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Evaluation of Parameters Affecting the Performance of the Spark Ignition Engine

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Abstract Natural gasoline has been taken **into** consideration because the most promising opportunity fuel for its cleanliness and abundance. Due to this utilization of natural gas engines has grown to be vogue in some of countries, significantly extra in growing ones. However, to fulfill stringent emission regulations changes need to be delivered approximately in natural gasoline engine generation as forecasted reserves of herbal gasoline imply that it is going to be a prominent fuel in after time. Due to numerous effective properties that natural gas possesses viz. high-octane number, high C/H ratio, wide flammability limits, and so forth. It's miles greater fruitful to result in adjustments in existing engine technology to make NG a possible fuel compared to gasoline or diesel. NG engines can be operated in lean regime or stoichiometric conditions coupled with either high compression ratio or exhaust gas recirculation depending on the form of optimization i.e., Fuel economic or emission. This paper highlights effect of changes in injection and spark timings on overall performance, combustion and emission characteristics of an SI engine the usage of CNG or HCNG as fuel and necessity of an engine management system which needs to be hooked up to employ an ECU to carry out the adjustments in injection and spark timing. Advancement of injection and spark has its own advantages. Too much advancement of any of the two is not preferred either. It was observed that with advancement in injection timing and spark timing, brake mean effective pressure and brake thermal efficiency higher whereas combustion periods lower. In emissions' context, HC concentration lower and NOx and CO2 higher.

Keywords: Spark Ignition Engine, Performance, Parameters, RSM, Emission Model.

1. Introduction Nowadays air pollution has turned into a master challenge for most of the countries in world. Thus, majority of sophisticated countries have already applied stringent emission norms to dominate air high-quality degree within the prescribed limits. However, in developing countries in which economic infrastructure is not so inflexible and catering to the energy desire of mass is a stiff challenge, trouble of air pollutants persists because most of energy demands are met using traditional fuels like fuel and diesel. Though day-with the aid of-day new technologies like the usage of EGR, catalytic converters, diesel particulate filters and many more are being applied along with those primary fuels yet their chemical composition and inadequate availability does no longer assignment them as a long-time resource. On the contrary, CNG which has a number of favorable characteristics like high research octane range (which makes it to run on high CR engines also), high H/C ratio (which makes it a leaner fuel), wide flammability limits, lower unburned hydrocarbons (UBHCs), lower NOx levels (at lean equivalence ratio), lower PM levels, etc. Is found in sufficient quantity in form of NG reserves in the world that it could suffice energy needs up to 60.2 years from now [1][2]. Generally, CNG engines run stoichiometric or in lean regime. However, they may be run the usage of EGR or in lean regime or with excessive compression ratios to compete gasoline engines in terms of torque, energy, efficiency and emissions [3][4].

To get better performance and decrease emissions, engine control unit (ECU) is the solution because it not only keeps the engine running but also provides the optimized gas quantity leading to lowered brake specific gasoline intake and for this reason stepped forward efficiency. An ECU itself detects the feedbacks sign from various sensors hooked up inside the engine for providing input to ECU about engine parameters such as speed, engine coolant temperature, and so forth. So, if engine runs on low load, it cuts off gas intake thereby decreasing unburned hydrocarbons and lowering fuel intake. An ECU accurately defines spark timing depending on rate of combustion needed by the situation. Thus, an ECU not only support in bringing down emissions most effective but also it simultaneously enhances performance of an engine.

