about 1500 rpm and reading was noted for base line 1.1m length of inlet pipe after that engine allowed to reach ambient temperature and inlet pipe length was modified based on 1.6m length. The repeatability of was maintained three times.

![Figure 1. Layout of experimental setup.](image)

1. Engine, 2. Flywheel, 3. Eddy current dynamometer, 4. Exhaust pipe, 5. Intake air manifold, 6. Air box and air filter, 7. Manometer, 8. Diesel burette system, 9. Engine, electronic system integration lines & fuel lines, 10. Base, 11. Rpm meter & load meter
Table 2. Engine Specification:

| Engine Specification          | Value                  |
|-------------------------------|------------------------|
| **Engine model**              | Kirloskar TV1          |
| Rated power                   | 5.2 kW @ 1500 rpm      |
| No of cylinders               | 1                      |
| Stroke                        | 4 Stroke CI            |
| Bore                          | 87.5 mm                |
| Stroke length                 | 110 mm                 |
| connecting rod length         | 234 mm                 |
| Compression ratio             | 17.5                   |
| Swept volume                  | 661.5 cc               |
| Inlet valve timing IVO, IVC   | 4.5ºbTDC, 35.5 ºa BDC  |
| Exhaust valve timing EVO, EVC | 35.5ºbTDC, 4.5ºa TDC  |

Table 3. Performance Parameters

| Parameter                               | Value |
|-----------------------------------------|-------|
| Orifice Diameter (mm)                   | 20    |
| Orifice Coefficient of Discharge (C_d)  | 0.6   |
| Dynamometer Arm Length (mm)             | 185   |
| Fuel Pipe diameter (mm)                 | 12.4  |
| Ambient Temperature (°C)                | 27    |
| Fuel Type                               | Diesel|
| Fuel Density (Kg/m^3)                   | 840   |
| Calorific value of fuel (kJ/kg)         | 42500 |
| Air chamber tank volume (cc)            | 20000 |

4. Results and discussion

4.1 Comparison of mass flow rate to the cylinder

While keeping engine speed constant at 1500rpm, mass flow rate is constant in all pipe length if we change pipe length according to Chrysler’s ram theory can increase mass of air by Ram induction in the intake pipe length of 1.6m compared to baseline 1.1m and it was found maximum of 6% at lower load and minimum increase of 4% at higher load. The comparison of mass flow rate with baseline for different length mentioned in figure 2, In order to get more mass flow rate of air in the intake pipe by changing to 2m pipe length mass flow rate decreases nearly 1g/s with tuned length of 1.6m because it violates the Chrysler’s ram theory, which means pressure wave too far during inlet valve opening.
4.2 Comparison of volumetric efficiency

Volumetric efficiency generally increases with effective air charge induction during suction stroke and decreases with speed. In this scenario modified inlet pipe length 1.6m is used to get Ram induction during suction and it was found maximum increase of 6% at lower load and minimum of 4% at high load. In order to get more volumetric efficiency by changing to 2m pipe length 2% increases compared to baseline, because of engine rated speed is constant and time available for cylinder filling with air charge is too short. The comparison of volumetric efficiency with baseline for different length mentioned in figure 3.

Figure 2. Comparison of mass flow rate of air.
4.3 Comparison of brake specific fuel consumption

Brake specific fuel consumption is generally high at low load because of improper mixing of air fuel mixture [11]. We have observed improvement in reduction of bsfc at low load is 10 % and for higher load 11% because of rated speed of engine leads to proper mixing of air fuel mixture inside the
cylinder and engine running at nearly stoichiometric mixture region gives better fuel economy. The comparison of bsfc with baseline for different length has mentioned in figure 4.

4.4 Comparison of brake thermal efficiency

Conversion of thermal energy into mechanical energy by making fuel droplets to find oxygen molecules for better mixing, brake thermal efficiency considerably increases by reducing the heat input at higher load [12]. It was observed for 1.6m length pipe BTE is maximum of 11% and minimum of 6% at higher part load compared to baseline 1.1m length, and also it was found there is no considerable change in 2m pipe length compared to baseline because of quantity of oxygen present in the air is less, but in 1.6 m length pipe fuel droplets can find oxygen molecules due to effective air charging. The comparison of brake thermal efficiency with baseline for different length mentioned in figure 5.

5. Conclusions

In this experimental study, brake specific fuel consumption, volumetric efficiency and Brake thermal efficiency analysed by varying inlet pipe length 1.6m and 2m and compared with baseline, and based on the comparison we conclude the effective tuning length of 1.6m by Chrysler’s ram theory is improved the performance parameter of an engine.

- The maximum enhancement of mass flow rate of air observed 6% in 1.6m pipe length.
- The maximum reduction of brake specific fuel consumption observed at lower load was 11% for 1.6m inlet pipe length.
- The volumetric efficiency improved for 1.6m pipe length is 4% at higher load.
- The maximum brake thermal efficiency observed 11% for 1.6m pipe length.
6. References

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