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INVESTIGATION OF QUALITY IN REDISTILLED DIESEL FUEL

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ABSTRACT

Generally, the ignition quality of diesel fuel is quantified by the Cetane number. Cetane number of diesel fuel is a measure of the fuel's delay of ignition time. Delay time is the amount of time between the injection of fuel into the combustion chamber and the actual start of combustion of the fuel charge. A parameter called Calculated Cetane Index (CCI) based on the distillation curve of diesel fuel is widely used in the diesel fuel operated automobiles. The CCI gives reasonable assessment of the cetane number. In this research, diesel fuel was re-distilled and mixed with super diesel according to knowing fraction. Then find the cetane index and that given higher value than existing cetane number of diesel. Again diesel mixed with gasoline and finds the cetane index. Compare the all cetane values of samples individually. An attempt was made in this exercise to assess the influence of redistilled diesel fuel quality on exhaust emissions. The emission concentration and the noise level were compared with the re-distilled diesel fuel with ordinary diesel fuel. It was revealed that the soot emission concentration is low, when the engine is running on re-distilled diesel fuel.

Keywords: Cetane Number, Calculated Cetane Index (CCI), Re-distilled Diesel Fuel

1. INTRODUCTION

Diesel is a very important automobile fuel used in heavy and light vehicles. Diesel is produced from petroleum (hydrocarbon mixture) by using the fractional distillation of crude oil between 200 °C and 400 °C at atmospheric pressure after distillation on gasoline and kerosene features of diesel fuel. The density of petroleum diesel is about 0.85 kg/l whereas gasoline has a density of about 0.72kg/l, about 15% less. When burnt, diesel typically release about 38.6MJ/l, whereas gasoline released 34.9 MJ/l, about 11% less. Petroleum-derived diesel is composed of about 75% saturated hydrocarbons (primarily paraffins including n-, iso-, and cycloparaffins), and 25% aromatic hydrocarbons (including naphthalenes and alkylbenzenes). The average chemical formula for common diesel fuel is $C_{12}H_{23}$, ranging from approximately $C_{10}H_{20}$ to $C_{15}H_{28}$.

In the spark ignition engine the fuel and the air are supplied pre-mixed to the cylinder. But in a diesel engine the fuel is not injected into the air until shortly before top dead center (TDC). Consequently, there is considerably less time for completion of the mixing and evaporation processes. Furthermore, the diesel engine is controlled by regulating the quantity of fuel injected per induction stroke. Because diesel engine having no throttle valve. The fact that ignition cannot occur until the temperature generated by compression is high enough to operate them. Therefore, it becomes obvious that fuel quality is even more important for the diesel fuel than the spark ignition engine.

Generally, the ignition quality of diesel fuelmainly depends on the quality of diesel fuel. But the quality of diesel depends on the cetane number. Cetane number of diesel fuel is a measure of the fuel's delay of ignition time. Delay time is the amount of time between the injection of fuel into the combustion chamber and the actual start of combustion of the fuel charge. The aim of the project is to assess the influence of redistilled diesel fuel quality on exhaust emissions. It is known that diesel fuel and other hydrocarbon fuels are received from crude oil after fractional distillation process. Hence the term "redistilled diesel fuel" for this new distilled diesel fuel will be used.

Cetane number is defined as the percentage of *n*-cetane + 0.15times the percentage of heptamethylnonane contents of the blend of reference fuel having the same ignition quality as the fuel under test. Ignition quality is determined by varying the compression ratio to give the same ignition delay period for the test fuel and two blends of reference fuels. The cetane index is calculated from API (American Petroleum Institution) gravity and volatility.

But this value originally was taken as represented by its mid-volatility, or mid-boiling point (50% recovery temperature, *T*50).Then cetane number is very important in explain of diesel engine performance, which is similar to the octane number rated ignition stability of gasoline engine.

2. LITERATURE SURVEY

Distillation is an important commercial process that is used in the purification of a large variety of materials. The process of heating a substance until it is vaporized, cooling the vapors, and collecting the condensed liquid is the base of a commonly used purification technique called distillation. The process by which a substance is transformed from the condense phase to the gas phase. For liquid, this process is called vaporization and for solid it is called sublimation. Both processes require heat to change their phases. Both vaporization and sublimation are process that can be used to purify compounds. Also determination of vapor pressure and boiling point is very important for distillation.

