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Aims and Scope

International Journal in IT and Engineering is a double blind peer reviewed, refereed monthly international journal that provides rapid publication of articles in all areas of Information Technology (IT) and Engineering through research and its relevant appropriation and inferential application. The journal hopes to accelerate development and governance in both developed and developing countries. The maximum length of intended articles for publication in the journal is 5000 words. A short abstract of 150-250 words with 4-5 key words should precede the introduction. We appreciate innovative and evolutionary contemplation over popular management ethics, differing from the humdrum bulk of monotonous content. The journal welcomes publications of high quality papers, book reviews and reports.

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Computational Investigations On The Effect of Start of Combustion Timing on The Performance and Emissions Characteristics Of A Four Cylinder Four Stroke Cycle Spark Ignition Engine With Hydrogen Direct Injection And GDI Modes

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ABSTRACT

This paper presents the results of the computational research investigations on a 4-stroke 4- cylinderspark ignition engine fitted with direct fuel injection system with hydrogen and gasoline as two alternative fuels. The simulated results were generated in the professional internal combustion engines software named as AVL BOOST. The software has a graphical user interface for modeling the complete engine system using various elements provided in its design. The software basically uses the conservation laws of mass, momentum and energy in its design codes.Further the software has the facility of using alternative thermodynamic models for combustion,heat transfer and frictional power etc.

First a GDI engine was modeled from the basic elements. The GDI engine was run under constant speed, constant air-fuel ratio and variable start of combustion timing operation. The results were generated for the engine performance and its emissions characteristics. The procedure was repeated by operating the engine with hydrogen as an alternative fuel under similar design and operating conditions. Again the results were generated its performance and emissions characteristics. The results showed that the power and the torque output of the hydrogen based spark ignition engine fitted with direct fuel injection system were higher than that of its corresponding GDI version. Also the hydrogen version of the direct fuel injection type of spark ignition engine consumes lesser quantity of fuel per unit of energy output as compared to its gasoline version. Further the hydrogen based engine does not produce any CO emissions. Moreover the soot and NOx emissions produced by the hydrogen based direct injection spark ignition engine were lower than those produced by its GDI version.

Keywords: Hydrogen, Gasoline, Direct Fuel Injection, Four Stroke Cycle, Multi-cylinder, Spark Ignition Engine.

INTRODUCTION

For hydrogen fuel, the stoichiometric equation is ($H2 + \frac{1}{2}$ (O2 + 3.773N2) = H2O + 1.887N2) and the stoichiometric (A/F) ratio is 34.3.For stoichiometric hydrogen-oxygen mixtures, no reaction occurs below 400C unless the mixture is ignited by an external source such as a spark; above 600C explosion occurs spontaneously at all pressures.[1]

Kimitaka Yamane conducted performance and emissions based experimental investigations on a 4-cylinder 4 stroke spark ignition engine having a displacement volume of 4.6-Litres with hydrogen as its fuel. In order to solve the challenges faced by the hydrogen fuelled engines till recently the use of LH2 pumps, hydraulically operated common-rail-type small GH2 injectors with no leakage of hydrogen gas, and a cryogenic LH2 fuel tank was done. This helped the development of a high pressure direct injection hydrogen internal combustion engine with near-zero CO2 emissions. This resulted in a workable alternative to the gasoline and diesel internal combustion engine platforms.[2]

Hydrogen has been considered so far mainly as a fuel alternative to gasoline in passenger car applications operating with spark ignition, with just a couple of examples of use of hydrogen as a fuel alternative to Diesel in passenger car applications operating compression ignition. Alberto Boretti conducted simulation studies on a heavy duty Diesel truck engine modeled and converted to run on hydrogen with goals to retain the same of Diesel full and part load efficiencies and power and torque outputs. The results were that the modeled hydrogen engine had actually better than Diesel fuel efficiencies all over the load range and it also permitted better full load power and torque outputs running about same stoichiometry. [3]

Choongsik Bae, Jaeheun Kim while covering the potential alternative fuels for automotive engine application for both spark ignition and compression ignition engines writes that up to 90% of propulsion for transportation still rely on the internal combustion engine and is likely to be so up to 2040. Therefore the global demand for transportation fuels is expected to grow continuously at between 1.2% and 1.4% per annum. About hydrogen he writes that it is widely used as the fuel for combustion over a wide range of industries, including the aerospace field, due to its high energy density in mass basis, high flame speed, and wide flammability range. There is no doubt that it can also be used in the transportation sectors. Hydrogen can be used under various combustion regimes, from conventional to advanced combustion concept.

Hydrogen can be produced from fossil resources, such as natural gas and coal, as well as renewable resources, such as biomass. Hydrogen can also be produced through electrolysis of water with solar generated electricity in terms of CO2 emission reduction. However this type of production scale is very small currently. Today, more than 90% of the hydrogen produced is derived from fossil fuels, including natural gas, oil and coal, via a steam reforming process. About the properties and combustion characteristics of Hydrogen fuel. He adds that the high octane number of hydrogen also provides the opportunity to increase the compression ratio to increase the engine efficiency. Its wide flammability limits also enable un-throttled operation with lean combustion. The high laminar flame speed, an order of magnitude higher than hydrocarbons, is a distinct combustion characteristic of H_2. The laminar flame speed is about 1.85 m/s for H_2, while the speed for hydrocarbon fuels range from 0.3 to 0.5 m/s. Therefore, a PFI engine operating with H_2 has a higher thermal efficiency over the conventional gasoline fueled engine, due to the availability of lean un-throttled operation, high flame speed, and potential for higher compression ratio. However, attentions should be paid on the possibility of greater heat transfer losses through the cylinder wall with H_2 fueled engines. The auto-ignition temperature of H_2 is 858 K, which is higher than that of gasoline fuel (around 550 K). However the minimum ignition energy of hydrogen is 0.02 mJ (while that for equivalent gasoline–air mixture is 0.24 mJ) and may cause backfire and pre-ignition, which are critical issues for H_2 fueled engines. Pre-ignition is a phenomenon whereby an ignition of the air–fuel mixture occurs before the spark plug fires, leading to engine damage. Pre-ignition mostly takes place at engine hot spots, such as spark electrodes, valves, or oil contaminants. Local hot spots can easily be created when the compression ratio of the engine, or the engine load (namely the equivalence ratio of the mixture) are raised too much. Such concerns bring boundaries to the operation windows, and thus limit the maximum power of the engines. H_2 combustion does not produce carbon related emissions, such as CO, CO_2 and PM, due to the absence of C atoms. However, note the carbon foot print if carbon based feed stocks are used to produce H_2. NO_x is the only non-trivial engine out emission pollutant. There are some available approaches to reduce NOx emissions. The first approach is to adopt an ultra lean combustion with an equivalence ratio (ϕ) lower than 0.45, in order to reduce the peak combustion temperature; however, this limits available engine torque. The low energy density on a volumetric basis also hinders the maximum torque characteristics. Another approach is to install an after treatment downstream of the engine. A lean NO_x trap (LNT) would be needed when operating at a moderately lean condition with equivalence ratio below 1 at higher cost; while a lower cost TWC is required when operating at stoichiometric conditions. However, research on the prevention of abnormal combustion, such as pre-ignition, needs to be resolved, prior to operation under the stoichiometric condition.[4]

S.C. Chen et. al., conducted experimental investigations with an onboard compact and high efficient methanol steam reformer installed in the tailpipe of a vehicle to produce hydrogen continuously by using the waste heat of the engine for heating up the reformer. This use of waste heat from engine enables an extremely high energy conversion of 113% to convert methanol into hydrogen with a low input cost. The investigations were conducted on 2 gasoline engine vehicles and 2 diesel engines. The results indicated a hike in engine efficiency, savings in fuel and a reduction in pollutants including a 70% reduction in exhaust smoke. [5]

