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# Alcohols as Alternative Fuels for Diesel Engines: A REVIEW

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***Abstract: The fuel which is used in Internal Combustion engines meant for transportation applications will satisfy all the requirements of cost effectiveness, maximum thermal efficiency, excellent engine performance, and still remain clean enough to protect the environment. Alcohol fuels such as methanol ($CH_3OH$), Ethanol ($C_2H_5OH$) are favorable for IC Engines because of their high octane rating, burning velocities, and wider flammability limits. Alcohols can be considered as attractive alternative fuels because they can be obtained from both natural and manufactured sources. The air quality deterioration is a vital issue that needs to be seriously monitored and limited. The transportation system is a major air pollution contributor due to the exhaust emissions such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxide ($NO_x$), carbon dioxide ($CO_2$), and particulate matter (PM). Extensive research and development is difficult to justify until the fuels are accepted as viable for large numbers of engines. Liquid fuels are preferred for Internal Combustion Engines because they are easy to store and have reasonably good calorific value. The main alternative is the alcohol. Methanol and ethanol are two kinds of alcohols that seem most promising fuels and will likely play an increasingly important role in the future. In this review, the physical and the combustion characteristics of alcohols have been discussed briefly after comparing with the diesel. The production methods of alcohols have been discussed. The safety aspects of alcohols have also been discussed.***

***Key words: Methanol, Ethanol, Diesel blends with alcohols and Diesel emulsion.***

## I. INTRODUCTION

Alcohols have been used as fuel for internal combustion engines since their invention. Reports on the use of alcohol as a motor fuel were published in 1907 and detailed research was conducted in the 1920s and 1930s [1]. In 1973 there was a severe energy crisis all over the world because the oil prices shot up four folds. Thus, 1973 is considered as the first oil shock. The world took this shock seriously and for the first time a need for developing alternative sources of energy was felt. Alternative energy sources were given serious consideration and huge founds are allocated for the development of these resources. The world faced two more oil shocks in 1979 and 1980.which further focused to the attention of alternative energy sources. The enormous increase in the number of vehicles has started dictating the demand for alternative fuels [2]. With the increased use and depletion of fossil fuels alternative fuel technology may become more common in the coming decades. Day-to-day, fuel economy of engines is getting improved and may continue to improve. Because of high cost of petroleum products and emission problems some developing countries are trying to use the alternative fuels for their vehicles. Alcohols are attractive alternative fuels because they can be obtained from both manufacturing and natural sources. Methanol and ethanol are the two kinds of alcohols that seem to be most promising [3].

## II. REVIEW OF LITERATURE

The engine performance can be studied by various parameters like torque, input power, output power, brake specific fuel consumption, brake thermal efficiency and exhaust gas temperature. Input power is the power produced by the amount of fuel injected to the engine. It is calculated based on the flow-rate and lower calorific value of the fuel. Actually, the input power can be influenced by the level of combustion whether it is complete or incomplete. Of course, it is almost impossible to get the complete combustion in an IC engine. But the more complete combustion, the more input power can be obtained. The calculated input power is the theoretical value and the maximum possible power can be obtained from the fuel if it is burned completely. There will be unburned fuel at every stroke as a result of incomplete combustion. According to a hypothesis, it is good for the

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cycle. Once the misfire occurred, a small amount of unburned methanol and air trapped in the clearance volume at the end of the exhaust stroke. This would become diluted during the following induction stroke, resulting in a very lean methanol-air mixture existing during the following compression stroke. At the end of compression just prior to the next fuel injection, there would be present in the cylinder a small percentage of fully vaporized methanol at an elevated temperature.

*A. Brake thermal efficiency*

Brake thermal efficiency is the percentage ratio of the output and the input. In this testing, the output is set to a certain load and the input can be calculated based on the amount of fuel used and time taken. With decreasing of input power, the efficiency of the engine increases. The engine efficiency is proportional to combustion efficiency. Improving the other factor such as input power, specific fuel consumption and exhaust temperature will lead to increase in brake thermal efficiency [4].

