A DISSERTATION REPORT

ON

OPTIMIZING ENGINE PARAMETERS TO IMPROVE EMISSION PERFORMANCE WITH THE HELP OF DESIGN OF EXPERIMENT

Submitted to:

UNIVERSITY OF PETROLEUM & ENERGY STUDIES

DEHRADUN, UTTARAKHAND

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OPTIMIZING ENGINE PARAMETERS TO IMPROVE EMISSION PERFORMANCE WITH THE HELP OF DESIGN OF EXPERIMENT

A report submitted in partial fulfilment for the award of the degree

Of

BACHELOR OF TECHNOLOGY

(Automotive Design Engineering)

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CERTIFICATE

This is to certify that the work content in this report title **"OPTIMIZING ENGINE PARAMETERS TO IMPROVE EMISSION PERFORMANCE WITH THE HELP OF DESIGN OF EXPERIMENT"** has been carried out by Mr. **ABHIJEET UDAI** of B.Tech [ADE] under my supervision and has not been submitted elsewhere for a degree.

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ACKNOWLEDGEMENT

I on the outset of this project, express my sincere gratitude & thank towards my project guide Mr.D.K Gupta , associate professor , UPES Dehradun for giving me a wonderful opportunity to take up this project.

I would like to express deep sense of gratitude for his kind Co-operation and guiding me so well for completing my Project. Working under his guidance was a privilege and an excellent learning experience

I extend my sincere thanks to DR Mukesh Saxena ,HOD Btech ADE for his continuous encouragement during the course of the project.

Finally, I would like to thank the University of Petroleum and Energy Studies (UPES) for providing us with the platform to present our innovative idea in the form of major project.

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LIST OF ABBREVIATION/DEFINATIONS

- **DOE -DESIGN OF EXPERIMENT**
- **COP -CONFIRMITY OF PRODUCTION**
- **CO -CARBON MONOOXIDE**
- **HC -HYDRO CARBON**
- **NOX - NITROUS OXIDE**
- **PM -PARTICULATE MATTER**
- **SFC -SPECIFIC FUEL CONSUMPTION**
- **NTP -NOZZLE THROUGH FLOW**
- **DQ -DELEVERY QUANTITITY**
- **TT -TIMER TRAVEL**

FACTORS: In this project we considered factor as a input engine parameters which somehow effect emission levels and power output, such as Injection Timing, NTP, Delivery Quantity, Timer Travel.

RESPONSES: in this project response are the output values or emission values which get affected by input parameters called as a factor.

ABSTRACT

This report being a part of the partial fulfillment of the academic curriculum focuses on "optimizing engine parameters with the help of design of experiment". The Projects that have been included contain both study projects as well as analyses on the software Minitab14.

This report is a medium of understanding need of design of experiment for optimizing the parameters which needs to be tuned for optimal performance. Adding to this, the interactions of various parameters play a significant role in controlling emissions and improving fuel consumption.. So with the help of DOE we get the optimum point, which also saves time as well as cost of the project.

In this project data has been taken of BS2 Engine for the analysis part to generate multiple effect plots& Interaction plots, to see the effect on emission levels and power output of the engine. In this project data on emission levels before EURO Norm and after it, also has been studied.

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Chapter 1

LITERATURE REVIEW OF DOE

1.1INTRODUCTION

In Modern Era, development, optimization and calibration of diesel engines have become extremely challenging. Modern engines have more than one parameter which needs to be tuned for optimal performance. Adding to this, the interactions of various parameters play a significant role in controlling emissions and improving fuel consumption.

Design of Experiment (DOE) is a statistical technique used to reduce development time and cost involved in various phases of Engine Optimization.

Design of Experiment: DOE plays an important role to analyze output response due to the changes made in input variables. In this project the effect of various Engine variables (called *Factors*) such as Injection Timing, NTP, Delivery Quantity, Timer Travel has been taken for the analysis and the effect of each factor has to be analyzed on the predefined value of responses such as CO, HC, NOx, PM, Power& SFC.

In DOE we use various steps such as, measurable target quantity of responses and customer demand. For example for engines in this project Particulate matter is the main criteria, another criteria is Power .Fractional factorial method can be used to reduce the number of tests, hence saving development time and cost.

1.2 ADVANTAGES OF DESIGN OF EXPERIMENT

In industry, design of experiment used systematically to investigate the process or product variables that influence the product quality. After you identify the process conditions and product components that influence product quality, you can direct improvement efforts to enhance a product's manufacturability, reliability, quality, and field performance.

Some industrial definitions design of experiment is:

1: Design of Experiment (DOE) is a structured, organized method for determining the relationship between factors (Xs) affecting a process and the output of that process (Y).

2: Conducting and analyzing controlled tests to evaluate the factors that control the value of a parameter or group of parameters.

