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Investigation on Performance of SI Engine to Improve the Combustion Characteristics by Using Pre-Heated Fuel

A. N. Basavaraju[1], Mallikappa[2], B. Yogesha[3]

[1]Department of Automobile Engineering, Malnad College of Engineering, Hassan-573202, Karnataka, India.

[2]Department of Mechanical Engineering, NMAM Institute of Technology, Nitte -574110, Karnataka, India,

[3]Department of Mechanical Engineering, Malnad College of Engineering, Hassan-573202, Karnataka, India.

Abstract: ***This paper describes feasibility of utilization of spark ignition (SI) engine in single fuel mode and to develop the optimum operating conditions. Many modifications were made for the developed direct fuel injection system to improve the performance of the 350 cc four stroke single cylinder gasoline engine. The engine is tested to conduct performance, combustion emission characteristics with normal mode engine operation, with the aid of carburetor and with fuel injector mode. As single cylinder small engines have low compression ratio (CR), and they run with slightly rich mixture, their power are low and emission values are high. In this study, Initial temperature of fuel 20°C and preheated fuel temperature 40°C was used to increase performance and decrease emissions of a single-cylinder engine. The test have been conducted under no load and at different loads maintaining the speed at a constant value of 240rpm throughout the test and the engine produced a maximum power of 7.65kW at an engine speed of 1330 rpm.***

Keywords: Spark ignition engine, performance, preheater and carburetion

1. Introduction

Twenty years ago, homogeneous-charge spark-ignition gasoline engines (using carburetion, throttle-body, or port-fuel-injection) were the dominant automotive engines. Advanced automotive engine development remained largely empirical, and stratified-charge direct-injection gasoline-engine production was blocked by lack of robustness in its combustion process [1]. The permanent aim of the automotive industry is to continue reducing the fuel consumption of internal combustion engines, thus reducing the contribution of the anthropogenic CO_2 emissions, caused by individual transportation, to the global greenhouse phenomenon [2]. SI engines are critically dependent on repeatable, reliable ignition to produce good performance and low pollutant emissions. Positive ignition of the charge in the cylinder of a SI engine is essential for good performance and efficiency as well as for meeting emission standards; Modem spark ignition systems provide sufficient energy at the selected time in the cycle for engines operated on gasoline at near stoichiometric air-fuel ratios with modest amounts of exhaust gas recirculation [3]. Electronically controlled gasoline injection, stoichiometric air–fuel ratio adaptively controlled by oxygen sensor and three-way catalyst converter are widely used in gasoline engine to control CO, HC and NOx emissions. However, stoichiometric mixture is not the economical mixture for gasoline engines, which may lead to the poor fuel economy and consequently the increase in CO_2 emission, a global green-house gas. So it is an important topic to improve the fuel economy of gasoline engines and make it operate at stoichiometric air–fuel ratio without deteriorating emissions from the engine [7]. Port-fuel injection, spark-ignition, gasoline engines power the great majority of passenger cars in the world [5].

Since fuel injection timing is very important operating parameter that affects spark ignition engine performance and efficiency and not much previous work was done on preheated fuel engine, thus this study concentrates on investigation of performance characteristics of engine fuelled with preheated gasoline. From published information [5-11], it will be possible to develop design methods to build engines with improved performance and low emission.

2. Test Engine and Experimental Study

2.1. Test Engine

The experiment was conducted on a single cylinder four stroke spark-ignition engine. The engine specifications are listed in Table 1.

2.2. Test Fuels

Test fuel for this study was gasoline. Table 2. Shows the physical and chemical properties of gasoline.