P.C. Jikar et.al have carried out experiments on methanol diesel blends at different engine speeds and obtained the values of various parameters such as torque, input power, output power, brake thermal efficiency, brake fuel consummation and exhaust gas temperature. They have used four stroke diesel engines with a compression ratio of 15.5:1. Experimental results showed that the output power and torque for diesel fuel is lower compared to methanol-diesel blended fuel at any ratio, the exhaust temperature for diesel fuel was higher compared to any mixing of the blended fuel, the brake specific fuel consumption for the three mixing ratios was not varying significantly but the lowest was for 30% Methanol and 70% Diesel but specific fuel consumption for diesel fuel was much lower compared to any mixing ratio.

*B. Effect of fuel blends on brake specific fuel consumption*

M.Al-Hassan et al. investigated the engine performance and exhaust emissions of diesel engine using 5%, 10%, 15% and 20% ethanol-blended diesel fuels. They have used four stroke single cylinder diesel engine. They have observed that the brake specific fuel consumption of the engine fuelled by the blends was higher compared with pure diesel [11].

The brake specific fuel consumption variation of the tested fuels at various engine speeds is shown in Figure 1. It is obvious that the BSFC decreases with the increasing of engine speeds up to 1400 rpm, but increases after 1400 rpm. The minimum BSFC lies between the engine speeds of 1200 to 1400 rpm for all fuel tested. In addition, it can be seen that the BSFC of fuel blends are higher than that of diesel fuel, and increases with the increase of ethanol concentration in the blends. This is because the lower heating value of ethanol and biodiesel is lower than that of diesel fuel. Therefore, more fuel is required to obtain the same engine brake power [22].

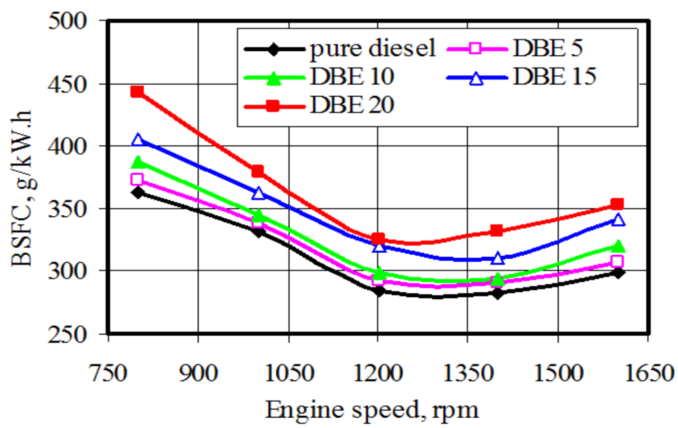


Figure 1: The variation of brake specific fuel consumption with

Figure 1: The variation of brake specific fuel consumption with different engine speeds for DBE blends and pure diesel fuel.

Huang et al [10] have also investigated the engine Performance and exhaust emissions of diesel engine when using 10%, 20%, 25% and 30% ethanol-blended diesel fuels. In their study, the results showed that the brake thermal efficiencies decreased with increasing amount of ethanol in the blended fuels.

Rakopoulos et al. studied the effects of ethanol blends with diesel fuel, with 5% and 10% on the performance and emissions of a turbocharged direct injection diesel engine. The results showed that increasing the ethanol amount in the fuel blend increased the brake specific

fuel consumption and decreased the brake thermal efficiency. Results of A.C.Hansen, Ozen Can and CY [12-14]. Lin shows that diesel fuel blended with ethanol up to 10 vol. % can be used to solve the fuel shortage problems, increase the energy conversion efficiency, improve fuel economy and reduce its harmful emissions. Also using ED fuel blends on diesel engine can yield a significant reduction of carbon monoxide and nitrogen oxide and particulate matter emissions. Nevertheless, a major drawback with using ethanol in diesel engines is the limited solubility of ethanol in diesel fuel; therefore, phase separation and water tolerance in ethanol–diesel blend fuel are vital problems [15-17]. The phase separation can be prevented in two ways: by adding an emulsifier that acts to suspend small droplets of ethanol within the diesel fuel, or by adding a co- solvent that acts as a bridging agent through molecular compatibility and bonding to produce a homogeneous blend. Emulsification usually requires heating and blending steps to generate the final blend, whereas co solvents allow fuels to be ‘‘splash-blended’’,thus simplifying the blending process [18-21].