Since there are numerous differences in physical and

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chemical characteristics of CNG and fuel for this reason to make CNG usable with SI or CI engines, a few engine modifications must be added to make it usable as fuel in those engines. Engine modifications do not always intend to reinvent the whole engine for CNG applications, rather more focus should be on should be on accomplishing efficient combustion of CNG economically in existing fleet of engines by doing minimal changes in either various combustion chamber design parameters or operational parameters or by way of introducing blends of CNG. Other parameters which may be taken into consideration are spark-plug-gas-injector (SPFI) technology and orientation of injector with corresponding to combustion chamber design [5]. There are several factors to be considered, namely, flame speed, activation power, auto-ignition temperature, and many others. Which perform an important function in combustion process. Moreover, on engine's side injection timing, spark timing, period of injection, etc. are the parameters which require to be changed to first run the engine for maximum overall performance and then to develop gasoline economy and decrease emissions. An ECU may be used to vary injection timings (preferably advancement) to enhance mixing of charge, ignitability of mixture, rate of combustion and finally engine's overall performance to counter balance the slow flame velocity of CNG which leads to excessive HC concentration. Duration of injection as well can be controlled efficaciously to convey down gas consumption and unburned hydrocarbons. Similarly, spark timing is likewise a prime determinant in combustion process. The primary inputs to the ECU are the outputs from the manifold pressure sensor, the engine speed sensor and the temperature sensors hooked up inside the intake manifold to monitor air temperature and engine block to record the water-jacket temperature-the latter being used to signify gas enrichment needs throughout cold-begin and warm-up [6]. With the assist of an ECU spark timing may be precisely defined for an engine's precise running status because spark timing determines the effectiveness of combustion process and duration of combustion.

The goal of this has a look at is to analyze the behavior of overall performance and emission characteristics below diverse gasoline injection timings and ignition timings in a natural gas SI engine.

Only concern is regarding the storage aspect of CNG due to very excessive vapor press. In phrases of safety considerations, decrease density and high diffusion rate is advantageous in case of leakage.

2. Engine Management System

The feature of an engine management system (EMS) is to manipulate all the engine parameters with the assist of its components to keep the engine strolling with most effective fuel intake, stepped forward overall performance and decreased emissions. An engine management machine (EMS) is composed of various additives like engine control unit, cam sensor, injector, ignition coil, and many others. To manipulate and measure parameters including engine velocity, engine coolant temperature, spark and injection timings. The ancillaries of EMS normally used are:

a) Engine Control Unit (ECU) - determines the amount of gasoline, ignition timing and different parameters an internal combustion engine wishes to preserve strolling.

b) Cam Sensor – is set up on cam wheel to inform approximately cam velocity to ECU.

c) Crank Sensor – conveys crank RPM to ECU.

d) Engine Coolant temperature Sensor – informs approximately the temperature of the coolant indicating the depth of combustion taking place.

e) Injector – injects the gasoline depending on feedback obtained by means of ECU.

f) Ignition Coil – offers spark to the spark plug relying on feedback acquired through ECU.

g) Current Transducer.

h) Graphic Interface/Software – renders provision to manually vary injection and spark timings depending on requirement.

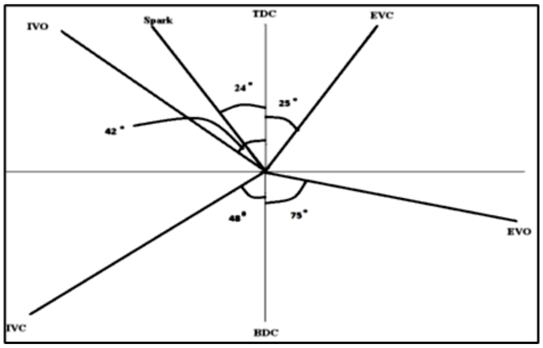

Fig. 1. A typical valve timing diagram

Since this paper discusses the relevance of variation in injection timing and spark timings in an SI engine to enhance gas economic system and reduce emissions consequently an engine control system becomes a vital tool to reap the desired variations in engine parameters. These variations may be completed best whilst precise valve timing diagram of an engine is known. It enables in figuring out the variety of values in crank angle earlier than TDC so that severe limits are recognized. Also, it offers the original spark timing and injection timing values as provided through the OEM. In order to gain the discount of engine exhaust emissions and to growth the performance, the fuel injection plays a vital rule.

