Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
ISSN NO. 2320-5407
Article DOI: 10.21474/IJAR01/2074
DOI URL: http://dx.doi.org/10.21474/IJAR01/2074

RESEARCH ARTICLE

HYDROGEN BOOSTING IN I.C ENGINE.

Aditya.K.Vasaikar * and Amey.A.Vasaikar
Mechanical Engineering Mumbai University.

Manuscript Info

Manuscript History

Received: 24 September 2016
Final Accepted: 25 October 2016
Published: November 2016

Abstract

Hydrogen a fuel which is available in abundance in our environment is quite neglected so this project deals in use of hydrogen as a secondary fuel in an internal combustion engine for load condition for better economy and increasing efficiency. Our setup injects a minute amount of hydrogen with the air intake of engine which leads to more power and output from existing structure.

Introduction:-

The project is a research project explaining the concept of hydrogen boosting in a four stroke gasoline engine. Hydrogen boosting is an addition of a small quantity of hydrogen to the air fuel mixture of an engine. The addition of hydrogen greatly improves the combustion characteristics of gasoline and improves the overall performance of the engine. An experimental setup was fabricated and designed to test this effect. Hydrogen was added with the air supply at the air intake and tests were taken particularly at lean conditions. The results showed a great improvement in the engine performance in terms of power, speed, efficiency, specific fuel consumption and combustion of gasoline. Among the existing technologies, the use of hydrogen as a fuel has greatly been desired primarily for its high calorific value abundant production and virtually emission free exhaust emissions. However due to the limitations associated with controlling its explosive nature, commercially viable model for a hydrogen engine is still greatly desired. This lead to the formation of a simple question in our minds: project begins on Hydrogen Boosting. In this project, hydrogen will add primarily for its combustion properties, not just as a fuel. With the addition of a small amount of hydrogen hoped to boost the combustion of gasoline in a four-stroke SI engine. These technologies can revolutionary's internal combustion engines. This concept can be potentially being applied to any four stroke gasoline engine stationary or vehicular. Further this concept improves range of operation of the engine in terms that Hydrogen boosted engine can be operated at higher compression ratios.

Experimental setup:-

Setup Explanation:-

At the heart of the setup is a 4-stroke spark ignition single cylinder engine. The engine used is that of the bike CD 100 made by Hero Honda. The engine has its clutch and gear box housing integrated with it. The clutch is engaged and disengaged with the help of clutch wire which is connected to a handle connected on the frame. The gear box is 4-step synchromesh. The appropriate gear selection is done with the help of lever at the side of the gear box housing. Upward motion of this lever raises the gear by one and corresponding lowering of the gear is done by lowering the lever.
The starting of the engine uses a kick start mechanism. No external battery or power source is required since

Corresponding Author:- Aditya.K.Vasaikar.
Address:- Mechanical Engineering Mumbai University.

spark plug is powered using a magneto ignition system. A key is used for the same. Furthermore the engine is air-cooled and the engine mountings are rigidly bolted to the setup frame.

This engine used was in running condition and already being used. Choosing this engine served dual purpose of testing the increase in performance of engine at normal operation and not just when it is newly made.

The charge supplied to the engine at the inlet manifold is mixed in the carburetor. A carburetor is used for this purpose further the quantity of charge supplied to the engine is controlled with the help of the throttle valve which is connected to the accelerator with the help accelerator wire. The accelerator is attached to the frame of the setup and is manually controlled according to the requirement. Further the air fuel ratio of the charge is controlled by adjusting the carburetor pin to required conditions.

Since a controlled quality of air is supplied to the carburetor the inlet is extended for lifting an air pipe. The pipe used for this purpose it was properly tested for leaks before attaching it to the setup. Furthermore air pipe was fitted using round ring and sealing tapes were used to avoid leakage. Further m-seal was applied to the ends. This ensures proper measurement of air and also eliminates any potential leakage since the mixing of air and hydrogen takes place in the pipe.

Air and hydrogen is supplied to the carburetor through this pipe. Both the intake of air and hydrogen is done with the help of a T-section connected to this pipe are two valves on provided to open and close the supply of air and hydrogen if required.

The measurement of air supplied is done by using venture meter. The pressure difference between the venture meter and the atmosphere i.e. a two sides of the orifice is measured with the help of a U-tube manometer in which water is used as measuring fluid. One end of the manometer is open to atmosphere and the other end is connected to the air box. The mass flow rate of air can be calculated by using the apparatus.

