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Review Article

Studies on Spark Ignition Engine-A Review

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Abstract

Over the last century, IC engines continued to develop, as our knowledge of engine processes has increased. With the advent of new technologies the demand for new types of engines has risen. Further, the environmental constraints on engines have become stringent during the recent years. Last three decades has witnessed explosive growth in engine research and development with the key issues like, market competitiveness, stringent emission norms and fuel economy. A very extensive study has been done in the past, the various approaches towards engine research have been presented in this paper.

Keywords: *Combustion, Simulation*

Introduction

The effect of combustion phenomenon in IC engine has been highly influenced by various parameters. Being heterogeneous in nature, controlling combustion in an engine significantly increases its efficiency and pollutant formation. Better understanding on the in-cylinder fluid dynamics, fuel sprays and combustion will help in meeting stiff challenges such as fuel economy and pollutant formation. Many approaches towards the combustion efficiency enhancement have been reported in the past. Critical review of the available literature pertaining to alternate fuels, compression ratio, emissions, Engine Design, simulation and other approaches are presented in the following section

Alternate Fuels in Spark Ignition Engines

The quasi-dimensional model was chosen for the simulation of the combustion part in the thermodynamic cycle of a SI engine. This model considers two zones in the combustion chamber: a zone with burned gases and a zone with the unburned mixture, divided by a spherical flame front. The combustion process is assumed to occur in two phases: first, unburned mixture is entrained into the flame front. In a second phase, this unburned mixture is burned. The combustion speed is calculated out of two differential equations. These take into consideration the characteristics of the turbulence in the combustion chamber and the laminar flame speed of the fuel (Sebastian Verhelst *et al*, 2000).

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The combustion speed obtained with this model allows the evaluation of the equations determining the evolution of the pressure (assumed to be uniform throughout the cylinder) and the temperatures (uniform for each zone). These equations are derived from the first law of thermodynamics. A set of equations determines the composition of the cylinder gases by assuming chemical equilibrium at the given pressure and temperature

(Jehad *et al*,2003) Mathematical modeling is such an effective tool available to the designer which not only helps in designing new engines but also allows optimization of the performance of old engines. Keeping this in mind, a computer model of a 4-stroke spark ignition engine was developed using LPG as a fuel. He found that the combustion duration (in milliseconds) decreases as the engine speed (in rpm) increases. This is a clear effect of turbulence. As the engine speed increases, the turbulence inside the cylinder increases, leading to a better heat transfer between the burned and unburned zones. operating at lean or rich mixtures the combustion duration tends to increase. This effect is more predominant at lower speeds. This is because of the less thermal energy liberated from the leaner mixture which increases the ignition delay and slows the flame propagation. The flame temperature is low at lean and rich mixtures. Further, the incomplete combustion due to oxygen deficiency at rich mixtures also has an adverse effect over the flame speed. The combustion duration decreases as the compression ratio increases. This is because of the increase in the end-of-compression temperature and pressure and decrease in the fraction residual gases as the spark is shifted from the peripheral position (i.e. XSP = 0.08) to the center (i.e.

XSP = 0.5), the combustion duration decreases. This is because of the decrease in the distance traveled by the flame. The spark location has greater effect on suppressing detonation. increase in the combustion duration causes the peak temperature (both burned and unburned) as well as the brake mean effective pressure to decrease. both CO and NOX emissions are lower when the combustion duration is higher than that for best performance. This implies that the conditions for minimum emissions are not the same as those for best performance.