Table 1: Specifications of the test engine

Items	Engine
Engine type	Four stroke, single cylinder
Engine displacement volume (cm3)	350
Compression ratio	7.5/1
Maximum speed (rpm)	2000
Fuel system	Carburettor
Cooling system	Air and water cooled

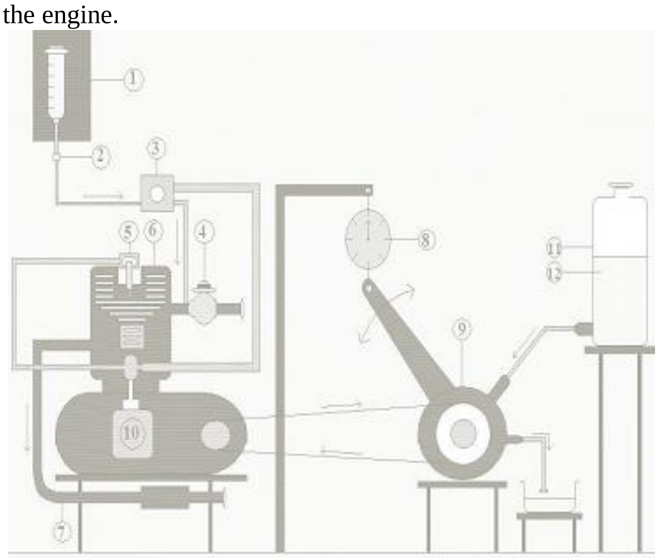
Table 2: The properties of gasoline

Fuel property	Gasoline
Formula	C8H18
Molar C/H ratio	0.445

Molecular weight (kg/kmol)	95–120
Latent heating value (MJ/kg)	44.3
Stoichiometric air/fuel ratio	14.6
Auto-ignition temperature (0C)	228–470
Heat of vaporization (kJ/kg)	305
Research octane number	95
Motor octane number	85
Boiling point (0C)	27–225
Density (kg/m3)	740

2.3. Test Set-Up

The Test set-up shown in figure.1 consists of a 350cc four stroke single cylinder petrol engine and a hydraulic dynamometer for loading and to measure the brake power of the engine for different loads. A mileage tank is connected to measure the fuel consumption of the engine. The performance test on the engine is carried out by the different ways using conventional carburetor, using fuel injector and by preheating the fuel. In conventional carburetor system the engine receives the air fuel mixture through the conventional carburetor. Gas Analyzer is very essential to determine the emission characteristics of the engine. This gas analyzer provides the, HC, CO and other emission characteristics of the engine.



1.Fuel tank with measuring scale 2.Control valve 3.Three way valve 4.Carburetor 5.Injector 6.Engine 7.Silencer 8.Spring balance 9.Dynamometer 10.Fuel pump 11.Water 12.Water tank

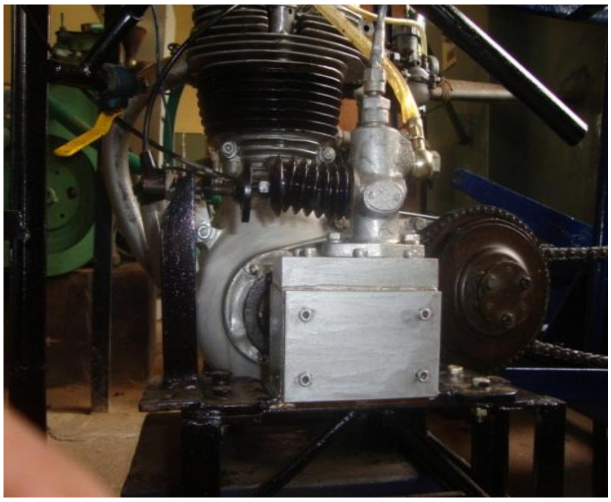


Figure 1: Test set-up

Preheater: The figure.2 shows preheater used in the test setup for preheating of fuel. To avoid vapor locking, the fuel should be heated within a temperature limit of 40^0C.