3:"Design of Experiments" (DOE) refers to experimental methods used to quantify indeterminate measurements of factors and interactions between factors statistically through observance of forced changes made methodically as directed by mathematically systematic tables.

Design of Experiments (DOE) is a key tool in the Six Sigma methodology. DOEs improve processes in a quantum fashion, and is an approach for effectively and efficiently exploring the cause and effect relationship between numerous process variables and the output or process performance variable.

Design of Experiments help in the following ways:

Accuracy :with the help of Design of Experiments we can able to reach at the optimum point it helps in identifying the affect of factor on each response and thus help us to reach at the point where all the desired emission and fuel consumption values will be at optimum level.

Time: Design of Experiments is a method by which we can save enormous amount of time by reducing the number of test by fractional method.

Cost: By reducing the number of test with the help of DOE we can able to cut down the large amount of cost, which could be, their if we have to run the entire test to vary each parameters on a test bed.

Evaluation: With the help of DOE we can study or analyze each effect of interaction between parameters and how much they effect on output response, like in this project I have done this with the help of software.

1.3 Need of Design of Experiment

Engine testing for research and development is characterized by frequent changes in project structures and design methodology, as understanding improves. In this situation

'Single parameters at a time 'approach to the experimental design has found favor.

Hence each parameters are varied in turn with the other parameters fixed, usually at the best values deduced from the earlier test so this can reduce the effect of importance of effect of factor on output response as in the case of interaction its result will be different so we realize the importance and the need of Design Of Experiment .

The problem used to come with this method is:

1. Optimum Point: Is the optimum point really obtained? This is the big question as we not able to study the effect of interaction between parameters.

2. Time: The enormous amount of time will be required, and hence ,cost is high to fix and vary parameters while trying to bring to its optimum point.

3. Interaction: Evaluation of effect of interaction between parameters is not possible

As the previous method were not sufficient to attain optimum point the concept of Design of Experiment was introduced by DR. Genechi Taguchi in 1950 which latter called as Taguchi method. A Taguchi design or an orthogonal array is a method of designing experiments that usually requires only a fraction of the full factorial combinations. An orthogonal array means the design is balanced so that factor levels are weighted equally. Because of this, each factor can be evaluated independently of all the other factors, so the effect of one factor does not influence the estimation of another factor

The work of DR Taguchi has been utilized in my project to get the emission optimization

With the help of Minitab 15 and DOE pro XL which is a statistical software.

1.4 OPTIMIZATION METHODOLOGY

Design of experiment (DOE) is the common term used which is defined as a structure and organized method in which planned changes are made to the input variables of a process or system and the effect of these changes on a predefined output are then analyzed in short it is a technique to discover cause and effect relationships. This method of analysis is to look for the differences between responses (output) readings for the different group of the input changes. These differences are then attributed to the input variables acting alone (called as single effect) or in combination with another input variables (called as interaction).

Like in this project it has been suggested to take five input parameters called as factor such as **Injection Timing, NTP, Delivery Quantity, Timer Travel so the effect of each factor has to be analyzed on the predefined value of responses such as CO, HC, Nox, PM, Power& SFC** individually as well as in interaction with two factors on responses.

Here two methods are generally proposed which tell the number of experiment runs has to be conducted for certain levels of the factor values.

1Full factorial

2ractional factorial

Full Factorial Method is the safest method, where all possible interactions are considered but are maximum of 4or 5 variables with only 2 levels, since the no of experiment increases exponentially with the number of factor we prefer fractional factorial method .

Though a full factorial design is the most desirable design wherein one could gather information on all the main effects, two way interactions, three way interactions and other higher order interactions are very unpractical to run due to the prohibitive size of the experiments. For a design of seven factors at two levels one would have to complete 128 runs, variables (4 variables = 24 = 16, 5 variables = 25 = 32, K variables = 2k experiments).

