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EFFECTS OF FUEL PROPERTIES AND SPRAYING FLUID ON GASOLINE ENGINES

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Abstract: In this study, the ignition delay measurement was determined numerically by using some practical equations. Outboard ignition engines take the fuel-air mixture into the cylinder and compress it. High compression ratio is an important parameter that increases engine efficiency. The compression ratio is kept away from the knock limit, which is also defined by self-ignition of the mixture. The ignition system should be able to initiate combustion without igniting the mixture at the appropriate moment and causing undesired mechanical and thermal stresses. The temperature at the tip of the spark plug at the time of ignition is proportional to the blur of the gauge voltage and usually ranges from 500-800 °C. A well-working flue gas should have a porcelain temperature of less than 500 °C and no more than 850 °C. The temperature at the end of the isolator is crucial for the development of ignition and combustion. Higher tip temperatures, premature ignition, and low temperatures cause spark plug contamination and kicking. Accumulation of unburned or slightly burnt hydrocarbons in the interior of the buoy is indicated as the responsibility of the contamination and therefore the singlet. Hydrocarbon deposits reduce electrical insulation too much over time, preventing the syringe from forming between spark plug nails. In our work, evaluations were made on hydrocarbon deposits in terms of insulator temperature and system self-cleaning temperature and so on.

Keywords: Fuel properties, Gasoline engines, Spray injection, Knock, Octane number.

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INTRODUCTION

Knowledge of the time to ignition upon sudden heating of a fuel-air mixture has immediate practical significance relative to the performance of some air-breathing engines and other high-intensity combustion systems (1). Measurements of ignition delays (or induction periods) in the laboratory have recently been carried out mainly with shock tubes, which provide virtually instantaneous heating of a gaseous fuel-oxidant mixture, Shock tube data further provide an important experimental reference for kinetic modeling, very analogous to flame profile data but possessing the great advantage from the chemical standpoint that transport of species and energy is negligible because of the very short times (microseconds to milliseconds) involved in the shock tube observations (2). Thus the equations to be solved are considerably simplified (3).

There are some difficulties in this approach. First, there is the experimental problem of defining the moment of ignition (*e.g.,* of a hydrocarbon-oxygen-diluent mixture) in shock waves, the features followed maybe the pressure, the concentration of one or more radical species (*e.g.,* OH) as measured by light adsorption, the emission from excited OH; CH, or C_2, or a combination of these (2). The end of the induction period is associated with rapid but not discontinuous increases in these features; hence the definition of the moment of ignition is necessarily somewhat arbitrary. Investigators usually choose to define it in a way that will yield consistent results and permit comparisons with theory. This one might, for example, take it as the moment when the OH concentration reaches some particular value (2).

Assuming that the delay has been well defined, one measures it in shocks having a wide range of compositions, temperatures, and pressures. A correlation is then sought among the variables that will produce a straight line on an Arrhenius-type plot. Thus Serry and Bowman (1970) found the most satisfactory correlation of their data on methane ignition to be given by

$$t[O_2]^{1.6}*[CH_4]^{-0,4}=A\exp(E/RT) \quad (1)$$

where t is the ignition delay time and A and E are constants. This plot alone may well serve as a useful empirical correlation that will permit predictions of ignition delays. Its value becomes greater if one proceeds to kinetic modeling of the ignition process. The objective is, of course, to reproduce the empirical correlation (4). The modeling consists of a computer program by which the coupled differential equations of chemical kinetics and the gas dynamic and state equations are numerically integrated, yielding the time dependence of all pertinent variables: concentrations, pressure, and so on. The analytical results for the induction times can then be compared to the experimental values for various starting conditions (1).

GASOLINE ENGINE

It has been attempted to increase gasoline production by breaking down heavy parts on the need to increase the petrol requirement and not to meet the petrol requirement, which is obtained only by the distillation of crude oil (5). Despite the fact that this cracking process precedes only to increase gasoline production, it is understood that the gasoline obtained in this way has a higher octane number. Thus, higher octane gasoline was found to have a higher octane number (6). Thus, high-compression, highly efficient engines are made with the benefits of high octane gasoline (see Figure 1.) (7).