There are three main distillation processes available in industry and laboratory situations. Distillation processes are specified according to their distillation substance and distillation temperature ranges.

- Simple Distillation
- Vacuum Distillation
- Fractional Distillation

Therefore simple distillation process will be used for distillation of diesel fuel. Simple distillation method is used to distillate low and some special boiling point liquids, as such as water and some hydrocarbons. It has low boiling point. Boiling point is the very important property of any liquid for distillation. Simple distillation process consists of the thermometer, the distillation head distillation flask, heat element and the arrangement of the flow of the cooling water (condenser).

Gasoline and diesel engines are a major source of the urban air pollution. The exhaust gases from these engines contain oxides of nitrogen (nitric dxide –NO, and nitrogen dioxide-NO_2, collectively known as NO_x), carbon monoxide (CO) and organic compounds, which are un-burnt or partially burnt hydrocarbon (C_xH_y).

The emission of hydrocarbons from a diesel engine is at a significant level though it is lower than the emission of hydrocarbon from a typical gasoline engine. Diesel engines convert the chemical energy contained in the fuel into mechanical energy. Diesel fuel is injected under pressure into the engine cylinder where it mixes with air and where the combustion occurs. The exhaust gases which are discharged from the engine contain several constituents that are harmful to human health and to the environment. Following table given typical output emissions of the basic toxic material in diesel fuel.

The lower values can be found in new, clean diesel engines, while the higher values are characteristic of older diesel engines. Soot and noise are other main emission characteristics of the diesel fuel. The soot mainly depends on the cetane number and other various factors.

Table 1: Emissions of Diesel fuel

Emission type	**CO**	**HC**	**DPM**	**NOx**	**SO_2**
Unit	ppm	ppm	g/m^3	ppm	ppm
Quantity	5-1,500	20-400	0.1-0.25	50-2,500	10-150

DPM- Diesel Particulate Matter

Cetane Index

Cetane index is a calculated quantity that is intended to approximate the cetane number. There are two methods of computing the cetane index and it represented by equation 1, 2.

<u>Method - 01</u>

Equation 01

$$Cetane\ Index = 454.74 - 1641.416D + 774.74D^2 - 0.554\,T50 + 97.603\,[log_{10}(T50)]^2$$

Where,

D – Fuel density at 150 ◦C

T50 – The temperature corresponding to the 50% point on the distillation curve in degree celsius

<u>Method – 02</u>

Equation 02

$$Cetane\ Index = 45.2 + 0.0892(T10N) + 0.131(T50N) + 0.0523(T90) + 0.901B(T50N) - 0.420B(T90N) + 4.9 \times 10^{-4}(T10)^2 - 4.9 \times 10^{-4}(T90)^2 + 107B + 6B^2$$

Where,

T10N=T10-215

T50N=T50-260

T90N=T90-310

When T10, T50 and T90 are temperatures at 10%, 50%, and 90% volume distilled in degree celsius

$$B = \{\exp(-3.5DN)] - 1$$

When DN = density at 150 ◦C (kg/l) – 0.85

3. OBJECTIVES

A parameter called Calculated Cetane Index (CCI) based on the distillation curve of diesel fuel is used in the automobile industry. The CCI gives a reasonable assessment of the Cetane number. In this research going to measure CCI in re-distilled and remixed diesel fuel.

In this project, an attempt will be made to assess the influence of redistilled diesel fuel quality on exhaust emissions. The emission concentration and the noise level were compared for the re-distilled diesel fuel with ordinary auto diesel. This study will be conducted as a screening analysis to determine cetane number of redistilled diesel fuel, which was mixing same quantity in all fractions (10% to 90%) and could have an impact on the engine performance and emission in diesel vehicle.

This research will be developing emission free diesel fuel by using the ordinary diesel fuel with distillation method. This will be introduced proper diesel fuel and emissions identification method, which was mainly concern about soot content in redistilled diesel fuel. Finally, I will be comparing the noise level of the distilled diesel fuel and ordinary diesel fuel by using diesel engine.

4. METHODOLOGY

The apparatus of the system was arranged as indicated in following figure 1. A 200ml of normal diesel and boiling chips were put in to a 250 ml distillation flask and distillation was started. Boiling chips are used to accelerate vaporization.