(Maher A. R *et al*,2006) A mathematical and simulation model has been developed to simulate a 4-stroke cycle of a spark ignition engine fueled with hydrocarbon, hydrogen and ethanol singly or in a blend. The program written from this simulation model can be used to assist in the design of a spark ignition engine for alternative fuels as well as to study many problems such as pre-ignition, knock, pollutant emissions, catalytic devices, exhaust gas re-circulating valves, effects of misfire and maldistribution of the fuel-air mixture. main results obtained from the present study are Hydrogen can be used as a supplementary fuel in modern spark ignition engines without major changes, and it can help save a considerable part of the available oil and save our environment from toxic pollutants. Ethanol can be used as a supplementary fuel up to 30% of gasoline in modern spark ignition engines without major changes, and it improves the output power and reduces the NOx emissions of a hydrogen supplemented fuel engine. The hydrogen added improves the combustion process, especially in the later combustion period, reduces the ignition delay, speeds up the flame front propagation, reduces the combustion duration, and retards the spark timing. The blending of ethanol reduces the CO and NOx emissions and peak temperature. The concentration of CO is reduced, and the concentration of NOx is increased due to hydrogen blending. The engine power is increased until a hydrogen fuel mass ratio of 2% and ethanol-fuel ratio of 30%. The blending of ethanol or hydrogen increases the heat release rate. The exhaust temperature is reduced, as is the crevices flow energy due to the blending of hydrogen or ethanol fuel.

The blending of hydrogen reduces the specific fuel consumption, while ethanol blending increases the specific fuel consumption. The addition of ethanol to gasoline fuel initially increases the Reid vapor pressure of the blended fuels to a maximum at 10% ethanol addition, and then decreases, indicating an increase in evaporative emissions for ethanol gasoline blended fuels. The addition of ethanol to gasoline fuel enhances the octane number of the blended fuels. An addition of 15% by volume of ethanol to gasoline produces the same effect as the addition of 0.6 g/l of lead or 15% by volume MTBE. The auto-ignition-free operational region tends to narrow significantly with increasing hydrogen-fuel mass ratio, compression ratio, intake pressure and/or intake temperature, and the retarding possibility in spark timing in the operational region was within about 2◦ to 3◦ crank angle from the optimum spark. timing at near the stoichiometric equivalence ratio. This represents a practical limitation to the improvement of the power and efficiency of hydrogen engines. The auto-ignition-free operational region tends to widen with the addition of ethanol fuel due to a reduction in the peak temperature through the power cycle.

(Jie WanG *et al*,2009) A numerical simulation of the influence of different hydrogen fractions, excess air ratios and EGR mass fractions in a spark-ignition engine was conducted. Good agreement between the calculated and measured incylinder pressure traces as well as pollutant formation trends was obtained. The simulation results show that NOconcentration has an exponential relationship with temperature and increases sharply as hydrogen is added. EGR introduction strongly influences the gas temperature and NO concentration in the cylinder. The difference in temperature will lead to even greater difference in NO concentration. Thus, EGR can effectively decrease NO concentration. NO concentration reaches its peak value at the excess air ratio of 1.1 regardless of EGR mass fraction.

(Yousef S.H. Najjar *et al*,2009) investigated three types of fuels Alcoholic fuels, gaseous fuels and liquid fuels. Their properties were inserted in a computer program which was specially designed to calculate the performance of a spark ignition engine over wide range of operating conditions (design and off-design). The design operating variable namely compression ratio, advance angle, engine speed and spark advance were chosen for each fuel based on the physical and chemical properties and the resulting fuel-engine interactions such as mixing, flammability and knock. The resulting performance includes power, specific fuel consumption and thermal efficiency. Their variation with equivalence ratio, engine speed and spark advance was calculated. The following results were observed, Iso-octane produces more brake power than gasoline by 1.2%, It shows an increase in brake thermal efficiency by 0.5% and reduction in brake specific fuel consumption bsfc by 2.7%, which means that they are almost equivalent. For the same energy input, Methanol produces more brake power than gasoline by 21%, It shows an increase in brake thermal efficiency by 11% and an increase in bsfc by 46%. Natural gas produces less brake power than gasoline by 10%, It shows an increase in brake thermal efficiency by 13% and reduction in bsfc by 18%. Gasoline-Hydrogen mixture produces brake power more than gasoline by 7%, It shows an increase in brake thermal efficiency by 2% and reduction in bsfc by 5%. Synthetic fuel produces less brake power than gasoline by 12%, It shows a decrease in brake thermal efficiency by 2% and an increase in bsfc by 65%. Spark advance from 0-15º BTDC increases the brake power by 5% and the brake thermal efficiency by 5%, and decreases bsfc by 4%. Spark advance from 15-25º

BTDC increases the brake power by 2% and the brake thermal efficiency by 1.5%, and decreases bsfc by 1.8%. The ratio of brake power to the engine speed increases by 15%. At low engine speed the brake thermal efficiency increases by 2% and the bsfc decreases by 1%. At high engine speed the brake thermal efficiency decreases by 1% and the bsfc increases by 2%.