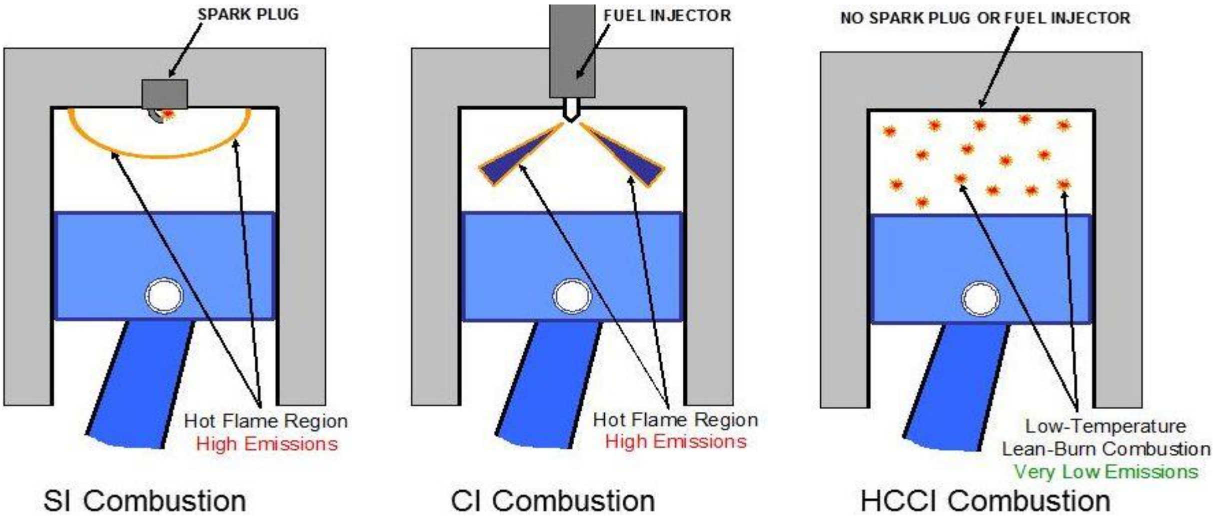

Figure 1. Homogeneous Charge Compression Ignition (HCCI) engines (2015).

During the operation of a four-stroke gasoline engine;
a) Suction
b) Compression
c) Enlargement
d) Exhaust
movements must be examined. Each of these movements is represented by a stroke, and these four strokes are completed in two cycles of the crank to provide useful work (8). The expansion stroke is also called work stroke.
Suction and Compression were examined in detail in the relevant sections separately, but the enlargement and exhaust events were presented together.

Suction stroke
The piston moves from the upper dead point (U.D.P.) to the lower dead point (L.D.P.) on the intake stroke. During this movement of the piston, the volume that is generated in the cylinder comes to grow with a vacuum. Due to this vacuum, the outside air enters the cylinder through the intake valve which is opened by passing through the air filter and the carburetor. The flow rate of this air entering the cylinder depends on the engine speed, the piston speed, and the channel cross-sections in the passages. When the speed change of the air passes through the carburetor, it flows into the bubbler, and when it passes through the carburetor, it moves in the direction of the fluid, and as it passes through the venturi throat in the carburetor, the velocity increases and hence the pressure decreases. This pressure drop is below the atmosphere at the point where the cross section is narrow. Since the pressure in the capillary gas cylinder present in the carburetor is always an atmosphere, the gasoline in the carburetor sprays into the air going into the cylinder because of this pressure difference. Under pressure, a low-pressure medium is sprayed from a capillary nozzle and the gasoline is evaporated by immediately separating it into small particles. The mixture of air and vaporized petrol brings the mixture to the water line and the mixture is sucked into the piston during suction stroking; this stroke ends with the piston sinking to the bottom dead point. In the meantime, the crank has made half a cycle (9).

Compression stroke
Following the completion of the suction stroke, the pistons that have come up to this time are now in the L.D.P. move from U.D.P. and it starts to compress the mixture which is filled in the cylinder slowly. By compressing the mixture into the increasingly constricted volume, the pressure and temperature rise and the piston U.D.P. the mixture with the spark plug is ignited.

