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Design of Lean Burn Engine for Scooters

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Abstract*: Internal combustion engine powered vehicles are widely used all around the world for mobility. Scooter is the most commonly used two-wheeler by people of all age groups due to its easy handling and riding comfort. Due to gearless transmission, the mileage of scooter is low compared to gear transmission bikes. Nowadays increase in petrol price makes the mileage as the most important factor for internal combustion engines. Using lean air-fuel mixture for combustion in a engine increases the mileage as well as reduces the pollution. The air-fuel ratio is said to be lean when the ratio of air-fuel is greater than 15:1, the stoichiometric ratio of air-fuel is 14.7:1. In this Study, the clearance between the piston and cylinder of a 125cc engine is reduced from 0.5mm to 0.25mm to run in lean air-fuel mixture. The lean fuel-air mixture is achieved by supplying extra air into the engine by making an additional hole in the carburetor outlet and the air is supplied through it. The excess air is supplied to the engine after the vehicle reaches above 40 kilometer per hour. The extra air supply is controlled by an solenoid valve which is actuated by an electronic circuit. The lean mixture usage increases the engine temperature more than usual and it is controlled by using synthetic engine oil. The result shows increase in mileage from 40 - 45 kilometer per litre to 50 - 60 kilometer per litre and reduction in the emission of Carbon monoxide (CO) and Hydrocarbon (HC). Thus an overall increase in mileage is about 15 - 20% from existing vehicle but emission of Nitrogen Oxides (NO_X) is slightly higher than usual. Combustion of lean air-fuel mixture produces less torque hence it cannot be used to move the vehicle from rest position, so lean mixture must be supplied to the engine after the vehicle reaches certain speed.

Keywords* : SI engine, Lean-burn engines , knock, combustion, Emission, Air–fuel ratio (AFR).

I. INTRODUCTION

Engines which burn any combustible fuel with the presence of oxygen from atmosphere in a closed air tight controlled, specifically designed chambers are called internal combustion engines. Spark ignition (SI) engine is one of the prime internal combustion engine known for light weight and smooth drive in automobile sector.SI engine is a major category internal combustion engine which uses petrol as a source fuel. The thoroughly mixed air and fuel compressed to high pressure and temperature inside the cylinder and exploded by the spark from spark plug. The explosion increases the pressure and temperature which tends the piston to move, resulting in mechanical energy.

Spark Ignition (SI) engine follows the Otto cycle and uses petrol with an octane rating of 90 ROZ and above in practice. Petrol engines operate in two stroke and four stroke cycles, where the former version is banned in automobile usage, a decade before due to its pollution factor. The working cycles of a four stroke engine such as suction, compression, power and exhaust stroke gets completed within 720 degree crank revolution. Emissions from automobiles are the major thread to the cleanliness of environment. By implementing new technologies in automobile sector, emissions can be mitigated. NO_X, CO and HC emissions are major toxic content from automobile to pollute the cleaner environment.

The operating range of the compression ratio for a petrol engine is in the range of six to twelve. Type of cooling is an important parameter which decides the range of compression ratio. Generally liquid cooled engines have slightly higher compression ratio when compared to same specification air cooled engines. The resisting parameters for higher compression ratio are higher operating temperature, lower octane rating fuels, air fuel ratio and vibrations.

Air fuel ratio of any internal combustion engine is decided by its intended purpose or type of application. The chemically correct air fuel ratio for any specification spark ignition engine is 14.7:1. Any SI engine running with an air fuel ratio above 14.7:1 is said to be operating towards economy region. The good acceleration of any engine needs rich mixture in the range of 12:1.Lean burn engines are specifically optimized engine to run in ultra-lean mode in the range of 50:1 to 85:1.Modernised Electronics integrated engines may run in different modes like lean mode (Economy) and power mode (Sports) to suit the versatile requirement of customers. Lean mode operation is encountered by a parameter called petrol knock which damages the engine components.

II. MATERIALS AND METHODS

A. Compression Ratio

Compression ratio is the ratio between maximum volume of the cylinder to the minimum volume of the cylinder. The sum of engine cylinder volume and clearance volume equals maximum volume. The gap between cylinder head and cylinder block, when the piston is at top dead centre is regarded as clearance volume. Higher compression ratio increases air standard efficiency and engine operating temperature which induces the engine to detonate.