## III.PHYSICAL PROPERTIES OF DIESEL AND ALCOHOLS

The alcohols are fuels of the family of the OXYGENATES. As is known to all, the alcohol molecule has one or more oxygen, which contributes to the combustion. The alcohols are named accordingly to the basic molecules of hydrocarbon which derives from them: Methanol (CH3 OH); Ethanol (C2H5OH); Propanol (C3H7OH); Butanol (C4H9OH). Theoretically, any of the organic molecules of the alcohol family can be used as a fuel. The list is somehow more extensive; however, only two of the alcohols are technically and economically suitable as fuels for internal combustion engines [24-29]. These alcohols are those of the simplest molecular structure, i.e., Methanol, Ethanol and Butanol. The fuel properties of alcohols and diesel are shown in Table 1.

Table 1. Fuel properties of alcohols and diesel

| Item | Diesel | Methanol | Ethanol | Butanol |
|---|---|---|---|---|
| Formula | $C_{12.35}H_{21.76}$ | $CH_3OH$ | $C_2H_5OH$ | $C_4H_9OH$ |
| Molecular weight | 170 | 32.042 | 46.07 | 74 |
| Carbon/Hydrogen (W) | 6.76 | 3.0 | 4.0 | 0.87 |
| % Carbon (W) | 87.13 | 37.5 | 52.17 | 64.86 |
| % Hydrogen (W) | 12.88 | 12.5 | 13.4 | 74 |
| % Oxygen (W) | 0 | 50.0 | 34.78 | 7.5 |
| Boiling point @ 1 atm °C | 170-340 | 64.5 | 78.40 | 118 |
| Freezing point @ 1 atm °C | -40 | -97.778 | -80.00 | -90 |
| Density (Kg/m$^3$) | 837 | 791 | 789 | 810 |
| Viscosity @ 20°C/1 atm, Centipoise | >3 (2.8) | 0.596 | 1.20 | 3.64 |
| Specific heat @ 25°C/1 atm BTU/lb | 0.43 | 0.6 | 0.6 | 0.6 |
| Heat of vaporization,@ boiling point/1 atm, BTU/lb | - | 473.0 | 361.0 | 430 |
| Heat of vaporization, @ 25°C/1 atm, BTU/lb | 100 | 503.3 | 396 | 562 |
| Heat of combustion @ 25°C, BTU/lb<br>Higher heating value (KJ/Kg) | 10800 | 9776 | 12780 | 15770 |
| Lower heating value (KJ/Kg) | 42600 | 19678 | 26795 | 33100 |
| Stoichiometric, Ib air/lb fuel | 14.45 | 6.463 | 9.0 | 11.2 |
| Flash point temp. °C | 70 | 11.112 | 12.778 | 35 |
| Auto-ignition temp. °C | 315 | 463.889 | 422.778 | 343 |
| Lower Flammability limits | 1 | 7.3 | 4.3 | 2.4 |
| Higher Flammability limits | 6 | 36.0 | 19.0 | 14 |
| Latent heat of vaporization @ 20°C, KJ/Kg | 220 | 1177 | 921.36 | 585 |
| Cetane number | 50 | 5 | 8 | 25 |
| Octane number | - | 112 | 107 | 87 |

From Table 1. It can be seen that the lower calorific value of the methanol is approximately 53% lower than that of the diesel that of ethanol is 30% lower

