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Performance & Thermal Analysis of Coal and Waste Cotton Oil Liquid Obtained By Pyrolysis Fuel in Diesel Engine

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Abstract
One of the techniques used to obtain alternative liquid fuel is pyrolysis. In this study, co- pyrolysis process was applied to waste cotton oil and coal. Samples were generated by mixing liquid fuelobtained from co-pyrolysis and diesel fuel at certain ratios. Nitrogen (N), carbon (C), hydrogen (H) andsulfur (S) content of samples were measured by elemental analyzes. The Thermal performance analysis with values of density, yield point,flash point and viscosity were analyzed in the laboratory. Aniline point of the samples was found and cetane number was calculated from these values found.

After measurements, the obtained samples were found to usable in diesel engine; then these samples were tested in a three-cylinder four-stroke diesel engine at a constant engine speed. As a result of experiments, it was concluded that, performance values of obtained liquid fuel and diesel fuel were similar. However, it was seen that, with the increasing rate of pyrolysis liquid in the mixture; CO and NO x emissions were increased and CO 2, HC and O 2 emissions were reduced. Also it was observed that fuel consumption and specific fuel consumption values were improved with addition of pyrolysis liquid. Nevertheless, liquid fuel usage and quality can be increased by further studies concerning with the enhancement in pyrolysis liquid quality and usage.

Keywords*: alternative fuel, coal, co-pyrolysis, pyrolysis liquid ,cotton oil, diesel engine, cetane number, emissions*

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I. INTRODUCTION

The world's most important energy sources are carbon based fuels. Although the oil and natural gas reserves of these are concentrated in certain geographical region soft heearth's crust, coal, which is extracted inapproximately50differentcountries, shows every common distribution. The total reserve of coal in the world is 826 billion tons. The world's largest coal reserves are in the United States (USA), Russia, China, Australia and India. World coal production was realized as 6.94 billion tons in2010 and it is seen that coal will meet the energy demand of the world for another 119 years with its current production rate. Major coal producers are China, the United States, India, Australia, Russia, Indonesia and the Republic of South Africa. The largest consumer is China, and it consumed approximately 50%of the world coal consumption, which was3.28billiontonsin 2009. Other major consumer countries are the United States, India, Russia, Germany,South Africa and Japan. IEA (International Energy Agency) estimates that world coalconsumptionwillincreaseby25%inthenext25years.

Due to the depletion of oil, gas and uranium reserves and the emission of carbon dioxide, the energy sector has turned from carbon-based fuels to nuclear, solar and other environmentally friendly energy sources. Despite this, coal still remains them ost reliable and common energys ourcein the world and provides 27% of the world's primary energy production and 41%ofelectricity production (Anonymous).

1.1 Experiment Material and Method

Figure1: DieselEngineGeneratorWhereExperimentsAreConducted

Experimentswerecarriedoutina1500rpmconstantspeed,differentloads,stand-bypowerof10.4kW,enginevolumeof1.4lt,athree-cylinderandfour-strokewater-cooledINTERNATIONALbranddieselenginegenerator.

Table1: TechnicalSpecificationsoftheGeneratorEngine

Type	Synchron,Brushless In12hours
Overload	110%for1hour, 150%for2minutes
InsulationStrength	Minimum1800Volt
Voltage	231/400V
VoltageTolerance	±0.5%

Figure2: ElectronicScaleUsedinFuelConsumption

Adigitaltimerwasusedtodeterminethefuelconsumptiontime.Insteadofthefueltankoftheengine,anotherfueltankisplacedonthescaleandconnectedtothefuellinebymeansofpipes. Thedataobtainedduringtheexperimentwererecordedaftertheenginereachedoperatingtemperature and kept at this temperature throughout the experiment. Before starting a newexperiment,themotorwasallowedtocooldownandrest.Inaddition,inorderforthefueltestedinthe previous experiment to be completely exhausted, the engine continued to be operated until itstopped,andthenthefueltankwasfilledwithnewfuelandthustheexperimentswerestarted.Theloading of the engine was made by connecting a receiver to the generator and drawing electricalenergy. Thefollowingequationisusedtocalculatetheaverageeffectivepressure.

$$P_{me} = \frac{60 \times P_e}{V_H \times n \times f}$$

The following equation (7.2) has been used to calculate the specific fuel consumption.

$$b_e = \frac{m_y}{P_e}$$

The technical specifications of the gas analyzer used in the measurement of exhaust emissions are given in Table.