(M.V. Mallikarjun *et al*, 2009) an experimental attempt has been made to know the level of variation of exhaust emissions (Carbon monoxide, Hydrocarbons, Nitrusoxides) in S.I. four cylinder engine by adding methanol in various percentages in gasoline and also by doing slight modifications with the various subsystems of the engine under different load conditions. For various percentages of methanol blends (0-15%) pertaining to performance of engine it is observed that there is an increase of octane rating of gasoline along with increase in brake thermal efficiency, indicated thermal efficiency and reduction in knocking. On the other hand exhaust emissions CO and HC are considerably decreased but CO2 and Nox simultaneously slightly increasing. It is notable that for these methanol blends combustion temperature is found to be high and exhaust gas temperature decreasing gradually

(Louis Sileghem *et al*, 2016) investigated the use of higher compression ratios and applying different load control strategies with respect to efficiencies and emissions of 3 methanol-adapted test engines. The efficiencies obtained with methanol are higher than with gasoline and the efficiencies obtained with both EGR and lean combustion are higher in comparison with throttled stoichiometric operation. With a high compression ratio (19.5:1) and turbocharging, efficiencies comparable to diesel engines are possible. Methanol reduces NOx emissions and the reduction is larger when EGR or lean burn is applied.

(J. M. Mantilla*et al*, 2010) presented a phenomenological combustion model using turbulentflame propagation theory developed by Keck and coworkers, 1974. Themodel was adapted to work with gasoline-ethanol blends, following correlations presented by Bayraktar,2005. New sub-models were introduced for intake valve velocity and combustion efficiency. These allow simulating the effect of compression ratio, spark timing and fuel change. Results show good agreement with the ones in the original work as well as with experimental results in a Cooperative Fuels Research (CFR) engine.

(Daniel *et al*, 2012) addressed the suitability of 2,5-dimethylfuran (DMF), to meet the needs as a biofuel substitute for gasoline in SI engines, using ethanol as the biofuel benchmark. Specific attention is given to the sensitivity of DMF to various engine control parameters: combustion phasing (ignition timing), injection timing, relative air-fuel ratio and valve timing (intake and exhaust). Focus is given to the window for optimization; The sensitivity when using DMF was lower than that with gasoline (due to the higher octane number). At 8.5bar IMEP, the ignition retard to maintain a 2% decrease in peak IMEP was 4.3CAD with DMF, compared to 1.5 CAD and 6.6CAD with gasoline and ethanol, respectively. This increased ignition retard allows isNOx reductions of up to 37% (at 3.5bar IMEP) to be found with DMF. Such reductions are consistent to gasoline with load. However, the lower ignition timing sensitivity of ethanol consistently produces the highest reductions in isNOx emissions (up to 64% at 3.5bar IMEP). With injection timing variations, DMF showed the lowest sensitivity to VE, whereas ethanol showed the highest sensitivity due to the greater effect of chargecooling. This allows a wider window for emissions optimization when using DMF. At 8.5bar IMEP, the SOI timing window to produce a 2% drop in IMEP (from the maximum) was 120CAD with DMF, compared to 90CAD with ethanol. The latest SOI timings (within this window) produced the lowest isNOx emissions with DMF, up to 10% (similar to gasoline). In terms of AFR, the sensitivity when using DMF was lower than with gasoline but higher than with ethanol. At 8.5bar IMEP, the limit of lean combustion (COV of IMEP $\leq$ 5%) for DMF was λ=1.29, whereas for gasoline this was λ=1.24 (λ=1.41 for ethanol). At this point, the indicated efficiency for gasoline decreases by 1.7% but there is minimal change for DMF and ethanol (the indicated efficiency actually increases by 0.3% when using DMF). However, the isNOx emissions reductions were lower for DMF (37%) than for gasoline (62%) an ethanol (81%) at this 8.5bar IMEP.