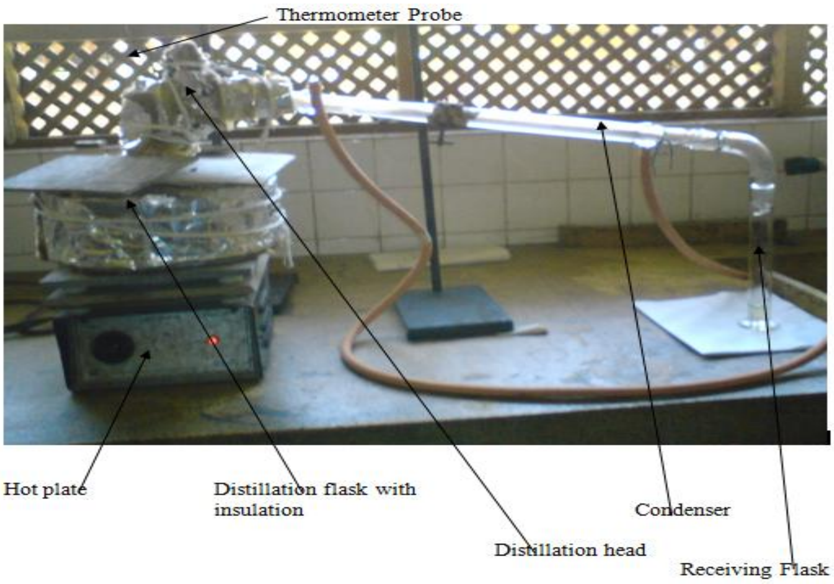

Figure 1: Complete Experimental Distillation System

Distillation head and insulating cup (around the distillation flask) were fully insulated for reduce heat dissipation to the environment. The distillation flask was dipped into the sand bath which is shown in figure 1.Temperature of distillation flask was measured by a thermometer, when the first drop fallen into the receiving flask.

Thermometer Specifications

Digital thermocouple thermometer, working range -250 °C to 400 ° C

Accuracy of thermometer

Below -238 ^{o}F (-150 ^{o} C)

+ or – 0.25%

Above -238 ^{o}F (-150 ^{o} C)

+ or – 0.1%

After that, inside temperature of the distillation flask was measured, when the receiving flask was filled with 20ml of distilled diesel. That was 10% of the initial diesel quantity in receiving flask. Then take the average of both temperature values as a distillation temperature. Continue the same procedure until finishing diesel amount inside the distillation flask. The distilled diesels mixed with gasoline and super diesel and continue same procedure. Then again temperature was measured and samples were collected according to separate fractions. Analysis of Distillation curve with temperature in redistilled diesel, diesel mixed with gasoline and super diesel. Investigate the effect of exhaust emission each diesel categories. The noise level for each fuel categories was analyzed. The performance of vehicle was investigated with each fuel categories.

5. OBSERVATION

Total observation summery

Table 2: Experimental Data in Diesel, Super Diesel and mixture of Diesel & Gasoline

Fuel Type	Test No	Fraction (%)										
		0	10	20	30	40	50	60	70	80	90	100
Normal Diesel	1	163	259	274	291	301	316	330	348			
	2	170	265	284	301	311	330	348				
	3	208	251	270	285	299	316	328	346	370		
	4	173	264	279	293	307	323	341				
	5	175	262	283	296	310	320	330				
	6	198	274	291	304	317	329	345	366	390		
	7	190	265	287	302	313	327	345	366	389		
	8	190	270	290	301	315	325	338	356	376	397	
Super Diesel	1	184	223	251	272	289	304	320	335	354	376	
	2	163	221	253	268	286	303	320	340	358	380	
Diesel mix with Gasoline	1	183	255	273	296	305	315	325	339	355	372	395

2. Soot analysis

This is the main part of my project, which is the analysis the soot of diesel engine.