Table2. Technical Specifications of Capelec Cap 3200 Gas Analyzer

Parameter	**Measuring Range**	**Precision**
HC	0-20000 ppm	1 ppm
CO 2nd	0-20%	0.1%

CO	0-15%	0.001%
NO x	0-5000 ppm	1 ppm

II. RESULT AND DISCUSSION

2. 1. Performance Values

Engine tests, engine operation under constant speed and different load made in cases. Motor power (P to) It is obtained by multiplying the power factor (cosθ) values of the motor since the current intensity (I), voltage (V) and alternating current read from the generator display panel to measure.

P to • I .V .cos• (Watt)

It was calculated. Calculation of the torque value; motor power (P to) and n (number of revolutions) values are written in the formula below and calculated with the following equation.

$$Md \cdot \Big((9550)\frac{Pe}{n}$$

In the average effective pressure calculation, the motor power (P e), n (number of revolutions), V H (7.1) by writing the values (cylinder volume) and the number of cycles (f) in a revolution calculated from the formula shown. The torque and average effective pressure values calculated by experiments with different loads are shown in Table.

Table 3: Performance Value l (1500 rpm)

Sample 1, 2, 3, 4	**Torque (Md)**	**Average Effective Pressure**
Unladen	0	0
1 kW	06366	0.57
2 kW	12733	1.14
3 kW	19098	1.71
4 kW	25466	2.28

2.2. Fuel Consumption

The following tables show the fuel consumption and specific fuel consumption values of the samples created by adding 4 different proportions of pyrolysis liquid to the eurodiesel fuel.

Table 4: PercentageFuel Consumption and Specific Fuel Consumption of 100 Eurodiesel Fuel at Different Engine Loads Values (n = 1500 rpm)

100% Eurodiesel	**Fuel consumption (g / h)**	**Specific Fuel Consumption (g / kWh)**
P me1 = 0.57 bar	10116	10116
P me2 = 1.14 bar	10926	546.3
P me3 = 1.71 bar	12392	4131
P me4 = 2.28 bar	14274	3568

Table 5: PercentageFuel Consumption of 97.5 Eurodiesel 2.5% Pyrolysis Liquid Mixture at Different Engine Loads and Specific Fuel Consumption Values (n = 1500 rpm)

97.5% Eurodiesel **2.5% Pyrolysis Liquid**	**Fuel consumption (g / h)**	**Specific Fuel Consumption (g / kWh)**
P me1 = 0.57 bar	9618	9618
P me2 = 1.14 bar	1152	576
P me3 = 1.71 bar	12912	430
P me4 = 2.28 bar	15138	378

Table 6: PercentageFuel Consumption of 95 Eurodiesel 5% Pyrolysis Liquid Mixture at Different Engine Loads and Specific Fuel Consumption Values (n = 1500 rpm)

95% Eurodiesel **5% Pyrolysis Liquid**	**Fuel consumption (g / h)**	**Specific Fuel Consumption (g / kWh)**
P me1 = 0.57 bar	10242	10242
P me2 = 1.14 bar	12084	6042
P me3 = 1.71 bar	13436	447
P me4 = 2.28 bar	1561	390

Table 7: PercentageFuel Consumption of 92.5 Eurodiesel 7.5% Pyrolysis Liquid Mixture at Different Engine Loads and Specific Fuel Consumption Values (n = 1500 rpm)

92.5% Eurodiesel 7.5% Pyrolysis Liquid	**Fuel consumption (g / h)**	**Specific Fuel Consumption (g / kWh)**
P me1 = 0.57 bar	992	992
P me2 = 1.14 bar	1198	559
P me3 = 1.71 bar	1401	467
P me4 = 2.28 bar	1689	422

2.3. Fuel Consumption

In fuel consumption values are given depending on the engine loads of the samples.