Figure 2: Preheater

Fuel Injection System: The chamber receives the pressurized fuel from the pump through atomizer, which is driven by the cam shaft in turn by the reduction gears. The filter is connected in between the fuel tank and the fuel pump, which traps any foreign particles. Through methodical analysis the crank shaft supplies power to the fuel injection pump. At the alternator end of the engine reduction drive has been designed and a suitable cam shaft is used to drive the fuel injection pump. The fuel injection pump is mounted on the transmission box ensuring proper contact of the pump follower with the injector is located in the hole meant for the spark plug and the spark plug is suitably oriented by placing it through the hole meant for decompression valve. In this manner a fuel injection system has been successfully installed in the engine. This engine also has a conventional carburetor, in order to compare the performance of conventional carburetor with that of fuel injection system.

2.4. Experimental Procedure

Initially the engine is tested using conventional carburetor with normal mode. The procedure is disconnecting the carburetor and connecting the fuel injector to the engine with varies the temperature. Repeat the same procedure for different temperature with the aid of carburetor. The engine is started and run for few minutes to reach a steady state condition. The engine once it reaches a steady state condition the engine rpm is set and the time taken for consuming a known volume of fuel is measured. This measurement is done under two conditions at constant speed of the engine, at no load and under the load. The power developed by the engine is measured and emissions of HC, CO and CO_2 were identified. In order to determine the engine capacities and suitability for applications, it is necessary to measure their levels of performance in meeting various requirements.

2.5. Parameter Considerations

The important parameters considered for the measurement of performance of the engine are:

2.5.1. Measurement of Speed

An electrical tachometer or a digital tachometer can be used to measure the speed of the shaft.

2.5.2. Measurement of Fuel consumption

In this the time taken for a known volume of fuel consumption is measured and the fuel consumption rate can be calculated. The fuel consumption rate can be calculated as,

Fuel consumption (kg/hr) = Xcc*specific gravity of fuel/1000*t

2.5.3. Measurement of Brake Power

It involves the determination of torque and power developed at the engine output shaft. The torque is measured by the hydraulic dynamometer. The hydraulic dynamometer is run by the chain sprocket arrangement provided between the engine output shaft and dynamometer's sprocket. Brake power=2πNT/60000kw

2.5.4. Specific Fuel Consumption

It is the amount of fuel consumed per unit of power developed per hour. It is a clear indication of the efficiency with which the engine develops power from the fuel.
SFC= (fuel consumed in kg/kW.hr)/(power developed)

2.5.5. Brake Thermal Efficiency

Brake thermal efficiency=brake power/ (heat supplied in sec).

3. Results and Discussions

To find optimum preheat temperature of SI engine a preheater was fabricated and tested. The performance and emission of petrol in SI engine for various levels of pre heat were found out and efficiency was calculated. It was noted that there was significant increase in the brake thermal efficiency of the engine when the fuel was pre heated, also lower specific fuel consumption and good emission characteristics. The engine ran noticeability smoother with less stalling. Thus the performance and emission characteristic of a 350cc bullet engine at various levels of pre heat was tested and the results and calculations are noted down as below shown in tables 3 to 5 and graphs are plotted on various parameter related to emission as shown in Figs 5 and 6.