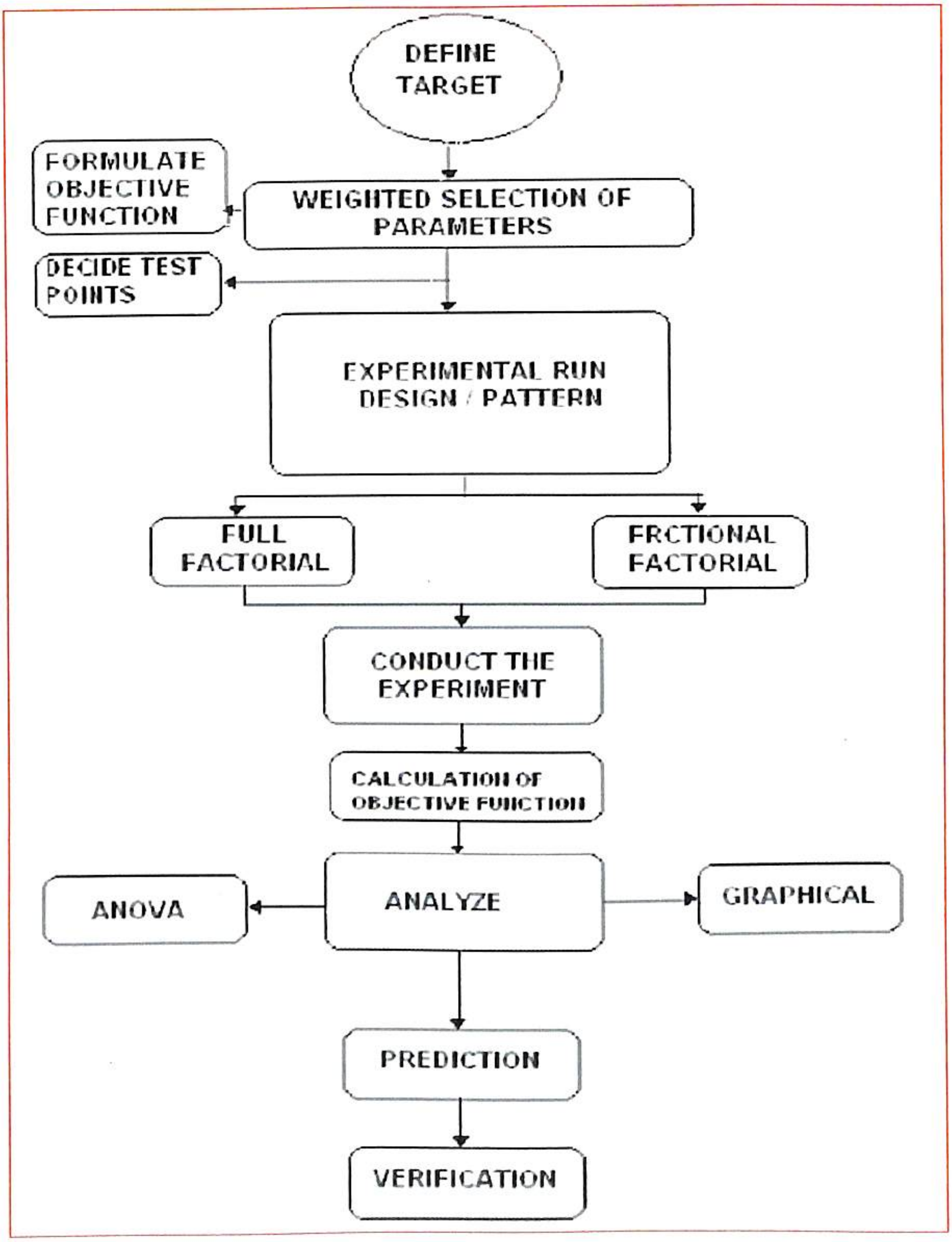
Fractional factorial method

This method is a practical method, with comparatively reduced number of experiments, if some important factors and interactions of 2^{nd} order are only considered having two factor values suppose we have 5factor having 2factor levels can be done by L8taguchi method by conducting only8experiments.

Chapter 2

METHODS &TECHNIQUE OF DESIGN OF EXPERIMENT

2.1 Design of Experiment Methodology Flowchart



2.2 DEFINE TARGET

In DOE methodology the first step is to understand the customer demand and define the targets, suppose if an diesel engine was selected is going for an conformity of production and it has to meet euro 2 norms, so the target was to meet euro norm for that particular engine and it was found that it's This engine model was selected for the improvement project since the particulate emission value was very close to the limit value and power output was very close to the lower limit. So we have to optimize the parameters in such a way that we can easily achieve our COP limit.

Diesel engine is the nominal rated Bharat Stage II engine, delivers power of 122 kW at 2400 engine Rpm.

Crossed two COP tests by ARAI.

COP Period	Power kW	Intermediate Speed Rpm	CO g/kWh	HC g/kWh	Nox g/kWh	PM g/kWh
2005 - 06 (I)	121.77	1800	0.72	0.16	5.69	0.133
2005 - 06 (II)	115.99	1700	0.92	0.2	5.62	0.145
COP Limit	115.9 - 131.76	1200 - 1600	4.000	1.100	7.000	0.150

This engine model was selected for the improvement project since the particulate emission value was very close to the limit value and power output was very close to the lower limit.

So in this project we had to find out the most influencing parameters and there interaction effect on output responses value which is particulate matter &power.

So here is the Steps for Optimizing the Parameters. we need to get the optimum value of most influencing parameter. there are so many parameters but with the help of weighted selection of parameters we find out the important factor according to our project requirement.

2.3 Weighted Selection Of Parameters:

In this we have large number of factors such as piston bowl design, high pressure pipe, mean swirl, injection timing, number of injector hole and many more parameters which may or may not, somehow influencing response values, it is not possible for us to take all the factors for experiment but if we do so it will be take too much time so it has to be reduced by homing-in methods.