H. An et. al., conducted numerical studies on the performance, combustion and emission characteristics of a hydrogen assisted diesel engine under various operating conditions. Simulations were performed using multi-dimensional software KIVA4 coupled with CHEMKIN. The Kelvine Helmholtz and Rayleighe Taylor hybrid break up model was implemented to accurately model the spray development. A detailed reaction mechanism was constructed to take into account the chemical kinetics of diesel and hydrogen. The results were validated against the experimental results with 0% of hydrogen induction. Simulation results showed that at low engine speeds, the indicated thermal efficiency, in-cylinder pressure and apparent heat release rate increased significantly with the induction of hydrogen. On the other hand, at high engine speed and high load conditions, no tangible changes on the engine performance, combustion characteristics were observed. In terms of emissions, CO and soot emissions were shown to be reduced under most of the engine operating conditions. Whereas for NOx emissions, a slight increase was observed at low engine speed of 1600rpm.[6]

J. M. Gomes Antunes et. al., conducted experimental studies on a direct injection compression ignition hydrogen engine. Test results showed that the use of hydrogen direct injection in a diesel engine gave a higher power to weight ratio when compared to conventional diesel-fuelled operation. The use of inlet air heating was required for the hydrogen fuelled engine to ensure satisfactory combustion. The hydrogen fuelled engine achieved a fuel efficiency of approximately 43% as compared to 28% in the conventional diesel mode. A 20% reduction in nitrogen oxides emissions was further observed.[7]

Maher A. R. Sadiq Al-Baghdadi et. al., conducted computational investigations on the effects of equivalence ratio, compression ratio and inlet pressure on the performance and NOx emissions of a four stroke supercharged hydrogen engine. The results were verified and compared with experimental data obtained from tests on a Ricardo E6/US engine. The results showed that supercharging was more effective method to increase the output of a hydrogen engine rather than increasing its compression ratio at its knock limited equivalence ratio. Both specific fuel consumption and engine efficiency improved for the hydrogen fuel, lean equivalence ratio and high inlet pressure of charge. Also under some range of operating conditions the engine developed power equivalent to its naturally aspirated gasoline version with same level of NOx emissions without any pre-ignition problems. Further it was found that the mathematical model was valid up to 1.8 bar of inlet pressure only as further increase in inlet pressure using the supercharger resulted in engine knock.[8]

Shuofeng Wang et. al., conducted experimental investigations on combustion of a hydrogen blended gasoline engine at high loads and lean conditions. The results showed that the addition of hydrogen was able to reduce the cyclic variation in indicated mean effective pressure. Moreover the fuel heat release rate and peak cylinder pressure were accelerated after the hydrogen addition. Both HC and CO emissions were reduced significantly after the hydrogen blending. NOx emissions were slightly increased after the hydrogen addition due to the high flame temperature of hydrogen.[9]

Gharehghani et. al., conducted computational investigations on the effect of hydrogen enrichment on the operating range and combustion characteristics by using a validated multi- dimensional CFD model coupled with detailed chemical kinetics mechanism. The results indicated that misfiring occurs in equivalence ratios of about 0.61, 0.48 and 0.42 for hydrogen fractions of 0%, 30% and 50% respectively. It was found that hydrogen fraction decreased the emissions of CO, HC and CO_2. Adding 30% hydrogen reduced CO_2 emission by 10.2% while 50% hydrogen fraction led to 22.7% CO_2 reduction.[10]

Baris Acikgoz et. al., conducted experimental investigations on a conventional twin cylinder four stroke spark ignited with methane-hydrogen blends. The engine was modified to realize hydrogen port injection by installing hydrogen feeding line in the manifolds. The results showed that the brake specific fuel consumption increased with the increase of hydrogen fraction in fuel blends at low speeds. On the other hand, as hydrogen percentage in the mixture increased, BSFC values decreased at high speeds. Further, brake thermal efficiencies were found to decrease with the increase in percentage of hydrogen addition. In addition, it was observed that CO_2, NOx and HC emissions decreased with increasing hydrogen. However, CO emissions tended to increase with the addition of hydrogen.[11]

THEORETICAL BASIS[12]
THE CYLINDER , HIGH PRESSURE CYCLE, BASIC EQUATION.

The calculation of the high pressure cycle of an internal combustion engine is based on the first law of thermodynamics:

$$\frac{d(m_c.u)}{d\alpha} = -\frac{p_c.dV}{d\alpha} + \frac{dQ_F}{d\alpha} - \sum\frac{dQ_w}{d\alpha} - \frac{h_{BB}.dm_{BB}}{d\alpha} \text{ --(Eq.1)}$$

where

$\frac{d(m_c.u)}{d\alpha}$ = change of the internal energy in the cylinder.

$-\frac{p_c.dV}{d\alpha}$ = piston work.

$\frac{dQ_F}{d\alpha}$ = fuel heat input.

$\sum\frac{dQ_w}{d\alpha}$ = wall heat losses

$\frac{h_{BB}.dm_{BB}}{d\alpha}$ = enthalpy flow due to blow-by

$\frac{dm_{BB}}{d\alpha}$ = blow-by mass flow

The first law of thermodynamics for high pressure cycle states that the change of internal energyin the cylinder is equal to the sum of piston work, fuel heat input, wall heat losses and the enthalpy flow due to blow-by.

In order to solve this equation, models for the combustion process and the wall heat transfer, as well as the gas properties as a function of pressure, temperature, and gas composition are required. Together with the gas equation

$$p_c = \frac{1}{V}.m_c.R_o.T_c \text{ -- (Eq.2)}$$

Establishing the relation between pressure, temperature and density, Eq. 2 for in-cylinder temperature can be solved using a Runge-Kutta method. Once the cylinder gas temperature is known, the cylinder gas pressure can be obtained from the gas equation.

COMBUSTION MODEL

Air Requirement And Heating Value modeling is given below.

The following equation for the stoichiometric air requirement specifies how much air is required for a complete combustion of 1 kg fuel:

$$L_{st}=137.85\left(\frac{c}{12.01}+\frac{h}{4.032}+\frac{s}{32.06}-\frac{o}{32.0}\right.\text{[kgAir/kgFuel] ------------------------------ (Eq.3)}$$

LEAN MIXTURE

For lean combustion, the total heat supplied during the cycle can be calculated from the amount of fuel in the cylinder and the lower heating value of the fuel.

RICH MIXTURE

In rich air fuel mixture combustion, the total heat supplied during the cycle is limited by the amount of air in the cylinder. The fuel is totally converted to combustion products even if the amount of air available is less than the amount of stoichiometric air.

HEATING VALUE

The lower heating value is a fuel property and can be calculated from the following formula:

$H_u = 34835 . c + 93870 . h + 6280 . n + 10465 . s - 10800 . o - 2440 . w$ [kj/kg] --------(Eq.4)

HEAT RELEASE APPROACH.

VIBE TWO ZONE

The rate of heat release and mass fraction burned is specified by the Vibe function given by equationNo.5 below.