(Osama H. Ghazal *et al*, 2013) investigated the effect of different fuels type on engine performance for different engine speed. Brake Power, Brake Torque, and specific fuel consumption were calculated and presented to show the effect of varying fuel type on them for all cases considered. A simulation model for one-cylinder spark ignition engine has been built and calculated. The analysis of the results shows that for methanol the power increases about 30% at 1000 rpm and 16% at 6000 rpm comparing with methane. For the same compared fuels the increment in fuel consumption is about 100% at 1000 rpm and 115% at 6000 rpm. The increment in brake thermal efficiency for gasoline is around 11% comparing with methane at 1000 rpm and 7% for methanol comparing with methane at 4000 rpm.

(Victor Pantile *et al*, 2013) carried out an experiment on monocylinder engine with normal admission system, three valves: one air inlet valve, one hydrogen inlet valve and one exhaust valve. And found that The effective power by hydrogen fueling is greater with almost 30 % comparative to gasoline at stoichiometric air-fuel ratio. The same effective power of gasoline engine can be obtained at leaner air-fuel ratio at use of hydrogen. The energetic brake specific fuel consumption is smaller comparative to gasoline due to the improvement of the combustion process The NOx emissions are greater at the use of hydrogen in the mixtures airfuel ratio area with λ<1.8 due to the higher combustion temperature but as the mixture is leaner the NOx emissions levels decrease significantly. The NOx emission level decreases by increasing the relative air-fuel ratio (qualitative control), obtaining approximately the same power output to gasoline engine operation. Hydrocarbons and carbon oxides emissions are every low and appear only from the oil burning inside the combustion chamber.

(K Rezapour *et al* ,2014) a mathematical model of a bi-fuel four-stroke spark ignition (SI) engine is presented for comparative studies and analysis. It is based on the two-zone combustion model, and it has the ability to simulate turbulent combustion. The model is capable of predicting the cylinder temperature and pressure, heat transfer, brake work , brake thermal and volumetric efficiency, brake torque, brake specific fuel consumption (BSFC), brake mean effective pressure (BMEP), concentration of CO2, brake specific CO (BSCO) and brake specific NOx (BSNOx). The effect of engine speed, equivalence ratio and performance parameters using gasoline and CNG fuels are analysed. Natural gas has smaller C/H ratio of fuel in comparison to gasoline and for this reason it produces the lower amounts of CO2 and CO, CNG fuel decreases volumetric efficiency, increases temperature of combustion and finally it produces more BSNOx when compared to gasoline, The BSFC of an engine fuelled with CNG is less than gasoline-fuelled.

(Chintan R. Patel *et al*,2014) all the four basic processes taking place in an S.I. engine are analyzed and the values of pressure and temperature at every 2° of crank rotation are found out with the aid of certain assumptions. The model involves good deal of calculations and iterations and hence, it is coded in 'c'. The simulation of suction pressure using discrete approach suggests that the pressure 30º after TDC and 30 º before BDC are of the order of 0.856 bar and 0.931 bar, respectively. This clearly indicates that the entry of hydrogen during this period will certainly offer back fire free operation of the engine . The pressure and temperature at the end of the compression process with discrete approach is 16.165 bar and 417.68 K respectively as against the pressure and temperature of 22.180 bar and 729.69 K with ideal Otto cycle analysis. The peak pressure and temperature obtained with discrete approach is of the order of 50.590 bar and 1341.17 K respectively. Thus, the present work offers new approaches for simulation of H2-air engine with delayed entry technique and advocates for the use of rotary type delayed entry valve for backfire free operation of multi-cylinder engine.