The best method for this is the 'weighted selection of parameters', which is a Subjective method evolved through a team meeting, where it can be decided according to condition of user, like what is possible for him to give the weight age of influencing parameters, or the factor which is influencing more on output response values.

The possible evolution criteria are *:taken from krottmaier ,j optimizing engine design(book)

Influence of parameters on response values (1 to 10 points).In this we take measure of how much the factor is influencing output parameters or response value. the influence value will remain same for all user as this engine factor will not be going to affect different, it means Injection Timing, NTP, Delivery Quantity, Timer Travel for that particular condition.

Cost entailed by the current parameters :This is the second evaluation method (1 to 10points)

If we see in terms of cost it is like, if we have to made certain changes in a factor it will take some time the longer the time it will take it will be high in terms of cost also as well as it will be also decided by the hardware cost involved in that parameters.

Suitability of the parameters for ease of experimental setup or manufacturing: This is the third method for giving weight age to factors present in the table. In this if we see that suitability for piston bowl design is 9 which is very high which is difficult to understand that how can it be possible for a test engineer to make changes in bowl design..As far as concerned to my knowledge it is a situation that a test engineer having 2piston present so that it can be possible to give higher values to piston bowl design in terms of suitability.

WEIGHTED SELECTION OF PARAMETERS CHARTS

Sr. No	Parameters	Evaluation			
		Influence A	Cost B	Suitability C	Priority A * B * C
1	Piston Bowl Design	7	7	9	441
2	Mean Swirl	9	4	9	324
3	No. Of Injector Holes	8	6	4	196
4	Injector Thru. Flow	8	7	8	448
5	Injection Timing	8	9	8	576
6	Nozzle Tip Protrusion	6	9	5	270
7	High Pressure Pipe Dia.	8	9	9	648
8	Intake Air Depression	5	6	8	240
9	Exhaust Back Pressure	6	7	7	294
10	Fuel Pump Plunger Dia.	6	7	5	210
11	Air Fuel Ratio	7	9	5	315

The product of these criteria gives the priority in 1 to 1000 points, based on which the number of important parameters which having higher values in priority list has been selected orthogonal L8array diagram in which we choose the factors which is affecting more to the response value, for further interactions effect we can only analyze these weighted parameters as this will be having more effect on output response comparing other parameters.

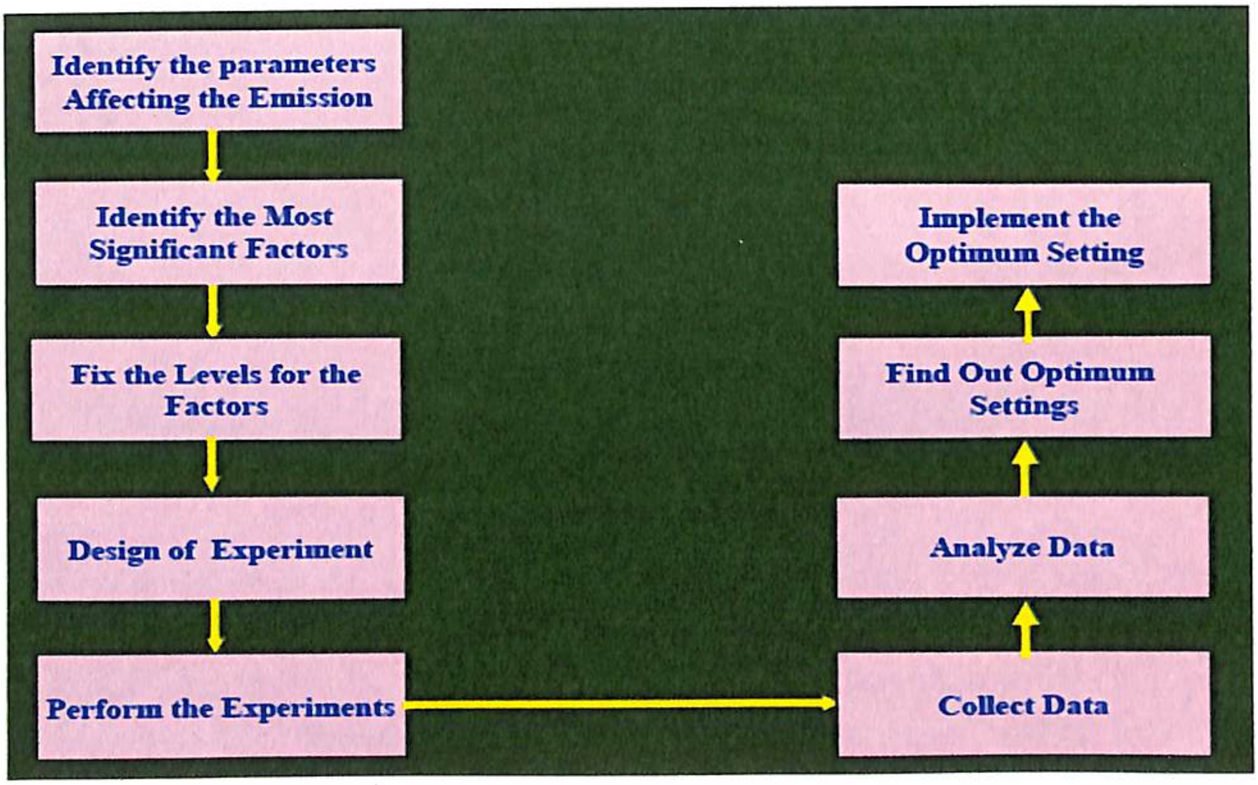
So finally while considering large number of variables, it was decided to evaluate their weight age and short-list them for Design of Experiments (DOE). In this project Injection Timing, NTP, Delivery Quantity, Timer Travel has been selected as main parameters.

