MAJOR PROJECT REPORT

"Measurement and prediction of diesel engine exhaust emissions and to find out the relationship between different parameters and exhaust emission"

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B.TECH: AUTOMOTIVE DESIGN ENGINEERING

(2009-2013)

UNDER THE GUIDANCE OF

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COLLEGE OF ENGINEERING STUDIES

UNIVERSITY OF PETROLEUM & ENERGY STUDIES

DEHRADUN, APRIL 2013

CERTIFICATE

This is to certify that the work contained in this project titled "Measurement and prediction of diesel engine exhaust emissions and To find out the relationship between different parameters and exhaust emission" has been carried out by **Shreya Sharma, Mridul Bagdwal, Abhijeet Vatsal** students of **B.Tech Automotive Design Engineering (2009-2013)** under my supervision and guidance.

This project embodies the original work done by the students during their full semester project training period.

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ACKNOWLEDGEMENT

A project always requires the goodwill, encouragement, guidance and support of many people to whom we are deeply indebted.

We would like to express our extreme gratefulness to our mentor **Mr. Narayan Khatri** for his valuable guidance in the course of this project work.

Finally we would like to thank the University for providing us an opportunity to apply our technical knowledge and see it materialize in the form of this project.

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Engineering

ABSTRACT

Automotive engines are major sources of air pollution among which diesel engine cause most of the particulate emission that consists of soot and absorbed hydrocarbon. In case of CI engine the amount of oxide of nitrogen (Nox) is comparable that in case of SI engine.

Diesel engine produces complex mixture of emission consisting a wide range of inorganic and organic compounds which leads to the rise of public health concern for various reasons such as The particulate emission of diesel engine are very small(less than 1 micron) making them easily breathe able, they have numerous chemical absorbed on their surfaces some of them are widely known mutagens and carcinogens. The gaseous phase of these chemicals contains many toxic chemicals. The oxides of nitrogen which are known to deplete the ozone are the major combustion product during gaseous phase.

In our project we will develop Mathematical correlation and do calculation which will help us understand the engine parameters and factors that influence it. We will derive a polynomial equation showing relationship between parameters and factors and hence we can tell how the emissions will be affected when the parameters are changed which will help us in optimization of factors, to control the diesel engine emissions accordingly.

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PROJECT OBJECTIVES

Aim

The aim of this project is:

- Measurement and prediction of diesel engine exhaust emissions
- To find out the relationship between different parameters and exhaust emission
- To reduce the exhaust emissions by correcting different parameters.

Methodology

- Understanding project specifications
- Literature Review
- Collection of appropriate data
- Calculations of various parameters
- development of correlations

Scope of the Project

Deriving a polynomial equation will tell us the relationship between parameters and factors and hence we can tell how the emissions will be affected when the parameters are changed which will help us in optimization of factors, to control the diesel engine emissions accordingly.

Project Limitations The correlations developed are purely theoretical and the data used in calculations is experimental in nature and is derived from just one specific diesel engine.

LITERATURE REVIEW

Measurement and prediction of diesel engine characteristics parameter and to develop the relations between parameters and factors affecting parameters is an important work which helps learners and experts to know about various characteristic parameters of diesel engine and the factors affecting these parameters and how parameters varies in accordance with difference factors combination. Various research's and works have been done to develop the correlations among important characteristic parameters and factors affecting them. Some of the work regarding diesel engine characteristics parameters and their measurement for different combination of factors are given .

1.Parametric studies for improving the performance of a Jatropha oil-fuelled compression ignition engine J. Narayan Reddy, A. Ramesh Internal Combustion Engines Laboratory, Mechanical Engineering Department, Indian Institute of Technology Madras, Chennai-600 036, India gives the idea of developing correlations and various methods.

2.Effect of advancing fuel injection point on performance of Low speed IDI engine fueled with Jatropha straight vegetable oil R K Tripathi*, PK Sahoo

College of Engineering Studies, University of Petroleum & Energy Studies, Dehradun, India.

3. Correlation for thermal NOx formation in compression ignition (CI) engine fuelled

with diesel and biodiesel S. Saravanan a,* G. Nagarajan b, S. Anand c, S. Sampath d

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1. INTRODUCTION

Overview

Automotive engines are major sources of air pollution among which diesel engine cause most of the particulate emission that consists of soot and absorbed hydrocarbon. In case of CI engine the amount of oxide of nitrogen (Nox) is comparable that in case of SI engine.

Diesel engine produces complex mixture of emission consists of a wide range of inorganic and organic compounds which leads to the rise of public health concern for various reasons such as

- The particulate emission of diesel engine are very small(less than 1 micron) making them easily breathe able, they have numerous chemical absorbed on their surfaces some of them are widely known mutagens and carcinogens. The gaseous phase of these chemicals contains many toxic chemicals. The oxides of nitrogen which are known to deplete the ozone are the major combustion product during gaseous phase

Diesel exhaust composition considerably varies and depends on

- Engine type
- Operating conditions
- Fuel
- Lubricating oil
- And presence of emission control system

With improvement in engine design and complete combustion of fuel taking place and providing of exhaust controlling devices in the engine the level of pollutant produced in now controlled compared to earlier engines.

In this report our objective is to develop correlation for exhaust emission using experimental measurements.