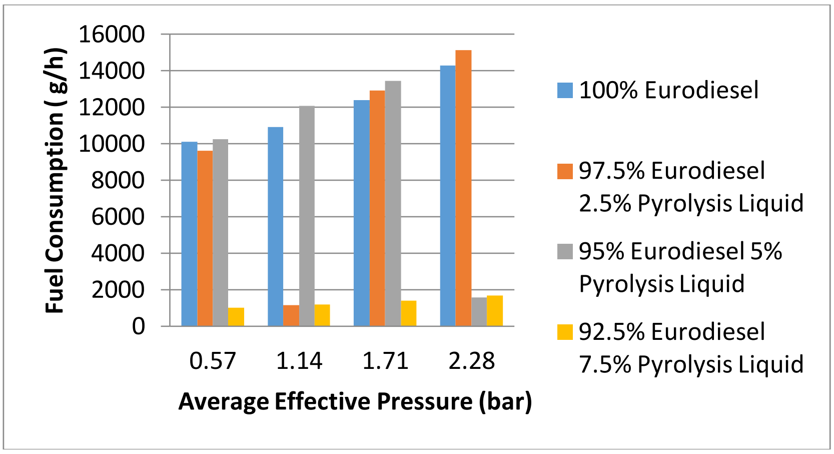

Figure 3: Fuel Consumption Values of Samples (n= 1500dev/min)

While the load of the engine is low, the fuel consumption of the fuels is at the lowest value, and as the engine is loaded, the fuel consumption values for all fuels increase. As the engine load, which is one of the factors affecting the fuel consumption in the engine, increases, the fuel consumption increases proportionally. Pme1, Pme3 and Pme4 The sample with the highest fuel consumption was 100% eurodiesel fuel. Adding pyrolysis liquid to eurodiesel fuel in these loads It has an effect that reduces fuel consumption. Pme 2nd On the other hand, fuel consumption increased with the addition of pyrolysis liquid.

2.4. Specific Fuel Consumption

The amount of mass fuel spent to obtain 1 kWh of energy (work) is called specific fuel consumption. Combustion efficiency and fuel properties are the main parameters affecting the specific fuel consumption. When low-power receivers are connected to the generator, that is, when the load of the engine from the engine is low, the specific fuel consumption of the fuels is at the highest value and as the engine is loaded, all There were reductions in specific fuel consumption values for fuels. In Figure, fuel consumption values are given depending on the engine powers of the samples.

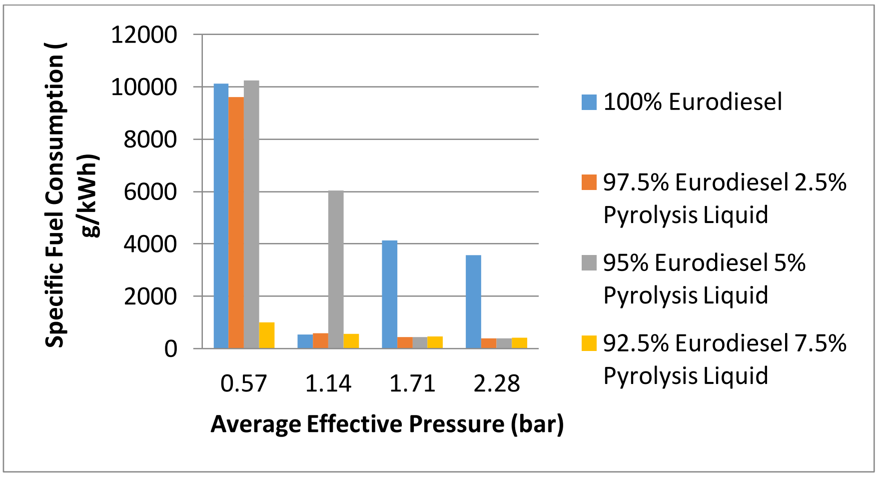

Figure 4: Specific Fuel Consumption Values of Samples (n= 1500dev/min)

When specific fuel consumption values are close to each other at engine load, the engine as the load increased, the differences became more apparent. Pme 2nd Specific fuel consumption of 100% eurodiesel fuel and 97.5% eurodiesel 2.5% pyrolysis liquid mixture in the load the value was about 25% lower than the other mixtures. It is seen that the specific fuel consumption increases as the rate of pyrolysis liquid in the mixture fuels increases. As the rate of pyrolysis liquid increases, the thermal value of the mixture decreases. It is known that the combustion efficiency decreases as a result of the worsening of atomization due to the increased viscosity. Considering these, it is normal for the specific fuel consumption to increase as the rate of pyrolysis liquid in the mixture increases. It is thought that the specific fuel consumption is very high at low loads of the engine and the low temperatures inside the cylinder at low loads are effective. As the concentration of the pyrolysis liquid in the fuel mixes increased, an improvement was observed in the specific fuel consumption.