Hydrogen is supplied using a hydrogen cylinder. The hydrogen cylinder used for this purpose is a 1.5 m^3 cylinder which is about 3 feet tall. A cylinder key is used for opening and closing of cylinder. Hydrogen is stored in the cylinder in pressurized gaseous form. All care and precaution must be taken when handling the cylinder. Around 1500 litter of hydrogen is stored in the cylinder when it is fully filled with hydrogen.

A pressure regulator is connected to the cylinder for controlling the pressure of hydrogen when supplied. A dual gauge pressure regulator is used for this purpose. This regulator shows pressure at both ends of this regulator i.e. the pressure at the cylinder and the pressure supplied to the flow meter. A threaded pin is used to control this regulator. By twisting it inward, more amounted the pressure is transformed ahead.

The pressure regulator is then connected to a flow meter. The flow meter used is known as a rotameter and uses a floating ball arrangement for measuring the flow. This entire assembly is tightly fitted to the cylinder and this was thoroughly checked to avoid leakages in any form. This controlled quantity of hydrogen is then supplied further form the flow meter to the air pipe with the help of a red weld pipe. This is pinned and connected to the flow meter and the T-section using suitable length changes operational. The pipe is 5 meter in length for safety purpose its ends are suitably sealed.

The fuel is stored in fuel tank which is rigidly bolted to the frame. This tank is connected to a burette which is used to measure the quality of fuel used. The burette is of 50 ml in capacity where each division of fuel drop represents a drop of 1ml of fuel. This fuel is then supplied to the carburetor for the measurement of power of the engine, rope brake dynamometer is used for the same. The engine output shaft is extended and a pulley is coupled with it. Appropriate balancing is done and the output shaft is supported with the help of ball bearings. The pulley is water cooled and belt is wound over half of its perimeter to provide frictional torque. Two spring balances are used to measure the torque on the pulley, one of which is fixed to the frame and other is attached to a threaded shaft which is adjusted to adjust the load on the pulley. A tachometer is used to measure the speed of rotation of the pulley.

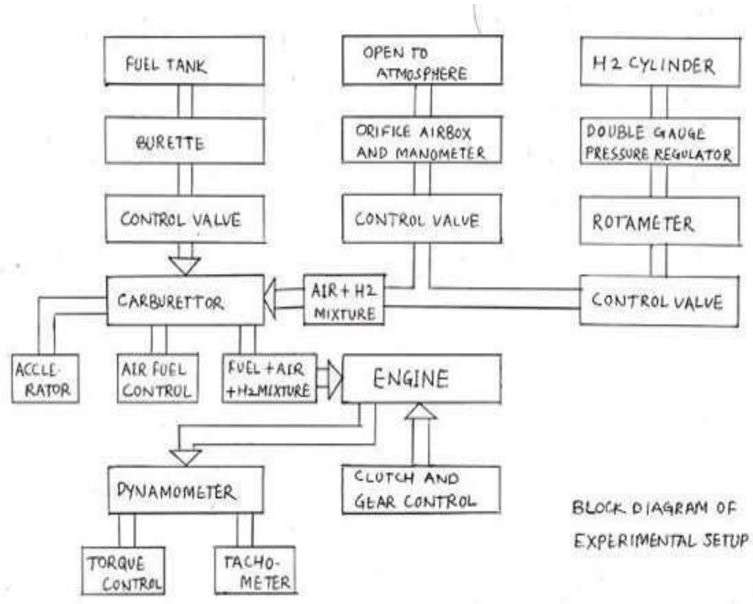

Fig. 1:- Block diagram of experimental set-up.

Technical Specification of Setup;-
Engine:-

1.	Name & make	:HERO HONDA CD100	
2.	Engine type	: 4-stroke, single cylinder, air-cooled	
3.	No. of cylinder	:	1
4.	Capacity	:	97.2cc
5.	Clutch type	:	Manual
6.	Clutch Secondary	:	Multi-plate wet
7.	Transmission	:	4-speed constant
8.	Starting	:	Kick starter
9.	Max Power	: 7.0 PS(5148.49watt) @ 5000 rpm	
10.	Bore & Stroke	:	50 x 49.5 mm
11.	Compression Ratio	:	9.0:1