The first law of thermodynamics is applied separately to the burned and unburned mixturewhile assuming that the temperatures of these two mixtures is different.

$$\frac{dx}{d\alpha} = \frac{a}{\Delta\alpha_c}(m+1) . y^m . e^{-a.y(m+1)} \text{ --------(Eq.5)}$$

$$dx = \frac{dQ}{Q} \text{ --------(Eq.6)}$$

$$y = \alpha - \frac{\alpha_0}{\Delta\alpha_c} \text{ --------=(Eq.7)}$$

The integral of the vibe function gives the fraction of the fuel mass which was burned since the start of combustion:

$$x = \int (\frac{dx}{d\alpha} . d\alpha) = 1 - e^{-a.y(m+1)} \text{ --------(Eq.8)}$$

GAS EXCHANGE PROCESS
BASIC EQUATION

The equation for the simulation of the gas exchange process is also the first law of thermodynamics:

$$\frac{d(m_c.u)}{d\alpha} = -\frac{p_c.dV}{d\alpha} - \sum\frac{dQ_w}{d\alpha} + \sum\frac{dm_i}{d\alpha.h_i} - \sum\frac{dm_e}{d\alpha.h_e} \text{ --------(Eq.9)}$$

The variation of the mass in the cylinder can be calculated from the sum of the in-flowing and out-flowing masses:

$$\frac{dm_c}{d\alpha} = \sum\frac{dm_i}{d\alpha} - \sum\frac{dm_e}{d\alpha} \text{ --(Eq.10)}$$

PISTON MOTION

Piston motion applies to both the high pressure cycle and the gas exchange process. For a standard crank train the piston motion as a function of the crank angle α can be written as:

$$s=(r+l).\cos\psi - r.\sqrt{1-\{\frac{r}{l}.\sin(\psi+\alpha)-\frac{e}{l}\}^2} \text{ --(Eq.11)}$$

$$\psi = \arcsin(\frac{e}{r+l}) \text{ ---(Eq.12)}$$

HEAT TRANSFER

The heat transfer to the walls of the combustion chamber, i.e. the cylinder head, the piston, and the cylinder liner, is calculated from:

$$Q_{wi} = Ai\ .\alpha_w\ .\ (T_c - T_{wi}) \text{ --(Eq.13)}$$

In the case of the liner wall temperature, the axial temperature variation between the piston TDC and BDC position is taken into account:

$$T_L = T_{L,TDC}\ .\ \frac{1-e^{-cx}}{x.c} \text{ ---(Eq.14)}$$

$$c = \ln\{\frac{T_{L,TDC}}{T_{L,BDC}}\} \text{ ---(Eq.15)}$$

For the calculation of the heat transfer coefficient, the Woschni 1978 heat transfer model is used.

WOSCHNI MODEL

The woschni model published in 1978 for the high pressure cycle is summarized as follows:

$$\alpha_w = 130.D^{-0.2}.p_c^{0.8}.T_c^{-0.53}.\left[C_1.c_m + C_2.\frac{V_D.T_{c,1}}{p_{c,1}.V_{c,1}}.(p_c - p_{c,o})\right]^{0.8} \text{ -------------------------(Eq.16)}$$

C1 = 2.28+0.308.cu/cm
C2 = 0.00324 for DI engines
For the gas exchange process, the heat transfer coefficient is given by following equation:

$$\alpha_w = 130.D^{-0.2}.p_c^{0.8}.T_c^{-0.53}.(C_3.c_m)^{0.8} \text{ --(Eq.17)}$$

$C_3 = 6.18+0.417.c_u/c_m$

FUEL INJECTOR

The fuel injector model is based on the calculation algorithm of the flow restriction. This means that the air flow rate in the fuel injector depends on the pressure difference across the injector and is calculated using the specified flow coefficients. For the injector model, a measuring point must be specified at the location of the air flow meter. In this case the mean air flow at the air flow meter location during the last complete cycle is used to determine the amount of fuel. As is the case for continuous fuel injection, the fuelling rate is constant over crank angle.

PIPE FLOW

The one dimensional gas dynamics in a pipe are described by the continuity equation

$$\frac{\partial \rho}{\partial t} = -\frac{\partial(\rho.u)}{\partial x} - \rho.u.\frac{1}{A}.\frac{dA}{dx}, \text{------------------------------}(Eq.18)$$

the equation for the conservation of momentum

$$\frac{\partial(\rho.u)}{\partial t} = -\frac{\partial(\rho.u^2 + p)}{\partial x} - \rho.u^2.\frac{1}{A}.\frac{\partial A}{\partial x} - \frac{F_R}{V}, \text{------------------------------}(Eq.19)$$

and by the energy equation

$$\frac{\partial E}{\partial t} = -\frac{\partial[u.(E + p)]}{\partial x} - u.(E + p).\frac{1}{A}.\frac{dA}{dx} + \frac{q_w}{V}. \text{------------------------------}(Eq.20)$$

The wall friction force can be determined from the wall friction factor λ_f :

$$\frac{FR}{V} = \frac{\lambda f}{2.D}.\rho.u.|u| \text{ ------------------------------}(Eq.21)$$

Using the Reynold's analogy, the wall heat flow in the pipe can be calculated from the friction force and the difference between wall temperature and gas temperature:

$$\frac{q_w}{V} = \frac{\lambda_f}{2.D}.\rho.|u|.c_p.(Tw - T) \text{ ------------------------------}(Eq.22)$$

During the course of numerical integration of the conservation laws defined in the Eq.20, Eq.21 and Eq.22, special attention should be focused on the control of the time step. In order to achieve a stable solution, the CFL criterion (stability criterion defined by Courant, Friedrichs and Lewy) must be met:

$$\Delta t \leq \frac{\Delta x}{u + a} \text{------------------------------}(Eq.23)$$

This means that a certain relation between the time step and the lengths of the cells must be met. The time step to cell size relation is determined at the beginning of the calculation on the basis of the specified initial conditions in the pipes. However, the CFL criterion is checked every time step during the calculation. If the criterion is not met because of significantly changed flow conditions in the pipes, the time step is reduced automatically.

An ENO scheme is used for the solution of the set of non-linear differential equations discussed above. The ENO scheme is based on a finite volume approach. This means that the solution at the end of the time step is obtained from the value at the beginning of the time step and from the fluxes over the cell borders

RESULTS AND DISCUSSIONS

EFFECT OF START OF COMBUSTION TIMING ON POWER DEVELOPED BY THE ENGINE

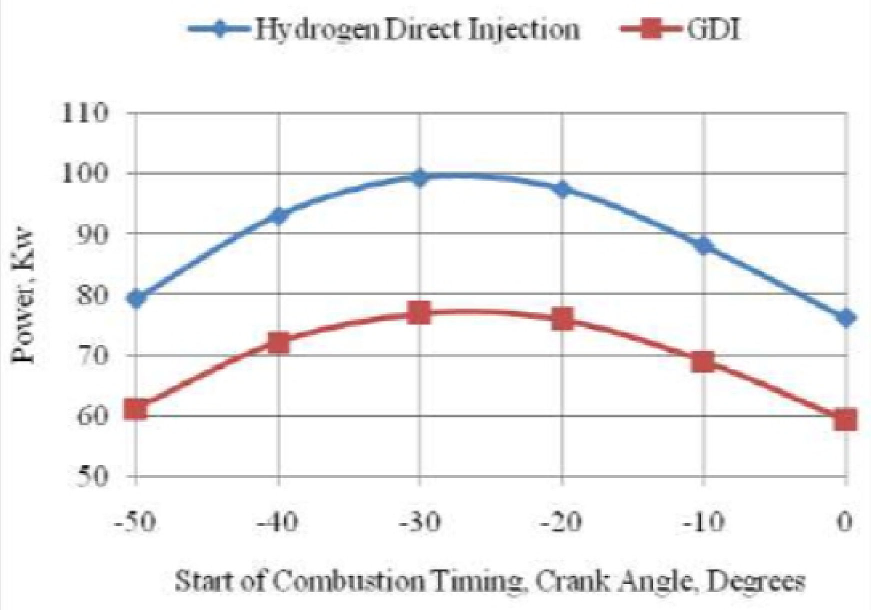

Fig 1 Effect of Start of Combustion Timing on Power Developed by The Engine in Hydrogen Direct Injection and GDI Modes

The Fig.1 below shows the effect of start of combustion timing on the power developed by the engine in hydrogen direction injection and GDI modes. It is clear from the graph that the hydrogen engine produces higher power output than the gasoline engine under constant speed and corresponding rich mixture operation in both the cases. The hydrogen engine produces more power than its gasoline version since the combined effect of the heating values and the operating values of the air-fuel ratios in each case are in favour of the hydrogen fuel. Further the power developed by the engine with each fuel varies with respect to the start of combustion timing. Under constant speed operation, the maximum power is developed by the engine with start of combustion timing at -30 degrees of crank angle corresponding to the maximum brake torque timing concept of internal combustion engines.