2.4 OBJECTIVE OF THE PROJECT.

- To Improve Current Emission Level.
- To meet COP requirements at 1440 rpm intermediate speed this is the worst speed for both NO x and PM.
- To make the engine Robust.

2.5 STEPS FOR OPTIMIZING THE PARAMETERS

In this flowchart it has been show that how we can optimize the parameters step by step.



2.6 Parameters affecting emission performance

There are 124 parameter affecting emission parameter of the engine. All the 120 parameters have been grouped into the following major parameters:

All these 124 parameters have been checked in the Engine and found to be within the specification.

S.no	Component / assembly	No of Parameters
1	Cylinder Block	8
2	Cylinder Head	19
3	Connecting Rod	13
4	Cam Shaft	9
5	Crank Shaft	9
6	Liner	9
7	Piston & Rings	9
8	Injector	7
9	Push Rod	3
10	Tappet	3
11	FIP	4
12	Engine Assembly	20
13	Rocker lever	7
14	Flywheel	1
15	Inlet manifold	2
16	Valve Stem Seal	1
	Total	124

Hence it was concluded that optimization of important parameters is a must which is Injection Timing, NTP, Delivery Quantity, Timer Travel for this project which is judged by weighted selection of parameters.

Parameters for Optimization

Following parameters have been identified for the Optimization Exercise as first step, because

1) These parameters are adjustable on the engine.

2) Easy Implementation possibility

If we are not getting the optimum result with these parameters then we may touch the other dimensions.

Four parameters are:

1. **Static Injection Timing** – Changes the period of fuel injection in every compression stroke and affects homogeneous mixture formation.

2. **Delivery Quantity** - Affects engine power output

3. **Timer Travel** - Changes the dynamic injection timing

4. **Nozzle Tip Protrusion** - Changes the spray position of injected fuel.

All the above 4 characteristics are highly critical and can be controlled in the manufacturing process itself.

So the four parameters are mentioned below ,it has been taken it for the 2factor levels, level 1 &level2 which is shown in the table.

S.No	Factor	Spec	Level1	Level 2
1	Injection Timing(Deg.BTDC)	1.25 - 1.35	1.29	1.34
2	NTP(mm)	2.7 - 3.3	2.7	3.1
3	Delivery Qty.(CC)	71 - 77	73	75
4	Timer Travel(mm)	1.8 - 2.4	1.9	2.4