(Hariram V *et al*,2015) deals with the experimental investigation of using gasoline-ethanol blends in a four stroke single cylinder overhead cam spark ignition engine for performance and emission characteristics. The performance parameters like brake specific energy consumption, brake thermal efficiency, mechanical efficiency and emission parameters like unburned hydrocarbons, carbon-monoxide and oxides of nitrogen were analyzed in detail. The BSEC was found to decrease with increase in ethanol blends at all loads where as BTE and mechanical efficiency showed a significant increase with addition of ethanol blends. The UBHC and CO emission was noticed to be higher initially during starting and found to decrease with addition of ethanol. NOx emission showed an increasing trend for the entire load condition with increase in ethanol blends

Compression Ratio in Spark Ignition Engines

(M. Aleonte *et al*, 2011) Using advanced fuelling systems like the air-assisted DI shows that not only theefficiency of the engine is increased but also the exhaust emissions and fuel consumption are lower. The air pressure was induced into the air-fuel mixture formation chamber of the air-assisted direct injection system with a pressure of 4.5…5.5 bars. The combustion process has a very good behavior in all cases due to the fact that the air-assisted DI was manually regulated in order to achieve this. In order to gain power output from a spark ignition engine without bringing important changes to it, increasing the compression ratio is one technical solution and the second solution is by using alcohols blended with super gasoline (E85) or in pure state as fuel. HC Emissions dropped by 73% in comparison with the carburetor fuelling system and they slightly increase by using alcohols in pure state (E100) or blended with Super Gasoline (E85), due to the lower heating value of Ethanol. Using the air-assisted DI fuelling system shows that the CO emissions are lower by 45% compared to the carburetor. CO2 emissions dropped also by 45% compared to the carburetor fuelling system. NOx emissions increase when using the air-assisted DI with super gasoline due to the fact that the engine worked with a leaner air-fuel mixture.

(Aina T *et al*, 2012) conducted an experimental and theoretical investigation of the influence of the compression ratio on the brake power, brake thermal efficiency, brake mean effective pressure and specific fuel consumption of the Ricardo variable compression ratio spark ignition engine. Compression ratios of 5, 6, 7, 8 and 9, and engine speeds of 1100 to 1600rpm, in increments of 100 rpm, were utilised. The results show that as the compression ratio increases, the actual fuel consumption decreases averagely by 7.75%, brake thermal efficiency improves by 8.49 % and brake power also improves by 1.34%. The maximum compression ratio corresponding to maximum brake power, brake thermal efficiency, brake mean effective pressure and lowest specific fuel consumption is 9.The theoretical values were compared with experimental values. The grand averages of the percentage errors between the theoretical and experimental values for all the parameters were evaluated. The small values of the percentage errors between the theoretical and experimental values show that there is agreement between the theoretical and experimental performance characteristics of the engine.

Emissions in Spark Ignition Engines

(M. S. Shehata *et al*, 2008) An experimental study is carried out to investigate engine performance parameters and methods of reducing emissions from spark ignition engine. EGR rate of 5%, 7%, 8%, 10% and air injection rate of 3%, 4%, 5%, 6% are used. The use of EGR in spark ignition engine is promising method for improving part load operation conditions. BSFC, UHC, CO concentrations and Texhaust increase with the increase of EGR. On contrast brake power, break thermal efficiency and AFR decrease with the increase of EGR. EGR improves combustion qualities by increasing the inlet charge temperature and UHC and CO re-burned with using EGR. Decreasing AFR, combustion deterioration and efficiency losses are largely attributed to increase pumping work with the increase of EGR. Catalyst converter installed in exhaust manifold provides significant reduction in UHC and CO concentrations on contrast Texhaust increases after catalyst than before catalyst due to some of heat release with oxidation of UHC and CO species into CO2 and H2O. Air injection in exhaust manifold is the simplest method for reducing UHC and CO concentrations due to increase oxygen concentration after exhaust valve opening which is used to oxidize UHC and CO to CO2 and H2O at high exhaust temperature. Texhaust decreases with the increase of mass of air injection due to increase AFR to very lean conditions which overcome heat release effects with air injection. Sound pressures level (SPL) increases with the increase of engine speed and load. Sound pressures level generated from combustion process is higher than SPL generated from flow process where SPL calculated from cylinder pressure higher than that calculated from inlet manifold or exhaust manifold. Engine cycle to cycle variation (CCV) is found to increase with the increase of engine speed due to increase the variation of AFR, fuel burning rate, heat release rate, turbulence intensity, mean effective pressure, volumetric efficiency, and engine cylinder pressure.