2.5. Emission Values

CO, CO_2 in different loads of samples, HC, O_2 and NOx emissions are shown in the tables below.

Table 8: Percentage Emission Values of 100 Eurodiesel Fuel (n = 1500dev/min)

100% Eurodiesel	COEmission	CO_2Emission	HC	O_2 Emission (%)	NO_xEmission (ppm)
P me0 = 0	0.04	2.3	25	16.5	170
P me1 = 0.57 bar	0.04	2.7	43	15.6	233
P me1 = 1.14 bar	0.04	3.2	44	15.2	307
P me1 = 1.71 bar	0.03	4.6	51	13.1	529
P me1 = 2.28 bar	0.02	4.6	53	13.1	543

Table 9: PercentageEmission Values of 97.5%Eurodiesel2.5% Pyrolysis Liquid Mixture (n = 1500dev/min)

97.5% Eurodiesel 2.5% Pyrolysis Liquid	COEmission	CO_2Emission	HC	O_2 Emission (%)	NO_xEmission(ppm)
P me0 = 0	0.05	2.1	32	17.3	141
Pme1 = 0.57 bar	0.04	2.6	39	16.2	210
Pme1 = 1.14 bar	0.04	3.1	41	15.4	271
Pme1 = 1.71 bar	0.03	4.5	44	13.3	499
Pme1 = 2.28 bar	0.02	4.5	49	13.2	508

Table 10: Percentage Emission Values of 95%Eurodiesel 5% Pyrolysis Liquid Mixture (n = 1500dev/min)

95% Eurodiesel 5% Pyrolysis Liquid	COEmission	CO_2Emission	HC	O_2 Emission (%)	NO_xEmission(ppm)
P me0 = 0	0.05	1.9	35	17.5	97
P me1 = 0.57 bar	0.05	2.5	36	165	171
P me2 = 1.14 bar	0.04	3.1	38	15.6	250
P me3 = 1.71 bar	0.03	4.5	43	13.5	472
P me4 = 2.28 bar	0.03	4.5	45	13.5	477

Table 11: PercentageEmission Values of 92.5%Eurodiesel 7.5% Pyrolysis Liquid Mixture (n = 1500dev/min)

92.5% Eurodiesel 7.5% Pyrolysis Liquid	CO Emission	CO_2 Emission	HC	O_2 Emission (%)	NO_xEmission (ppm)
P me0 = 0	0.06	1.8	26	17.8	76
P me1 = 0.57 bar	0.05	2.5	30	16.9	155
P me2 = 1.14 bar	0.05	3.1	34	15.7	231
P me3 = 1.71 bar	0.04	4.5	39	13.5	455
P me4 = 2.28 bar	0.04	4.5	45	13.6	473

2.6. CO Emissions

The variation of CO emissions according to the average effective pressure is given in Figure

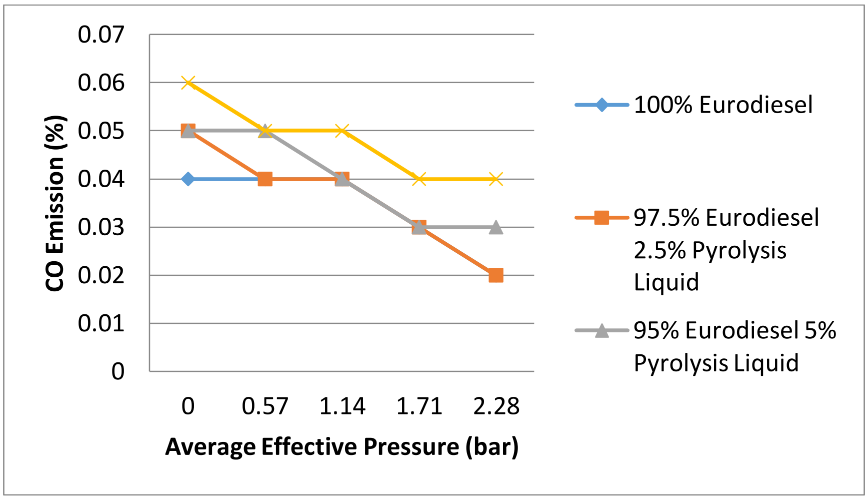

Figure 5:CO Emissions Pme Change According to Their Values (n= 1500dev/min)