Specification of Vehicle:

Model = Mazda T3500, Canter, four-cylinder, overhead-valve engine, Inline Pump

Manufacturing year = 1990

Cylinder Bore = 100 mm

Cylinder Stroke = 110 mm

Engine Power = 66.2 kW

Rated Speed = 2000 rpm

Maximum Torque =227Nm

Fuel type =Diesel (Naturally aspirated)

Specification of noise Meter

Frequency range = 20Hz – 8 kHz

Measuring Level =30dB – 130dB

Operating Temperature = 0 ^{o}C – 40 ^{o}C

Accuracy = + or – 1.5 dB

According to standard specification of diesel soot [10]

Maximum K value 2.50 m^{-1}

K: - Index of absorption (density) of smoke (m^{-1})

Normal diesel

Table 3: K values of ordinary diesel in Step 01

min^{-1}	rpm	s	K max (m^{-1})
690	3640	0.9	3.88
700	3640	0.7	5.76
700	3700	1.0	3.67

Maximum Deviation = 2.09 m^{-1}Mean Value = 4.44 m^{-1}

Table 4: K values of ordinary diesel in Step 02

min^{-1}	rpm	s	K max (m^{-1})
690	3670	0.8	3.93
690	3670	0.8	2.94
700	3710	0.9	3.29

Maximum Deviation = 0.99 m^{-1}

Mean Value = 3.38 m^{-1}

Distillation diesel

Table 5: K values of re-distilled diesel in Step 01

min^{-1}	rpm	s	K max (m^{-1})
650	3320	0.7	1.32
660	3460	0.8	3.14
670	3310	0.8	1.53

Maximum Deviation = 1.61 m^{-1}

Mean Value = 1.99 m^{-1}

Table 6:K values of re-distilled diesel in Step 02

min^{-1}	rpm	s	K max (m^{-1})
650	3450	0.8	2.17
650	3380	0.8	2.29
650	3440	1.0	2.09

Maximum Deviation = 0.20 m^{-1}

Mean Value = 2.18 m^{-1}

3. Noise Analysis

Noise of the enginewas measured by using noise meter that located in four side of the engine.

Normal diesel fue

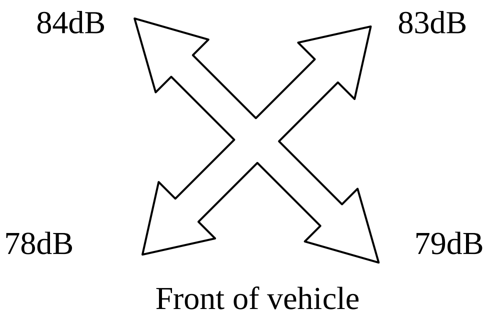

Figure 1: Noise level of normal diesel

Distillation diesel fuel

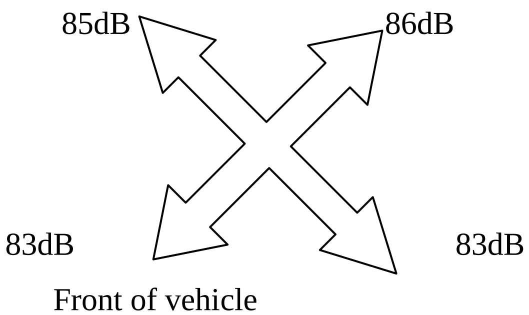

Figure 2: Noise level of distillation diesel

6. CALCULATIONS

Following equation is used for calculate cetane index in each samples. This equation was developed in MS excel platform according to theory.

Equation - 01									
CI	454.74	1641.415	0.853	774.74	0.554	97.803	319		2.50379
							54.719		
Equation - 02									
CI	45.2	0.0892	0.131	0.0523	0.0901	0.42	0.00049	107	60
						-0.0129			
T10N	255	215	40	1600					
T50N	319	260	59						**57.43**
T90N	384	310	74	5476					

Figure 3: MS excel based mathematical equationwith sample calculation

7. RESULTS

Summary of Calculation

Table 7: Summary of Cetane Index Values

Sample / Method	1	2	3	4	5	6	7	8	SD 9	SD 10	Average
CI -1	54.0	55.6	54.0	55.0	54.7	55.7	55.3	54.9	52.4	52.7	**54.7**
CI - 2	57.6	60.1	56.5	59.1	58.4	61.3	59.8	59.9	51.9	51.6	**57.4**

CI – Cetane Index calculated method 1and 2

SD – Super Diesel

Table 07 is shown in calculated values of cetane index for each sample. There are the maximum values in data range. Therefore I selected data range is 10% to 90%. Now we can tabulate the data for average value of the temperatures and fractions. Then drawn graphs by using tabulated data for various samples. Therefore select the sample 03 and sample 08 for draw the graphs.