The valve timing diagram informs concerning the duration for which inlet valve stays open to allow access of fuel (in case of port gasoline injection system) which can be used to adjust the length relying on strolling circumstance of engine. However, in case of direct injection, valve timing diagram helps in maintaining a take a look at on inlet valve remaining to thus range the volumetric performance, which might lower if too early injection is completed due to the fact CNG at excessive pressure will have a tendency to prevent an equal quantity of air getting into the engine cylinder. Since valve timing diagram of an SI engine determines the opening and final of ports/valves, injection timing and spark timing, consequently to vary injection or spark timing thorough understanding of valve timing diagram is to be completed. Depending on technique of gasoline injection, i.e., Port gas injection or direct injection, the variety of version of injection and spark timing can be decided. However, ideally DI engines are used to carry out the version in injection timing due to the fact they permit wide range of intense limits.

An EMS accomplishes optimized going for walks of engine by using receiving comments alerts from its numerous sensors that are mounted at diverse locations in engine to deliver the brief country of engine via measured parameters viz. Crank rpm, cam speed, engine coolant temperature, lambda sensor, and so on. If engine is jogging too lean, lambda sensor will maintain in check that ECU is being knowledgeable approximately the air-gas ratio. If load at the engine will increase suddenly, then crank speed will suggest requirement of extra fuel, thereby increasing duration of injection of gasoline, lambda sensor suggests the quantity to which aggregate will become wealthy and ECU instructs injector for this reason to inject required amount of fuel.

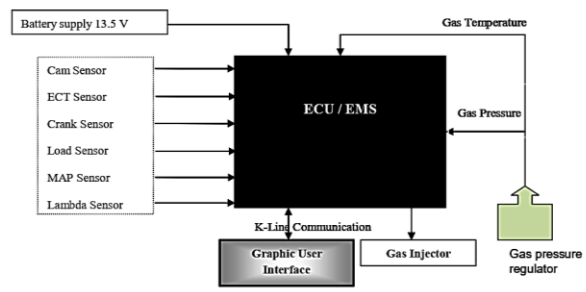

Fig. 2. Schematic of Engine Management System and its components

3. Effects of Variation in Injection Timing [7,8,9]

Advancement of injection timing is vital so that you can accomplish the gas injection technique to compensate for highly longer injection duration earlier than ignition begins. Moreover, advancement would additionally help in right air-gas blending earlier than combustion manner starts. It must be stated that injection timing and spark timings cannot be various at the identical time. Thus, spark timing and period of injection is to be stored steady. Effects of advancement of injection timing on diverse parameters are as follows:

Air-Fuel Ratio: In case of a DI engine, for the reason that duration of fuel injection is constant then with development of injection timing, air-gas ratio decreases. This takes place due to the fact remaining of consumption valve is constant because of which in advance the injection starts Lesser would be the air inducted as a part of herbal gasoline would be injected at some stage in consumption stroke and CNG coming at excessive pressure tends to displace quantity of sparkling air entering thereby reducing engine's volumetric performance and growing common equivalence ratio. However, due to accelerated cylinder stress there is a lower in consumption pumping losses. Over-late injection timing does not provide sufficient time for air-gas mixing consequently forming negative high-quality combination which displays numerous drawbacks within the form of sluggish combustion duration, decreased mean powerful pressure, high HC emission, etc. [7].

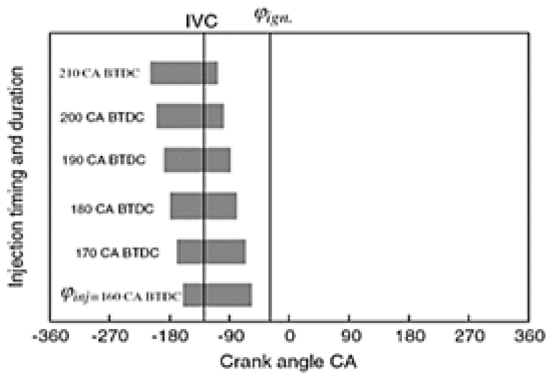

Fig. 3. Injection timings and duration [7].