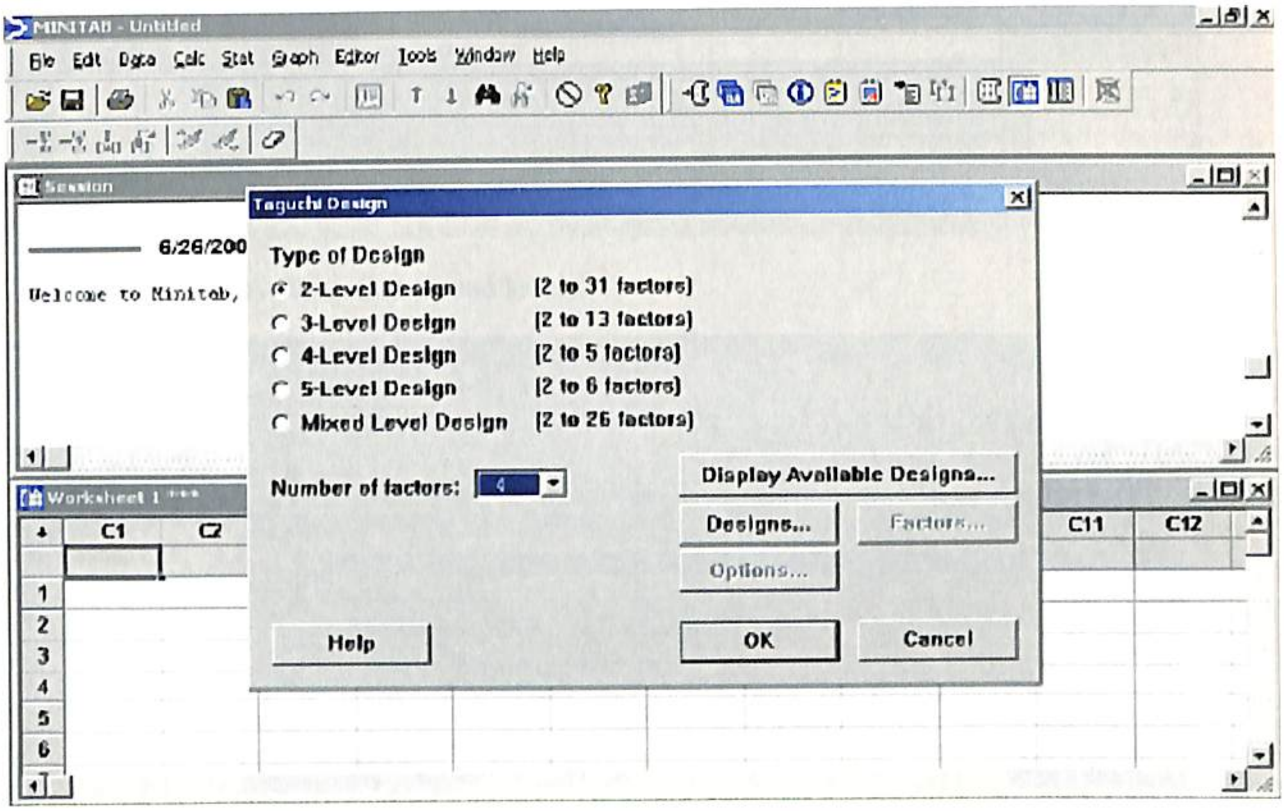
4FACTOR &2LEVELS

So in this we will do the fractional factorial design method to reduce the no of test on test bed to save our time as well as cost. With the help of above table values we will able to implement **L8 Taguchi experimental Design method.**

2.7 Experiment Design

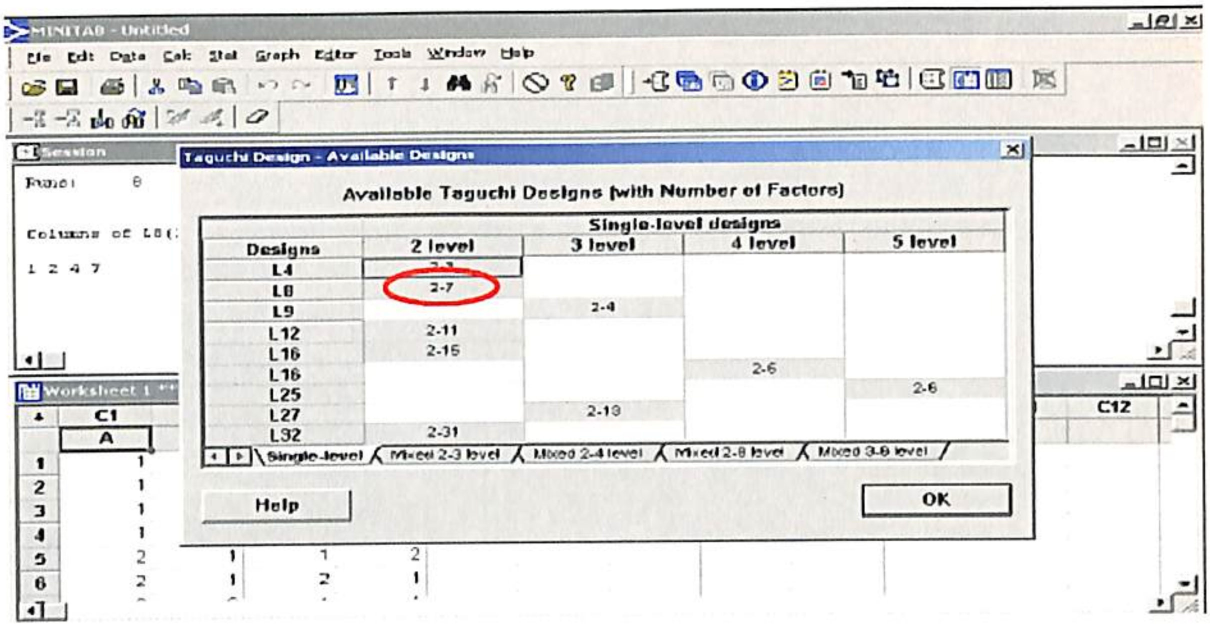
For 4 factors and 2 Levels, to select the Suitable Orthogonal array we have used the Minitab 14 , statistical software