Itisseenthatastherateofpyrolysisliquidinthemixturefuelsincreases,theCOvaluesincreaseatthesamemeasurementpoints.
As the rate of pyrolysis liquidincreases, the viscosity increases and thethermal value decreases. It isalsoknownthatthecombustionefficiencydecreasesasaresultofthedeteriorationofatomization.Sincelowcalorificvalueandlowcombustionefficiencycausethecycletemperaturetodecrease,itcanbesaidthattheamountofCO willincrease.
COemission,insufficientO_2inthecombustionchamberfindingfuelItoccurswhentheCatomsinitcannotbefullycombusted.COemissionsoffuelIt isalso relatedto thenumber ofCatoms inits chemicalcomposition (Heywood,1988).

2.7. CO_2 Emissions

Thehigherviscosityanddensityofpyrolysisliquidmixturescomparedtoeurodieselfuelaffectstheatomizationrate,especiallyatlowenginespeeds.
Inaddition,thehydrogen/carbonratioofhighmolecularweightfuelstoCO_2.ItaffectstheformationCO_2.Thevariationoftheemissionsaccordingtotheaverageeffectivepressureisshownin Figure

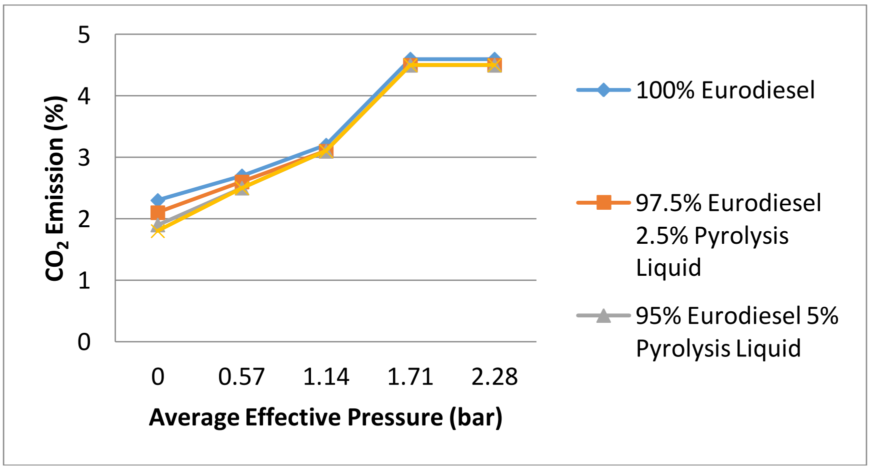

Figure6: CO_2 Emissions Pme Change AccordingToTheirValues (n=1500dev/min)

AscanbeseenfromFigure,astheengineisloaded,thetemperatureinsidethecylinderandCO_2emissionwithincreasingpressure.Analmostlinearincreasehasbeenobservedinallfuelssincetheconversiontoemissionhasincreased.
Figure;carbondioxide(CO_2)Itshowsthatitsemissionsincreasewithincreasingengineloadanddecreaseastheproportionofpyrolysisfluidinthemixtureincreases.

2.8. HCEmissions

TotalHCemissionsconsistofunburnedorpartiallyburnedhydrocarbonfuels. The main reasons for the formation of HC emissions can be listed asincomplete combustion resulting from too rich or poor mixtures, highly burntexhaust gases in the air-fuel mixture, flame extinguishing on the combustionsurfaces,carbondepositsinthecombustionchamberandfuelretentionoftheoillayerinthe cylinder wall(Senbahceetal.,2014).