### *A. Methanol*

This is the simplest alcohol containing one carbon atom per molecule. It is a colorless, tasteless liquid with a very faint odour. It is toxic and tasteless liquid with a very faint odour. It is toxic and corrosive. In case of spills, methanol is biodegradable and dilutes quickly in water. Liquid methanol can be absorbed through the skin. Most of the methanol is currently made from coal and natural gas, but it can also be made from renewable sources, such as wood or waste paper. Methanol is commonly known as 'wood alcohol' [5-9]. As an engine fuel it can be used as M100 (neat methanol), but actually it is used as M85, a blend of 85 per cent methanol and 15 per cent gasoline. It has an octane number of 112. Because M85 is a liquid, it can be stored and distributed in the liquid distribution system in much the same way as gasoline. To use M85 a vehicle has to be adapted (e.g. a higher compression ratio, the intake system redesigned to achieve sufficient vaporization and materials and lubricants must be resistant to the aggressive nature of methanol) [30]. Vehicles designed to use methanol and gasoline in any combination from a single tank are often referred to as FFVs (Flexible Fuelled Vehicles). Such vehicles are equipped with a special sensor that detects the ratio of alcohol to gasoline and provides a signal to the electronic control unit to adjust the fuel delivery require a special lubricant which is more expensive than typical oil because it is produced in limited quantities. Today it is produced in very large quantities from natural gas by the reformation of the gas into carbon monoxide and hydrogen followed by passing these gases over a suitable catalyst under appropriate conditions of pressure and temperature. Historically, alcohols have been added to the engine intake air (fumigation) since they do not mix well with diesel. It has been observed that engines running on methanol alone were prone to pre-ignition, in spite of high octane rating of the fuel. Due to the cost factor and other technical problems, the use of methanol as fuel was confined mainly to the racing arena. Emissions from methanol cars are low in reactive hydrocarbons (which form smog) and in toxic compounds. (1) Methanol-fuelled trucks and buses emit almost no particulate matter (which cause smoke, and can also be carcinogenic), and much less nitrogen oxides than their diesel-fuelled counterparts. (2) Methanol can be manufactured from a variety of carbon-based feedstock such as natural gas, coal, and biomass (e.g. wood). Use of methanol would diversify the country's fuel supply and reduce its dependence on imported petroleum. (3) Methanol is much less flammable than gasoline and results in less severe fires when it does ignite. (4) Methanol has a higher laminar flame propagation speed, which may make combustion process finish earlier and thus improve engine thermal efficiency. (5) Methanol is a high-octane fuel that offers excellent acceleration and vehicle power. Though the latent heat of methanol is higher, measures are not necessary for the mixture preparing due to lower fraction, while it may increase engine volumetric efficiency and thus increase engine power. Methyl alcohol has the lowest combustion energy of all the fuels listed. However, it also has the lowest stoichiometric or chemically correct air-fuel ratio. Therefore, an engine burning methyl alcohol would produce the most power. It also is possible to take advantage of the higher octane ratings of methyl (and ethyl) alcohol and increase the engine compression ratio. Increases in compression ratio increase the efficiency of converting the potential combustion energy to power. Finally, alcohols burn more completely, thus increasing combustion efficiency.

***B. Ethanol:*** This can be produced from biomass such as potatoes, cereals, beets, sugar cane, wood, brewery waste and many other agricultural products and food wastes in the process of fermentation, and is called bio ethanol; it can also be produced from natural gas and crude oil. Ethanol is not considered toxic; it is soluble in water and is biodegradable. It is more flammable than gasoline. Neat ethanol is rarely used as a fuel. Usually it is mixed with gasoline as an oxygenate to meet clean fuel requirements. For many years a 10 per cent ethanol mixture with gasoline, called 'gasohol' or E10, has been used in the United States. Bio ethanol (made from sugar cane) is the primary fuel in Brazil. Because ethanol contains approximately 60 per cent of the energy content of gasoline, it takes more ethanol to get the same mileage as a similar gasoline vehicle. With current technology and price structures, ethanol is more expensive than gasoline. Ethanol does not mix well with gasoline and diesel fuel. Ethanol is a low cost oxygenate with high oxygen content (35%) that has been used in ethanol diesel fuel blends. The use of ethanol in diesel fuel can yield significant reduction of particular matter (PM) emissions for motor vehicle. However, there are many technical barriers to the direct use of ethanol in diesel fuel due to the properties of ethanol, including low cetane number of ethanol and poor solubility of ethanol in diesel fuel in cold weather. In fact, diesel engines cannot operate normally on ethanol-diesel blend without special additives. The main properties of methanol and ethanol in comparison with diesel are given in Table 1.