(Wojciech Tutak *et al* 2011)., presented the results of modelling thermal cycle of internal combustion engine including exhaust gas recirculation. The test engine can not achieve the optimum parameters of work due to occurrence of the knock combustion. The influence of EGR on the limits of the knock occurrence in the engine was studied. It turned out that few percent of exhaust gases in the fresh charge effectively shifts the knock limit to higher ignition advance angles. The values of the limit ignition timing for the test engine was determined in order to avoid combustion knock. Larger share of EGR caused too much slowing the spread of the flame inside the combustion chamber of the test engine. EGR at constant angle of ignition was very effective in limiting the content of NO in the exhaust, but on the other hand it has an adverse effect on the engine parameters. The engine operate with exhaust gas recirculation in order to obtain the possible best parameters the ignition timing should be optimized. However, that with increasing values of the thermodynamic parameters of thermal cycle of engine increased NO content in the exhaust.

(Mehrnoosh Dashti *et al* 2013).,A spark ignition engine cycle simulation based on first law of thermodynamics has been developed. The model effectively described the thermodynamic processes and chemical state of the working fluid by considering a closed cycle containing compression, combustion, ignition delay and expansion processes. The two-zone model was used for simulation of the combustion process and the species including CO2, CO, H2O, H2, N2, O2 , NO and UHC were considered as exhaust gases. It is found that the simulated results show reasonable agreement with the experimental data. Parametric studies have been carried out for investigation of the equivalence ratio, compression ratio and spark timing effects on the engine performance. Within the context of sustainability, such models could be utilised for application with alternative fuels or to predict and improve the emissions from conventional fuels..

(Carrie M. Hall *et al*, 2012) Combustion efficiency is typically tied to an optimal CA50 (crankangle when 50% of fuel is burned) for an engine. a physically-based, generalizable combustion phasing model for fuel-flexible SI engines with VVT has been developed and demonstrated to accurately capture changes in CA50 due to variation in thermodynamic conditions, valve overlap, spark advance, and ethanol blend fraction at over 500 points across the engine operating range of a 4-cylinder fuel flexible SI engine utilizing VVT. The model captures the rate of fuel burn from SIT to CA50 within 10% of the actual experimental values at a majority (over 90%) of these points. Furthermore, its computational simplicity and the fact that it uses only available engine sensor measurements make in extremely valuable for efforts to control combustion phasing. In current control methods, static look-up tables are used extensively for control of ignition and while such tables provide acceptable control in steady state for their intended fuel, performance is lost during transients and when other alternative fuels are utilized. Since the model detailed in this paper can predict CA50 on a cycle-to-cycle basis for multiple fuels, it can be used in future work for feedback control or in a feed forward predictive manner to improve control during transients and when operating with alternative fuels.

Simulative Studies on Spark Ignition Engines

(Hai-Wen Ge *et al*, 2010) An efficient multi-grid (MG) model was implemented for spark-ignited (SI) engine combustion modeling using detailed chemistry. The model is designed to be coupled with a level-set-G-equation model for flame propagation (GAMUT combustion model) for highly efficient engine simulation. The model was explored for a gasoline direct-injection SI engine with knocking combustion. The numerical results using the MG model were compared with the results of the original GAMUT combustion model. A simpler one-zone MG model was found to be unable to reproduce the results of the original GAMUT model. However, a two-zone MG model, which treats the burned and unburned regions separately, was found to provide much better accuracy and efficiency than the one-zone MG model. Without loss in accuracy, an order of magnitude speedup was achieved in terms of CPU and wall times.

(Dr.P.V.K.Murthy*et al*, 2012) Investigations were carried out to evaluate the combustion parameters experimentally for a two-stroke copper coated (copper of thickness 300 microns was coated on the piston crown and cylinder head) spark ignition engine of brake power 2.2 kW at a speed of 3000 rpm, and were correlated with two-zone and multi-zone combustion models. Multi-zone combustion model gave results very close (deviation being 7%) to experimental values, while two-zone combustion model deviated from actual (experimental) results by 9%.