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B. Air Fuel Ratio

Cylinder bore and stroke length variation creates changes in power output and torque of an engine. Volumetric efficiency of an engine depends upon the piston diameter. Bigger piston diameter results in larger combustion chamber surface area which opposes lean burning. Smaller diameter piston is more apt for lean burn engines where much scope is available for smaller surface area of combustion chamber. Optimized engine cooling system is essential for an engine to operate with lean fuel. Quality petroleum fuels with high octane rating can supplement higher compression ratio and repel knocking.

C. Combustion Chamber

A Combustion Chamber is the area within the Cylinder where the compressed air fuel mix is ignited. Piston compresses the air fuel mix and ignited by the Spark Plug, the pressure is created and pushed out the piston in the form of energy. The Cylinder houses have important components like the Injector Nozzle, Piston, Spark Plug, Combustion Chamber, and others.

D. Lean Burn Engine

Lean-burn engine runs always above stoichiometric air fuel ratio. Successful running of lean burn engine in all climatic conditions is possible only with modern electronic control engine. Lean burn engine operating temperature is always high when compared to all other engines**.**

E. Solenoid Valve

A solenoid valve is an electromechanical device which operate with 12volt direct current from scooter battery and it regulates the air flow into the inlet manifold according to the signals from arduino board. Figure 1 shows the simple solenoid valve.

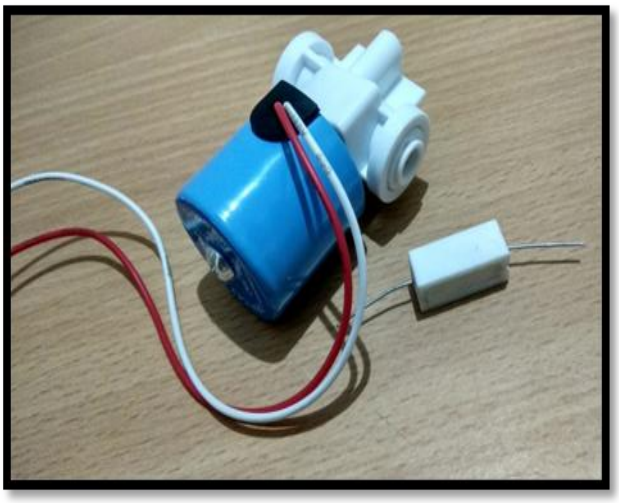

Fig. 1. Solenoid Valve.

Specifications :

- Pressure: 0 - 125 psi
- Working Volt: 12 - 24 volts
- Working Amps:1 - 3 Amps

F. Electronic Circuit

List of components used in the electronic circuit are :

- Arduino UNO
- 5V Relay
- 10 KΩ resistor
- Proximity Sensor
- LED

The circuit connections were made by connecting the air filter and solenoid valve, solenoid valve and carburetor outlet with pneumatic tubes. Figure 2 shows the circuit connections of battery, solenoid valve and proximity sensor. Programming was written and fed to the arduino by connecting with the computer using a data cable.

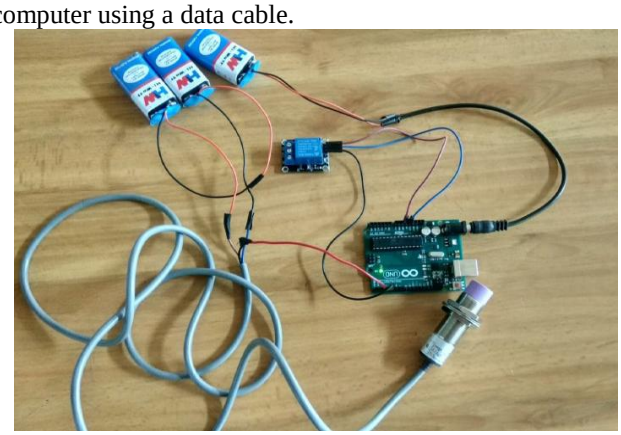

Fig. 2. Electronic Circuit.

G. Arduino Uno

Arduino board carried the control of components like pneumatic solenoid valve and rear wheel speed sensing sensor. Figure 3 shows the arduino board used in this work. The pneumatic valve was kept normally in closed position. When the rear wheel speed exceed 40 kilometer per hour speed, the pneumatic valve got energized and the excess air from air filter is allowed into the inlet manifold. C language was used to develop the programming for this module.

Fig. 3. Arduino Uno.