1.1 Introduction to diesel engines

A diesel engine (also known as a compression-ignition engine) is an internal combustion engine that uses the heat of compression to initiate ignition to burn the fuel that has been injected into the combustion chamber. This

is in contrast to spark-ignition engines such as a petrol engine (gasoline engine) or gas engine (using a gaseous fuel as opposed to gasoline), which uses a spark plug to ignite an air-fuel mixture. The engine was developed by German inventor Rudolf Diesel in 1893.
The diesel engine has the highest thermal efficiency of any regular internal or external combustion engine due to its very high compression ratio. Low-speed diesel engines (as used in ships and other applications where overall engine weight is relatively unimportant) can have a thermal efficiency that exceeds 50%. Diesel engines are two strokes and four stroke

The diesel cycle

it is a thermodynamic cycle, invented by Rudolph Diesel. Combustion, which is the first process, takes place at constant pressure. When the temperature of the compressed gases increases, the fuel is injected at that point and the high temperature inside the cylinder ignites the fuel

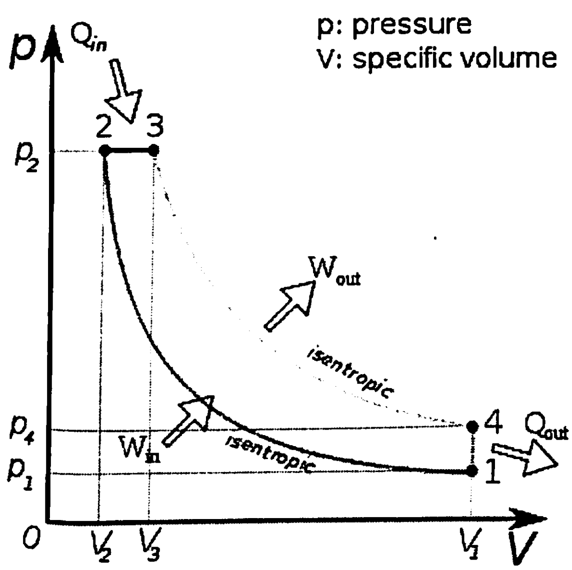


Fig. 1

Process 1 to 2 is isentropic compression of air (blue color)

Process 2 to 3 is reversible constant pressure at which heat is injected into the cylinder (red)

Process 3 to 4 is isentropic expansion and work is obtained (yellow)

Process 4 to 1 is reversible constant volume in which the heat is rejected, exhaust (green)

The maximum thermal efficiency of a Diesel cycle is depends on the compression ratio and the cut-off ratio

$$\eta_{th} = 1 - \frac{1}{r^{\gamma-1}}\left(\frac{\alpha^{\gamma}-1}{\gamma(\alpha-1)}\right)$$

Where

η_{th} is thermal efficiency

α is the cut-off ratio $\frac{V_3}{V_2}$ (ratio between the end and start volume for the combustion phase)

r is the compression ratio $\frac{V_1}{V_2}$

γ is ratio of specific heat (C_p/C_v)[2]

The cut-off ratio can be expressed in terms of temperature as shown below:

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = r^{\gamma-1}$$

$$T_2 = T_1 r^{\gamma-1}$$

$$\frac{V_3}{V_2} = \frac{T_3}{T_2}$$

$$\alpha = \left(\frac{T_3}{T_1}\right)\left(\frac{1}{r^{\gamma-1}}\right)$$

$$\eta_{otto,th} = 1 - \frac{1}{r^{\gamma-1}}$$

1.2 Definitions

1. **Thermal efficiency** – It is the ratio of work done to heat supplied.

Nth= work done/ heat supplied

= Qr- Qs/ Qs.

2. **Injection timing** - An engine which uses an injector in the intake manifold, it would be possible to phase the firing of the injectors during the intake stroke. so that it only sprays at a precisely correct time when the airflow in the cylinder is maximum, in the cylinder. Thus providing proper atomization of air fuel mixture

3. **Injection pressure**- the pressure at which the fuel is injected into the cylinder. When the pressure is maximum. Temperature rises this causes combustion of fuel in diesel engine

4. **Engine load**- Load is the measurement of how hard engine works. It is measured in terms of percentage.

5. **Sources of pollutant formed in CI engine**

- Different regions of Fuel Spray & Flame front contribute to forming of NO, HC and Soot Particulates during combustion.
- NO formed in high temperature flame region.
- HC formed in over lean fuel regions because of flame quenching and fuel entering towards end of combustion (poor mixing).
- Soot formation takes place in rich core of injection spray which is subjected to high temp. & pressure. Later the oxidation of soot takes place if it comes in contact if the available free oxygen is present and oxidizing species in flame.
- CO is formed from partial oxidation of over lean fuel mixtures and/ or fuel over rich regions (high load).

Unburned hydrocarbon- These are formed due to incomplete combustion of fuel in the combustion chamber. It depends on combustion chamber design, engine speed, engine load, etc. Flame Ionization Detector is used for the measurement of unburned hydrocarbon. When unburned hydrocarbon is burned in hydrogen-oxygen flame, the ionized carbon particle produce electric current as detection.

6. **Nox emission**- Nox, generic term used for mono nitrogen oxide NO NO2(nitric oxide and nitrogen dioxide). These are produced due to reaction of nitrogen and oxygen in air particularly at high temperature. Nox reacts with ammonia moisture and other compounds and forms vapour of nitric acid. The small particle can penetrate in the lung tissue and cause damage which leads to premature death. Nox destroys ozone.

NO formed during combustion in three ways:

a) Thermal NO is formed by the oxidation of atmospheric (molecular) nitrogen at elevated temperatures in the burned gases left behind in the flame front.

b) Oxidation of fuel-bound nitrogen (about 0.6% m/m) takes place at a relatively low temperature to form fuel NO. During the reaction of fuel nitrogen first intermediate nitrogen is produced which contains compound and reactive radicals like HCN, NH_3, CN, NH, etc. which are then oxidized to form NO by species containing oxygen.

c) NO formed at the flame front by a mechanism which is different than the above two mechanisms is called prompt NO. Prompt NO (5- 10%) is formed by intermediate species of CN group with O & OH radicals in the flame. Contribution of Prompt NO becomes significant under lean burn operation and use of EGR.