Carburetor:-
Carburetor for Hero Honda CD100/Splendor/Passion:-

Dynamometer:-
Rope Brake Dynamometer:-

1.	Thickness of belt	:3 mm
2.	Width of belt	: 1 inch.
3.	Spring balances	:25 kg and 10 kg
4.	Brake drum pulley diameter	:23.5 cm

Fuel Measurement:-

1.	Burette capacity	:	50ml
2.	Burette	:	11.25 mm diameter

Air Measurement:-

Manometer	: U-Tube manometer

Hydrogen Cylinder:-

1.	Cylinder size	: 85x14 cm & weight 16 kg
2.	Flow meter	: Tube type gas flow meter
3.	Pressure regulator	: Double gauge pressure regulator

Procedure:-

This chapter describes the procedure for the operation of the test rig. This procedure should be followed to ensure proper working and accurate readings while performing the experiment. Also great care should be followed when using hydrogen due to its explosive nature.

The procedure given below are divided into separate sections corresponding to each function and testing conditions of this engine and test rig as a whole.

Starting of the engine:-

1. Before starting the engine, check the fuel level.
2. Make the air supply and fuel supply valves are open.
3. Place and rotate the engine key.
4. Start The engine using foot operated kick mechanism.
5. In case of starting difficulty during cold start, use the choke to start the engine.

Gear and accelerating conditioning:-

1. Press the clutch and shift the gear. Gear shifting is done by gear shifting pedal provided at the left of the engine.
2. For forward gears, press the pedal up and for backward gears press the pedal down.
3. Maintain the speed of the engine to the desired level by accelerometer.

Procedure for Fuel Consumption Measurement:-

1. Fill the burette with fuel.
2. Close the supply to the engine from the fuel tank.
3. Use a stopwatch to measure the time for drop in fuel level.
4. Measure the drop in fuel level.
5. Calculate the fuel consumption with the formulae calculated later.

Procedure for Air Consumption Measurement:-

1. Measure the pressure difference on the u tube manometer.
2. Calculate the air consumption with the formulas

Procedure for Power Measurement:-

1. Tight the belt of dynamometer by rotating the nut.
2. Measure the load on spring balance.
3. Calculate the power of the engine by formulae calculated later.

Procedure for Adjusting Air Fuel Ratio and Carburetor Setting;-

1. Control the engine speed and fuel intake by setting the carburetor.
2. For rise in engine speed, rotate the pin at left of carburetor in a clockwise manner. For reduction in speed, rotate the pin in anticlockwise manner.
3. To increase the air fuel ratio, rotate the pin at the right of the carburetor in anticlockwise manner. To reduce the air fuel ratio, rotate the pin in the clockwise manner.

Leakage Testing:-

1. Put soap foam on the connections and run the engine.
2. If any bubbles are found then there is a leakage.
3. If any leakage found, hydrogen cylinder should turn off.
4. Remove all the leakages and make the connections.
5. Do the leakage tests again till you get leak proof connections.

Procedure for Hydrogen Boosting:-

Procedure to Follow before use of Hydrogen:-

1. Do the leakage test for the test rig. If any leakage found, repeat the test till we get leak proof setup.
2. Open the hydrogen control valve before hydrogen is added to the engine.
3. Turn on the hydrogen cylinder by rotating the knob in clockwise direction.
4. Control the hydrogen flow rate with the help of gas flow meter. Once the hydrogen flow rate is controlled, connect the hydrogen pipe to the end of flow meter and seal it.
5. Do the leakage test for the hydrogen cylinder connections. If any leakage found, repeat the test till we get leak proof connections.

Procedure to Follow for Supply and Regulation of Hydrogen:-

1. Start the engine and run for some time.
2. Add the hydrogen to the engine by controlling through gas flow meter.
3. Check the various parameters. After measurement is done, turn off the hydrogen flow and run the engine for some time on petrol. So it will use remaining hydrogen in the pipe and avoid any leakages.