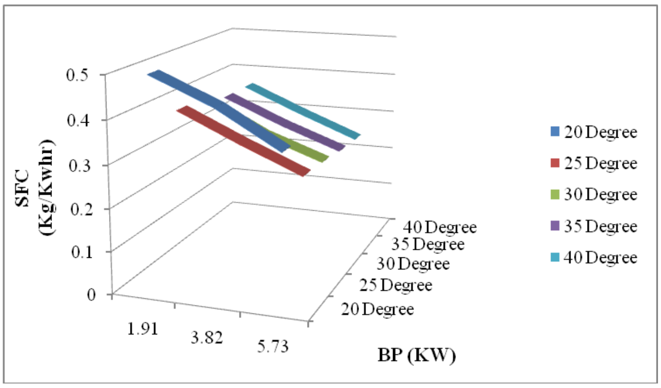


Figure 3: Performance Curves for Carburetor

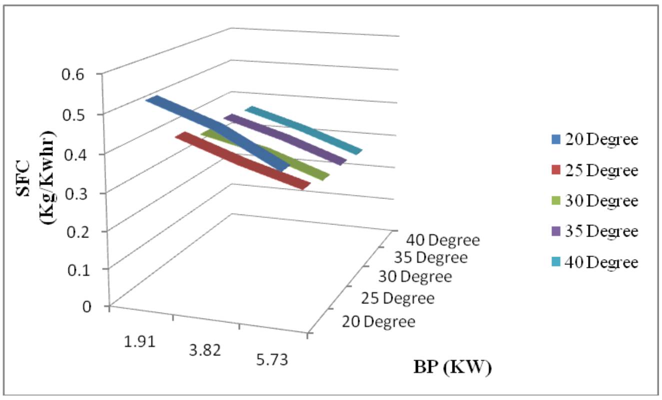


Figure 4: Performance curves for Fuel injector

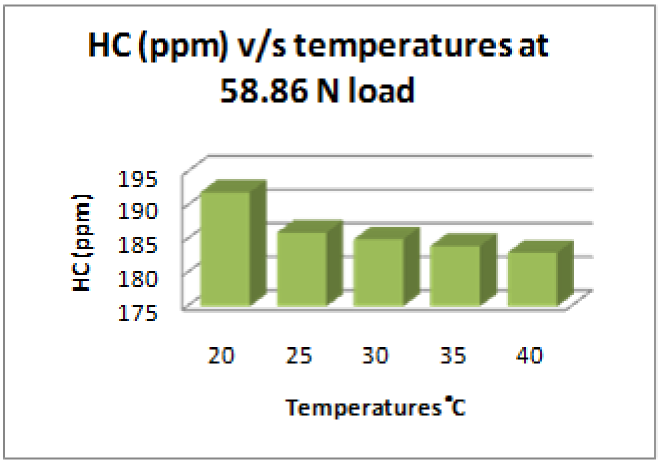


Figure 5: Emission Characteristics for carburetor at various preheating temperatures

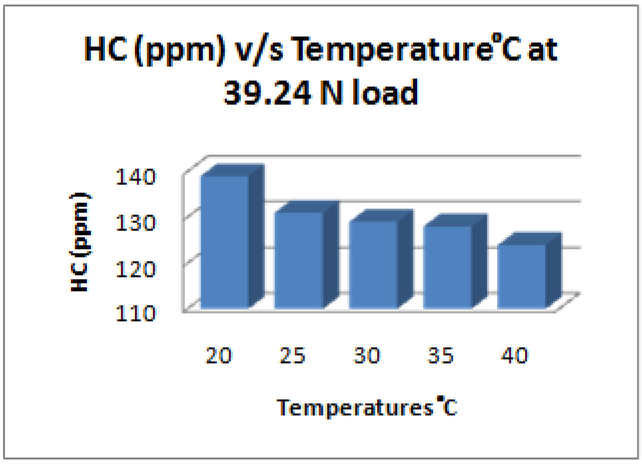


Figure 6: Emission Characteristics for fuel injector at various preheating temperatures

4. Conclusion

The concept of preheating to the fuel injector for SI engine has been implemented successfully to a 350 cc four stroke SI engine. After the experimental set up the engine tested under the conditions of carburetor and fuel injector with preheated mode. The test have been conducted under no load and at different loads maintaining the speed of the hydraulic dynamometer at a constant value of 240rpm throughout the test and the engine produced a maximum power of 7.65kW, at an engine speed of 1330 rpm. Testing this engine for higher speed has resulted in uncontrollable vibrations. Therefore loading has been done to generate a maximum power of 7.65 kW and speed being 1330rpm.The comparative test result has obtained from figures indicate a slight improvement in performance when engine is working with preheated mode.