Chemical Reactions proposed by Zeldovich to form NO are:

$$O + N_2 \leftrightarrow NO + N$$

$$N + O_2 \leftrightarrow NO + O$$

$$N + OH \leftrightarrow NO + H$$

NO formation in CI engine

- In IDI engines combustion takes place in two stages. In second stage most fuel burn as lean mixture. At light loads, most NO may form in pre-chamber and at high loads, additional NO formation takes place in main chamber . Although temperature is higher in pre-chamber but mixture is rich, except under light loads, hence overall NO formed in IDI engines is lower.

NO_2 formation in CI engine

- In diesel engines NO_2 can constitute up to 10 – 30 % of total NO_x
- High temperature burned gases rapidly mix with colder air caused by high turbulence quench reactions responsible for conversion of NO_2 back to NO resulting in relatively high level of NO_2 as compared to SI engines.

$$NO + H_2O \rightarrow NO_2 + H_2$$

$$NO + O_2 \rightarrow NO_2 + O$$

$$NO_2 + O \rightarrow NO + O_2$$

7. In IC engine exhaust gas recirculation (EGR) is a reduction technique used to reduce nitrogen oxide. In EGR the exhaust gas from the engine is recirculate back into the cylinder. In CI engine the excess of oxygen is replaced by the exhaust gas as Nox is formed when oxygen and nitrogen react at high temperature. Therefore, EGR reduces the temperature and hence reduce the formation of Nox. Thus, a compromise has to make between economy and power as EGR makes the combustion in the engine less efficient. Selective catalytic reduction, in these methods the nitrogen oxide is converted into N2 and water with the help of a catalyst. The gases used for reduction are anhydrous ammonia, aqueous ammonia , urea. Mostly, Nox reduction with Ammonia is preferred

$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O + CO_2$

$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$

$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$

Catalyst used are vanadium and tungsten. Honeycomb structure is used in SCR setup.

6. **Particulates** – these are tiny particles found in the atmosphere and are termed as atmospheric aerosol. They have effects on human health as well as on the climate. They can be further classified as.
Suspended particulate matter
Respirable suspended particle
fine particle
soot

They may be generated from volcano's, forest fires or burning of fossil fuels. The techniques used to control particulate matter emissions are inertial collectors, electrostatic precipitators and wet scrubbers. High level of fine particles can cause lung cancer and other cardiac problem, asthma.

7. **Soot** - Soot is formed due to incomplete combustion of hydrocarbon. Soot is present in the air, contaminates the environment. Soot is present in very low concentration causes darkening surfaces or particle agglomerates similar to ventilation system appears black. Soot also cause ghosting which is the decolouration of walls and ceiling where the meet. Formation of soot strongly depends on fuel consumption. Soot is powder like form of amorphous carbon and classified as, human known carcinogens. Soot especially from diesel exhaust causes over 1 quarter of total hazardous pollution in the environment and disproportionately high share for the sickness and death which are caused due to pollution. Exposure for long term to this type of urban pollution which contains soot increases the rate of heart diseases.

1.3 Effect of CI engine operating parameters on emission produced

- **Compression Ratio** - An increase in CR - shorter ignition delay & higher comb. temp. tend to oxidize ubHC - lower HC and higher NOx. For lowest NOx & particulate optimum CR required.
- **Engine Load** -With the increase in engine load the overall air- fuel ratio decreases and the combustion and exhaust temp. increases.

  At high speed ; pumping losses increase, cooling decreases and residual gases are hotter - NOx inc. HC & PM have an opt. at mid speed : time for oxidation decreases with increase in speed .

  Increase in coolant temp.-reduce heat tr.- high NOx but reduction in HC,PM and fuel consumption.
- **NOx**-particulate trade off- When one parameter is adjusted to dec. combustion temperature for reducing NOx, an increase in smoke & particulate results.

  By retarding the injection timing as combustion temp. decrease - reduction in NOx accompanied but with increase in soot due to reduction in soot oxidation.

  Similar effects are obtained when EGR rates increased or any other measure to reduce combustion temperature. Therefore optimum engine design parameters are required.
- **Fuel quality**- Higher CetaneNumber has beneficial effects on reducing HC & NOx at all loads.

  While higher fuel volatility increases premixed burning because of faster fuel evaporation. An increase in NOx & HC may be observed with more volatile diesel fuel. Fuel sulphur increases adsorption of sulphates on soot and hence increase in particulate mass.

1.4Exhaust formation kinetics

Let A and B be two reactants and C their product, therefore

A+B→C, hence the rate of reaction can be written as

V= -d(C)/nd(t),

Where V= rate of formation of product, n= stoichiometric efficiency, t= time taken

This can also be written as per Arrhenius law

$V = k. A^a .B^b$

k = Arrhenius coefficient which depends on temperature and pressure, a &b are reactants order.

Applying arrhenius single rate equation for combustion taking place

Air+ fuel→ pollution+ other product

$V=A(cf)^a (ca)^b \exp(-E/RT)$

Cf & ca are unburned fuel and oxides mass fractions, R is universal gas constant.

In actual calculation this method has many problems and is not used. As the combustion taking place depends on the turbulence and diffusion of thermal or mass is not considered. The reaction being considered depend on pressure and temperature and as pressure inside the cylinder always vary hence it is necessary to make the rate of formation of products the function of engine speed also for corrective value.

$V= A. w. (cf)^{aw}. (ca)^{bw}$

A, a ,b are function of engine speed.