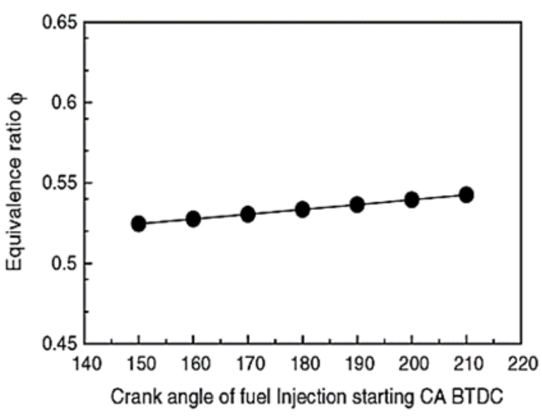

Fig.4. Overall equivalence ratio versus fuel injection timings [7].

Brake Mean Effective Pressure: With advancement of injection timing, the brake mean powerful stress increases. This happens because of enough time for gas air blending therefore making a higher great aggregate which subsequently effects in shortened combustion duration and improved cylinder strain. However, too much development does now not solid any impact on bmep after a certain restrict. Late injection results in formation of non-uniform combination within the cylinder. Moreover, penetration distance of gas jet gets decreased due to improved cylinder strain considering that piston compression is takes location at that time. Due to this formation of rich stratified mixture close to nozzle tip takes place resulting in negative and erratic combustion, decreased power and extended emissions.

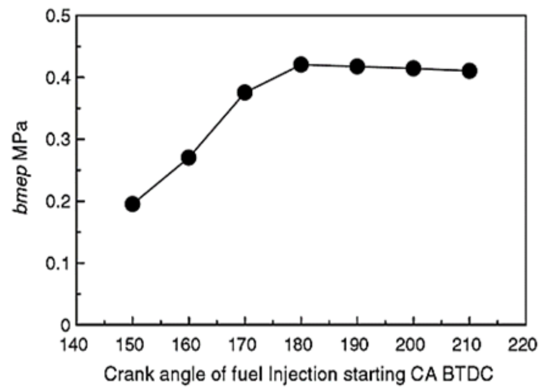

Fig.5. Brake mean effective strain Versus fuel injection timings [7].

Brake Thermal Efficiency: BTE increases with development of injection timing. It takes place due to progressed gas air blending, higher combustion, shortened combustion intervals and increased bmep. However, an excessive amount of advancement did not mark any full-size upward push in BTE as on one hand engine is strolling leaner which decreases flame propagation pace and increases combustion length however alternatively with advancement, equivalence ratio increases resulting in reduced pumping losses which balances the effect of decreased flame velocity and expanded combustion length.

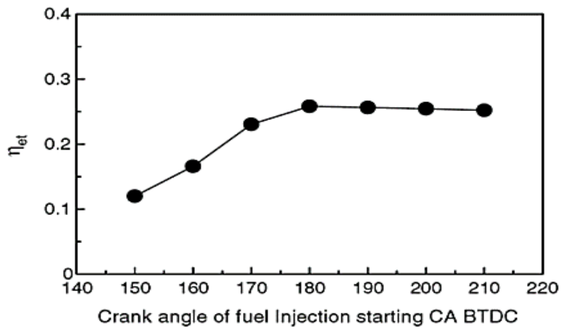

Fig. 6. Effective thermal efficiency versus fuel injection timings [7].

Combustion Duration: Since sufficient time of mixing makes a uniform combination inside the cylinder for this reason combustion periods have a tendency to shorten with development in injection timing. However, too late or too early injection effects in growth in combustion period.