EFFECT OF START OF COMBUSTION TIMING ON TORQUE DEVELOPED BY THE ENGINE

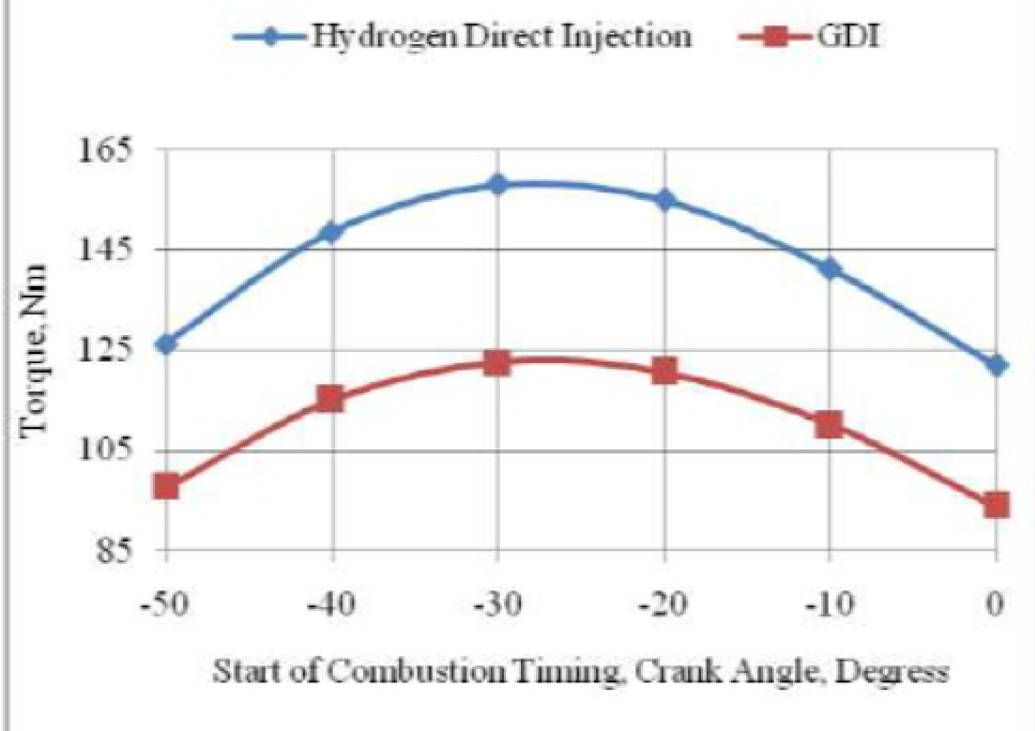

Fig 2 Effect of Start of Combustion Timing on The Torque Deveoped by The Engine in Hydrogen Direct Injection anf GDI Modes

The Fig.2 below shows the effect of start of combustion timing on the torque developed by the engine in hydrogen direct injection and GDI modes. It is seen from the graph that the torque developed by the engine varies as the start of combustion timing is advanced or retarded with respect to the optimum or maximum brake torque timing. The torque developed by the engine with either of the two fuels is maximum with the start of combustion timing at -30 degrees of crank angle. This is because the piston motion inside the engine cylinder towards top centre faces minimum resistance with this timing for the start of combustion. Also further delay in the start of combustion timing drops the peak value of pressure developed inside the engine cylinder due to piston movement under the constant duration of combustion period. Further it is seen that the engine develops more torque than in the hydrogen mode as compared to gasoline mode. This is because the combined effect of the heating values of the two fuels under consideration and the corresponding operating value of air-fuel ratios in each case is in favour of the hydrogen engine than the gasoline engine.

EFFECT OF START OF COMBUSTION TIMING ON BRAKE SPECIFIC FUEL CONSUMPTION OF THE ENGINE

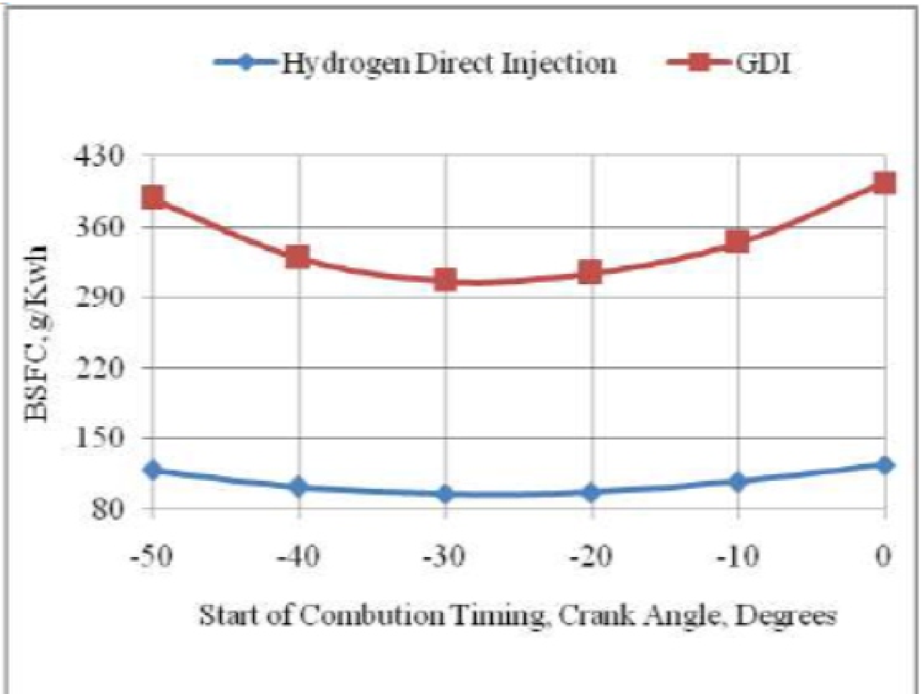

Fig.3 Effect of Start of Combustion Timing on The Brake Specific Fuel Consumption of The Engine in Hydrogen Direct Injection and GDI Modes

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The Fig.3 below shows the effect of start of combustion timing on the fuel consumption per unit of energy output of the engine in the hydrogen direct injection and GDI modes. It is clear from the figure that the hydrogen engine consumes less fuel per unit of energy output as compared to the gasoline engine under constant speed and corresponding rich air-fuel ratio operation. This is because the combined effect of the heating values and the stoichiometric air-fuel ratio values of each of the two fuels are in favour of the hydrogen operated engine.

Further it is clear that the hydrogen engine consumes less fuel per unit of energy output as compare to the gasoline engine since the hydrogen engine develops more power as compared to the gasoline engine under similar conditions.