2. EXPERIMENTAL SETUP

4 STROKE DIESEL ENGINE

1. single vertical cylinder

2. 1580 cc

3. bp=7.4 kw

4.N=1000 rpm

5. solid indirect injection

6. Compression ratio=17:1

7. Data Acquisition System

8. PC

3.Overview of Equations & Methods

To carrying out the analysis of the engine parameters and factors that influence it, a mathematical equation has to be developed for which relates the parameters and factors and shows the relationship between them.

Derivation of polynomial equation showing relationship between parameters and factors

Let Y be a parameter which is a function of certain variables or factors

$Y= f(x1,x2,x3)$

Therefore a general polynomial equation for three variables –

$Y= a0+a1x1+a2x2+a3x3+a4x1^2+a5x2^2+a6x3^2+a7.x1.x2+a8.x1.x3+a9.x2.x3$

Where a0,a1,a2,a3,a4,a5,a6,a7,a8,a9 are arbitrary constants; x1,x2,x3 are the factors on which parameter depends

Range of values for variables

Average value of variables

$X1avg= (x1max+x1min)/2$

$X2avg= (x2max+x2min)/2$

$X3avg= (x3max+x3min)/2$

Difference

$\Delta X1= (x1max-x1min)/2$

$\Delta X2= (x2max-x2min)/2$

$\Delta X3= (x3max-x3min)/2$

Therefore normalized values for the variables to make the error as minimum as possible are written as

$Xn1= (x1- x1avg)/\Delta x1$

$Xn2 = (x2 - x2avg)/\Delta x2$

$Xn3 = (x3 - x3avg)/\Delta x3$

Hence the polynomial in terms of normalized values can be written as

$Yp = a0+a1Xn1+a2Xn2+a3Xn3+a4Xn1^2+a5Xn2^2+a6Xn3^2 +a7.Xn1.Xn2 + a8.Xn1.Xn3 +a9.Xn2.Xn3$

In the above equation the values of the constants have to be calculated in order to develop the correlation. The values of the constants can be calculated manually by mean square error method – $F = \sum_{i=1,n} (Yp-Y) = \min$

Differentiating the above equation with respect to each constant several simultaneous equation will be formed.

Solving of these simultaneous equations is a very laborious. Hence these equations can also be solved with the help of Matlab software.

The values for the factors and parameter can be taken from the table and values of constants can be calculated. For solving of equations in Matlab Cramer's matrix rule is applied which is

$[A]\times[B] = [C]$

$[B] = [A]^{-1} \times [C]$

Where [A]= matrix A contains array of values of factors

[C]= matrix Ccontains array of values of parameters

$[A]^{-1}$= inverse of matrix A

[B]= matrix B contains array of values of constants that is to be calculated

3.1Developing correlation for thermal efficiency of diesel engine

Let Yp be thermal efficiency of the engine. The three factors selected which affects thermal efficiency are engine load, injection timing, injection pressure. Therefore polynomial is

$Yp = a0+a1\ Xn1+a2\ Xn2+a3\ Xn3+a4\ Xn1^2+a5\ Xn2^2+a6\ Xn3^2 +a7.\ Xn1.\ Xn2 + a8.\ Xn1.\ Xn3 +a9.\ Xn2.\ Xn3$

Where Xn1= load; Xn2= injection timing; Xn3= injection pressure

In our project the values of thermal efficiency is taken at full load. Therefore the load variable is not taken in the polynomial equation hence the new equation with two variable is

$Yp = a0+a2\ Xn2+a3\ Xn3+a5\ Xn2^2+a6\ Xn3^2+a9.\ Xn2.\ Xn3$

Now values of fewer constants have to be calculated by putting the values of thermal efficiency, injection timing, injection pressure into the polynomial equation.

X2avg= (30.5+34.5)/2= 32.5

X3avg= (205+260)/2= 232.5

ΔX2= (34.5-30.5)/2= 2

ΔX3= (260-205)/2= 27.5

Normalized values for injection timing at various crank angle

Xn2= (30.5-32.5)/2= -1

Xn2= (32-32.5)/2= -0.025

Xn2= (33.5-32.5)/2= 0.5

Xn2= (34.5-32.5)/2= 1

Normalized values for injection pressure

Xn3= (205-232.5)/27.5= -1

Xn3= (220-232.5)/27.5= -0.45

Xn3= (240-232.5)/27.5= 0.272

Xn3= (260-232.5)/27.5= 1

Putting these in equation

25.7= a0+a2 (-1) +a3 (-1) +a5 (-1) ^2+a6 (-1) ^2+a9. -1. -1

28.9= a0+a2.-0.25+a3.-0.45+a5.-0.25^2+a6.-0.45^2+a9.-0.25.-0.45

28= a0+a2.-1+a3. 0.272+a5. -1^2+a6. 0.272^2+a9.-1. 0.272

27.3= a0+a2. 0.5+a3. -1+a5. 0.5^2+a6. -1^2+a9.0.5. -1

26.8= a0+a2.0.5+a3. -0.45+a5. 0.5^2+a6. -0.45^2+a9. 0.5. -0.45

27.5= a0+a2. -0.25+a3.1 +a5. -0.25^2+a6. 1^2+a9.-0.45. 1

Applying Cramer's rule for solving of constants

[A]= [1 -1 -1 1 1 1

1 -0.25 -0.45 0.0625 0.2025 0.1125

1 -1 0.272 1 0.073984 -0.272

1 0.5 -1 0.25 1 -0.5

1 0.5 -0.45 0.25 0.2025 -0.225

1 -0.25 1 0.0625 1 -0.25]

[B]= [a0

a2

a3

a5

a6

a9]

[C]= [0.257

0.289

0.28

0.[illegible]

0.268

0.275]

[B]=[A[illegible]×[C]