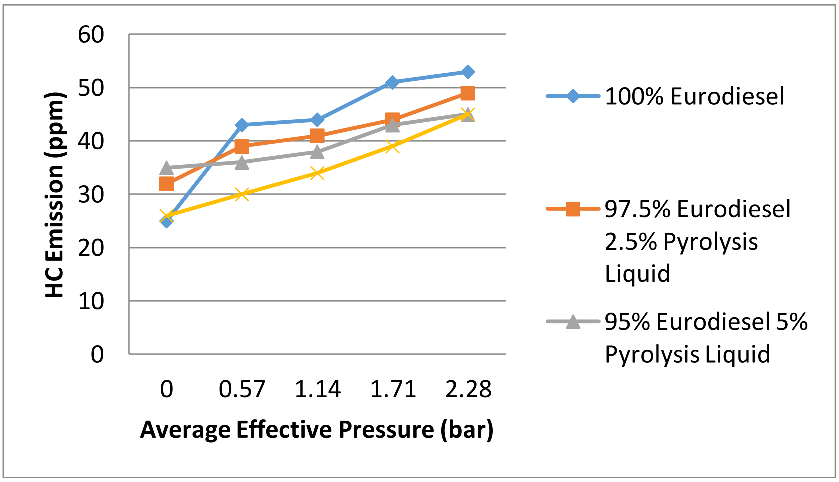

Figure7: HC Emissions PmeChangeAccording to Their Values (n=1500dev/min)

The reason for the presence of unburned HC (hydrocarbon) among the combustionproducts is that the fuel cannot be oxidized or is semi-oxidized due to the fuel not reachingthe ignition temperature or the lack of oxygen in the environment (Challen and Baranescu,1999).

As the load of the engine increases, the amount of fuel sent to the cylinderincreases. In this case, the engine runs with a rich mixture and the fuel cannot beburnt sufficiently because it does not reach the ignition temperature. This situationcauses HC emissions to increase in direct proportion to the amount of load. Thehomogeneityofthemixtureatlowloadsandthehigheramountofoxygencauses lessHCemissions.

From the valuesin Figure, hydrocarbon (HC) emissions; It can be seen that it increases withincreasingengineloadanddecreasesastheproportionofpyrolysisliquidinthemixtureincreases.

2.9. O_2Emissions

Asthe loadof themotor increases,O_2 adecrease in emissionswas observed.This situationis due tothe consumptionof morefuel as theengine isloaded andaccordingly theneed.

Itcanbeexplainedbytheincreaseintheamountofoxygenheard.Sincethereisoxygeninthepyrolysisliquid,thepyrolysisliquid-addedfuelsemitmoreoxygenthantheeurodieselfuelatallpowerchanges

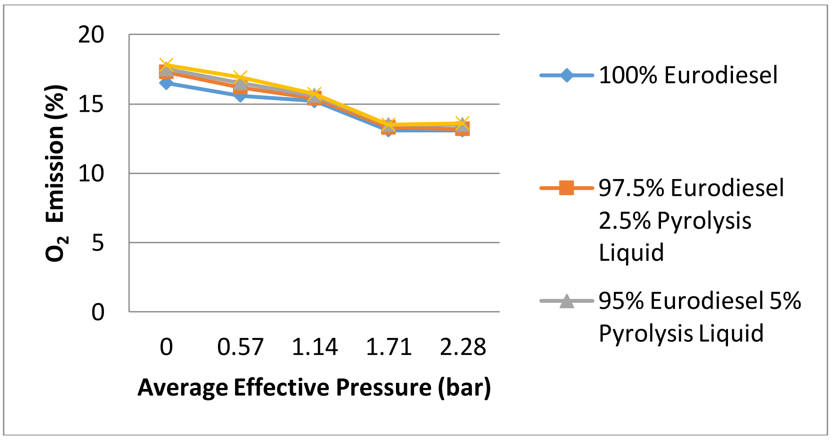

Figure8: O_2EmissionsPmeChangeAccordingtoTheirValues(n=1500dev/min)

The above tables are oxygen (O_2) emissions; It shows that it decreases with increasing engine load,andincreasesastheproportionofpyrolysisliquidinthemixtureincreases.

Since the combustion process worsens for fuels with a mixture of pyrolysis liquid-euro diesel as the load on the engine increases,O_2its emission has increased.