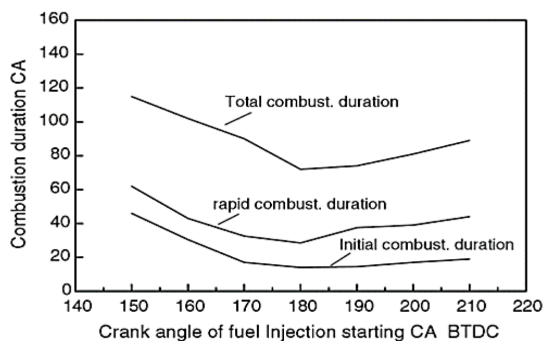

Fig. 7. Combustion duration versus fuel injection timings [7].

HC Emission: With development of injection timing, HC attention in exhaust decreases due to the enough gas–air blending and the homogeneous aggregate combustion, whereas within the case of past due injection, due to insufficient fuel-air mixing, fraction of the unburned gas within the cylinder increases.

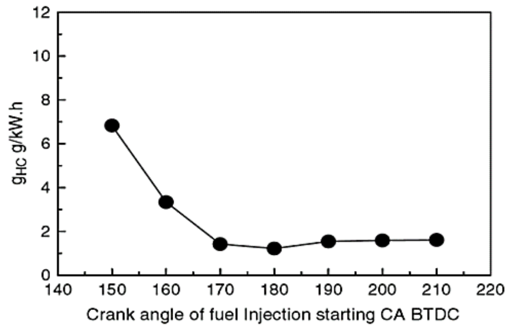

Fig. 8. Exhaust HC vs injection timings [7].

NOx Emission: As injection timing is superior, the attention of NOx emissions increases hastily on the grounds that improved blending and reducing of air-gasoline ratio results in higher combustion which subsequently ends in accelerated combustion temperatures. When late injection is carried out, combustion technique will become sluggish ensuing in decreased in-cylinder gas temperature and as a result reduced NOx emission.

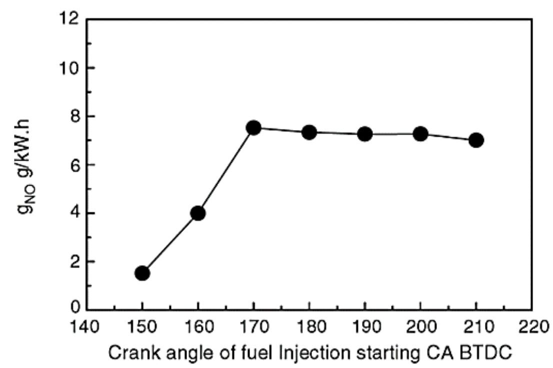

Fig. 9. Exhaust NOx vs injection timings [7].

CO Emissions: Though with development air-gasoline ratio gets reduced i.e., Wealthy aggregate is being sent in yet there's no popping up of CO concentrations as commonly speculated. Thus, with development of injection timing there may be very insignificant version in CO concentrations in exhaust because richening of combination with development is counter-balanced via improved combustion. However, CO emissions display high values throughout late injection phase which can be attributed to drop in engine power output all through overdue injection manner.

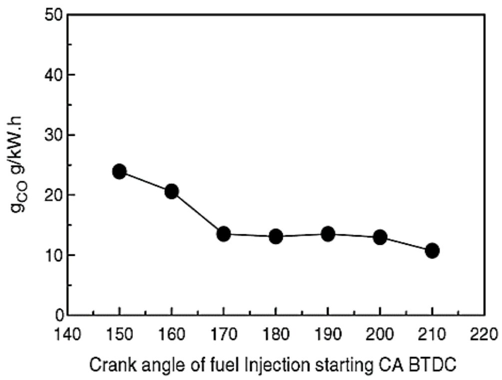

Fig. 10. Exhaust CO vs injection timings [7].

CO2 Emissions: Richening of air gasoline ratio with advancement leads to increase in combustion gas concentrations attributable to improved blending and higher combustion. This is the reason for extended CO2 concentrations with development of injection timing.

