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EVALUATION OF MIXTURE FORMATION TO IMPROVE COMBUSTION EFFICIENCES & REDUCED EMISSION IN INTERNAL COMBUSTION ENGINE: A STUDY

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Abstract
The call for decrease in contamination has been commanded by government arrangements around the world. This defiance the IC engine manufacturer to make balance between engine performance and emissions. However,with developing innovation in the field of mixture formation and fuel injection equipment, the task has become realizable. For recent years it has been the interesting issue to improve combustion efficiency and emission of internal combustion engine by improving the fuel injection approachand optimum mixture formation. For example spray characteristics, fuel injection pressure ,injection timing and nozzle configuration can enhance the atomization of fuel and after while increase the combustion performance and NO_X, proceeds high brake thermal efficiency ,resulting lower CO, HC ,PM emissions .The aim of the present article is to complete review of various mixture formation parameters varying injection pressure ,injection timing ,spray characteristics, nozzle geometry for engine to improve the engine efficiencyand emissions regulation .Whereas each fuel injection approach has its particular benefits as well asnegative marks ,they are clarified inparticularity,in the prospect of ,advice investigator to select the good approach for the better combustion and emission of IC engine.

Keywords: *Injection Pressure, InjectionTiming, Spray Characteristics, Nozzle geometry, Emissions*

Introduction

Due to developing significance of future emission restriction, it is required to upgrade the and combustion process and mixture formation in IC engines in order to reduced engine raw emission. For this it is important to improve the combustion system and mixture formation. The improvement of combustion systemand mixture formation is also important for combustion efficiency and emission. Injection pressure, Injectiontiming, spray characteristic and injector nozzle geometry are the key parameters for better combustion processes and mixture formation. Injection approach like injection pressure, injection timing, spray pattern and number of nozzles, fuel quantity is directly affecting the combustion, emission and performance of an IC engine.

Injection Pressure: The combustion, emissions and performance characteristics of an Internal combustion engine is directly affected by several factors including fuel injection pressure.High Injection Pressure reformed the spray Properties.High injection pressure increases the spray penetration length and low ambient density, increment in ambient density, spray angle increases. Fuel injection pressure varies from 250 to 2500 bar which is depends on the fuel injection system used. It is presented by many research that high the injection pressure, reformed the combustion efficiency andemissions regulation [1][2].Spray penetration is enhancedby highinjection pressure [3][4].Fuel injection pressure is very useful to alternate fuel like biodiesel and its blends along diesel for improving the combustion efficiency and emission characteristics of an IC engine[5][6].Higher injection pressure affects the air fuel mixture, results to enhance combustion and influences pollutants . Higher injection pressure provided small droplet diameter which decrease the ignition delay during combustion [7]. If the fuel injection pressure is too high, ignition delay time isshort so that homogeneous mixture decreasesanddecrease in combustion performance. Effect of high injection pressures on the IC engine performance and emissions studies by the Pierpont and Reitz [8]. Dodge et al. found that by the high injection pressure,decreasethe PM emissions and unessential increase the NOx emission and less soot formation [9]. Higher fuel injection pressure causes a high level of scatteringof fuelalongthe improved atomization and air fuel mixture. The purpose for fuel injection process in a compression ignition is to the formed a mixture of air-fuel to accomplish a perfect and better combustion process [10][11]. Icıngur and Altiparmak performed an experiment ,impact of fuel injection pressure on CI engine performance and emissions and calculated the outcome of low injection pressure of 100,150,200,250bar and found at pressure pressure of 250 bar, increased in NOx pollutants , and decreasedin sootand also increased in power output and torque from the engine and also conclude that SO_2, CO_2 and $O_2$was decreased at highinjection pressure whilelowinjectionpressure was suitable for decreased in soot emissionand NO_x [12][13].Higher injection pressure are suitable for Significant decreased in particulate matter (PM) and soot emission from Direct Injection diesel engine [14][15]. High injection pressureplay an important role to enhance the exhaust odour. Fuel atomization are increased by increased in fuel injection pressure at nozzle outlet and arise more dispersed in vapour phase which improves mixing.Fuel injection system with high injection pressure keep significant decrement in injection period anddelay in combustion and peak heat release rates increased and decrement in combustion time [16] [17]. Better air fuel mixture formation is achievable at high fuel injection pressure. The lower injection pressure allowsbigger droplet diameter soto increasein ignition delay during combustion process. Higher fuel injection pressure gives good droplet atomization and long pre-mixed duration thus decreased in soot emission [18] [19]. Reitz and Pierpont calculated that theimpact of high fuel injection pressure on the performance and emissionof an internal combustion engine [20].Canakci studies the impact of injection pressures on methanol blends and results the decreases in HC and CO [21].