## IV. COMBUSTION CHARACTERISTICS

There are some important differences in the combustion characteristics of alcohols and hydrocarbons. Alcohols have higher flame speeds and extended flammability limits. Also, alcohols produce a great number of product moles per mole of fuel burnt, therefore, higher pressure are achieved. The alcohols mix in all proportions with water due to the polar nature of OH group. Low volatility is indicated by high boiling point and high flash point. Alcohols burn with no luminous flame and produce almost no soot, especially methanol. The tendency to soot increases with molecular weight. Therefore, methanol produces less soot than ethanol. Combustion of alcohol in the presence of air can be initiated by an intensive source of localized energy, such as a flame or a spark and also, the mixture can be ignited by application of energy by means of heat and pressure, such as happens in the compression stroke of a piston engine. The energy of the mixture reaches a level sufficient for ignition to take place after a brief period of delay called ignition delay, or induction time, between the sudden heating of the mixture and the onset of ignition (formation of a flame front which propagates at high speed throughout the whole mixture). The high latent heat of vaporization of alcohols cools the air entering the combustion chamber of the engine, thereby increasing the air density and mass flow. This leads to increased volumetric efficiency and reduced compression temperatures [24-29]. Together with the low level of combustion temperature, these effects also improve the thermal efficiency by 10%. The higher flame speed, giving earlier energy release in the power stroke, results in a power increase of 11% at normal conditions and up to 20% at the higher levels of a compression ratio (14:1). Blending ethanol with gasoline at 0.1%, the power rises to about 0.1%. Power continues to rise steadily as the mixture is enriched to an equivalence ratio of about 1:4. Because of the low proportion of carbon in alcohols, soot formation does not occur and therefore alcohols burn with low luminosity and therefore low radiation. In conjunction with lower flame temperature, about 10% less heat is lost to the engine coolant. The lower flame temperature of alcohols results in much lower NOx (Nitrogen Oxides) emissions. The wider flammability limits of alcohols permit smooth engine operation even at very lean mixtures. But aldehyde emissions are noticeably higher. For ethanol, emissions are acetaldehydes and for methanol, emissions are of formaldehydes. Increasing compression ratio from 9 to 14, aldehyde emissions can be reduced by 50%, to level compared to that for gasoline. An addition of 10% water reduces aldehyde emissions by 40% and NOx by 50%. Addition of 10% water in the alcohol can be tolerated without loss of thermal efficiency. The oxygen content of alcohols depresses the heating value of the fuel in comparison with hydrocarbon fuels. The heat of combustion per unit volume of alcohol is approximately half that of isooctane. However, the stoichiometric fuel-air mass ratios are such big that the quantity of energy content based on unit mass of stoichiometric mixture become comparable with that of hydrocarbons. Methanol is not miscible with hydrocarbons and separation ensues readily in the presence of small quantities of water, particularly with reduction in temperature. Anhydrous ethanol, on the other hand, is completely miscible in all proportions with gasoline, although separation may be effected by water addition or by cooling. If water is already present, the water tolerance is higher for ethanol than for methanol, and can be improved by the addition of higher alcohols, such as butanol. Also benzene or Acetone can be used. The high heat of vaporization and constant boiling point make cold starting very difficult with neat alcohols. The problem is not as severe as in case of alcohols blended with gasoline. Ethanol has a constant boiling point of 80 ° C (78.8° C). Gasoline which has a high vapour pressure (therefore highly volatile) can be used for cold start. Gasoline or petrol is a light, volatile mixture of hydrocarbons for use in internal combustion engines and as an organic solvent.

The amount of energy released is dependent on the oxidation state of the carbons in the hydrocarbon which is related to the H/C ratio. The more hydrogen per carbon the lower the oxidation state results in more energy that will be released during the oxidation reaction, thus the greater the H/C ratio and better energy release on combustion. Ethanol generally has H/C ratio nearly 3 promotes an improved combustion, and even the blends of ethanol-diesel may have similar effects.

## V. ENGINE RESPONSE TO ALCOHOL

The mass caloric value, or the energy available per unit of mass of the fuel in a liquid state, is the most important characteristic of a fuel. There are some figures: Gasoline =43961 KJ/kg, Ethanol= 26795 KJ/kg, Hydrated ethanol (5% water) =25120 KJ/kg, Hydrated methanol (5% water) =19678 KJ/kg. Another important property is the heat of combustion, or the energy available per unit of volume of a mixture chemically correct (stoichiometric) of a fuel and air: Gasoline=3600 KJ/kg, Ethanol=3412 KJ/kg, Methanol=3181 KJ/kg. The engine power is proportional to the heat of combustion (or the energy content of the gases inside of the cylinder). Note, there is not much difference between various liquid fuels. The fuel consumption is inversely proportional to the caloric value. This characteristic alone would lead to a consumption 64% bigger than gasoline (75% for hydrated ethanol): Ethanol (anhydrous): petrol/ethanol=43961/26795=1.64 therefore, 64% increase; Hydrated ethanol: 43961/25120=1.75 therefore, 75% increase Methanol: 43961/19678=2.23 therefore, 123% increase. Other properties, however, are favorable to the increase of power and reduction of fuel consumption. Such properties are as follows: 1).Number of molecules or products is more than that of reactants; 2).Extended limits of flammability; 3).High octane number; 4).High latent heat of vaporization; 5).Constant boiling temperature; 6).High density. The increase of the number of molecules during combustion implies in a higher pressure inside the cylinder, regardless of the effects of combustion itself [24-29].