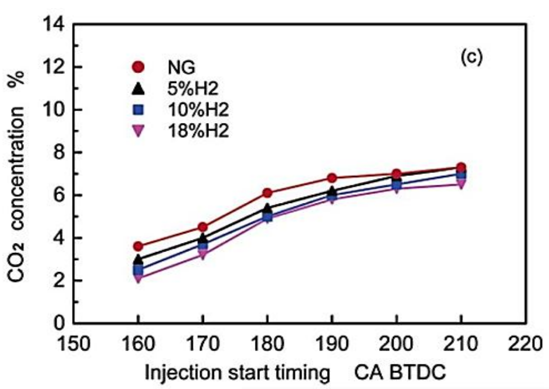

Fig.11. Exhaust CO2 vs injection timings [9].

4. Effects of Variation in Spark Timing [10,11,12]

Variation in spark timing is some other parameter dealt with in this paper which were published in [12,13,14,15,16]. Spark timing of an SI engine is the crank attitude at which spark plug generates spark to provoke combustion of notably compressed price. Spark timing plays a crucial function in determining the character and results of combustion which ultimately affect the overall performance and emission characteristics of an engine. Thus, exciting consequences are obtained when version in spark timing is finished.

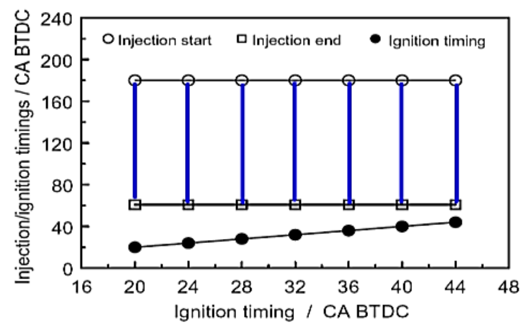

Fig. 12. Intervals between ending of injection and ignition at various ignition timings [11].

Since both injection and spark timing cannot be various on the same time subsequently injection timing and length of injection need to be kept constant and spark timing can be various. Following are the repercussions of variation in spark timing on numerous engine parameters:

Air-Fuel Ratio: Since duration of injection and injection timing remain constant therefore air-gasoline ratio remains unchanged. Thus, variation of spark timing does not affect air-gas ratio.

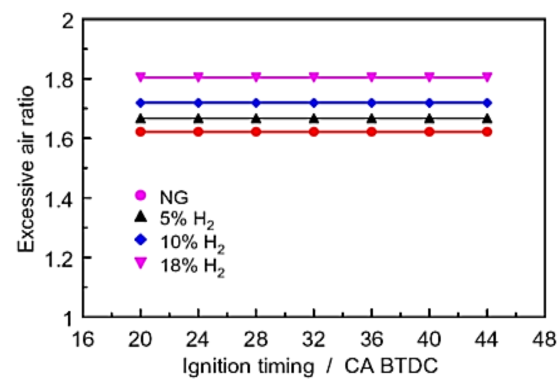

Fig. 13. Excessive air ratio of fuel blends versus ignition timings [11].

Brake Mean Effective Pressure: With development in spark timing, bmep increases because the time c language among the give up of gasoline injection and ignition timing decreases with development in ignition timing because of which excessive turbulence receives triggered which increases the burning speed ensuing in better combustion. If engine runs in lean regime and aggregate stratification takes vicinity due to reduction in time c program language period among cease of gasoline injection and ignition timing, then this fee stratification is visible as favorable component since it improves burning pace.