Injection Timing: Injection Timing act as very essentialpart in combustion operation and pollutants emission. Injection timing is very important parameter for reducing the harmful pollutants like HC, CO and NO_x.Due to change in pressure and airtemperature,ignition delay is affected by the ignition timing near the top dead centre (TDC). With slow injection timing, it was conceivable to accomplish decreased in CO, HC and $NO_x$and discharges with immaterial impact on fuel utilization rate. Particulate number concentration is decreased at higher injection pressure (FIP) by advancing the injection timing because advanced injection timing gives further time for air-fuel mixture before the beginning of combustion. At high engine loads, advance injection timing decreased the overall particulate concentration.minimum particulate concentration was found at 1000 bar fuel injection pressure on 4.875^{o}before top dead centre (BTDC) Start of Injection[22].Ramesh and Reddy found the impact of injection timing on Jatropha oil and calculated that an increased in the brake thermal efficiency (BTE) and reduction in CO, HC and soot by advanced the injection timing by 3^o from the original injection timing of diesel [23].Sayin and Gumus investigate the effect of injection timing on biodieselblended diesel and studies three distinct injection timing that is 15^o, 20^o and 25^{o}before top dead centre (BTDC) and concludethat at injection timing of 20^{o}before top dead centre (BTDC)provided finest outcome of and brake thermal efficiency,brake specific energy consumption as well as brake specific fuel consumption (BSFC) compared to advancing or retarding injection timing . More Advance injection timing provided the more time for carbon oxidationresulting reduced the temperature of the combustion cylinder and pollutants like CO,HC and NOxare decreased [24].Pandian examine the importance of injection timing on the emission and performance of Pongamia biodieseldiesel blendand conclude that HC,smoke and CO were decreased by injection timing advance from 18º to 30º before top dead centre (BTDC) and increased in NOx emissions and betterresulting parameters were found at 21ºBTDC[25]. Monyem investigate the effect of injection timing on bio-diesel and conclude that there was decrease in HC and COwere decreased in the range of injection timing and NOx emissions were increased by 3º advance and reduced considerably by 3º retardation from the default injection timing[26].Kegl found that an ideal injection timing for biodiesel fuelled internal combustion engine decreased toxic emissions and superior performance[27].Carbon Monoxide (CO) and unburned methaneare decreased by 6 and 5 times when compression ignition injection timing is advancing from 10º-50º BTDC. During advanced diesel injection timing in the range of conventional dual-fuel combustion (10º- 30ºBTDC) admirable CO the unburned methane emission is achieved. Diesel injection timing of 30º BTDC is the resolving point for different combustion of conventional dual-fuel. Decreased in NOx, CO and unburned methane emission produced when advancing the diesel injection timing beyond the 30ºBTDC.Very advanced diesel injection timings of 46º and 50ºBTDC simultaneously Decreased in NOx, CO and unburned methane and the results shown that with advancing diesel injection timing from 10º to 50º BTDC, NOx and CO, unburned methane are decreased respectively, by 65.8%, 83%, and 60% and indicated thermal efficiency is raise by 7.5% [28].Advanced Start of Ignitionprovided more time for mixing process, resulting better mixture of air-fuel hencereduction in HC and CO emission.VS Yadav et al. investigated the impact of injection timings on engine performance in hydrogen-fuelled direct DI diesel engine and found,11.6% increase in brake thermal efficiency by the supply of 120 g/h of hydrogen at ideal fuel injection timing as compared to diesel due to improved combustion performance of hydrogen [29]. Ganapathy et al. investigate the effect of injection timing on Jatropha methy ester and conclude that decrease in HC and CO but increase in NO_x [30].