In this experiment 4factor has been taken for the experimental design for two factor levels, and further for the analysis of their individual as well as interaction effect on output response, which are CO, HC, Nox, PM, Power& SFC

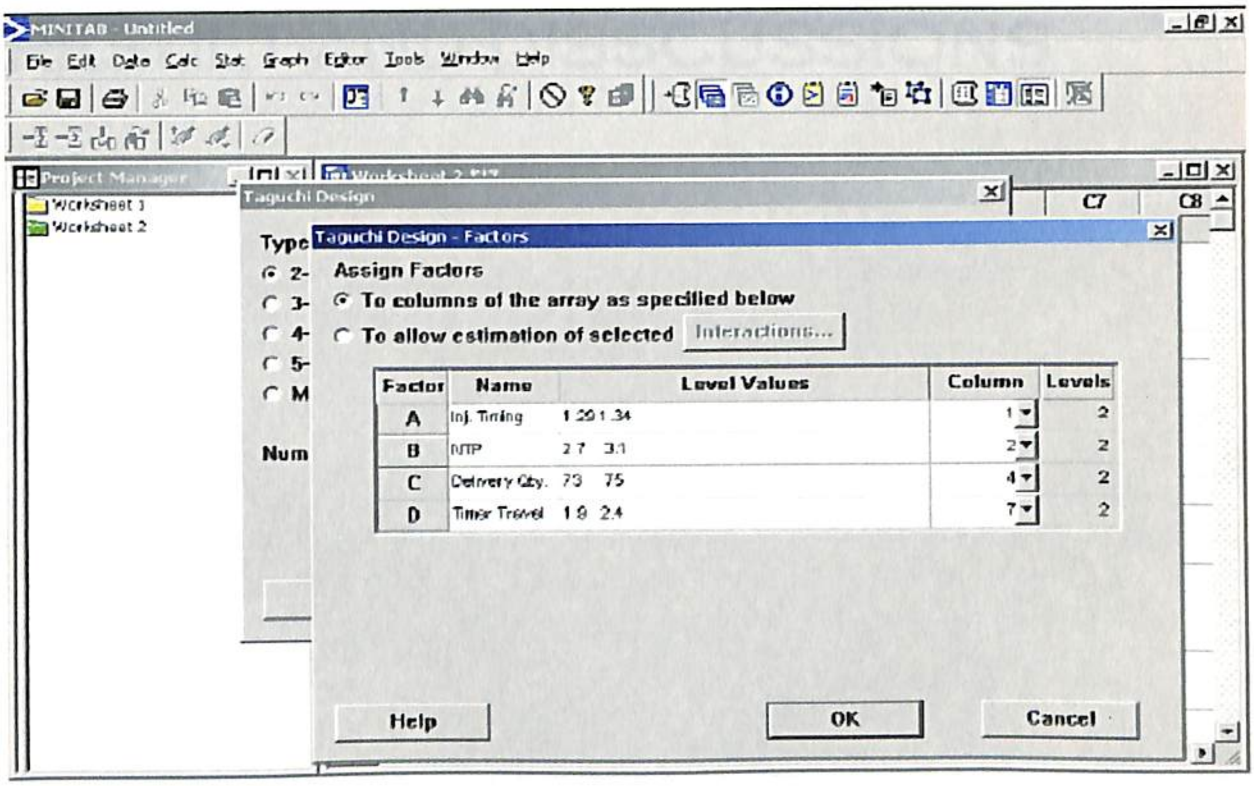


From the Minitab output, we have selected L8 orthogonal array

So after performing above methods in Minitab software we will able to get the experimental output value of 8runs and after getting this we will do the analysis part with the help of graphical approach on a software, of each factor such as Injection Timing, NTP, Delivery Quantity, Timer Travel to study its effect on response value such as CO, HC, Nox, PM, Power& SFC and also the interaction effect of most influencing parameters on response value.



Experiment Design – With factors and levels



Experiment Design – With factors and levels

Chapter 3

RESULT AND DISSCUSSIONS

3.1 Basics of Minitab

Minitab Inc. is the leading global provider of software and services for quality improvement and statistics education. With the help of Minitab we can easily calculate ANOVA problem of multiple interaction of different factors in this project such as Injection Timing, NTP, Delivery Quantity, Timer Travel has been taken for the analysis. It provide the tools and resources to solve complex problems ,in this project Minitab has been used to draw a multiple plots of each factor on each responses values such as CO, HC, NOx, PM, Power& SFC.

DOE Pro XL

DOE PRO XL Software integrates into Excel providing Design of Experiments (DOE) functionality. Features include computer-aided design selection, multiple response regression and optimization, prediction, and advanced plotting. Whether your needs are for Six Sigma, DOE, or general use DOE PRO XL can help you design and analyze your experiments.