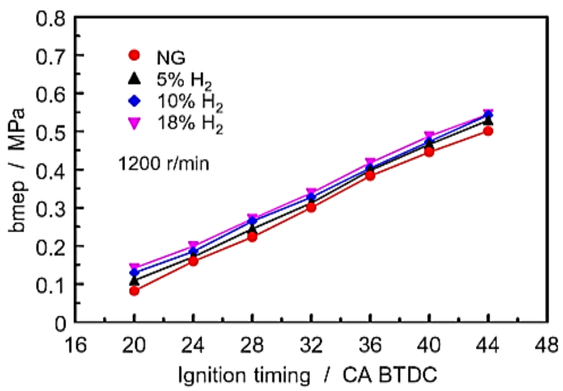

Fig. 14. Brake mean effective pressure of fuel blends versus ignition timings [11].

Brake Thermal Efficiency: BTE of an engine increase with development of ignition timing. This can be without delay connected to the growth in bmep while quantity of heat released per cycle remains about regular with advancement in ignition timing. Best overall performance is generally received at maximum brake torque (MBT) timing. Inadequate development of ignition timing results in past due combustion which occurs while downward motion of piston due to which growth ability of burnt gases thru complete range is lost and consequently deceased overall performance is determined. However, an excessive amount of advancement ends in reduction in net work considering the fact that burning of fuel takes vicinity during upward motion of piston. There are probabilities that cumulative impact of growing strain and rising piston might also result in excessive knocking.

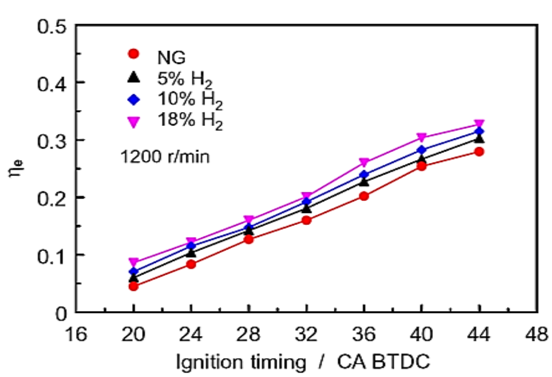

Fig. 15. Effective thermal efficiency of fuel blends versus fuel ignition timings [11].

Combustion Duration: Duration of combustion receives reduced with advancement of spark timing. This takes place due to the fact advancing ignition timing shortens the time length between the stop of gasoline injection and spark timing thereby forming exceptionally stratified aggregate within the combustion chamber and relatively wealthy mixture near the spark plug, making the aggregate liable to get ignited easily and for this reason reduces the ignition delay and the flame development length.

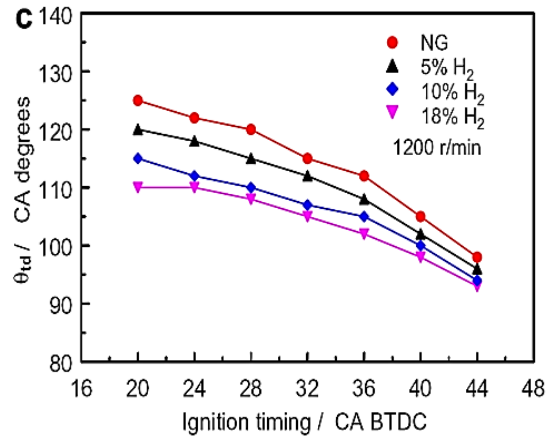

Fig. 16. Combustion duration of fuel blends versus fuel ignition timings [11].

HC Emission: Main source of the HC emission in an engine is from the flame quenching during the flame propagation from combustion sector close to the spark plug to unburned area close to the cool wall of the cylinder. Exhaust HC awareness decreases with advancement in ignition timing. This happens because decrease in time c program language period between quit of gas injection and ignition timing creates excessive aggregate stratification resulting in speedy combustion and multiplied combustion temperature. However, put off in ignition timing outcomes in weakening of stratified combination main to increase in fraction of lean aggregate within the combustion chamber which further will increase the unburned fraction of fuel in lean region.