## VI. CETANE NUMBER AND CETANE IMPROVING ADDITIVE

For a fuel to burn in a diesel engine, it must have a high cetane number or ability to self-ignite at high temperatures and pressures. There exists a significant difference among gasoline, diesel and alcohol in terms of cetane number and auto ignition. A high cetane number leads to a short ignition delay period, whereas a low cetane number results in a long ignition delay period. From Table 1, it can be seen that alcohols have lower cetane number than that of diesel, which is not desired when diesel engines are converted to alcohol. Fortunately, some additives, an example of which is nitrate glycol, can increase the cetane number of alcohols. This means that ignition delay period will become short, which will reduce tendency to cause a diesel knock. However, too short ignition delay period will cause a lower rate of heat release which is not wanted.

## VII. ALCOHOL-DIESEL EMULSIONS

Because alcohols have limited solubility in diesel, stable emulsion must be formed that will allow it to be injected before separation occurs. Hydro shear emulsification unit can be used to produce emulsions of diesel-alcohol. However, the emulsion can only remain stable for 45 seconds. And, 12% alcohol (energy basis) is the maximum percentage. In addition, this kind of method has several problems which are as follows: 1).Specific fuel consumption at low speed increases; 2).High cost; 3).Instability. Therefore, other methods are developed [24-29].

## VIII. HEATED SURFACES

Alcohol can ignite with hot surfaces. For this reason, glow-plugs can be utilized as a source of ignition for alcohol. In this system, specific fuel consumption depends on glow-plug positions and temperatures. It must be noted that the temperature of glow-plugs must vary with load. However, the glow-plug becomes inefficient at a high load. In addition, the specific fuel consumption is higher than that of diesel.

### *A. Viscosity*

High viscosity means incomplete burning, severe accumulation of carbon and dirty lubricant. From the Table1 it can be seen that alcohols have lower viscosity than diesel

### *B. Octane number*

Octane number is an index of quality that shows the ability of fuel to resist explosion and burn evenly when subjected to high pressures and temperatures inside the engine and therefore reduces knocking. (Abnormal combustion in the cylinder) Addition of tetra methyl lead and tetra ethyl lead raises the octane numbers, but is prohibited in some countries because the exhaust contains dangerous emissions containing lead.

### *C. Molecular weight*

Alcohols have lower molecular weight than diesel. Alcohols burn producing almost no soot. The tendency of an alcohol to soot formation increases with molecular weight. Methanol has lower molecular weight than ethanol. Therefore less soot is produce by burning methanol.

## IX.DISADVANTAGES OF ALCOHOLS

The disadvantages of the alcohol fuels can be summarized as follows: the economics of production of alcohols may play a role for use as an alternative fuels in Internal Combustion Engine Unless the cost of alcohol production from renewable resources is made cost-effective, there will be no demand for it. These alcohols could be produced from biomass, coal, and natural gas. The second disadvantages of alcohol is associated with the flammability, Flame visibility of alcohol is difficult to be detected, which might be hazardous. The lack of visibility is due to the small number of carbon atoms present in the alcohol. Since there is very little carbon, there is no soot formation to give the flame color. Cold stat abilities problem is yet another disadvantage Due to their low vapor pressure, high latent heat of vaporization, and single boiling point, alcohols, especially ethanol, have difficulty meeting industry standards for starting in cold weather. The last two of these disadvantages, however, can easily be solved. By the addition of a small amount of gasoline to the alcohol mixture, a more visible flame will be produced and the effect of cold weather on engine startablity can be brought well within the industry standards. Although these alcohols, when used near their stoichiometric air-fuel ratios, produce more power, a larger quantity of fuel is required to produce a specified power output. For example, in an automobile, more fuel is required for each mile driven [31]. Since the price of alcohol and conventional fuels both fluctuate, miles per rupee should be an important factor in which fuel type or blend percentage to use. Using alcohol or gasoline-alcohol blends generally reduces fuel economy (miles per gallon), but if the alcohol is cheaper, the economics (miles per dollar) may still be favourable. The relatively low boiling points and high vapor pressures of methyl and ethyl alcohol indicate that vapor lock could be a serious problem, particularly at high altitudes on warm summer days. Vapor lock occurs when the liquid fuel changes state to a gas while still in the fuel delivery system. Vapor lock can cause reduce engine power or stalling. Butyl alcohol, because of its low vapor pressure, is the least likely of the alcohols to cause vapor lock. The relatively high latent heats of methyl and ethyl alcohol cause problems in mixing these alcohols with air and transporting them through the intake manifold of the engine. Heating the intake manifold may be necessary in cold weather or before the engine reaches operating temperatures. Without external heat to more completely vaporize the fuel, the engine may be difficult to start and sluggish for a considerable time after starting. Butyl alcohol is the least likely to cause starting difficulties or problems during warm-up. Note that its latent heat is almost the same as the latent heat of octane.