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Table 3: Performance with aid of carburetor

Case (i) At 20°C preheating temperature

SL No.	*Load (N)*	*Speed (RPM)*	*Time Sec*	*TFC Kg/hr.*	*SFC Kg/Kw-hr*	*BP (Kw)*	*ή$_{bt}$ (%)*
1	0	1330	210	0.64	-	-	-
2	19.62	1330	142	0.95	0.497	1.91	16.45
3	39.24	1330	81	1.66	0.435	3.82	18.83
4	58.86	1330	67	2.014	0.35	5.73	23.29

Case (ii) At 25°C preheating temperature

SL No.	*Load (N)*	*Speed (RPM)*	*Time Sec*	*TFC Kg/hr.*	*SFC Kg/Kw-hr*	*BP (Kw)*	*ή$_{bt}$ (%)*
1	0	1330	262	0.515	-	-	-
2	19.62	1330	182	0.74	0.387	1.91	21.1
3	39.24	1330	110	1.227	0.32	3.82	25.5
4	58.86	1330	91	1.48	0.258	5.73	31.69

Case (iii) At 30°C preheating temperature

SL No.	*Load (N)*	*Speed (RPM)*	*Time Sec*	*TFC Kg/hr.*	*SFC Kg/Kw-hr*	*BP (Kw)*	*ή$_{bt}$ (%)*

1	0	1330	264	0.515	-	-	-
2	19.62	1330	185	0.729	0.381	1.91	21.44
3	39.24	1330	115	1.17	0.306	3.82	26.71
4	58.86	1330	93	1.45	0.253	5.73	32.33

Case (iv) At 35°C preheating temperature

SL No.	*Load (N)*	*Speed (RPM)*	*Time Sec*	*TFC Kg/hr.*	*SFC Kg/Kw-hr*	*BP (Kw)*	*$\acute{\eta}_{bt}$ (%)*
1	0	1330	271	0.49	-	-	-
2	19.62	1330	193	0.69	0.36	1.91	22.65
3	39.24	1330	118	1.14	0.298	3.82	27.42
4	58.86	1330	96	1.40	0.244	5.73	33.5

Case (v) At 40°C preheating temperature

SL No.	*Load (N)*	*Speed (RPM)*	*Time Sec*	*TFC Kg/hr.*	*SFC Kg/Kw-hr*	*BP (Kw)*	*$\acute{\eta}_{bt}$ (%)*
1	0	1330	274	0.49	-	-	-
2	19.62	1330	195	0.69	0.36	1.91	22.65
3	39.24	1330	118	1.14	0.298	3.82	27.42
4	58.86	1330	97	1.39	0.24	5.73	33.73

Table 4: Performance using fuel injector

Case (i) At 20°C preheating temperature

SL No.	*Load (N)*	*Speed (RPM)*	*Time Sec*	*TFC Kg/hr.*	*SFC Kg/Kw-hr*	*BP (Kw)*	*$\acute{\eta}_{bt}$ (%)*
1	0	1330	200	0.67	-	-	-
2	19.62	1330	131	1.03	0.53	1.91	15.18
3	39.24	1330	74	1.82	0.47	3.82	17.13
4	58.86	1330	61	2.21	0.38	5.73	21.21

Case (ii) At 25°C preheating temperature

SL No.	*Load (N)*	*Speed (RPM)*	*Time Sec*	*TFC Kg/hr.*	*SFC Kg/Kw-hr*	*BP (Kw)*	*$\acute{\eta}_{bt}$ (%)*
1	0	1330	251	0.53	-	-	-
2	19.62	1330	173	0.78	0.40	1.91	20.03
3	39.24	1330	101	1.33	0.34	3.82	23.49
4	58.86	1330	80	1.68	0.29	5.73	27.90

Case (iii) At 30°C preheating temperature

SL No.	*Load (N)*	*Speed (RPM)*	*Time Sec*	*TFC Kg/hr.*	*SFC Kg/Kw-hr*	*BP (Kw)*	*$\acute{\eta}_{bt}$ (%)*
1	0	1330	254	0.53	-	-	-
2	19.62	1330	186	0.72	0.37	1.91	21.70
3	39.24	1330	104	1.29	0.33	3.82	24.22
4	58.86	1330	84	1.60	0.27	5.73	29.30