Procedure to Follow after use of Hydrogen:-

1. While removing hydrogen attachment; first close the hydrogen flow valve.
2. Turn off the hydrogen cylinder by rotating the knob in clockwise manner.
3. Remove the hydrogen pipe and turn on the flow meter and pressure regulator so that hydrogen present inside escapes into atmosphere.
4. Turn off the engine and close the air and fuel supply valve

Calculations:-

Brake Power;-

$$\text{Brake Power} = \text{Angular Velocity} \times \text{Torque} = \frac{2\pi \times N \times \tau}{60}$$

Now,

$$\tau = (W_1 - W_2)\, r \times g$$

$$\text{Brake Power} = \frac{2\pi \times N \times (W1 - W2)\, r \times g}{60}$$

Where,

r = radius of pulley of dynamometer

W_1, W_2= weights in kgs

g= gravity force

N= Pulley rpm

τ = Torque

Fuel Consumption

$$(mf) = \frac{\text{Fuel Utlized}}{\text{Time (t)}} = \frac{[X] \times \rho f}{t} \times 10^{-6}$$

Where,

mf = Mass flow rate of fuel

t = Time in seconds

ρf = Density of fuel (petrol) = 720 kg/m^3

[X] = Drop in fuel level in divisions

Air-Fuel Ratio

$$\frac{A}{F} = \frac{\text{Air flow}}{\text{Fuel consumption}}$$

$$= \frac{5.6716 \times 10^{-4} \times (h_1 - h_2)^{\frac{1}{2}}}{\frac{7.2 \times [X] \times 10^{-4}}{t}} \text{ kg/sec}$$

Where,

T= Time in sec
h_1& h_2 = Manometer Head in mm
[X]= Drop in fuel level in division

Brake Specific Fuel Consumption
Without Addition of Hydrogen :

$$BSFC = \frac{\text{Fuel Consmption} \quad kg/sec}{\text{Brake Power} \quad watts}$$

$$= \frac{\frac{7.2\times[X]\times10^{-4}}{t}}{\frac{2\pi\times N\times(W_1-W_2)\times r\times g}{60}}$$

With Addition of Hydrogen :

$$BSFC = \frac{\text{Fuel Consmption} \quad kg/sec}{\text{Brake Power} \quad watts}$$

$$= \frac{\frac{7.2\times[X]\times10^{-4}}{t}+m_h}{\frac{2\pi\times N\times(W_1-W_2)\times r\times g}{60}} \text{ kg/watts sec}$$

Brake Thermal Efficiency :
Without Addition of Hydrogen :

$$\acute{\eta}_{bth} = \frac{\text{Brake Power}}{M_f\times \text{Calorific value}}$$

Where, C_v = 48000 kJ/kg

1) With Addition of Hydrogen

$$\acute{\eta}_{bth} = \frac{\text{Brake Power}}{(M_f\times C_v)+(m_h\times C_{vh})}$$

Where, C_{vh}=141790 kJ/kg

Results:-

The performance of the engine varies with the addition of hydrogen. Around 1 lit/min was added to the engine along with the air-fuel mixture. On doing so the results that were observed showed a distinct rise in the engine performance due to both factors namely the energy of combustion of hydrogen and also the improved combustion of gasoline due to the influence and pressure of hydrogen.

Another observation was noticeable improvement in engine performance at lean mixtures. This chapter deals with the practically measured output of the engine along with its theoretical implications.

Effect of Hydrogen Boosting on Engine Speed:-

For the speed test we set the engine at lean condition initially. Then upon setting a constant accelerator condition we measured the speed of shaft. Repeating this test for both engines running on only petrol and on the engine boosted by hydrogen, we could compare the respective change in speed. A large variation in engine speed was observed on comparing the readings.

The table provided below shows the change in speed by addition of hydrogen at different speeds. It should be noted however that the speed shown in this graph are the rotational speeds as shown by the tachometer.

Table 1:- Speed

Speed (RPM)			
Sr.no	**N -Speed(rpm) Without hydrogen**	**N -Speed(rpm) With hydrogen**	**% increase in speed**
1.	1366	2058	50.658
2.	1416	1946	37.429
3.	1755.2	2753.6	56.882
4.	1418.8	2043.6	44.037
5.	1720.4	2706	57.289