EFFECT OF START OF COMBUSTION TIMING ON THE CO EMISSIONS PRODUCED BY THE ENGINE

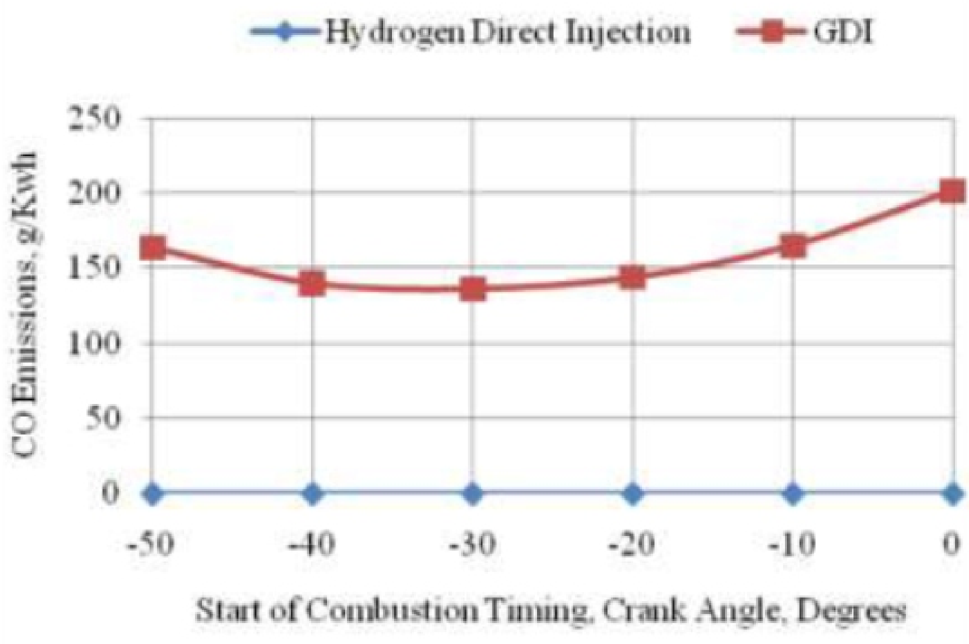

Fig.4 Effect of Start of Combustion Timing on The CO Emissions Produced by The Engine in The Hydrogen Direct Injection and GDI Modes

The Fig.4 below shows the effect of start of combustion timing on the CO emissions produced by the engine in hydrogen direct injection and GDI modes. It is seen from the graph that the engine does not produce any CO emissions with hydrogen fuel. This is because there is no carbon atom in the molecular structure of hydrogen. The engine produces CO emissions with gasoline as its fuel which vary as the start of combustion timing varies. The gasoline operated engine produces minimum CO emissions with -30 degrees of crank angle as the start of combustion timing. This is because this is the optimum combustion timing of the engine for best possible combustion characteristics under the chosen design and operating conditions.

EFFECT OF START OF COMBUSTION TIMING ON THE SOOT EMISSIONS PRODUCED BY THE ENGINE

The Fig.5 below shows the effect of start of combustion timing on the soot emissions produced by the engine in the hydrogen direct injection and GDI modes. It is seen from the graph that the soot emissions produced by the engine with either of the two fuels under consideration vary with the start of combustion timing.

The hydrogen engine produces lesser soot emissions as compared to the gasoline engine. This is because the soot emissions produced with hydrogen operated engine are from the combustion of the lubricating oil under circulation only and not from the carbon free hydrogen fuel. The soot emissions, per unit of energy output of the engine, produced by the gasoline engine under constant speed and rich mixture conditions are maximum with the start of combustion timing at -30 degree of crank angle. This is because more soot emissions are contributed by the lubricating oil in the otherwise best possible combustion timing. This is because higher pressures developed in the engine cylinder at the MBT timing force more soot emissions out of the engine displacement and crevice volumes. More quantity of lubricating oil is forced out with the carbon particles both from the gasoline and lubricating oil under adsorbed conditions in the form of soot. Further in general the soot emissions increase when the start of combustion timing is retarded. This is because the time available for possible conversion of carbon based soot particles into corresponding oxides is reduced with retarded start of combustion under constant duration of combustion and fixed exhaust valve timing.

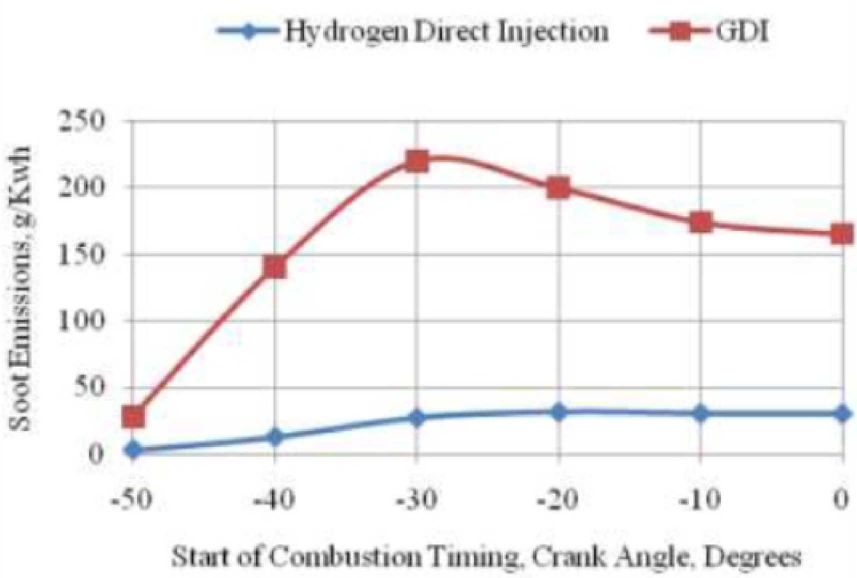

Fig.5 Effect of Start of Combustion Timing on The Soot Emissions Produced by The Engine in The Hydrogen Direct Injection anf GDI Modes

EFFECT OF START OF COMBUSTION TIMING ON THE NOx EMISSIONS PRODUCED BY THE ENGINE

The Fig.6 below shows the effect of start of combustion timing on the NOx emissions produced by the engine with hydrogen and gasoline fuels with direct injection of each fuel. It is clear from the graph that the NOx emissions with either of the two fuels are reduced when the start of combustion timing is retarded with respect to top centre. This is because the time needed for possible conversion of nitrogen and oxygen of the air into NOx emissions is reduced with the retarded start of combustion timings. Since the stoichiometric air-fuel ratio of hydrogen is higher than that of gasoline more quantity of free air could be available with gasoline fuel as compared to hydrogen fuel. This helps in the formation of higher NOx emissions with gasoline engine as compared to the hydrogen engine up to -20 degree of crank angle based start of combustion timings. Beyond this the higher temperatures produced with the hydrogen fuel help in the formation of higher NOx emissions with hydrogen as compared to gasoline fuel.

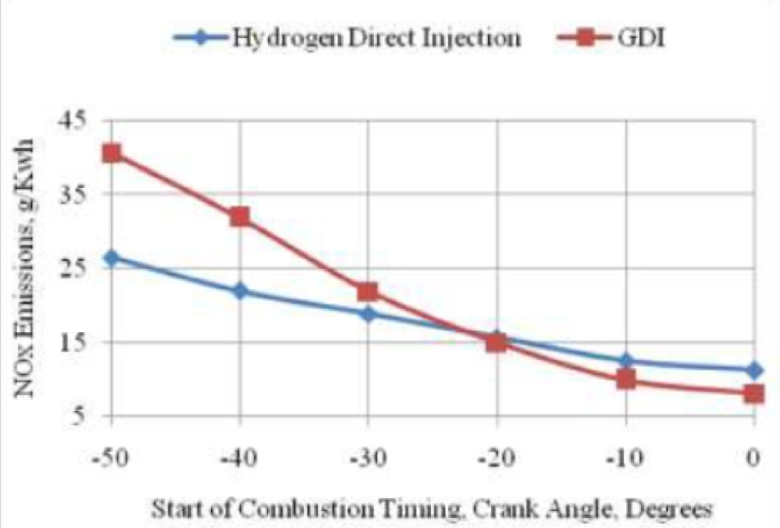

Fig.6 Effect of Start of Combustion Timing on The NOx Emissions Produced by The Engine In Hydrogen Direct Injection and GDI Modes

EFFECT OF START OF COMBUSTION TIMING ON THE EXHAUST GAS TEMPERATURE OF THE ENGINE

The Fig.7 below shows the effect of start of combustion timing on the temperature of the exhaust gas emitted from the engine with hydrogen direct injection and GDI modes. It is seen from the graph that the temperature of the exhaust gas is higher with hydrogen fuel as compared to the gasoline fuel due to higher quantity of heat released with hydrogen fuel as compared to gasoline fuel. Further it is seen that the temperature of the exhaust gas, with either of the two fuels, increases as the start of combustion timing is retarded with respect to the top centre of the engine cylinder. This is because of reduced heat transfer across the system boundary with retarded start of combustion timings.