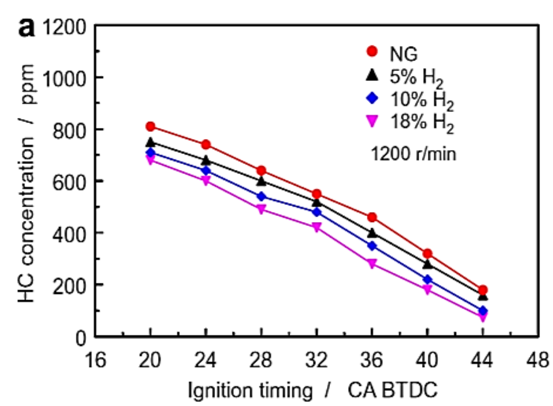

Fig. 17. Exhaust HC vs ignition timings [11].

NOx Emission: With development of ignition timing

Nox emissions increase. Since time c language among give up of gas injection and ignition timing gets reduced with advancing ignition timing, as a result combination stratification takes vicinity which quickens the combustion process and will increase combustion temperature resulting in extended Nox concentrations. With advancement in ignition timing, in-cylinder gasoline pressure and temperature upward push that is some other cause for growth in Nox concentrations.

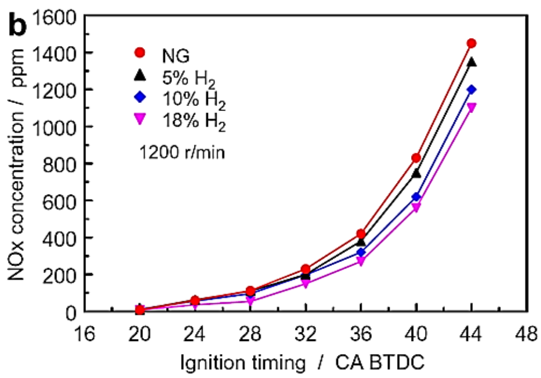

Fig. 18. Exhaust Nox vs ignition timings [11].

CO Emission: Concentration of CO emissions remains low because the engine runs in lean regime. However, development does no longer cause any vast change in CO concentrations.

CO2 Emission: With advancement in injection timing CO2 concentrations generally tend to boom due to the fact HC emissions decrease owing to better combustion.

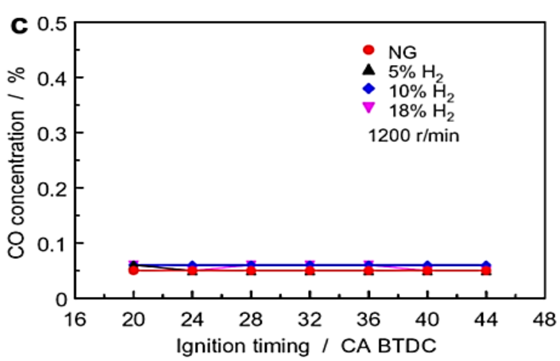

Fig.19. Exhaust CO vs ignition timings [11].

5. Conclusions

Due to their great durability, affordable manufacturing, and high-power density, internal combustion engines have played a crucial role in human society in a variety of applications. Yet, the combined effect of many parameters has a significant impact on the combustion process in engines. The other design and operational factors for internal combustion engines must be adjusted for emission, which is one of the key parameters. After examining the effects of three operating parameters on the three emissions of SI engines using theoretical, experimental, and RSM methods, this study uses the most popular optimization technique (response surface method) to further predict the performance and exhaust gas emissions of SI engines. From the numerous findings from this paper, the following conclusions may be made; The engine speed, loading condition, and time were found to have a significant effect on the emission, according to models of HC, CO, and NOx emissions.

With advancement in injection timing:

a) Air fuel ratio decreases, bmep will increase and BTE will increase.

b) Combustion durations decrease.

c) HC concentration decreases, NOx increases, CO2 will increase and CO stays invariant.

With advancement in spark timing:

a) Air fuel ratio stays unchanged, bmep increases and BTE increases.

b) Combustion duration decrease.

c) HC concentration decreases, NOx will increase, CO2 increases and CO stays invariant.

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