H. Pollution Norms

Stringent government regulations on vehicle pollution paved ways for many technological development. No significant change in bharat stage four and bharat stage six norms for the hydrocarbon and carbon monoxide pollutants. Changes in the quality of fuel such as reduced content of sulpur and lead is found in bharat stage six norms. The major change between the previous and upcoming norms is in the area of oxides of nitrogen emission. Table 1 shows the bharat stage four and bharat stage six norms for spark ignition engines of automobiles.

Table- I: Bharat Stage Four and Six Norms for SI Engines.

BS-IV Norms				BS-VI Norms		
Petrol Vehicles	**Unit**	**Two Wheeler ≤ 115cc**	**Two Wheeler ≤ 50cc**	**Two Wheeler ≤ 130 cc**	**Two Wheeler ≤ 115cc**	**Two Wheeler ≤ 50cc**
CO	g/km	2.00	0.60	1.00	1.00	0.50
HC	g/km	-----	---	0.10	0.10	0.35
HC + NO_x	g/km	0.60	0.65	-----	-----	----
NO_x	g/km	0.325	0.15	0.05	0.05	0.15

Bharat stage six norms brought a reduction of 72% in NO_x emission for engines up to 130 cc with a design top speed of 140 kilometer per hour. No control for hydrocarbon emissions in bharat stage four norms.

Table-II: Exiting and Modified Engine Comparison

Specification	Existing Engine	Modified Engine
Engine type	Single Cylinder 2-Valve Engine	Single cylinder 2-Valve Engine
Displacement	124 CC	129 CC
Bore	53.5 mm	54.5 mm
Stroke	55.2 mm	55.2 mm
Compression ratio	9.6 : 1	9.96 : 1
The clearance between the piston and Cylinder wall	0.5 mm	0.25 mm

Table 2 shows the change in compression ratio between the existing engine and the modified setup. The gap between cylinder wall and piston is reduced from 0.5mm to 0.25mm.The reduced gap minimizes the blow by from the combustion area to crankcase which increases the brake thermal efficiency as well as the life of lubricating oil by minimizing carbon inclusion.

The flow path of additional air intake is clearly shown in figure 4.The arduino uno receives speed of the rear wheel through the proximity sensor. The solenoid is energized according to the wheel speed programmed in arduino.

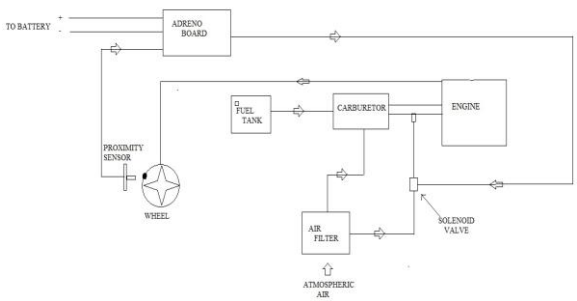

Fig. 4. Model Outline.

The fabricated lean burn engine was attached with scooter setup is shown in figure 5.

Fig. 5. Fabricated Model.

III. RESULTS AND DISCUSSION

Table 3 clearly shows the correlation between mileage and excess air intake.

Table- III: Diameter of the Inlet Tube and Mileage of the Engine.

S.NO	DIAMETER OF INLET TUBE IN mm	MILEAGE in km/Litre
1	2	50
2	3	53
3	4	57
4	5	60

Carbon monoxide and hydrocarbon emissions are the common emissions problem for engines running with rich air fuel mixture. Table 4 shows that the lean mixture results in low values of HC and CO.

Table- IV: Emission Levels.

DIAMETER OF INLET TUBE IN mm	HC ppm	CO % Vol	NO_X ppm
2	595	0.38	80
3	435	0.31	155
4	254	0.22	210
5	138	0.15	295

Lean mixture leads to increase in operating temperature of the engine which in turn leads to slight increase in oxides of nitrogen emission.

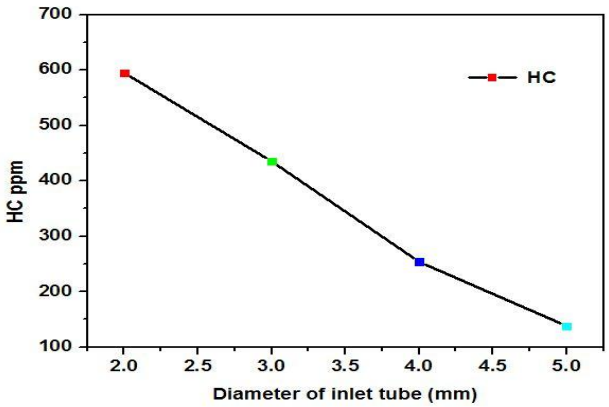

Fig. 6. HC level Vs Diameter of inlet tube.