## X. ADVANTAGES OF ALCOHOLS

Although there are a few minor disadvantages to the use of alcohol fuels, the advantages more than outweigh its easily solvable problems. The advantages are as follows: Methanol can be made out of organic material such as biomass and municipal waste. In the long-term, it could even be made out of coal. The United States has 25% of the worlds' supply of coal, which will be abundant for years to come. Alcohol combustion produces higher combustion pressures inside the combustion chamber of the ICE due to the higher molar products to reactants ratio, compared to gasoline, which improves power output and thermal efficiency. Alcohols have a higher average octane rating {(RON+MON)/2=104} compared to gasoline. Increasing the compression ratio of the engine to 12: 1 or higher increases power and fuel efficiency by 20% and 15% respectively. Alcohols have better combustion characteristics and performance due to the increased volumetric efficiency of alcohol fuels, which is why methanol is a preferred racing fuel. Acceleration time decreases with power increase. In case of fire, alcohols have higher visibility for escape-rescue, low asphyxiation, produce cool flame and low heat output which causes low bums, low smoke damage, and residue is easily washed away, and are extinguishable with water and more readily by powders and foams. In case of leaks and spillages, alcohols are miscible in water and could be washed out with water for quick and easy removal. They are easily metabolized if absorbed by the ground. Alcohol fuels have a lower evaporative emission. Not as many harmful by products will be released into the atmosphere by using alcohol fuels. Since the carbon content in alcohol fuels is very small, a negligible amount of soot is formed and released to the atmosphere when burned in the ICE [31]. Alcohol fuels are liquids, which make them accessible using the same means of transportation and handling infrastructure of the conventional fuels with minor modifications.

## XI.SAFETY ASPECTS OF ALCOHOLS

Since methanol vapour is heavier than air, it will linger close to the ground or in a pit unless there is good ventilation, and if the concentration of methanol is above 6.7% in air it can be lit by a spark, and will explode above 54 F / 12 C. Once ablaze, the flames give out very little light making it very hard to see the fire or even estimate its size, especially in bright daylight. If you are unlucky enough to be exposed to the poisonous substance through your respiratory system, its pungent odor should give you some warning of its presence. However, it is difficult to smell methanol in the air at less than 2,000 ppm (0.2%), and it can be dangerous at lower concentrations than that [3].

## XII. TOXICITY

Methanol is poisonous; ingestion of only 10 ml can cause blindness and 60-100 ml can be fatal, and it doesn't have to be swallowed to be dangerous since the liquid can be absorbed through the skin, and the vapors through the lungs. US maximum allowed exposure in air (40 h/week) is 1900 mg/m³ for ethanol, 900 mg/m³ for gasoline, and 1260 mg/m³ for methanol. However, it is less volatile than gasoline, and therefore decreases evaporative emissions. Use of methanol, like ethanol, significantly reduces the emissions of certain hydrocarbon-related toxins such as benzene and butadiene. But as gasoline and ethanol are already quite toxic, safety protocol is the same [3].

## XIII. CONCLUSIONS

*A.* Alcohols burn more completely than petroleum based fuels thereby increases the combustion efficiency. The mixing of alcohol with gasoline produces gasohol. Similarly alcohols can also be blended with diesel fuels to produce diesohol. Mixing alcohol with gasoline tends to increase the octane rating and reduce carbon monoxide and other tail pipe emissions. The octane number of a fuel indicates its resistance to knock (Abnormal combustion in the cylinder).

*B.* Methyl alcohol has lowest combustion energy and the lowest stoichiometric air fuel ratio. Because of the low stoichiometric air fuel ratio only a small quantity of methyl alcohol mixed with gasoline without affecting the performance. Another advantage of alcohols is that alcohols can also be produced from renewable sources.