(K.M Pandey *et al*,2012) an analysis is performed in a port fuel injection SI engine using computational fluid dynamic (CFD) code FLUENT to determine the level of intake swirl induced by poppet intake valve and its reduction along the length of the cylinder. From the study it was found that the surface which is closer to the poppet intake valve shows higher tangential velocity at various locations compared to the surfaces which are at higher distance from the intake valve i.e. the intensity of swirl decreases along the stroke length of the engine cylinder.

(Kota Sridhar *et al* ,2013) A two dimensional, four stroke spark ignition (SI) engine with port injection is considered. Standard k-€ turbulence model for fluid flow and eddy break-up model for turbulent combustion were utilized. CFD analysis has been used extensively to improve each of these processes. The simulation model developed successfully captures the single cylinder spark ignition engine operating with Hexane as fuel. Result were noted with different crank angles at different flow time. It is found Maximum and Minimum Volume-Average static pressures, Mass-Average static Temperatures at different flow time, Predicted C6H14 Mass fraction Distribution and Predicted Static Temperature Distribution of Hexane Fuel. The operational range of the model is wide and computational run time is short, thus making the simulation model suitable for use with thermodynamically based cycle simulations in spark ignition engines running with ignition improver with Hexane fuel. Due to its simplicity, the model can be used for wide range of different fuels to optimize the design.

(Ashish J.Chaudhari *et al* ,2013) single-zone zero-dimensional model for any hydrocarbon fuel based on Wiebe heat release function has been implemented in Simulink to test the performance of spark ignition engine. Annand's model for convective heat losses is taken for modeling of engine cycle. The Simulink results are validated with experimental results from literature. The peak pressure during combustion drops with decrease in intake pressure which is similar to the experimental trend. With increase in speed from 1000rpm to 4000rpm, the brake thermal efficiency drops from 25% to 17% while the indicated efficiency is seen to be almost constant (32%). Two dimensional Computational Fluid Dynamic model using FLUENT of experimental test engine is prepared for axisymmetric flow in the combustion chamber. It is a setup for closed cycle simulation that can predict pressure, mass burn fraction. CFD Simulation is carried out on an experimental engine set up at rated rpm of engine (1.8 HP @3600 rpm). The CFD results with the validated Simulink model for this engine configuration shows that at low speeds (1000 rpm), the maximum cylinder pressure prediction is about 8% higher for CFD analysis while this deviation is seen to be about 3% at higher speed (3600rpm). The Simulink model is subsequently used to test the predications of brake power and subsequently compared with the experimental results and CFD studies. Both the predictions are found to be in good agreement with the experimental results.

(Reinhard Tatschl *et al* ,2014) a scalable simulation methodology is presented that enables the assessment of the impact of SI-engine cycle-to-cycle combustion variations on fuel consumption and hence CO2 emissions on in-cylinder, engine and vehicle level. On the detailed in-cylinder level, a 3D-CFD approach is used to study the impact of the turbulent in-cylinder flow on the cycle-resolved flame propagation characteristics. On full engine level, cycle-to cycle combustion variations are analysed in terms of their impact on the cycle-resolved heat release rate, aiming at an estimation of the possible fuel consumption savings when cyclic variations are minimized. Finally, on the vehicle system level, a combined mean value engine/crank-angle resolved cylinder modeling approach is used to assess the potential fuel consumption savings under realistic vehicle drive-cycle conditions. The achieved results clearly demonstrate the fuel consumption reduction potential of minimizing SI-engine cycle-to-cycle combustion variations under stationary and real drive-cycle conditions.

Conclusion

From the above study it is evident that various experimental approaches have been adopted for enhancing the efficiency in spark ignition engines. Along with these a considerable research has also been done using the simulation tools to help predict the effect of various parameters on engine performance. The research done proves that simulation tools can be further used for complex combustion, emission and efficiency analysis in spark ignition engines.

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