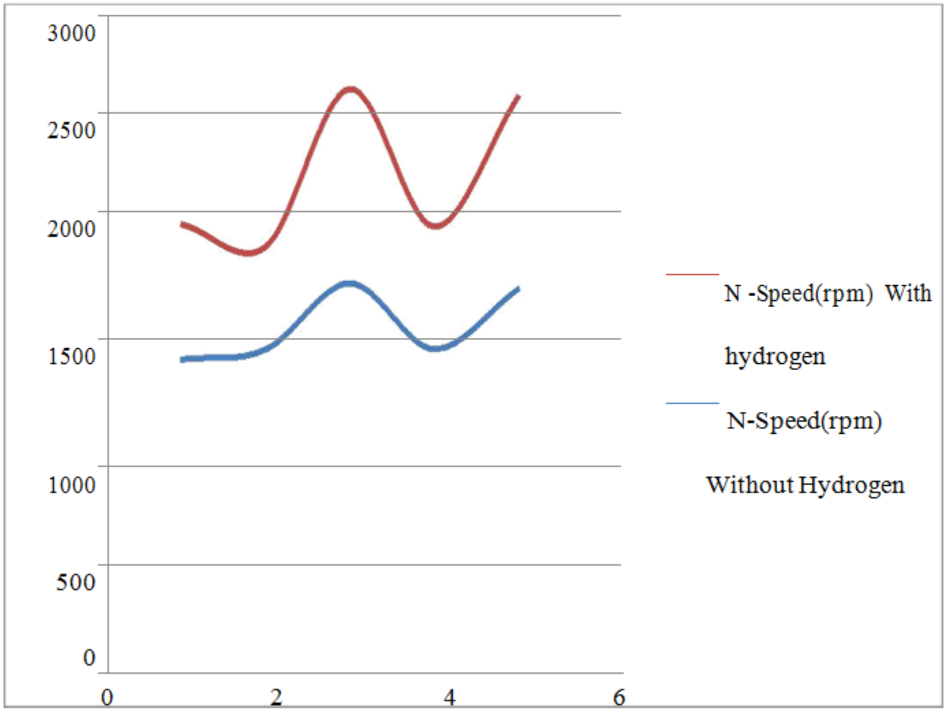

Fig 1:- Speed

In all these condition there is addition of hydrogen at around 1lit/min. There is large change in speed of the engine upon addition of hydrogen

On average there is a 50% increase in the speed of the engine .at some conditions there is even a rise of over 55 %. This condition generally corresponds to higher accelerator conditions . Hence addition of hydrogen increases the speed of the engine .this is not only the result of the combustion of the hydrogen but primarily due to more effective combustion of gasoline. Also at lean conditions, the presence of hydrogen avoids the jerky motions of the output shaft and gives smoother output.
It should be noted however that since engine runs on both gasoline and hydrogen therefore when the speed is increased, the rate of consumption of fuel is also slightly increased, since at higher speed engine needs more fuel however it must be noted that there is distinct drop in the specific fuel consumption.

Effect of Hydrogen Boosting on Brake Power:-

Aforementioned, there is a great rise in the speed of the engine on boosting it with hydrogen there is a great rise in power in these conditions the measurement in break power of engine was done using a simple rope break dynamometer A large variation in the output power was observed. The table showing the rise in power is as shown below.

Table 2:- Brake Power.

				BRAKE POWER (WATTS)				
	Without hydrogen				**With hydrogen**			
Sr.no	**N**	**(W1 – W2)**		**Power**	**N**	**(W1 –W2)**	**Power**	**%**
	Rpm	**kg**		**(W)**	**Rpm**	**kg**	**(W)**	**Power Increases**
1.	683	1		82.44	1000	0	0	0
2.	860.2	1.9		197.28	1200	1.5	217.27	10.13
3.	877.3	1.95		206.5	1353	1.8	293.28	42.02
4.	937.4	2		225.77	1401	2.1	355.13	57.29
5.	1426.6	4		686.80	1650	3.2	759.01	10.51