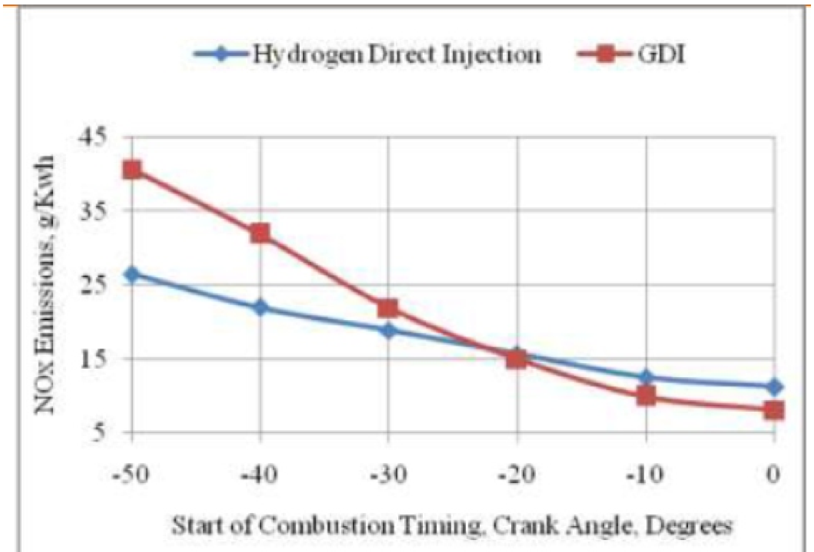

Fig.6 Effect of Start of Combustion Timing on The NOx Emissions Produced by The Engine In Hydrogen Direct Injection and GDI Modes

EFFECT OF START OF COMBUSTION TIMING ON THE EXHAUST GAS TEMPERATURE OF THE ENGINE

Fig.7 Effect of Start of Combustion Timing on The Exhaust Gas Temperature of The Engine in The Hydrogen Direct Injection and GDI Modes

The Fig.7 below shows the effect of start of combustion timing on the temperature of the exhaust gas emitted from the engine with hydrogen direct injection and GDI modes. It is seen from the graph that the temperature of the exhaust gas is higher with hydrogen fuel as compared to the gasoline fuel due to higher quantity of heat released with hydrogen fuel as compared to gasoline fuel. Further it is seen that the temperature of the exhaust gas, with either of the two fuels, increases as the start of combustion timing is retarded with respect to the top centre of the engine cylinder. This is because of reduced heat transfer across the system boundary with retarded start of combustion timings.

CONCLUSIONS

1. Hydrogen can successfully be used as an alternative fuel to the conventional gasoline in the direct injection version of the spark ignition engines.
2. The performance of the spark ignition engine designed with the direct injection type of fuel supply system is thermodynamically better with hydrogen fuel as compared to gasoline fuel.
3. The hydrogen operated spark ignition engine fitted with direct fuel injection system does not produce any CO emissions.
4. The soot emissions produced by the hydrogen fuel in the direct injection type of spark ignition engine are much lower than that produced by gasoline fuel with the same engine.
5. The hydrogen operated direct fuel injection engine produces lesser NOx emissions than its GDI version if the spark ignition system of the engine is designed corresponding to the start of combustion timing at -30 degrees of crank angle with respect to top centre of the engine cylinder.

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APPENDIX-A

NOMENCLATURE

a = speed of sound, m/sec

A = pipe cross-section, m^2

A_{eff} = effective flow area, m^2

A_i = surface area (cylinder head, piston, liner), m^2

AF_{CP} = air fuel ratio of combustion products

A_{geo} = geometrical flow area, m^2

c = mass fraction of carbon in the fuel

c_V = specific heat at constant volume, J/Kg.K

c_p = specific heat at constant pressure, J/Kg.K

Cm = mean piston speed, m/sec

Cu = circumferential velocity, m/sec

c_u = circumferential velocity, m/sec

D = cylinder bore, m

dm_i = mass element flowing into the cylinder, kg

dm_e = mass element flowing out of the cylinder, kg

d_{vi} = inner valve seat diameter (reference diameter), m

$\frac{dm_{BB}}{d\alpha}$ = blow-by mass flow, kg/degree of crank angle

e = piston pin offset, m

E = energy content of the gas (=$\rho . \bar{cv} . T + \frac{1}{2} . \rho . u^2$) J

f = fraction of evaporation heat from the cylinder charge

F_R = wall friction force, N

h = mass fraction of hydrogen in the fuel

h_{BB} = enthalpy of blow-by, J/Kg

h_i = enthalpy of in-flowing mass, J/Kg

h_e = enthalpy of the mass leaving the cylinder

H_u = lower heating value, J/Kg

k = ratio of specific heats

l = con-rod length, m

m = shape factor.

m = mass flow rate, kg/sec

m_c = mass in the cylinder, kg

m_{ev} = evaporating fuel, kg

m_{pl} = mass in the plenum, kg

n = mass fraction of nitrogen in the fuel

o = mass fraction of oxygen in the fuel

p = static pressure, bar

P_{01} = upstream stagnation pressure, bar

Pc,o = cylinder pressure of the motored engine ,bar

Pc,1 = pressure in the cylinder at IVC, bar

p_{pl} = pressure in the plenum, bar

p_c = cylinder pressure, bar

p_2 = downstream static pressure, bar

q_{ev} = evaporation heat of the fuel, J/kg

q_w = wall heat flow, J

Q = total fuel heat input, J

Q_F = fuel energy, J

Q_{wi} = wall heat flow (cylinder head, piston, liner), J

r = crank radius, m

R_0 = gas constant, J/mol.K

s = piston distance from TDC, m

t = time , sec

T = temperature, K

Tc,1= temperature in the cylinder at intake valve closing

(IVC), K

T_c = gas temperature in the cylinder, K

T_{wi} = wall temperature (cylinder head, piston, liner), K

T_L = liner temperature, K

$T_{L,TDC}$ = liner temperature at TDC position, K

$T_{L,BDC}$ = liner temperature at BDC position, K

T_w = pipe wall temperature, K

T_{01}= upstream stagnation temperature, K

u = specific internal energy, J/Kg

u = flow velocity, m/sec

V = cylinder volume, m^3

V = cell volume (A.dx), m^3

VD = displacement per cylinder, m^3

w = mass fraction of water in the fuel

x = relative stroke (actual piston position related to full stroke)

α = crank angle, degrees

α_o= start of combustion, crank angle degrees

$\Delta\alpha_c$= combustion duration, crank angle degrees

α_w = heat transfer coefficient, $J/m^2.K$

ρ = density, kg/m^3

$\mu\sigma$ = flow coefficient of the port

ψ = crank angle between vertical crank position and

piston TDC position, degrees

λ f = wall friction coefficient

Δt = time step, sec

Table-1

Engine Specifications	
Engine Type	Four Stroke
Method Of Ignition	Spark Ignition
Displacement, cc	1570
Compression Ratio, under direct injection mode	11.9
Number Of Cylinders	4
Rated Speed, rpm	6000