Cetane index values are calculated for various fraction ranges, which are 10% to 50%, 20% to 70%, 10% to 90% etc. Since, from 10% to 90% fraction range were given most optimal or maximum values for cetane index. There for, it is the most suitable fraction of this experiment.

Table 08 : Temperatures for Average Diesel Fuel, Average Super Diesel and mixture of diesel & gasoline samples according to fraction

Fraction %	**Temperatures (Average normal diesel sample)**	**Temperatures (Super diesel sample)**	**Temperatures (Mixture of normal diesel and Gasoline)**
0	181	174	183
10	255	222	255
20	276	252	273
30	291	270	296
40	305	288	305
50	319	304	315
60	335	320	325
70	351	338	339
80	373	356	355
90	384	378	372
100	Not accepted	Not accepted	395

Table 08 is shown in temperatures with fraction in normal diesel, super diesel and mixture of normal diesel and super diesel samples. Then plot the distillation curves for each sample and analysis boiling ranges in these curves.

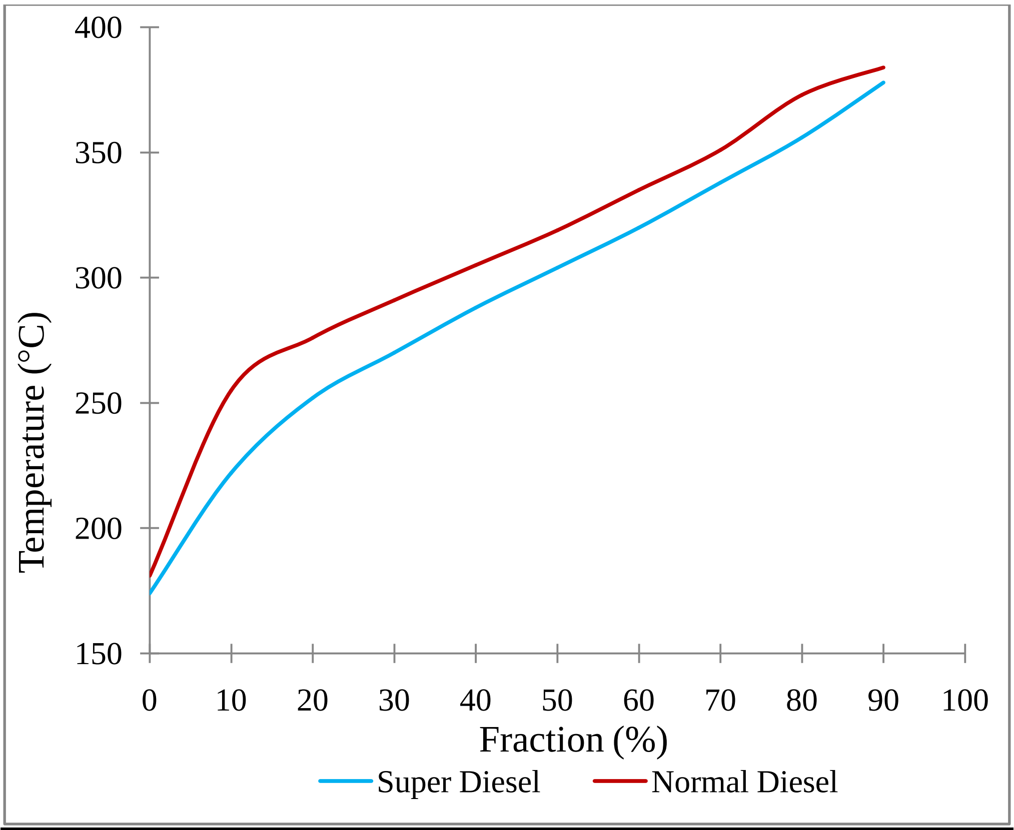

Figure 4 Distillation curves for Normal diesel and super diesel

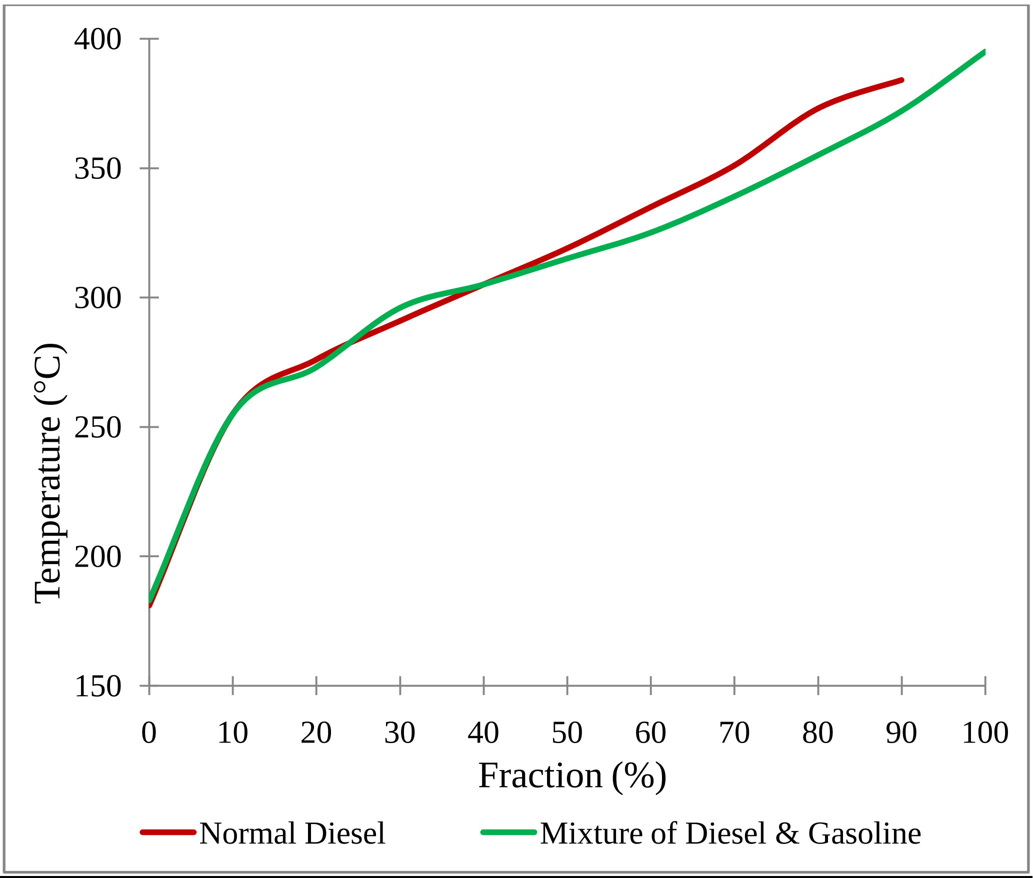

Figure 5 Distillation curves for Normal diesel and mixture of diesel & gasoline

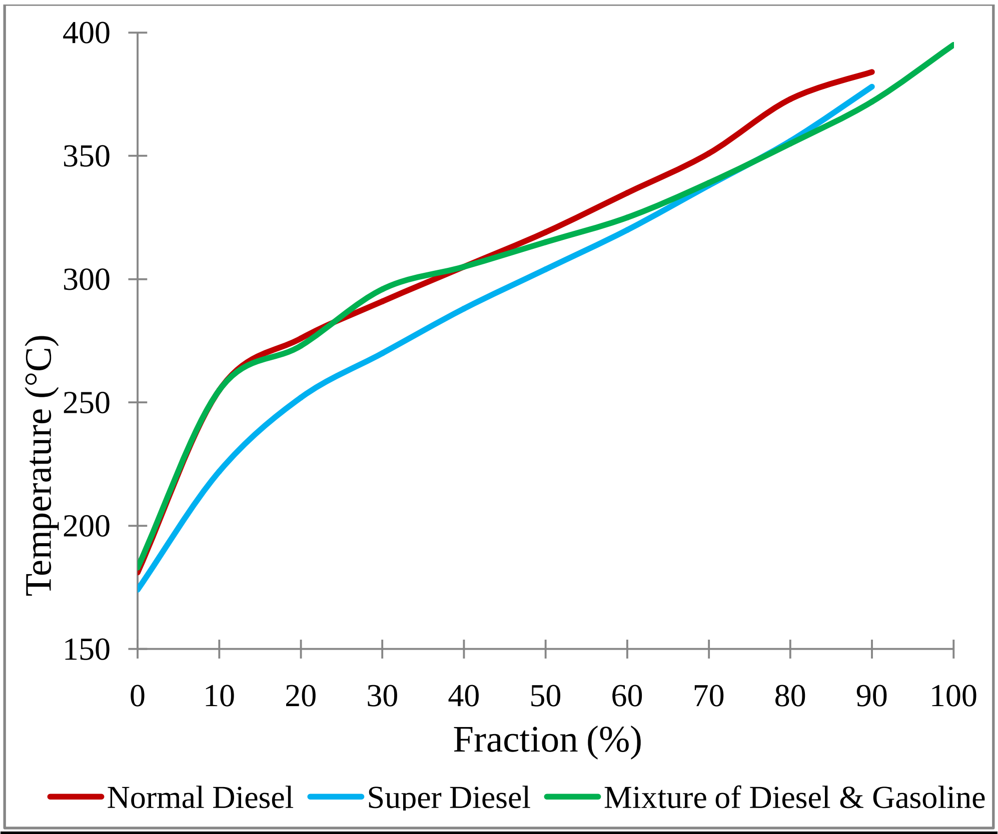

Figure 6 Distillation curves for ordinary diesel, super diesel and mixture of diesel & gasoline

8. CONCLUSION

In the spark ignition engine the fuel and air are supplied pre-mixed to the cylinder. But in diesel engine the fuel is not injected into the air until shortly before TDC. Consequently, there is considerably less time for completion of the mixing processes. Furthermore, the diesel engine, having no throttle, is