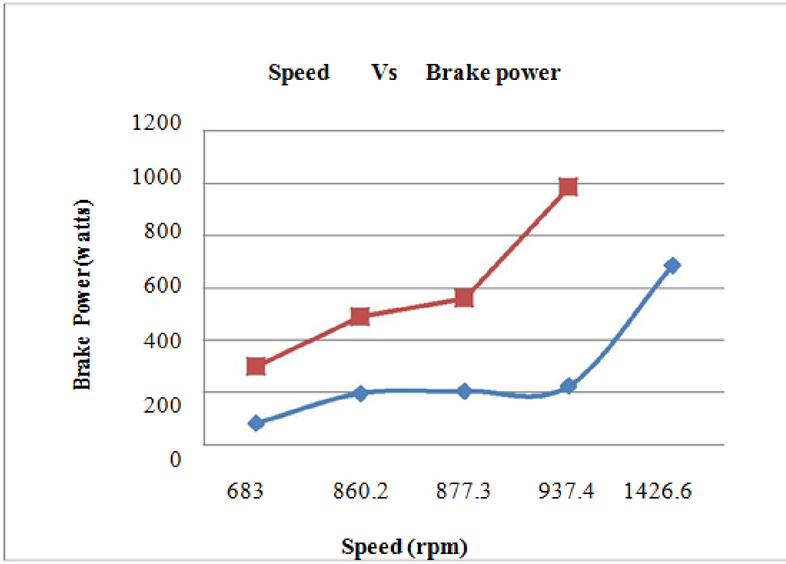

Fig 2:- Brake Power

The power in this table is calculated by inputting the various values of speed, spring balance readings. The formula used to calculate is:
Brake power = $2\pi N \tau /60$

Corresponding there is a large rise in output power of the engine. in each case there is a rise in power of over 30%. On average there is a rise of around 30% in power and these increases at leaner mixture hence from this it can be concluded that addition of hydrogen is particularly helpful in lean conditions and is advantageous even in normal conditions.

Effect of Hydrogen Boosting on Brake Specific Fuel Consumption:-
As discussed earlier the speed and power of the engine increases when it is boosted with hydrogen, however it is noted that at high speeds, the engine takes in more fuel i.e. the mass flow rate of the fuel increases. This however, the corresponding power output is much greater than that due to increase in fuel consumption. In other words the specific fuel consumption reduces.

The table below represents the BSFC of the engine:
Table 3:- Brake Specific Fuel Consumption

			BRAKE SPECIFIC FUEL CONSUMPTION (bsfc)(KG/WATT.SEC)						
			Without hydrogen				With hydrogen		
Sr.no	X in 'cm'	T Sec	N rpm	(W1 – W2) kg	b.s.f.c * (10^{-7})	T Sec	N rpm	(W1 – W2) kg	b.s.f.c * (10^{-7})
1.	5	74	683	1	5.90	61.5	1000	0	0
2.	5	65.5	860.2	1.9	2.785	60	1200	1.5	2.199
3.	5	62.5	877.3	1.95	2.78	53	1353	1.8	1.98
4.	5	55	937.4	2	2.89	52	1401	2.1	1.63
5.	5	36	1426.6	4	1.45	49	1650	2.3	1.218

Effect of Hydrogen Boosting on Efficiency:-
Exploring further along this line of thought of the rise in engine power and the reduction in the BSFC of the engine, it can be accessed that the efficiency of the engine has increased.

With our setup we measured the brake thermal efficiency (η_{th}) of the engine and found a distinct rise in efficiency of the engine. Now, the brake thermal efficiency can be represented by:

$$\acute{\eta}_{bth} = \frac{\text{Brake power}}{Mf \times C.V}$$

Hence the contribution of the combustion of hydrogen should be considered when showing the increase in efficiency.