Using Ma[illegible] solve the matrix

Code written

B[illegible] a*c

Hence the values obtained

[B]=[0.2834

-0.0292

-0.0105

-0.0352
-0.0086

-0.0223]

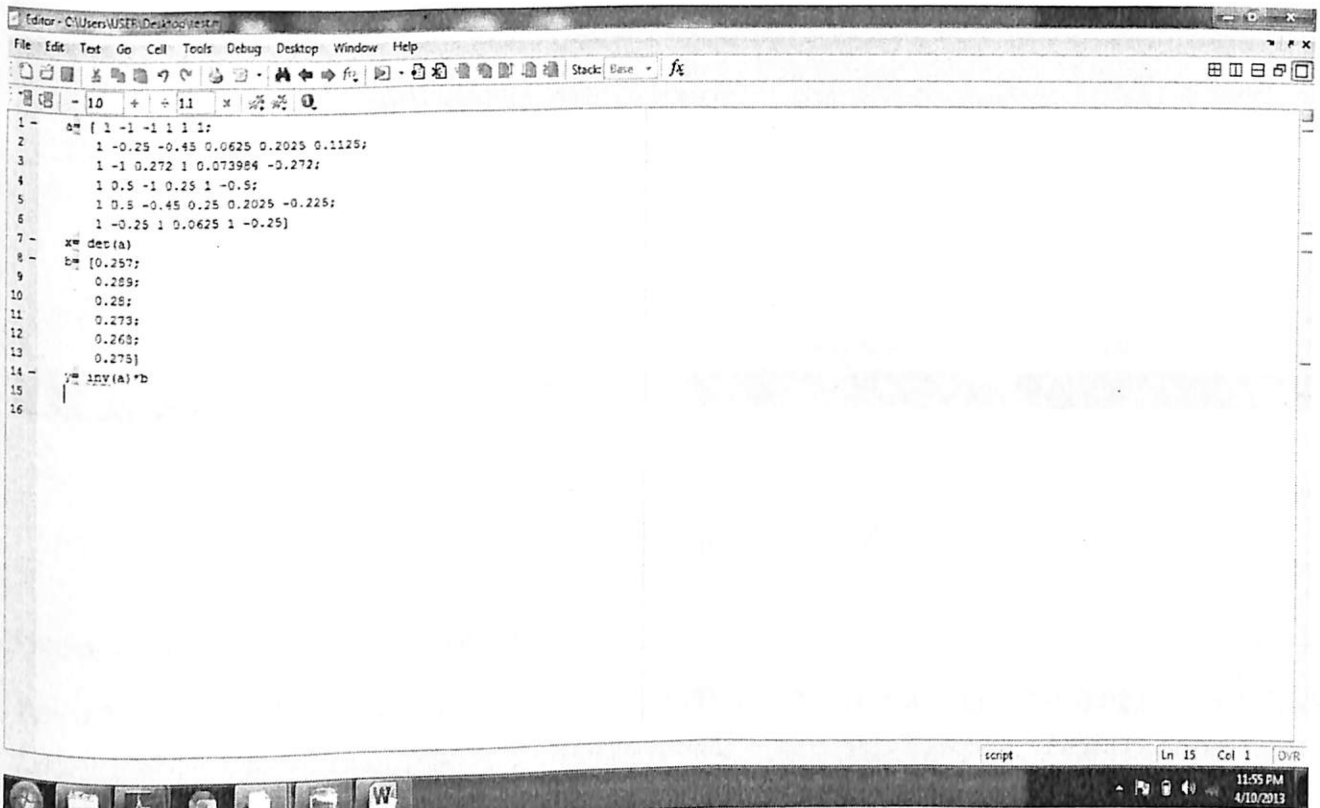


Fig.2

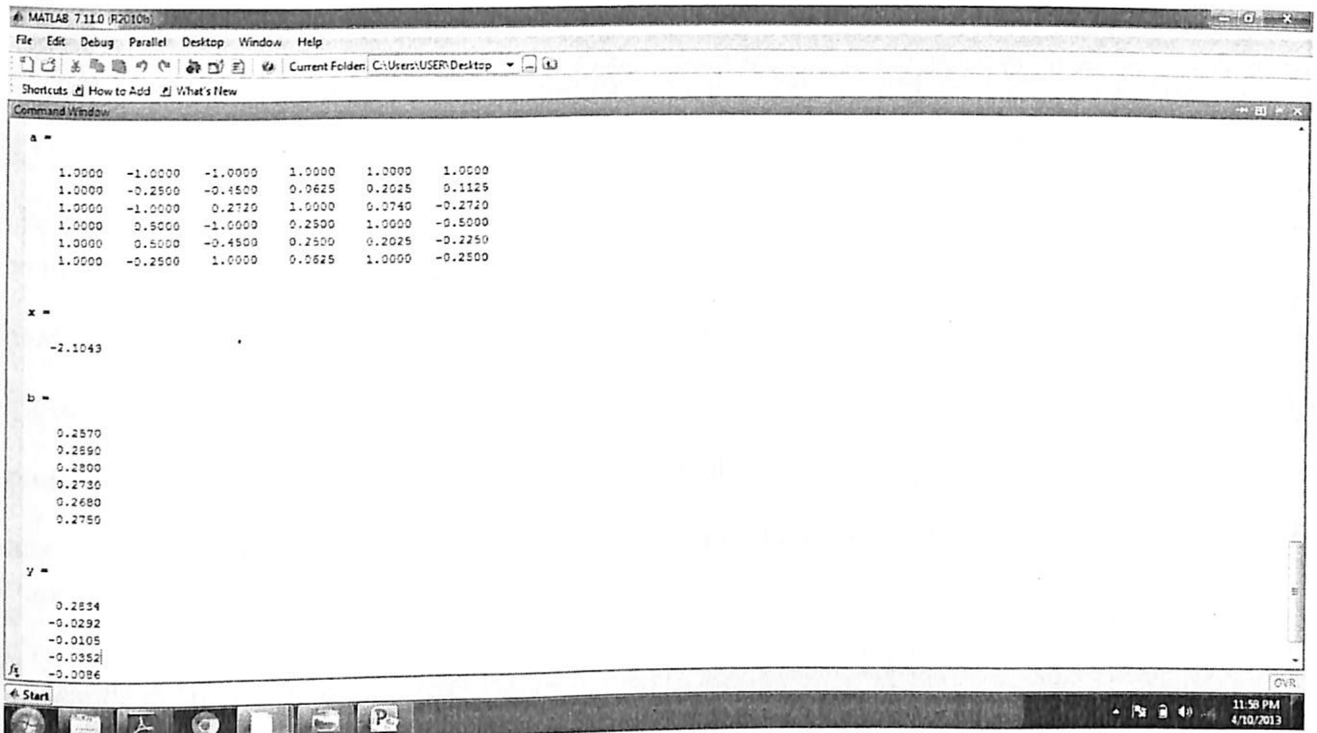


Fig 3

Putting values of constants in equation

Yp= 0.2834+(-0.0292) Xn2+(-0.0105) Xn3+(-0.0352) Xn2^2+(-0.0086) Xn3^2+(-0.0223). Xn2. Xn3

Checking for the adequacy of the polynomial

The values of the constants are put in the polynomial and a general equation is developed. The values of the factors are kept in the polynomial and value of parameter is calculated. Then calculated values are compared with actual values to check the adequacy of polynomial. Once adequacy of polynomial is checked the polynomial can be used to evaluate the parameters values for different combination of factors.

Yp= 0.2834+(-0.0292) 0.5+(-0.0105)(-1)+(-0.0352) 0.5^2+(-0.0086) (-1)^2+(-0.0223). 0.5. (-1)

= 0.27285 or 27.2% (xn2,xn3 are the calculated normalized value)

On comparing Yp calc. = 27.2% with Yp exp. = 27.3, we find that polynomial is adequate for further calculation.

3.2Developing correlations for NOx emissions in diesel engine

Let Yp be NOx emission of the engine. The two factors selected which affects NOx emission of engine are injection timing, BMEP. Therefore polynomial is

Yp= a0+a1 X1n+a2 X2n+a3 X1n^2+a4 X2n^2+ a5. Xn1. Xn2

Where X1n= injection timing; X2n= injection pressure