Enlargement and exhaust
Before arrival of the piston U.D.P., the reasons for the start of the ignition are as follows:
a) Burning event, piston U.D.P. and the pressure drop due to the expansion action of the piston is the result of the inability to reach the expected burning. For this reason, the piston U.D.P. is necessary to take into account the combustion of the fuel.

b) The high pressures resulting from the expansion combustion increase the piston speed to 25-30 m/s by adding a new pressure to the downwardly moving piston and gain power to the piston. This piston is the third stroke and the work stroke and crank complete the first half cycle of the second turn.

c) After completing the exhaust expansion stroke, that is, at the end of the movement in which the work is obtained, have arrived. This burning is finished and the exhaust valves are opened. U.D.P. This movement of the piston moving upward from the exhaust gas is discharged to the outside of the exhaust valve. Since there is no counter pressure, in this case, the operation is very easy. The piston moves in the direction of U.D.P. the fourth stroke is completed and the crank completes the second round at this time to obtain the work (10).

KNOCK

When an explosive device such as a gas-air mixture is ignited with a spark, the part near this spark is first ignited. This burning eventually increases the pressure and temperature of the other parts. The flame spreads in succession to other parts at a speed of 25 m/s and when one part burns, the pressure and temperature of the rest increase more. As this burning continues, the unburned gases become easier to ignite as a result of the temperature rise caused by the burned part. Because of this pressure and temperature rise, mixtures far away from the flame front are self-igniting and combustion becomes abnormal. Thus, the pulsating waves go to the cylinder face, the pistons and the cylinder head to hit the undesired phenomenon called "knock". As a consequence, we see that the reason for the knock is due to the pressure and temperature exceeding a critical limit. The sudden increase in pulse waves, high pressures and rapid increase in pressure after such a boundary are explained as follows: At the beginning of combustion, other peroxides and aldehydes form carbon monoxide (CO) and carbon dioxide (CO_2). These compounds, which are very unstable, burst at a critical pressure and temperature, bringing them to the pulse, the knocker. These peroxides depend on the type of chemical that burns. This means that aromatic hydrocarbons that are slow-burning and heavy, bring less knocking than light but fast burning paraffins. The knock is further dependent on the distance the flame spreads to the mixing parts. The bigger this distance, the quicker it will be because the knock will reach the critical value without the last flame coming out. Compression chambers in the form of hemispheres delay the detuning (11).

The knock is very harmful for the following reasons:
1- The maximum pressure is sudden and very high, which causes a severe impact on the engine. This dynamic effect vibrates the elastic parts of the engine and causes the piston to collapse after a period of time.

2- Due to the high temperature, the pistons are defeated after a while, especially at the places where they meet the knocking, and they break long after long. Since the pulsation raises the piston face and, if necessary, the gas boundary layer over the cylinder rings, the thermal conductivity coefficient increases, the piston becomes very hot, and the cylinders cause the cooling water or air to become very hot.

3- Because the temperature is too high, some of the carbon from the depression will burn out into black smoke.

4- Motor power is reduced.

5- Since the temperature in the cylinder is very high, the mixture ignites spontaneously without reaching the end of compression and without sparking, and the engine works very irregularly, causing great shaking. This is called spontaneous ignition (12).
It depends on the type of hits you burn. Some hydrocarbons, like n-heptane, are very prone to knock. These are called knockers. Some of them are resistant to knocking, which is also called non-knocking. Iso-octane is the one of this kind. At this point, these two classes of hydrocarbons can be mixed with each other in different amounts to obtain different fuels.

There are some chemical compounds, which when added to benzene, reduce the knock, which is called knocking. Hydrocarbons comply with the following sequence in terms of knock resistance.
1. Aromatics,
2. Isoparaffins: Unlike regular paraffins, they show a branched structure, so they are very difficult to break down. Knock resistance is high.
3. Cycloparaffins (Naphthenes),
4. Olefins,
5. Normal paraffins,
The scale correctly indicating the knock resistance of the burners is the "octane number" (12).

OCTANE NUMBER

When the engine is running, the piston is fully raised. The volume between the cylinder and the cylinder head is called the "compression ratio" of this engine to the rate of volume remaining in the cylinder when the piston is fully down. For petrol engines, this ratio is at least 1/6, at most 1/12 today (13).