controlled by regulating the quantity of fuel injected per induction stroke. Add to this the fact that ignition cannot occur until the temperature generated by compression is high enough, and it becomes obvious that fuel quality is even more important for the diesel than the spark ignition engine.

Since diesel fuel contains hydrocarbons with a higher boiling point, hence with higher molecular weight, some pyrolysis already occurs when the fuel is atomized. This contributes to the grater complexity of the unburnt and partially burnt hydrocarbons found in diesel exhausts and which cover a wider spectrum of molecular compositions. Moreover, most of the heavier hydrocarbons are absorbed on the soot particles in the form of soluble organic factions.

Then most familiar emission from a diesel engine is the characteristic smoke or soot particles produced when the vehicle operates under load. The smoke or soot is comprised of solid particles and liquid droplets generated by poor combustion of the fuel. In following parameters are effects to the diesel emissions. There are viscosity, density and distillation interval, cetane number (indirectly aromatics contents), sulfur content, additives etc.

In addition, the properties of manufactured diesel fuels are generally closely inter-correlated. Efforts made to totally separate the aromatics, cetane, sulfur content and distilled points are not always successful.

With increasing kinematic viscosity, smoke and unburnt HC emissions increase and NO_x emissions decrease. The kinematic viscosity has little influence on the soluble organic fraction, but dry soot increases with an increase in kinematic viscosity. Also the higher density of diesel fuel results in greater particulate emissions.