Spray Characteristics: Spray characteristic plays an important part on the affecting the thermal efficiency of Internal combustion engines and outstanding for the incomplete combustion process. Mainly two physical processes involved in spray characteristic (I) Wall spray impingement (II) Wall film Evaluation. Wall spray impingement gives a negative as well as positive effect which depends on the wall temperature and volume of fuel deposit on the wall. In case of low temperature, liquid wall film formation significantly, increased the HC and soot emission as of incomplete burning due to slow evaporation of wall film [31]. Wall Fuel film build on the wall after the spray wall impingement which increase the mixture near the wall and decreased the temperature of mixture near the wall with the film evaporation which leads produced smokeemission, unburnt HC and CO [32] [33]. Useful air -fuel mixture is distressed by the spray characteristics andflow of air inner to the engine cylinder. Higher soot emission and high oxidation rate is produced by high wall temperature. Ignition delay, flame luminosity intensity, and soot formation is affected by the wall temperature strongly [34]. As the wall temperature increases, flame luminosity intensity also increases, and decrease in ignition delay. Higher wall temperature formed more smoke in the flame. Moon et al. investigate the impact of various types of nozzles on the wall impinging spray flames and examine that micro-holeand group-hole nozzles upgrade combustion process and decreased theemission of soot [35] [36] [37]. Spray impinging at higher engine speeds is increasing due to more fuel injection and less time available for droplet evaporation of the spray. At higher engine speeds, turbulence intensity and average piston surface temperature increases. So, wall film evaporation is raised, and mixture formation is optimized. Because of less available time, high wall temperature, more spray impinging, high turbulence intensity and fast mixture formation on impinging zones at high engine speeds, soot concentrations tend to decrease substantially without a considerable change in NOx formation [38]. As compared to the free spray flame, soot emission level is low in wall impinging spray flame. [39] [40].Mohammadi et al. conclude that the spray-wall interaction improved the ambient gas entrainment, asemission formation and combustion process arechanged from the spray-wall interaction [41]. H. Luo et al. found that impinging spray on the walls of the engine is affected by the high ambient temperature, high ambient temperature favours the fuelevaporation,sothat spray tip penetration and height of impinging spray of liquid phase reduced [42]. If many droplets are in close to one another, they will be enclosed by vapor that could be an either rich combustion zone for combustion and rich combustion zone have high soot formation rates. Some of soot is oxidized but some remains unoxidized and is expelled with the exhaust gasses. Under most engine running conditions, soot is the primary component of particulate emissions. So, decrease in the volume of rich combustion zones will result in less particulate emissions. Han et al. showed this to be due to the decreasing the supply of fuel in the rich zone at the spray's tip, resulting in better mixing [43].