The air-gasoline mixture that is sucked into the cylinder must rise to a temperature that it will not self-immobilize during this compression, and the firing time of the spark must be well calculated. If the ignition time of the buzzard is normally delayed or occurs beforehand, then the burners will make a hammer stroke on the piston. It is called knock. It is closely related to the octane number of the gasoline (14).

In engines with high compression ratios, the use of low octane gasoline results in knock and knocking problems (15).

In vehicles with compression ratios, the use of high-octane gasoline, which is engine-intensive octane gasoline, reduces knock-out and removes knock-outs. Higher octane gasoline is more costly, and when used in engines with compression ratios, increases efficiency and power, reducing fuel consumption. This saves fuel costs. For example, if you use 85 octane gasoline and 80 octane gasoline with a compression ratio that is reasonable to use, there will be a decrease in efficiency and strength. If 85 octane gasoline is used, the fuel consumption is reduced by 3% with the increase in efficiency and power (10).

As a result, using a gasoline engine instead of low octane gasoline in a certain motive, it reduces the knocking sickness and provides a reduction in fuel consumption to provide equal power (14).

The above benefits are not obtained if higher octane gasoline is used that is necessary in low compression ratios. When engines with low compression ratios use a gasoline on the required motor, there is no knock due to the fuel. When high-octane fuel is used, there is no increase in efficiency and power (10).

Although a power boost can be provided by slightly increasing the ignition advance of the engine, it can be manufactured for a certain power, but the motor produced for a given power is excessively forced and the motor life is shortened due to excessive force. The use of high-octane gasoline in such an environment is not economically viable either (10).

As it increases from sea level, the need for octane decreases for every 300 m. A decrease in the number of octanes for height is required 3500 m. This value is 300 m. for 7-7.5 units (14).

Because some engines with suitable structure use higher octane fuel, more power can be obtained. However, as high octane fuel in normal transportation is used, we can not get extra power and speed. Under some operating conditions, when increasing the number of octane to 68 denier, it is seen that there is a 15% increase in the speed of the car, but there is no rapid development or even a decrease in some other types of cars (10).

In our country, there are approximately 600,000 gasoline-powered vehicles, 75% of which have compression ratios of 1/7.3 and 80 octane gasoline. In recent years, high-octane (87-90) petrols have been supplied to the market in order to meet this demand in other countries due to the increase of high-compression-ratio vehicles. There is even a 100-octane gasoline in America (14).

Determine the number of octanes

The ability of the gas to burn uniformly without knocking on the motor is specified by the number of octane. There is a jam in the cylinders during the movement of the engine piston. If the space left in the cylinder just above and above the piston during the upward and downward movement of the piston is 1/6 of the space at the bottom of the piston, the compression ratio of this engine is called six times. During this compression, the temperature of the mixture increases. This ratio is adjusted so that the temperature of the mixture does not reach the point where it can burn itself. (The gas-air mixture reaching a certain pressure and temperature can start to self-ignite even without sparking) (15).

Increasing the compression ratio increases its efficiency and power. If the compression ratio is lowered, the mixture burns more appropriately. In other words, it is more slowly and relatively tactile, and it is more appropriately lit. So it is a slower and relatively tactical combustion. In turn, the resulting power is reduced (10).

As can be understood from the above explanation, the gas vapors in the combustion chamber increase in relative power and efficiency, which can be compressed before igniting. Since this compression rate is limited, it can not be compressed anymore (5).

In today's gasoline engines industry, great emphasis is placed on high-compression engines because stronger and faster cars are in great demand (10). That is, as the compression ratio is raised, the probability of a uniform combustion is reduced, a sudden combustion occurs. It explodes briefly. At the beginning of combustion, aldehydes and peroxides are formed beside CO and CO_2. These chemical substances, which are very unstable, can not burn under pressure and temperature, but they explode. This event can occur at several places in the combustion zone. This is called "Knock". We can compare it to a hammer crush, which is down to the piston. Only a small fraction of the energy generated at such an uneven side is converted into useful energy. Much of this is tired of parts of the machine and parts. The only thing to do is to control the burning of the gas. If you have to produce a fuel that will burn evenly under high compression (even if it is stuck), it shows resistance to sudden burns, explosions, impacts and knocking. This type of combustion is achieved only with high octane gasoline. As we have said above, the characteristic of a gasoline to burn uniformly without knocking on the motor is indicated by the number of octane (14).