Case (iv) At35°C preheating temperature

SL No.	*Load (N)*	*Speed (RPM)*	*Time Sec*	*TFC Kg/hr.*	*SFC Kg/Kw-hr*	*BP (Kw)*	*$\acute{\eta}_{bt}$ (%)*
1	0	1330	260	0.52	-	-	-
2	19.62	1330	182	0.74	0.38	1.91	21.11
3	39.24	1330	107	1.26	0.33	3.82	24.80
4	58.86	1330	87	1.55	0.27	5.73	30.24

Case (v) At 40°C preheating temperature

SL No.	*Load (N)*	*Speed (RPM)*	*Time Sec*	*TFC Kg/hr.*	*SFC Kg/Kw-hr*	*BP (Kw)*	*$\acute{\eta}_{bt}$ (%)*
1	0	1330	264	0.511	-	-	-
2	19.62	1330	186	0.72	0.37	1.91	21.70
3	39.24	1330	109	1.23	0.32	3.82	25.41
4	58.86	1330	88	1.53	0.26	5.73	30.64

Table 5: Emission Characteristics Using Carburetor

Case (i) At 20°C preheating temperature

SL No.	LOAD (N)	HC (ppm)	CO (%)	CO_2 (%)
1	0	110	4.76	2.88
2	19.62	118	4.81	2.92
3	39.24	134	4.82	2.99
4	58.86	192	5.60	4.14

Case (ii) At 25°C preheating temperature

SL No.	LOAD (N)	HC (ppm)	CO (%)	CO_2 (%)
1	0	106	4.62	2.82
2	19.62	114	4.15	2.88
3	39.24	130	4.08	2.92
4	58.86	186	5.10	4.08

Case (iii) At 30°C preheating temperature

SL No.	LOAD (N)	HC (ppm)	CO (%)	CO_2 (%)
1	0	106	4.78	2.88
2	19.62	116	4.99	2.54
3	39.24	130	4.23	2.62
4	58.86	185	4.26	2.28

Case (iv) At 35°C preheating temperature

SL No.	LOAD (N)	HC (ppm)	CO (%)	CO_2 (%)
1	0	107	4.53	2.72
2	19.62	115	4.92	2.53
3	39.24	131	4.21	2.58
4	58.86	184	4.08	2.12

Case (v) At 40°C preheating temperature

SL No.	LOAD(N)	HC (ppm)	CO (%)	CO_2 (%)
1	0	105	4.91	2.23
2	19.62	114	4.83	2.14
3	39.24	130	4.23	2.08
4	58.86	185	4.08	2.05

Table 6: Emission Characteristics Using Injector

Case (i) At 20°C preheating temperature

SLNo.	LOAD (N)	HC (ppm)	CO (%)	CO_2 (%)
1	0	112	4.90	2.88
2	19.62	124	4.96	2.67
3	39.24	139	5.02	2.54
4	58.86	162	5.10	2.65

Case (ii) At 25°C preheating temperature

SL No.	LOAD (N)	HC (ppm)	CO (%)	CO_2 (%)
1	0	108	4.82	2.81
2	19.62	115	4.91	2.63
3	39.24	131	5.00	2.51
4	58.86	159	5.03	2.36

Case (iii) At 30°C preheating temperature

SL No.	LOAD (N)	HC (ppm)	CO (%)	CO_2 (%)
1	0	102	4.82	2.81
2	19.62	110	4.91	2.63
3	39.24	129	5.10	2.51
4	58.86	151	5.03	2.36

Case (iv) At 35°C preheating temperature

SL No.	LOAD (N)	HC (ppm)	CO (%)	CO_2 (%)
1	0	98	4.82	2.81
2	19.62	112	4.91	2.63
3	39.24	128	5.10	2.51
4	58.86	149	5.03	2.36

Case (v) At 40°C preheating temperature

SL No.	LOAD (N)	HC (ppm)	CO (%)	CO_2(%)
1	0	102	4.12	2.12
2	19.62	116	4.56	2.23
3	39.24	124	5.02	2.45
4	58.86	138	5.10	2.36