Nozzle configuration: Today's nozzleconfiguration is a main concern in order to achievecurrent emission guidelines due to the control on internal flow, cavitation aspect, spray characteristics and atomization behaviour, which are very essential for IC engines performance and emission. The injector nozzle is very essential parts of anIC engine. Spray characteristics and atomization behaviour is affected by the Nozzle geometry which issignificant for engine performance and emission. Nozzle geometry affect the in-nozzle flow dynamics,which influencethe initial jet breakup, atomization, and combustion process. Quality of the diesel spray is very important factors in direct injection diesel engine. An advancement in the air /fuel mixtureprovidedimproved combustion process which gives higher performance, and control pollutantemissions [44]. Attributes of the flow internal the injection nozzle hole is strongly influenced by the spray characteristics [45] [46].The internal flow of nozzle is mostly dependent on the existence of the cavitation phenomena, as presented by Soteriou et al. [47].Yoshio et al. was performed a comparison between the 5-hole injection nozzle and 3-hole injection nozzle with regards to NOx,and COand HC emissions. When a little amount of fuel is injected, HC and CO were decreased but as injection fuel quantity increased, also increased in HC and CO with the 5-hole injection nozzle. On the other hand, in the 3-hole injection nozzle HC arecomprehensive high but decrease as thefuel injection quantity increases [48].NOxwas increases,as increases of nozzle diameter, peak at 4mm nozzle diameter [49]. The best emissions performance and the second best BSFC performance was obtained with the nozzle with the fewest number of holes and the smaller hole size [50]. Chaves et al. found in his studies that cavitation increases the spray cone angle which affect the combustion process [51]. With smaller hole size nozzle could lead to better mixture formation resulting in lower level of emissions [52].

Table 1. Brief of Fuel Injection pressure and fuel injection timing on engine performance and emissions.

Author	Injection approach	Fuel used	HC	CO	NO_x
Gumus et al. [5]	Injection Pressure	Bio-diesel blends	↓	↓	↑
Sayin and Gumus [6]	Injection Pressure	Bio-diesel blends	↓	↓	↑
Su et al. [8]	High Injection pressure	Diesel	NA	NA	↑
Dodge et al. [9]	High Injection pressure	diesel	NA	NA	↑

Fang and Lee [11]	Multiple/split injection	Bio-diesel blend	NA	NA	↓
Icıngur and Altiparmak [12]	Injection Pressure	diesel	NA	NA	↑
Celıkten et al. [13]	Injection Pressure	diesel	NA	NA	↓
Su et al. [14]	High injection pressure	diesel	NA	NA	↑
Pierpont et al. [20]	High injection pressure	diesel	NA	NA	↑
Canakci et al. [21]	Injection Pressure	Methanol blends	↓	↓	↑
Gumus and Sayin [23]	Injection timing	Bio-diesel blends	↓	↓	↑
Pandian et al. [24]	Injection timing	Pongamia methylester	↓	↓	↑
Monyem et al. [25]	Injection timing	Bio-diesel	↓	↓	↑
Kegl [26]	Injection timing	Biodiesel	↓	↓	↓
Ganapathy et al. [29]	Injection timing	Jatropha methyester	↓	↓	↑

↑ - Increase, ↓ - Decrease, NA – Details Unavailable

Conclusion

A study was done by the researchregardings emission regulation in Internal combustion engines by various fuel mixture formation. The parametersdiscussed in this study are varying injection pressure, injection timing, spray characteristics and nozzle configuration. Table 1 display the brief of the comprehensive research done on the injection approaches like injection pressure and timing. The table gives a judgement on the impact of injection pressure and Injection timing on engine performance and emissions carry through experimentally. Some of the outstanding points display the response of above saidparameters on engine performance and emissions for diesel and alternatives fuels are given below:

- An enhanced injection pressure optimizedthe ignition timing,because of good atomization introduced by the high injection pressure and, high injection pressure makes the fine fuel droplet, the diversion of the air increases, resulting combustion period and ignition delay is short due to fine and uniform spray.
- The highest injection pressure provided lower level of smoke emission and CO and gradually higher HC emission and high pressure strongly effect the influence on great extent the NOx formation.
- It is found that an improvement in injection timing from the default value generategreatdecreasedin HC, COandBSFC, CO, HC and sootemission and an increase in break thermal efficiency,greatNOx emission andheat release rate and.
- An advance injection timing must be found for any internal combustion engine and fuel to strike anequilibriumbetweenemissions and engine performance.
- wall temperature has stronglyaffected the ignition delay, soot evolution and flame luminosity intensity. As the

temperature increases, delay in ignition and increased in flame luminosity intensity.High soot is formed at the flame at higher wall temperature.

- Nozzle configuration and cavitation greatly affect to the atomization of fueland evaporation of fuel and enhance the mixture formation.

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