In order to increase the resistance of the gasoline to knocking, it is provided either by making a change in the inside of the molecule to convert it into a more or less aromatic or isoparaffinic form, or by the addition of carburizing units with very slow oxidation of benzene and by the addition of benzene lead tetraethyl (8).

There is a misunderstanding among the people about the issue of octane; high-octane gasoline is thought to be a gasoline type that burns more easily than a low-octane gasoline and can easily burn. Such an idea is wrong, and the opposite is more or less the case. The number of octane in the gasoline is determined by the single-cylinder, special octane engines located in the fuel oil laboratory. The compression ratio of this motor can be adjusted to the desired state (9).

There are different methods to be applied for the test. It should be indicated that the method has been applied firstly. The fuel to be assigned to the engine is filled into the engine's tank and the engine is started. Whichever method is applied, the values indicated by the method are provided (engine revolution and gasoline inlet temperature of the engine). The compression ratio is changed to bring the motor to the knocking stage. The amount of knock is determined by the "knock meter". The engine is stopped. The fuel which is being tried to be assigned to the boiler is discharged. Instead, reference fuel prepared in different proportions (iso-octane + n-heptane mixture) is filled. The engine is started. Since the compression ratio remains unchanged the cycle and temperature (gasoline engine inlet temperature) are set. This reference fuel mixture ratio is iso-octane + n-heptane. Various experiments are carried out by varying the n-heptane quantities so that you get the same amount of knock under the same conditions. The reference octane number in the reference fuel mixture, which gives equal knock to the gasoline knock to be assigned to the octane, is 100 (octane number) and the normal heptane is zero (0) (14).

For example, if an equal knock of a gasoline knocker gives a mixture of 95% iso-octane and 5% n-heptane, the octane of the fuel is 95 [9].

PRE-IGNITION

The hot spark plugs, hot carbon deposits, or the cylinder head does not cool properly form a number of hot spots in the combustion cell. These points act like a spark plug. In fact, at the end of the compression time, it is only through the spark plug that it is inevitable that it starts at these hot spots. So instead of burning is an explosion. The knocking from the square is also called the early firing knock. There is nothing to do with the knocking that comes from fuel quality (14).
The knock from the fuel quality decreases as the engine revolves. The knocking from the early ignition increases the engine revolutions by an order of magnitude [8].

To increase the octane number of the gasoline:
a) Lead Tetra Ethyl (TEL):
The most appropriate amount is 1. gallon gasoline 3 mL. There are some drawbacks to using octane in order to increase the number (10).
E.g:
a) Lead oxide formation at the engine combustion site.
b) Spark plug clogging, short circuit, and consequently loss of power
c) If there is no special design, the exhaust valve burns,
d) It is too toxic.
"Ethylene bromide" is added to prevent the harmful effects of lead, which becomes

gaseous lead bromide, easily removed from the suploat (10).

b) Benzene

The octane number can be increased by mixing 10% of unleaded benzene with pure benzene. However, as mentioned before, benzene is harmful because it is an aromatic substance and will destroy other qualities of gasoline (14).

c) Alcohol

In countries with high alcohol consumption, alcohol is mixed to increase the number of octane. For example, if the 67 octane gasoline is mixed with 20% alcohol, the octane number is 78 to 80. This should be in the purity of alcohol (100% - 96%). The only problem is that it is expensive and the water present in the alcohol decomposes and rusts on the surface of the metal (15).

IGNITION DELAY

There are two types of combustion in internal combustion engines or appliances. The first is that the reactive mixture is ignited from the outside (pilot flame, spark plug etc.) and the reaction of the born flame ceiling continues. The other is to prepare the reactive system thermally and actively for the reaction and to ensure that the ignition is spontaneous (see Figure 2.) (13).