In our project the values of NOx emission is taken at full load.

Now values of fewer constants have to be calculated by putting the values of NOx emissions, injection timing, BMEP into the polynomial equation.

X1avg= (30.5+34.5)/2= 32.5

X2avg= (6+0)/2= 3

ΔX1= (34.5-30.5)/2= 2

ΔX2= (6-0)/2= 3

Normalized values for injection timing at various crank angle

X1n= (30.5-32.5)/2= -1

X1n= (32-32.5)/2= -0.025

X1n= (33.5-32.5)/2= 0.5

X1n= (34.5-32.5)/2= 1

Normalized values for BMEP are

X2n= (0-3)/3= -1

X2n= (1-3)/3= -0.66

X2n= (2-3)/3= -0.33

X2n= (4-3)/3= 0.333;Putting the values in equation

240=a0+a1(-1)+a2(-0.66)+a3(-1)^2+a4(-0.66)^2+a5(-1)(-0.66)

500=a0+a1(-0.25)+a2(-0.33)+a3(-0.25)^2+a4(-0.33)^2+a5(-0.25)(-0.33)

1150=a0+a1(0.5)+a2(0)+a3(-0.5)^2+a4(0)^2+a5(-0.5)(0)

680=a0+a1(1)+a2(-0.33)+a3(1)^2+a4(-0.33)^2+a5(1)(-0.33)

1300=a0+a1(-0.25)+a2(0.33)+a3(-0.25)^2+a4(0.33)^2+a5(-0.25)(0.33)

1150=a0+a1(-1)+a2(0.33)+a3(-11)^2+a4(0.33)^2+a5(-1)(-0.33)

Applying Cramer's rule for solving of constants

[A]= [1 -1 -0.66 1 0.435 0.66

1 -0.25 -0.33 0.0625 0.1089 0.0825

1 0.5 0 0.25 0 0

1 1 -0.33 1 0.1089 -0.33

1 -0.25 0.33 0.0625 0.1089 -0.0825

1 -1 1 0.33 1 0.1089 -0.33]

[B]= [a0

a1

a2

a3

a4

a5]

[C]= [240

500

1150

680

1300

1150]

[B]=[A]^-1×[C]

Using Matlab to solve the matrix

Code written

B= inv a*c

Hence the values obtained

[B] = [998.5

215.7

1365.7

174.7

-509.4

614.3]