The table showing the rise in efficiency is shown below:-

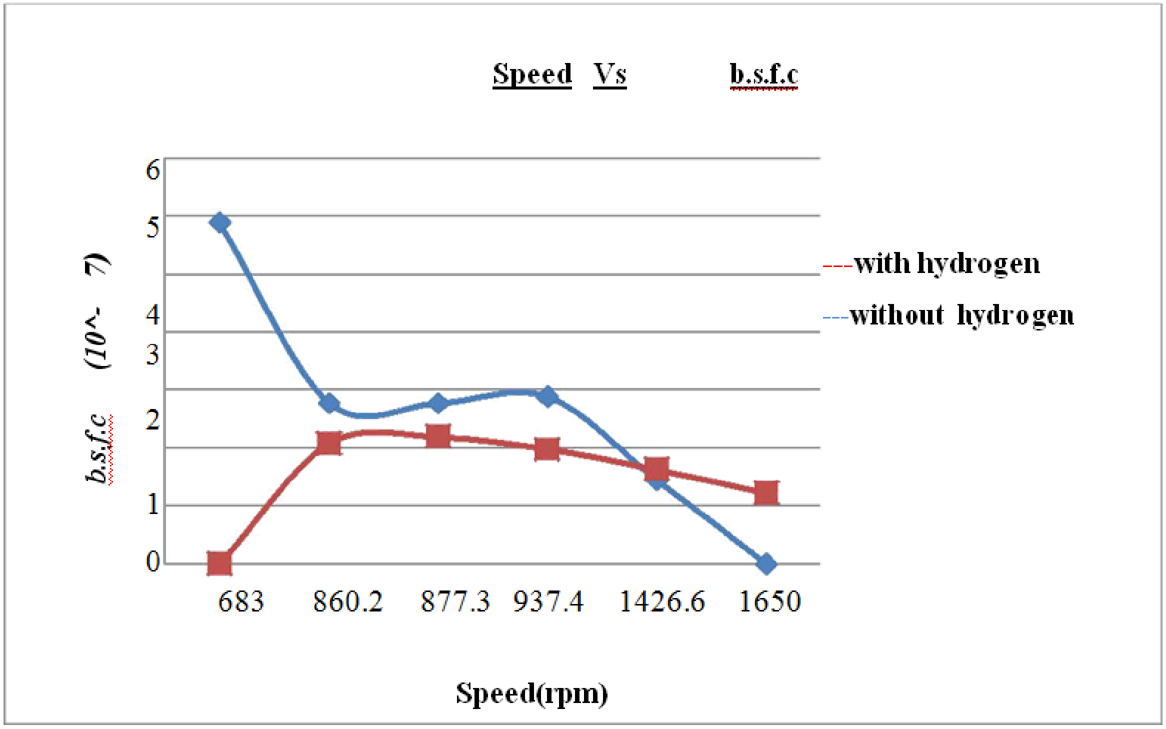

Fig. 3:- Brake Specific Fuel Consumption.

Table 4:- Brake Thermal Efficiency.

			Without hydrogen					With hydrogen					
Sr.no	**X in**	**T**	**N**		**(W1 –W2)**	**Efficiency**	**T**	**N**	**(W1 –W2)**		**Efficiency**		**%**
	'cm'	**Sec**	**rpm**		**kg**	**(%)**	**Sec**	**rpm**	**kg**		**(%)**		**efficiency**
													increases
1.	5	74	683		1	3.53	61.5	1000	0		0		0
2.	5	65.5	860.2		1.9	7.07	60	1200	1.5		7.48		5.79
3.	5	62.5	877.3		1.95	7.468	53	1353	1.8		9.10		21.85
4.	5	55	937.4		2	7.19	52	1401	2.1		10.11		40.61
5.	5	36	1426.6		4	14.35	49	1650	2.3		12.33		16.38

References:-

Research papers:-

1. John F. Cassidy ; "EMISSIONS AND TOTAL ENERGY CONSUMPTION OF MULTICYLINDER PISTON ENGINE RUNNING ON GASOLINE AND A HYDROGEN-GASOLINE MIXTURE " ; NASA technical note ; 1977.
2. Changwei Ji, Shuofeng Wang, Bo Zhang ;" Performance of a hybrid hydrogen–gasoline engine under various operating conditions" ; www.elsevier.com ; 2011.
3. Daniel r cohn, leslie Bromberg, alexander rabinovich, john B. Heywood ; "HIGH COMPRESSION RATIO, HYDROGEN ENHANCED GASOLINE ENGINE" ; US petent no 6655324 B2 ; 2003
4. F.W.hoehn, M.D.dowdy ; "FEASIBILITY DEMONSTRATION OF A ROAD VEHICLE FULLED WITH HYDROGEN ENRICHED GASOLINE" ; Jet propulsion lab.,pasadena California.
5. Hydrogen properties ; "Hydrogen Fuel Cell Engines and Related Technologies"; December 2001
6. Olga BIČÁKOVÁ * and Pavel STRAKA ; " THE RESOURCES AND METHODS OF HYDROGEN PRODUCTION" ; Acta Geodyn. Geomater., Vol. 7, No. 2 (158), 175–188, 2010
7. Kaveh Mazloomi1,*, Nasri b. Sulaiman1, Hossein Moayedi2;" Electrical Efficiency of Electrolytic Hydrogen Production" ; Int. J. Electrochem. Sci., 7 (2012) 3314 – 3326

Reference Books:-

1. V Ganeshan ; "Internal Combustion Engines" ; Tata McGraw-Hill companies ; third condition
2. Eugene l. keating ; "Applied Combustion" ; CRC press ; second edition 3. Chung k. law ; "Combustion Physics" ; Cambridge
3. Willard w. pulkrabek ; "Engineering Fundamentals of the Internal Combustion Engine"