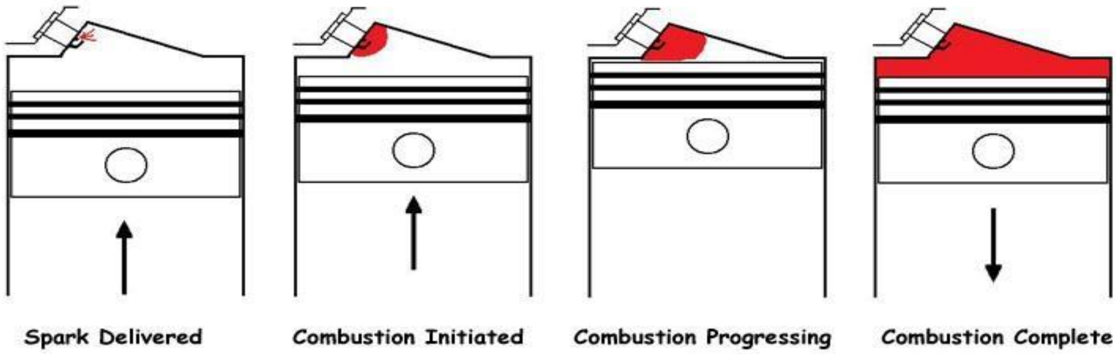

Figure 2. Typical ignition process (2015).

Because the fuel-oxidant system does not self-ignite in gasoline engines, gas turbines, and some rockets and ramjet engines, high kinetic energy electrons (spark) are delivered to the molecules in the system by a spark plug. Thus, the disintegrating molecules give the active ingredients (H, O, OH, CH_3, CHO, etc.). These active ingredients give exothermic reactions to the stable molecules and reveal a luminous region at high temperature called the "flame front" (In particular, it depends on the genus of the light). Since the flame ceiling is at high temperature, 2000-5000 K, molecules accelerate the entry into the reaction and maintain the event (see Figure 3 for the combustion problems) (13).

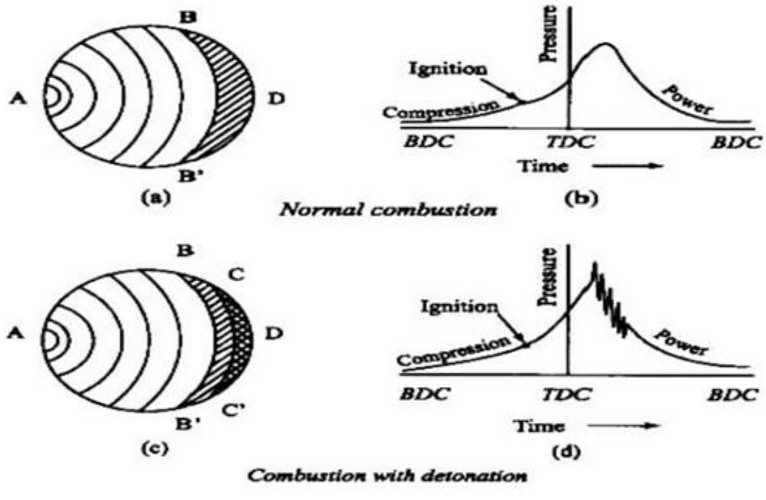

Figure 3. Normal (a,b), abnormal (c) combustion and problems (d) (Poonia 2014).

In diesel engines or some rockets, the system is designed to show self-ignition. That is, when the oxidant and the reactant come together, there can be reactions between the molecules in the temperature and concentration conditions. However, for a noticeable increase in temperature or pressure, a certain preparation time is passed which is called the ignition delay (TG) (13).

As the temperature increases in a reactive system, the kinetic energies of the translational motions increase and the probability of the molecules colliding with each other increases. In particular, self-ignition events arise from the autocatalytic behavior of the system, although there is no external effect (see Figure 4 for the ignition delay mechanism) (13).