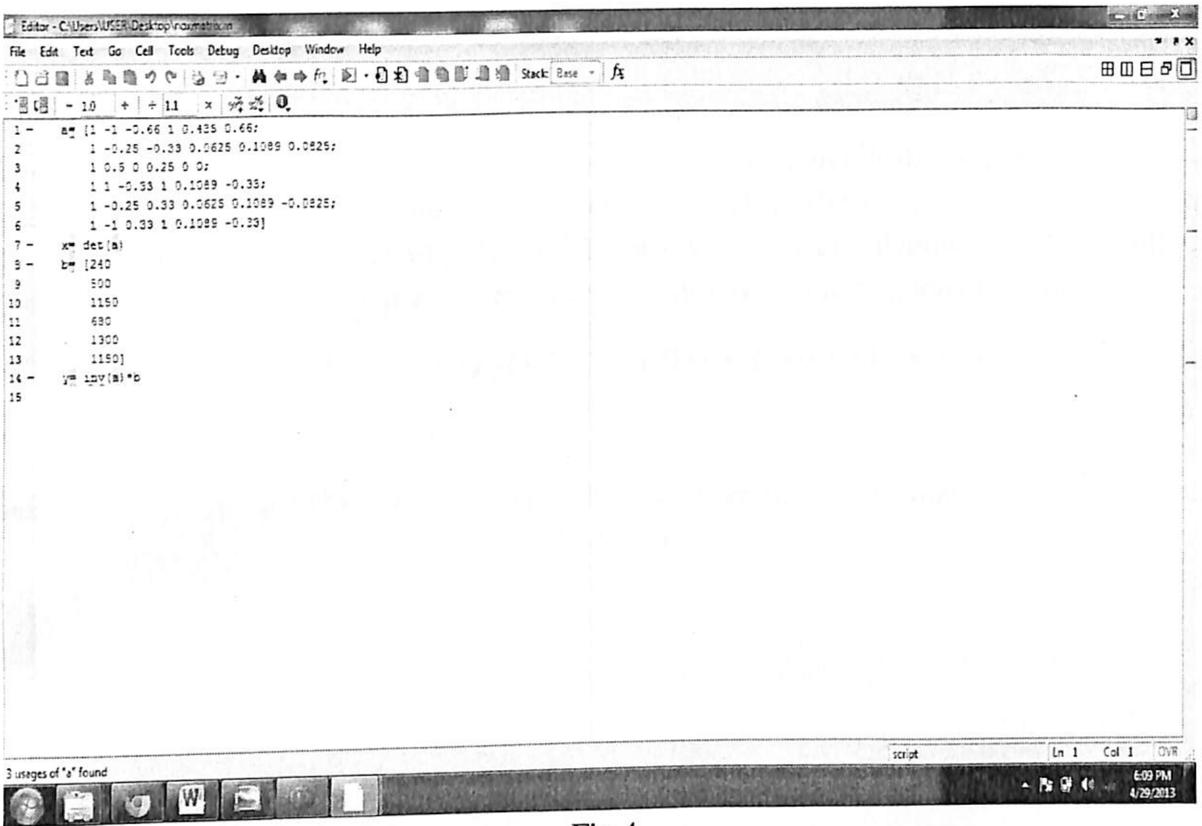

a= [1 -1 -0.66 1 0.435 0.66;
1 -0.25 -0.33 0.0625 0.1089 0.0825;
1 0.5 0 0.25 0 0;
1 1 -0.33 1 0.1089 -0.33;
1 -0.25 0.33 0.0625 0.1089 -0.0825;
1 -1 0.33 1 0.1089 -0.33]
x= det(a)
b= [240
500
1150
680
1300
1150]
y= inv(a)*b
3 usages of "a" found