Increase in the air supply considerably reduces hydrocarbon levels. Figure 6 shows that supply of excess air through 5mm inner diameter pipe registers 138 ppm of HC level which is low when compared with all other values.

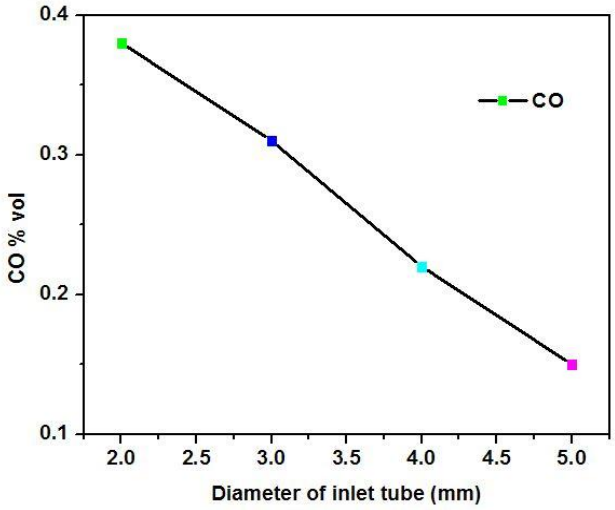

Fig. 7. CO level Vs Diameter of inlet tube.

Relationship between Carbon monoxide levels and air supply values are depicted in figure 7. 0.15 % volume of CO is registered as a minimum level in this engine when measured using AVL gas analyzer.

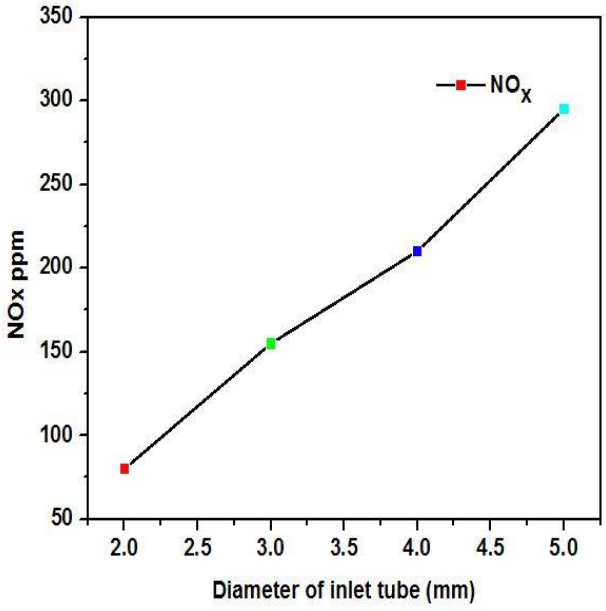

Fig. 8. NO_X level Vs Diameter of inlet tube.

Increase in the operating temperature of engine leads to marginal increase in oxides of nitrogen. Figure 8 exposes the increase in NO_x emission as the air inlet increases.

IV. CONCLUSION

Combustion process gets smoother and complete due to the additional amount of air supplied. Fuel consumption gets reduced by supplying a lean mixture. Reduced hydrocarbon and carbon monoxide emission is achieved due to complete combustion of fuel.

FUTURE SCOPE

Arduino Programming and sensor setup may be changed to supply various levels of excess air according to the speed of the engine.