Table-2

Physical And Chemical Properties Of Petrol And Hydrogen[1]

Fuel Property	Petrol	Hydrogen
Formula	C_4 TO C_{12}	H_2
Density, Kg/M^3	750	0.09
Lower heating value, MJ/Kg	44	120
Stoichiometric Air-Fuel ratio, Weight	14.6	34.3
Octane No. MON RON	 84 92	 ≥120

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More Digital Portals Overview In Indian Universities A Glance Study"

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ABSTRACT

In India there are a number of college degree libraries which might be in the method of conversion to Digital libraries. There is a mission to create a portal for the digital library of India. A virtual library portal that gives an integrated web-based user interface to a wide range of on-line oceanographic weather facts units. The portal presents a single point of entry set to the units, and displays them in a not unusual and clean to navigate format. Moreover, it presents a way of searching the meta-information and other characteristics of statistics sets; to simplify the control of records sets, and to offer authentication and access manage mechanism for sensitive records.[5] In essence, we are focusing on designing methodologies for internet pages; home pages for books/research papers/theses/a ramification of virtual resources to facilitate a neighborhood cold fusion for scripting for get admission to mechanism and digital assert management primarily based on semantic webs. The cause of the virtual Libraries motto must were a a success however the studies has proven that digital libraries are underutilized, due to their infancy consumer interfaces and records overload. [6] In addition to that, the fee impact has come to be an obstacle to the development of the Digital Libraries

Keywords: Digital libraries, Web portals, Meta-data, Web 2.0.Digital library portal

INTRODUCTION

Digital Library: A digital library is for that reason a massive-scaleprepared collection of complex and dynamic multimedia data and understanding, and tools and methods to enable seek and control and to present the specified facts and understanding through Internet. Even even though we had been provided the technical environment for having access to the data effortlessly, digital Libraries are posing challenges to present day technology due to the following the motives. Usability is one of the maximum distinguished and challenging troubles in the design and improvement of the digital libraries. Since the digital libraries handy through the Internet and their Customers are from various mental, academic and social backgrounds, the utility and usage of the digital libraries varies from user to user. The digital library usability relies upon some of components and specially on its user interface. The modern-day technology pose terrific demanding situations in designing of the User Interface and make researchers to dedicate their studies to answer the problems raised by way of it just because the unpredictability of the users" behaviour and necessities, sizable and assorted facts and adjustments inside the interplay sample. [2] We were attracted and stimulated by those challenges and posed in the erratic nature and necessities of the person. We have dedicated our research work to discover, examine and look at the user interface troubles of virtual libraries for its effective implementation. It is right if the digital library consumer interface addresses all of the requirements of the consumer interactions without affecting the overall performance of the device. The consumer requirements play a vital function in designing the user interface. Several researchers have studied the user requirements with admire to psychology, records presentation, seek, herbal language queries, visualization and many extra there's an increase in dynamism: putting forward, creating, editing and disposing entire virtual libraries "on demand". The scope to examine potential user interactions of the digital library consumer interfaces in the context of Web 2.0.[10] This distinct project has given the scope to pay attention on reading the interfaces designing and devising standards for powerful design of the user interfaces for virtual libraries.[3] For this research we have started out our research by developing a prototype virtual library person interface machine which facilitates rich person interactions within the context of Web 2.0 and Semantic Web technologies, and to extend the equal for cell access conforming to the 2G and 3G standards.

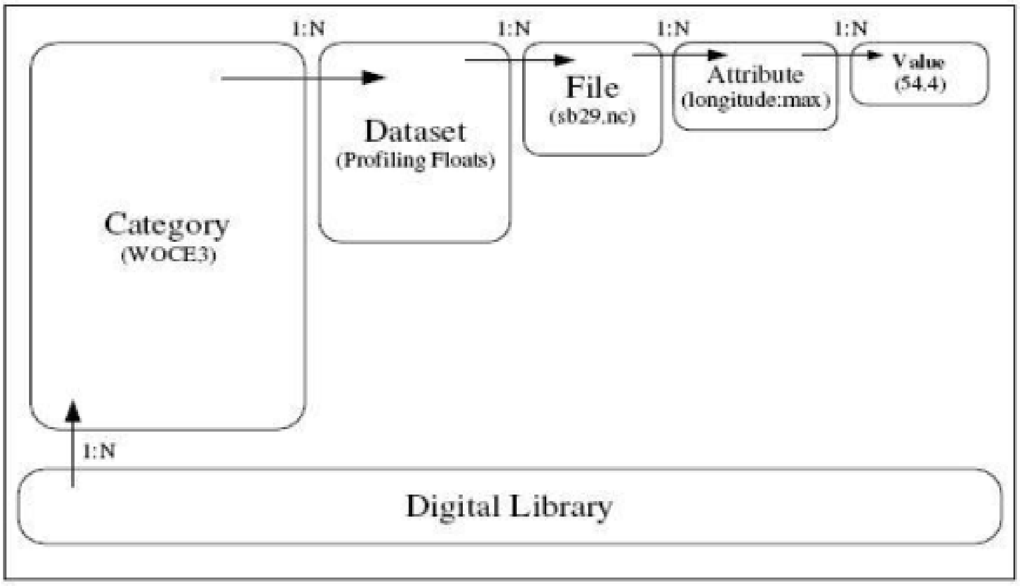

Fig 1: Overview of the digital library.

Digital libraries are considered through many to be a very tough studies location, as it requires development and integration of numerous noticeably sophisticated hardware and software technology, and polling collectively of multidisciplinary expertise. Many of the technologies required for the improvement and deployment overall performance desires to be sealed up to deal with very huge virtual collections in networked environment.[6] Some of the Major regions of recognition are:

- Multimedia item storage, retrieval and transmission.
- Data compression
- Digitization (multimedia data taking pictures and conversion)
- Hyper media navigation.
- Authoring equipment for growing digital documents.
- Multimedia object representation (Eg.HTML, SGML)
- Meta Data
- Display technologies
- User interfaces
- Search, retrieval and routing smooth ware.
- Natural Language Queries.
- Web Portals

In India there are a number of university level libraries which might be in the procedure of conversion to Digital libraries. There is a mission to create a portal for the digital library of India via the ministry of conversation and information generation (Govt of India) with IISc and Carnegie- Mellon University USA as partners.[4] The national challenge forces on IT and software improvement has given some treasured guidelines for development of digital libraries in the u . S . A .. The digital library portals of several higher level libraries in India. We are brought about believe that semantic internet based totally portals could be better desirable for in a massive u . S . A . Like India. Several specialized libraries for artwork and culture; language centric resources; numerous branches of technology, era, agriculture and plant illnesses and so forth; pharmaceutical, medical; sociological and many other regions are wished in India. No single portal might be able to provide get right of entry to the full virtual repositories in view of the prices and storage necessities.

II. DIGITAL LIBRARY PORTAL

A digital library portal that provides an integrated net-primarily based consumer interface to a huge variety of online oceanographic weather information sets.[5] The portal gives a unmarried point of entry set to the units, and presentations them in a not unusual and smooth to navigate layout. Moreover, it offers a means of looking the meta-information and other traits of records units; to simplify the control of records units, and to provide authentication and get admission to manage mechanism for sensitive facts.