Fig.4

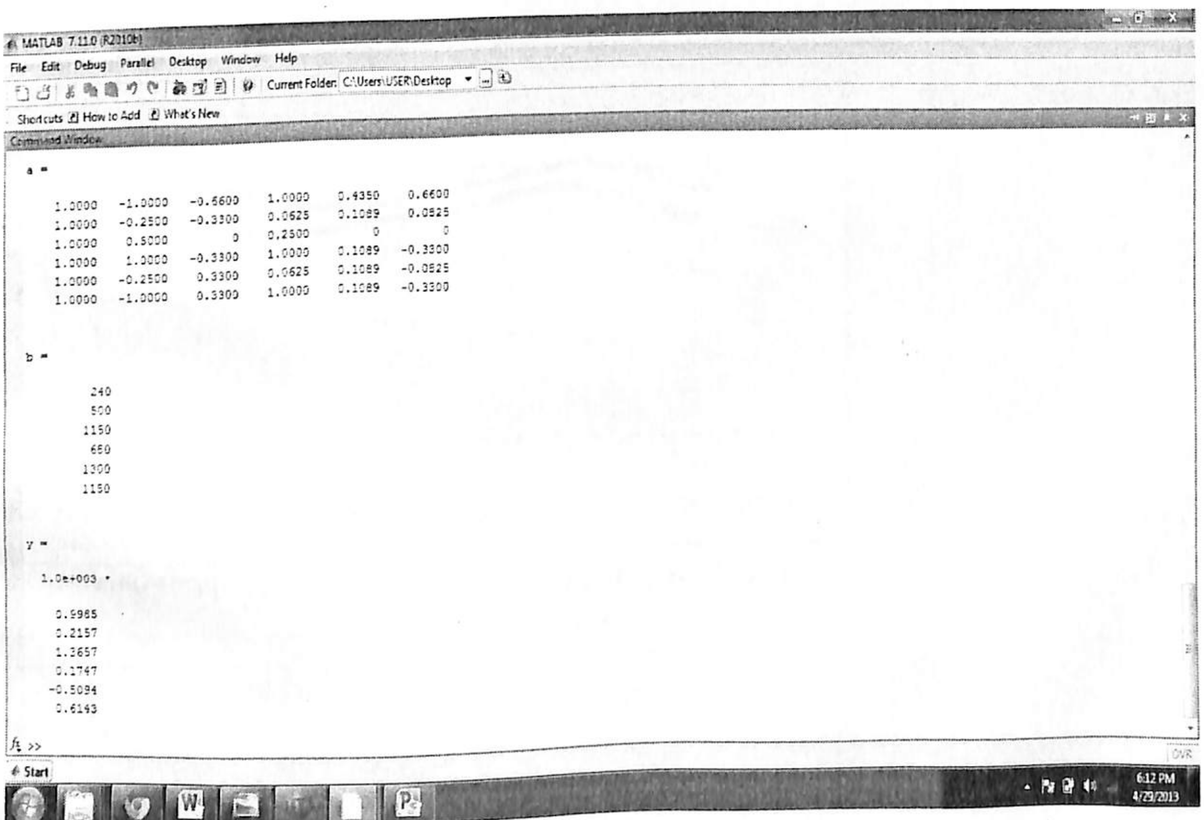

MATLAB 7.11.0 (R2010b)
Current Folder: C:\Users\USER\Desktop
a =
1.0000 -1.0000 -0.6600 1.0000 0.4350 0.6600
1.0000 -0.2500 -0.3300 0.0625 0.1089 0.0825
1.0000 0.5000 0 0.2500 0 0
1.0000 1.0000 -0.3300 1.0000 0.1089 -0.3300
1.0000 -0.2500 0.3300 0.0625 0.1089 -0.0825
1.0000 -1.0000 0.3300 1.0000 0.1089 -0.3300
b =
240
500
1150
680
1300
1150
y =
1.0e+003 *
0.9985
0.2157
1.3657
0.1747
-0.5094
0.6143

fig 5

Checking for the adequacy of the polynomial

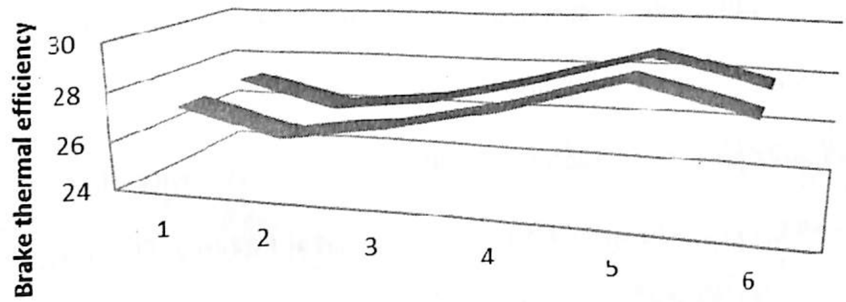
The values of the constants are put in the polynomial and a general equation is developed. The values of the factors are kept in the polynomial and value of parameter is calculated. Then calculated values are compared with actual values to check the adequacy of polynomial. Once adequacy of polynomial is checked the polynomial can be used to evaluate the parameters values for different combination of factors.

Yp= 998.5+215.7(-1)+(1365.7)(-0.66)+(174.7)(-1)^2-509.4(-0.66)^2 +614.3 (-1)(-0.66)

= 239.68

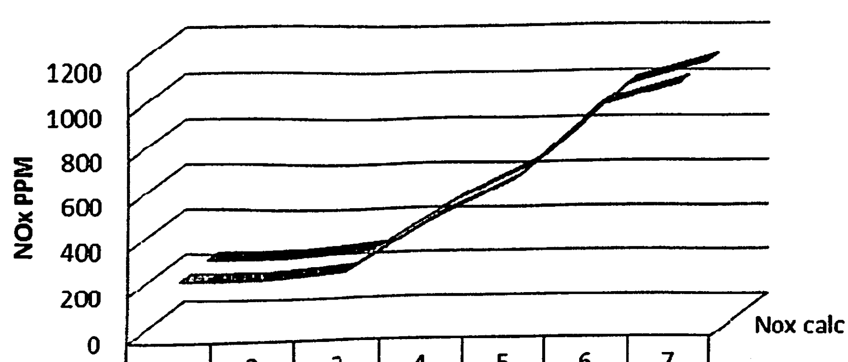
On comparing Yp calc. = 239.68 with Yp exp. = 240, we find that polynomial is adequate for further calculation.

4.Results and conclusions



	1	2	3	4	5	6
Brake thermal efficiency calc	27.2	26.12	26.68	27.65	28.88	27.84
Brake thermal effic iency actual	27.3	26.2	26.7	27.7	28.9	27.9

Fig.6



	1	2	3	4	5	6	7
Nox calc	239.68	249.45	279.66	499.98	678.99	1000.1	1100.1
Nox actual	240	250	280	500	680	1000	1100

Fig.7

This work deals with Diesel engine pollutants estimation. Although, the combustion process in internal combustion engine is very complex, the formation of products can then be predicted in order to reduce or to control automotive polluting emissions. With approximations, we have built a physical model, writing and solving equations related to our system. This model is based on our knowledge of the combustion process. In actuality, the regression model is based on engine speed (rpm), air flow, fuel flow.

The graphs drawn for actual and calculated values of different parameters i.e. thermal efficiency and NOx emissions of diesel engine clearly tells that corelations developed are adequate and result from them are in accordance with experimental values.Thus corelations can be used for different combination of affecting factors and no. of corelations can be developed to predict the behaviour of diesel engine with different operating conditions.The method of developing corelations is very useful in determining the behaviour of any specific engine for the affecting factors and hence by knowing the behaviour of engine with respect to different factors ,the output of engine can be improved.

5. Refrences

[1] Parametric studies for improving the performance of a Jatropha oil-fuelled compression ignition engine J. Narayan Reddy, A. Ramesh Internal Combustion Engines Laboratory, Mechanical Engineering Department, Indian Institute of Technology Madras, Chennai-600 036, India

[2] Effect of advancing fuel injection point on performance of Low speed IDI engine fueled with Jatropha straight vegetable oil R K Tripathi*, PK Sahoo

College of Engineering Studies, University of Petroleum & Energy Studies, Dehradun, India.

[3] Correlation for thermal NOx formation in compression ignition (CI) engine fuelled

with diesel and biodiesel S. Saravanan a,* G. Nagarajan b, S. Anand c, S. Sampath d

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