2.10. NOxEmissions

In order for nitrogen to react with oxygen, the combustion temperature inside the cylinderis1800^0 K and the time required for there action is effective It has been reported (Heywood,1988) within creasing injection, aricher mixtureis formed in the pre combustionchamber,thecombustiontemperaturerisingNO_xemissionsareincreasing(Hottaetal.,1997). It is formed by the oxidationofnitrogenintheenginecylinderanditsmainsourceistheoxidationofatmosphericnitrogen.Inadditionto nitrogen,whichis79%intheairduringitsformation,nitrogeninthefuel(N_2)constitutesapotentialresource.Formationofnitrogenoxides;stayabove1800Kofflametemperaturetime,enoughO_2maximumtemperatureandcurrentO_2 withN_2Itdependsontheamount(Gold,1988).NO_xinFigurethechangesoftheemissionsaccordingtotheaverageeffectivepressurearegiven.

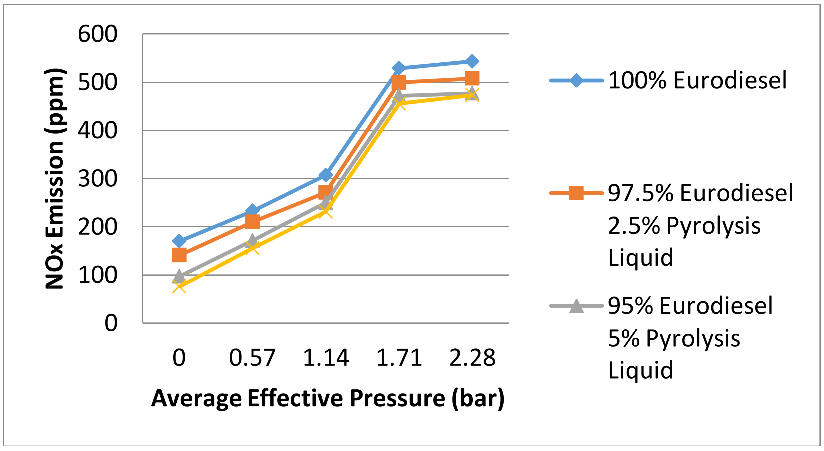

Figure9: NO_x Emissions Pme Change According to Their Values (n=1500dev/min)

Theabovetablesarenitrousoxide(NO_x)emissions;showsthatitincreaseswithincreasingengineloadanddecreasesastheproportionofpyrolysisliquidinthemixtureincreases. NO_xthetemperatureinsidethecylindergreatlyaffectsitsformationandasthetemperatureincreases. Itisknownthattheamountincreasesrapidly.Theincreaseintheendofcombustiontemperaturesastheengine is loaded, the NO_x of all mixtures and 100% eurodiesel fuel has increased its emission. This situation isrelatedtotheincreaseinthetemperatureattheendofcombustion(Usta,2005).

In pyrolysis liquid-eurodieselfuelmixtures,theincreaseinviscosityduetotheincreaseintheratioofthepyrolysisliquid,delayed reaching tohightemperaturesasaresultofcombustionandasaresult,NO_xemissionsalsodecreasedaspyrolysisliquidwasadded.

III. CONCLUSION AND FUTURE SCOPE

Since fossil fuels are faced with the danger of extinction, alternative liquid fuelproductionmethodshavebeendevelopedandresearched. Asaresultofthesestudies,thepyrolysis method wasusedandsufficientresultswereobtained.

Pyrolysisliquidwasobtainedfromwastecottonoilandcoaltogetherwithpyrolysismethodandsampleswereformedbymixingthisliquidwith2.5%,5%and7.5%eurodieselfuel.

Elemental analysis of the mixtures was made and the nitrogen, carbon and hydrogenpercentagesinthemixtureswerealsoanalyzed. Ithasbeenobservedthateurodieselfuelisclosetoeachotherwithitselementcontents.Thecarbon(C)contentofthepyrolysisliquidwas13.35%lowerthantheeurodieselfuel,andthenitrogen(N)contentwas23.53%lower.Inaddition,theamountofhydrogen(H) was 17.75% lower than eurodiesel fuel. The fact that the cetane number valuescalculated after the determination of the aniline point are very close to the cetane number of theeurodieselfuelalsosupportsthesuitabilityofitsuseintheengine.Thecetanenumberofthe7.5%pyrolysisliquid92.5%eurodiesel fuelmixturewas 5%higherthanthe 100%eurodieselfuel.

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