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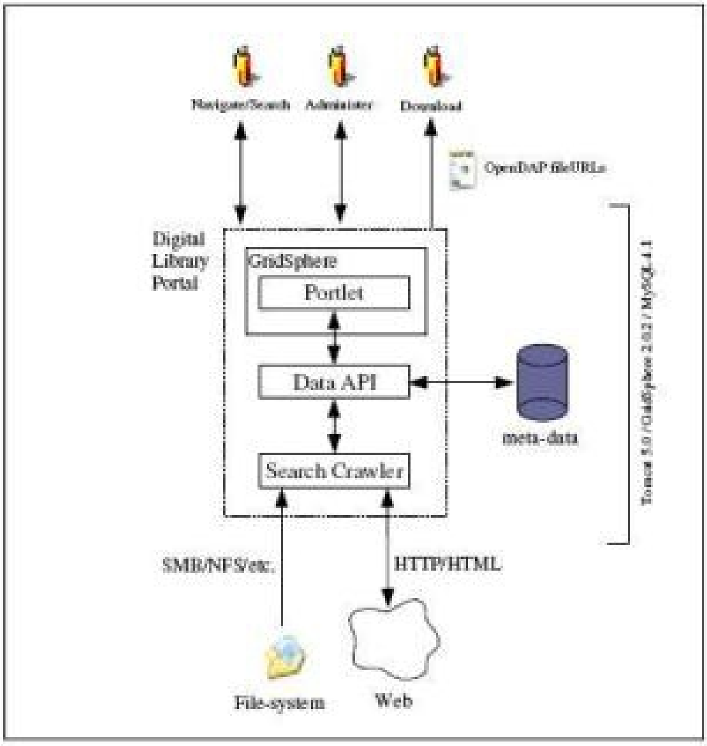

Fig 2: Digital Library portal frame work

In essence, we are targeting designing methodologies for web pages; domestic pages for books/research papers/theses/a diffusion of virtual assets to facilitate a local bloodless fusion for scripting for get admission to mechanism and digital assert management based on semantic webs. The motive of the virtual Libraries motto ought to were a a hit however the research has proven that digital libraries are underutilized, because of their infancy consumer interfaces and statistics overload.[6] In addition to that, the fee impact has emerge as an obstacle to the improvement of the Digital Libraries.

Universities' Students search for portals that convey collectively special assets of records related to their affairs and subjects and be easy to get admission to (Singh and Mahajan, 2010). Many useful training had been won from the research that was carried out on Tébessa portal. (Laouar, Hacken and Miles, 2009) summarized the most three crucial features they are searching for which might be; content control, federated searching and authentication. They have discovered that there are different thrilling feathers to benefit within the destiny, one in every of those features is the adaption to all students profiles and easing the get admission to for all legal customers to combine into scalable machine. They supposed to have this feature because the Tébessa portal had no specific online garage related to their private records and integration. A wide take a look at turned into executed in Emirate University to take a look at the alternatives that scholars searching for regarding the route management. The examine indicated that scholars want to easily get right of entry to the internet via keying inside the person call and password as soon as, add and drop publications, acquire notification related to publications from instructors and directors, smooth to shop information and updates, importing fabric related to courses and finally being able to adjust facts to your profile (Zaneldin, 2011). Nevertheless, (Neubauer and Piguet, 2009) in their take a look at concluded that there may be no clean and unique requirements for required student portal functions. They believe that customers themselves are the best those who ought to decide on the functions and portal design required. Users' evaluations and needs should be taken from the users immediately through different instruments along with interviews or questionnaires.(Masrek, Jamaludin and Mukhtar, 2010) defined of their study that a pupil satisfaction refers to the level of the satisfaction or displeasure that a scholar feels whilst his/her wishes being met or no longer. The extra fulfilled students' desires are the higher stage of delight students have. The take a look at showed that UiTM college students were given more satisfied with the library portal as it helped them to extra improve and increase their observe productiveness and overall performance. Students in well-known do not problem approximately contraptions getting used to obtain their necessities as a great deal as they challenge approximately getting things accomplished. The strong EST detail of getting students happy in School of Nursing and Midwifery is the good belief that scholars had towards the academic team of workers who is inquisitive about supporting their students in the course of their mastering development. Achieving student wishes growth their pride level in addition to their productiveness (Smith and Rogers, 2011). Universities students' desires may be defined in many exceptional factors. They might be related to the human aspect or even to technological one. A take a look at turned into conducted in Bangladesh to evaluate students' pleasure in public universities in regards of using the digital data sources. The finding administrated that all college students aren't happy in any respect about their supporting academic system. They diagnosed numerous important troubles which embodies inside the very constrained range of computer systems and having very bad IT infrastructure. Lacking to offer the specified basic digital wishes had caused have students a good deal less capable to access the library and pupil portal. The results of the above mentioned elements have made student unwilling and unhappy to use the records assets (Ahmed, 2013). However, the outcomes of another take a look at which aimed essentially to assess the level of postgraduate college students had been totally distinctive compared with two examples cited of Bangladeshi universities. (Ahmed and Amjad, 2014) performed their have a look at in two Pakistani universities. The outcomes virtually showed that extra than 80% have been very glad with the facts assets systems. The have a look at emphasizes that the extra the students satisfied is the greater a college productive. Quality of scholar portal services provided for IIUM as properly as GSM college students have a widespread effect on how students perceive their educational group at massive. Technical factors which include; form of carrier supplied in addition to managerial factors including; reacting to feedback acquired from college students are vital in shaping college students' typical perceptions on their respective group. This is so because pupil portals are critical for all college students to be used one time or another and the reports they go through while the usage of them generally lasts for long. It is important for IIUM as well as GSM to better their understanding of the offerings wished with the aid of their students, creating an encouraging machine for feedback to accept by means of college students and ultimately making use of received remarks the most effective and green manner feasible.

The critical aspects of the examine on this phase consists of the following
1. Estimating the users‟ psychology, conduct and necessities.
2. Understanding various demanding situations in designing of Web portals for digital libraries.
3. Identifying the concepts for designing the Web portals of digital libraries.
4. Developing Digital Library User Interface Framework. We adopted the subsequent Design methodology to enforce present studies observe.
1. To apprehend the various digital libraries and associated statistics to explore the Web portal Challenges and Data Centers in Digital Libraries.
2. To look at the various useful contemporary technologies like Web 2.Zero, Semantic Web etc., to implement in designing of Web Portals and Data Centers of digital library for green utilization.
3. Devising the Principles to design effective person interfaces for digital libraries based on stated above two studies activities
4. Developing Digital Library Data Centers and Web Portals based totally on stated above research activities.
5. Scalability to mobile get entry to The World Wide Web has come to be the dominant software at the Internet due to flexibility and rising upgrades. „Portal‟ imply a few sort of searchable network information retrieval provider, powered by way of an effective search engine that offers get admission to content material. Whereas „gateways‟ or „hubs‟ absolutely present descriptions of data sources and content, portals give the consumer both descriptions and a method of pulling the defined objects thru to the consumer.[7] A portal can have 3 possible objectives: to provide information, training, or amusement, despite the fact that someone portal can pursue multiple. The usability of any web portal relies upon the high-quality of records provided with the aid of it, locating the precise records from it by using the way of looking with its powerful search facilities. Popular internet portals such as Yahoo and

Netscape classify and gift vital statistics consisting of news, weather and entertainment in only one internet page so the consumer does no longer should spend too much time in locating valuable records. Digital library net portal helps the interfaces which can be gambling a prominent role in helping customers to acquire a smooth and powerful get right of entry to to the facts which they want. Digital libraries net portals are more than virtual repositories and search engines which desires powerful customized person interfaces with a purpose to assist the users in acquiring the up to date, newly arrived, hot documents in addition to commonplace documents which can be relevant to their queries

III. CONCLUSION

A comprehensive version portal for records centric multi consumer customizable virtual library has been proposed and its distinctness and higher adoptability for organising user interfaces for digital libraries with special connection with Indian universities has been advanced on this paper. The scalability its person to cell get admission to have additionally been mentioned. The proposed model is possible and implementable with the functionality to adopt for an expansion of users as per their picks.

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