Fuel densities above the engine calibration range produce an over fueling effect and a sharp increase in emissions. This effect has been observed on the atmospheric or turbo-charged direct injection engine.

The distillation intervals also affect particulate emissions. In this project that is the 80% distilled point must be under 370 ^{0}C and the 65% distilled point above 330 ^{0}C. In that change from a fuel with a 90% distilled at 374 ^{0}C to a fuel at 384 ^{0}C does not change the gaseous emissions but increases particulate emissions by about 12 to 50% depending on the cetane number.

The aromatics content of diesel fuel directly affects the cetane number. The two parameters are antagonistic. Only the addition of procetane additives helps to break the relationship. Unburnt hydrocarbons, particles, and the extractable soluble organic fractions increase with the aromatics content. Increasing the aromatics content of the fuel from 25 to 45% could cause a threefold increase in CO and HC emissions. NO_x is relatively unaffected. On a light duty engine, transient operation enhances the influence of fuel characteristics on pollutants. CO, HC and particulate emissions increase with the aromatic content. However for an engine already displaying low emissions and for fuels with a cetane number higher than 50, the effect of fuel quality on pollutants is not pronounced.

The lengthening of the ignition delay caused by a drop in the cetane number leads to increased emissions of unburnt hydrocarbons, particulates and CO, but decreased emissions of smoke and dry soot.