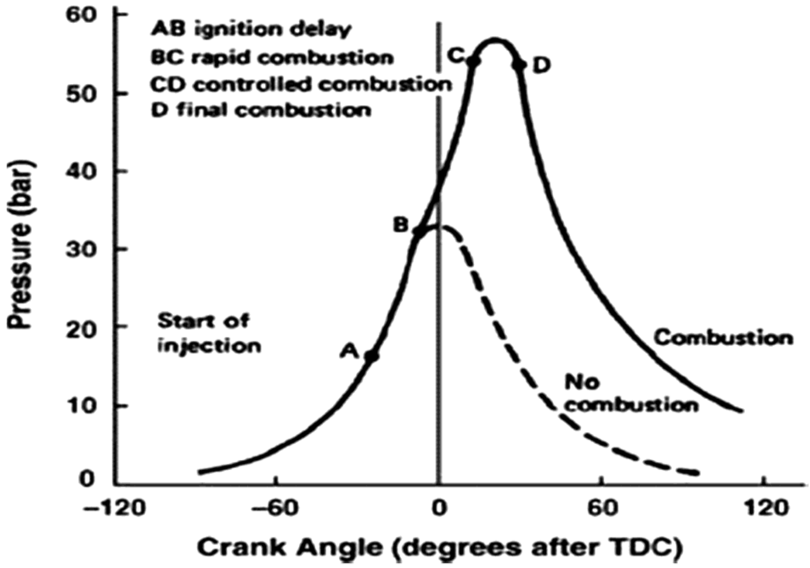

Figure 4. Ignition delay mechanism (Imdadul et al. 2015).

As can be seen in Figure 4, during fuel combustion after sparking phase, the most expected point is the U.D.P. level for the highest amount of pressure should be occurred (13, 18).

In this review, the past studies referred in the literature summarized in Table 1 (12).

The details of the studies in table are summarized in Table 2 (12).

As can be seen from Table 1, the maximum number of studies compared to the numbers before 2005 increased after 2012, reaching 52 adjectives until 2015. It is seen from this increase that the debate on increasing exhaust emissions in recent years has led to an increase in the number of such studies. As can be seen from Table 2, the Optics studies are more shallow with the maximum work done (72 pieces) depending on the knockout analysis, whereas the higher theoretical work (66 pieces) carried out in the transition to industry 4.0, mostly increases the combustion efficiency and achieves aforementioned lower emission shown in Table 1.

Table 1. The review of past studies (12).

Year	Web of Science	SAE
before 2005	111	183
2006	13	17
2007	11	13
2008	11	11
2009	17	16
2010	15	10
2011	10	8
2012	25	17
2013	31	21
2014	35	27
2015	52	28
within 2016-2017	7	12

RESULTS AND DISCUSSIONS

Fuel burning has a significant effect on the pre-ignition and high-octane burning possibilities. Most experiments in the literature show that there is no relationship between pre-ignition intensity of fuel and RON or MON. Indeed, in some experiments, the frequency of early ignition shows a further decline in the number of octanes. With the increase in the RON of the pre-ignition temperature, there is a high likelihood that the pre-flame temperature is more associated with RON and MON. However, the octane numbers (RON and MON) are particularly high, but ethanol has a relatively high tendency to premature ignition due to high intake manifold pressures. This can be explained by the fact that fuels such as ethanol and hydrogen are very sensitive to early ignition due to high laminary burning rates and lower laminary flame geometry thickness. The width of the flame of the circle in the flame center is a stable flame indicator and the flame is higher than the laminar flame. On the other hand, the tendency of ethanol fuel to be lower than gasoline fuel is due to the high ethanol evaporation temperature. In summary, pre-ignition with high octane fuel may not cause high knocking due to higher resistance to automatic ignition. As seen in Table 2, optical detection techniques, fuel properties and additives for gasoline engines can be recommended for future work.

Table 2. Details of previous studies (12).

Contents of Study	Number	Topics
Knock detection	72	1. Knock sensor development 2. Knock characterization and detection 3. Knock control logic and knock controller
Numerical simulation	68	1. The stroke model 2. Pressure oscillator modeling 3. LES model development LES model implementation delayed without ignition 4. 0-3 dimensional simulation for the 4th knockout 5. Heat transfer estimation 6. Effect of emission-type, fuel combustion conditions on the formation of combustion
Optical detection	25	1. Display of pressure waves 2. Exhaust gas automatic ignition display 3. PLIF control for HCHO estimation 4. Chemiluminescence study for intermedia products 5. Final product temperature measurement 6. Spectroscopic analysis
Theoretical study	66	1. Automatic combustion prediction 2. Hot spot auto-burn mode 3. Reaction mechanism and chemistry 4. Flame dynamics, acoustic and pressure analysis 5. Heat transfer analysis
Engine Optimization	72	1. Knock and pre-burn prevention 2. Engine operating conditions and performance
Fuel specification, Fuel additives	36	1. Octane number ratio 2. High octane fuels (alcohol, furan, NG, LPG, etc) 3. Fuel design 4. Oil additives

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