REFERENCES

1. Wu, H.-M., & Tafreshi, R. (2019). Observer-based internal model air–fuel ratio control of lean-burn SI engines. IFAC Journal of Systems and Control, 9, 100065.
2. Hutter, R., De Libero, L., Elbert, P., & Onder, C. H. (2018). Catalytic methane oxidation in the exhaust gas after treatment of a lean-burn natural gas engine. Chemical Engineering Journal, 349, 156–167.
3. Zhu, C., Wang, P., & Liu, Z. (2018). Model Prediction Control of Fuel-Air Ratio for Lean-Burn Spark Ignition Gasoline Engine. IFAC-Papers On Line, 51(31), 640–645.
4. Yu, X., Guo, Z., Sun, P., Wang, S., Li, A., Yang, H., Shang, Z. (2019). Investigation of combustion and emissions of an SI engine with ethanol port injection and gasoline direct injection under lean burn conditions. Energy, 116231.
5. Yu, X., Du, Y., Sun, P., Liu, L., Wu, H., & Zuo, X. (2017). Effects of hydrogen direct injection strategy on characteristics of lean-burn hydrogen–gasoline engines. Fuel, 208, 602–611.
6. Chen, Y., Liu, A., Deng, B., Xu, Z., Feng, R., Fu, J., Zhou, L. (2019). The influences of ignition modes on the performances for a motorcycle single cylinder gasoline engine at lean burn operation: Looking inside interaction between flame front and turbulence. Energy, 179, 528–541.
7. Park, C., Lee, S., & Yi, U. (2016). Effects of engine operating conditions on particle emissions of lean-burn gasoline direct-injection engine. Energy, 115, 1148–1155.
8. Gong, C., Li, Z., Yi, L., & Liu, F. (2019). Comparative study on combustion and emissions between methanol port-injection engine and methanol direct-injection engine with H2-enriched port-injection under lean-burn conditions. Energy Conversion and Management, 200, 112096.
9. Gong, C., Yi, L., Zhang, Z., Sun, J., & Liu, F. (2020). Assessment of ultra-lean burn characteristics for a stratified-charge direct-injection spark-ignition methanol engine under different high compression ratios. Applied Energy, 261, 114478.
10. Zhu, C., Wang, P., & Liu, Z. (2018). Model Prediction Control of Fuel-Air Ratio for Lean-Burn Spark Ignition Gasoline Engine. IFAC-PapersOnLine, 51(31), 640–645.
11. Qi, Z., Dong, H., Yu, H., Zhao, M., & Yu, H. (2017). In-situ electrochemical NO x removal process for the lean-burn engine exhaust based on carbon black gas diffusion electrode. Journal of Cleaner Production, 151, 465–474.
12. Sapra, H., Godjevac, M., De Vos, P., Van Sluijs, W., Linden, Y., & Visser, K. (2020). Hydrogen-natural gas combustion in a marine lean-burn SI engine: A comparitive analysis of Seiliger and double Wiebe function-based zero–dimensional modelling. Energy Conversion and Management, 207, 112494.
13. Korb, B., Kuppa, K., Nguyen, H. D., Dinkelacker, F., & Wachtmeister, G. (2020). Experimental and numerical investigations of charge motion and combustion in lean-burn natural gas engines. Combustion and Flame, 212, 309–322.

14. Da Costa, R. B. R., Rodrigues Filho, F. A., Coronado, C. J. R., Teixeira, A. F., & Netto, N. A. D. (2018). Research on hydrous ethanol stratified lean burn combustion in a DI spark-ignition engine. Applied Thermal Engineering, 139, 317–324.
15. Shi, C., Ji, C., Ge, Y., Wang, S., Bao, J., & Yang, J. (2019). Numerical study on ignition amelioration of a hydrogen-enriched Wankel engine under lean-burn condition. Applied Energy, 255, 113800.

AUTHORS PROFILE

Mr. S. Dhamotharan had done his Master in Computer Aided Design and Computer Aided Manufacturing in the early years of this decade. Presently doing research in the area of IC engine. Currently designated as Assistant Professor in KEC, Erode, Tamil Nadu. Conducted SAE events in college level and involved in various events of Society of Automotive Engineers. Catering service to the student community by knowledge dissemination in different field. Member of the Indian Society of Technical Education. Graduated in bachelor of engineering in the field of mechanical engineering.

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Mr. K. Kathirvel had completed masters of engineering in the discipline of Computer Aided Design and Computer Aided Manufacturing in BIT, Sathyamangalam, Tamilnadu. Currently doing research work in the area of renewable source of energy, particularly in solar Cells. Published more than 3 papers in various journals and presented research work in more than 12 conferences. The published journals covers technical areas like solar cell, optimization and physical coating techniques. Presently working as an Assistant Professor in KEC, Erode, Tamil Nadu. Member of the Indian Society of Technical Education and Society of Automotive Engineers.

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Mr. G. Bharath has pursuing his Post Graduate in Engineering Design at Kongu Engineering college, Tamilnadu, India and aslo did Under Graduate in department of Automobile Engineering in KSR College of Engineering. Now doing project work in solar cell to improve the efficiency. In the area of alternative fuel for IC engine , project work has done in the UG. Presented paper and attend the international conference in the area of alternative fuel, solar cell and various pressure of IC engine. Published paper "Enhancement Open Circuit Voltage of Calcium Titanate AR Coated Magnesium Solar Cell" in IJRTE.