*C.* Alcohols have the higher octane rating. This means engine compression ratio can also be increase. An increase in the compression ratio of an engine increases the efficiency of converting the potential combustion energy to power.

*D.* All the alcohols are soluble in water, but butyl alcohol is relative in soluble compare to methyl and ethyl alcohols. The engine power is produced low as the water content of alcohol increases. The vapour lock, fuel mixing, and starting problems increase with water.

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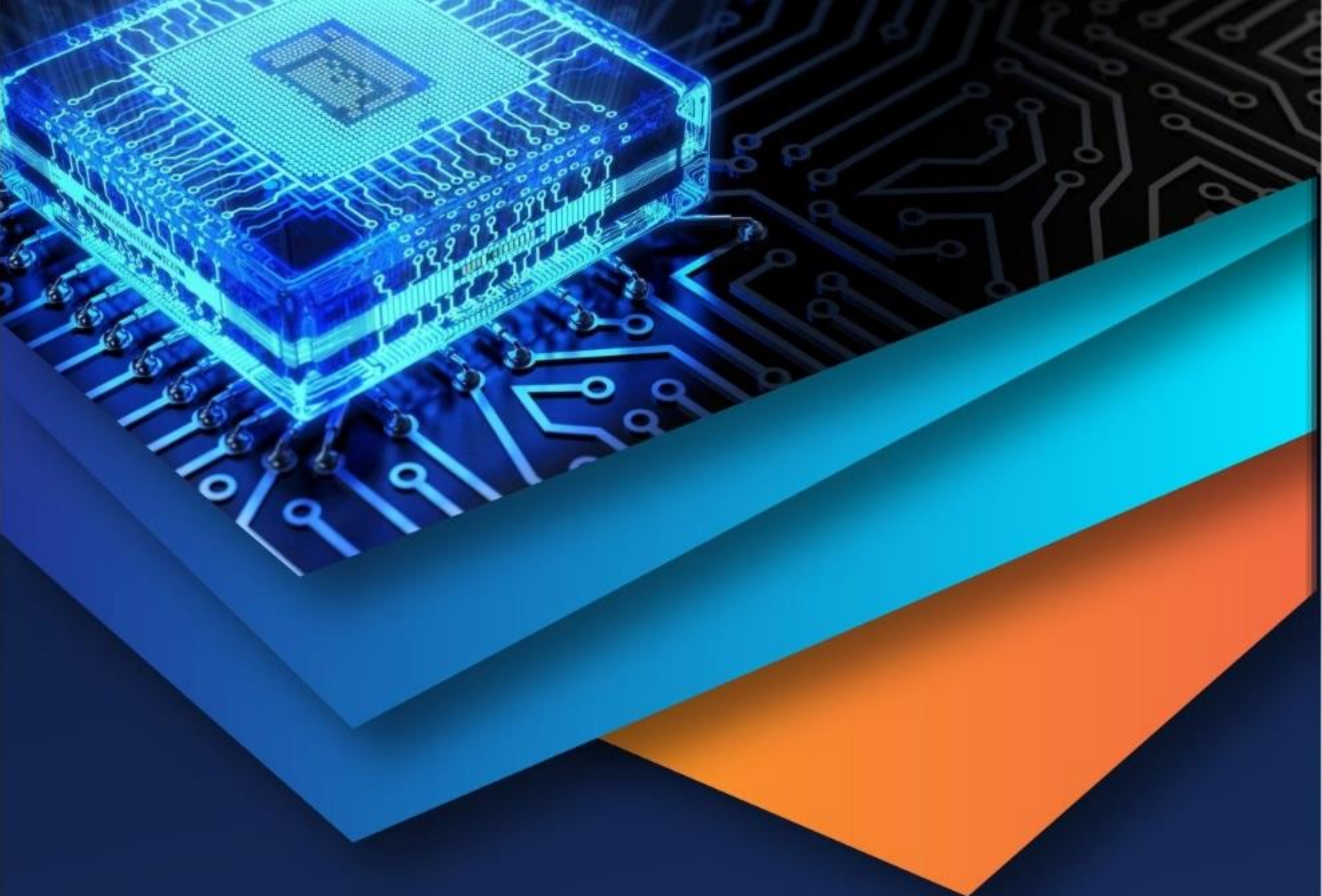

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