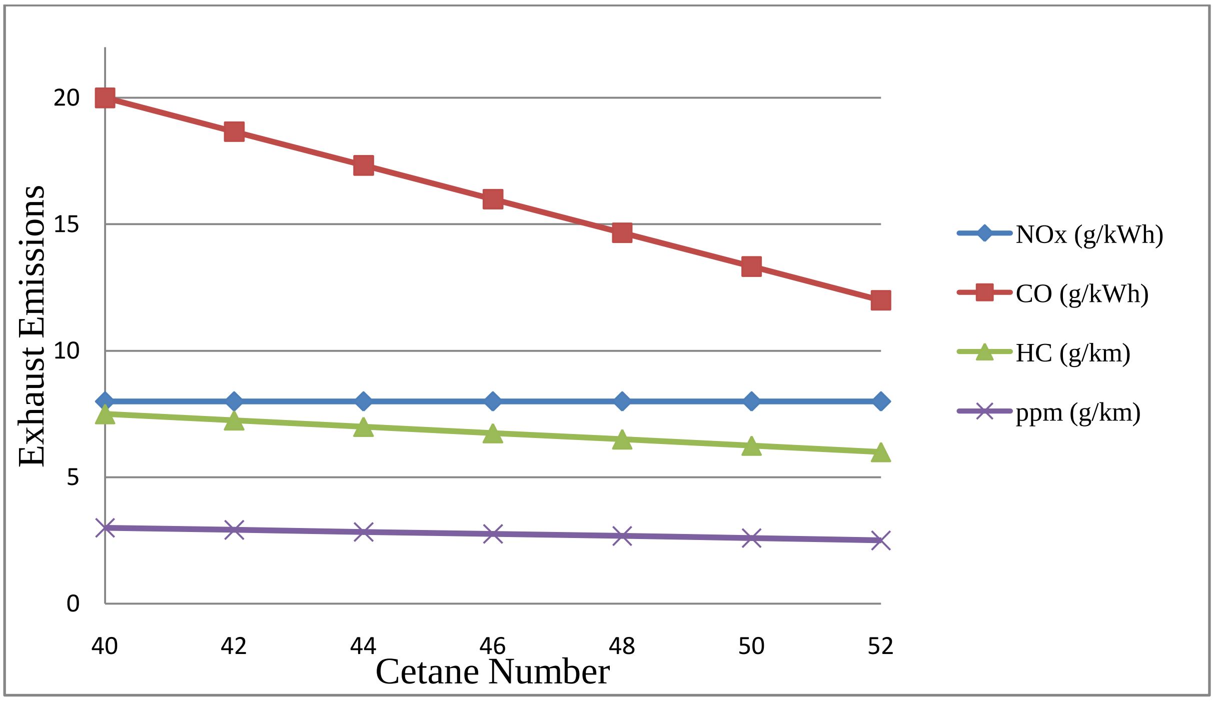

Figure 06:- Effect of cetane number on diesel engine emissions [3]

Figure 6 shows effects of the cetane number on the pollutants emitted by a diesel engine NOxis the least sensitive to the cetane number. However, it may result in an increase in the dry soot emissions as the pre-mixed burnt fraction decreases. An increase in the cetane number results in a decrease in CO, HC, NO_x and soot, with little effect on particulates. On diesel engines, the effect of the cetane number essentially concerns the extractable soluble organic fraction part and the insoluble carbon fraction remains practically unaffected[3].

The cetane number also affects emissions of blue and white smoke, which are exhaust mists consisting of droplets of unburnt diesel produced when starting and at high altitude due to a drop in the barometric pressure. The tendency for this process to occur, as identified by the negative pressure in the manifold when it appears, is grater as the cetane number decreases.

Another means to reduce the scale of soot formation is to lengthen the ignition delay by using a fuel with a low cetane number. However, this may present serious drawbacks.

Besides, the unacceptable noise already mentioned, if ignition is excessively delayed, droplets of liquid fuel may reach the cylinder walls and form deposits that burn very poorly and generate unburnt hydrocarbons and soot. Redistilled diesel fuel has low emissions than ordinary diesel fuel and super diesel fuel. Mainly its soot content is very low. Therefore redistilled diesel fuel is environmental friendly and has no effect on humans. It can be conducted that redistilled diesel fuel is more suitable for vehicles. However it is costly since the distillation process is an expensive process.

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