DOE PRO XL includes multiple built in designs including full and fractional factorials, Taguchi, Box-Behnken, Central Composite Designs (CCD), and more. A computer-aided design selection feature can help you pick the design that best meets your needs. If you are working with historical data or would like to design your matrices, DOE PRO XL make this easy .

A Taguchi design , or an orthogonal array, is a method of designing experiments that usually requires only a fraction of the full factorial combinations. An orthogonal array means the design is balanced so that factor levels are weighted equally. Because of this, each factor can be evaluated independently of all the other factors, so the effect of one factor does not influence the estimation of another factor

Interaction

When the effect of a one factor depends on the level of the other factor. You can use an interaction plot to visualize possible interactions.

For example, a food scientist is looking for the combination of whey and supplements for a pancake mix that yields the best quality. She runs an experiment with four levels of whey content

(0%, 10%, 20%, 30%) and two different supplements (1 and 2), and draws an interactions plot of the results.

Parallel lines in an interaction plot indicate no interaction. The greater the difference in slope between the lines, the higher the degree of interaction. However, the interaction plot doesn't tell you if the interaction is statistically significant.

This plot indicates an interaction between the supplement and the whey content. The supplement with the highest quality level depends on the whey content. Specifically, supplement 1 is better when the whey content is 0 and 10%, while supplement 2 is better when the whey content is 20 and 30%. Interaction plots are most often used to visualize interactions during ANOVA or DOE.

Minitab draws a single interaction plot if you enter two factors or a matrix of interaction plots if you enter more than two factors.

Run (DOE)

Each experimental condition or factor level combination at which responses are measured. Typically, each run corresponds to a row in the worksheet and results in one or more response measurements, or observations. For example, you conduct a full factorial design with two factors, each with two levels. Your experiment has four runs:

Run	Factor1	Factor2	Response
1	-1	-1	11
2	1	-1	12
3	-1	1	10
4	1	1	9

Note When conducting an experiment, the run order should be randomized.

Each run corresponds to a design point, and the entire set of runs is the design. Multiple executions of the same experimental conditions are considered separate runs and are called replicates.

The following table displays the L8 (27) Taguchi design (orthogonal array). L8 means 8 runs. 2, 7 means 7 factors with 2 levels each. If the full factorial design were used, it would have 27 = 128 runs. The L8 (27) array requires only 8 runs a fraction of the full factorial design. This array is orthogonal; factor levels are weighted equally across the entire design. The table columns represent the control factors, the table rows represent the runs (combination of factor levels), and each table cell represents the factor level for that run.

3.2 Analyses of Data on Software

In the graphical method I have taken the value of factor levels of Injection Timing, NTP, Delivery Quantity, Timer Travel which is shown in this table.

S.No	Factor	Spec	Level1	Level 2
1	Injection Timing(Deg.BTDC)	1.25 - 1.35	1.29	1.34
2	NTP(mm)	2.7 - 3.3	2.7	3.1
3	Delivery Qty.(CC)	71 - 77	73	75
4	Timer Travel(mm)	1.8 - 2.4	1.9	2.4

Which we have to give while performing in the software, while working on the Minitab I have used Taguchi method where it asked about the factor levels of each, as well as replication. Like here we are conducting 8experiment only for one time so the replication should be one as an input in software. While in DOE Pro XL I have used L8 Taguchi method where I have given replication 1 while responses values given as 4, in this value off factor levels has been given so finally after giving input for required condition we get main effects plot and interaction effect plot of each factors. But according to targeted value its necessary to see the interaction effect between each parameters on its response.

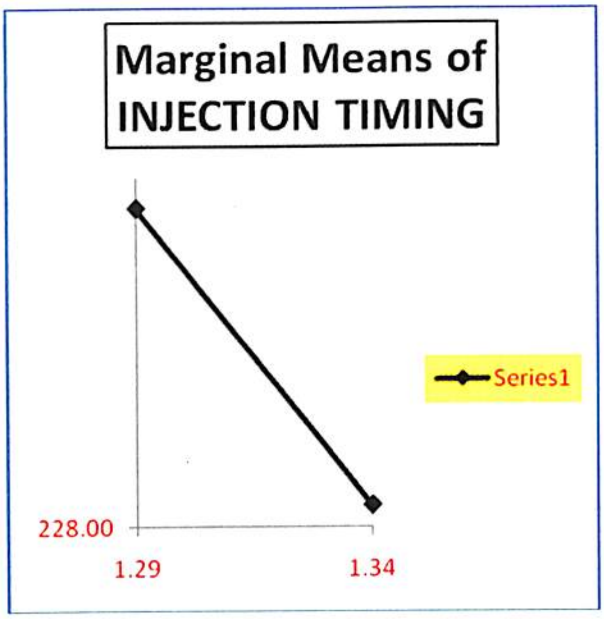
SFC DESIGN SHEET

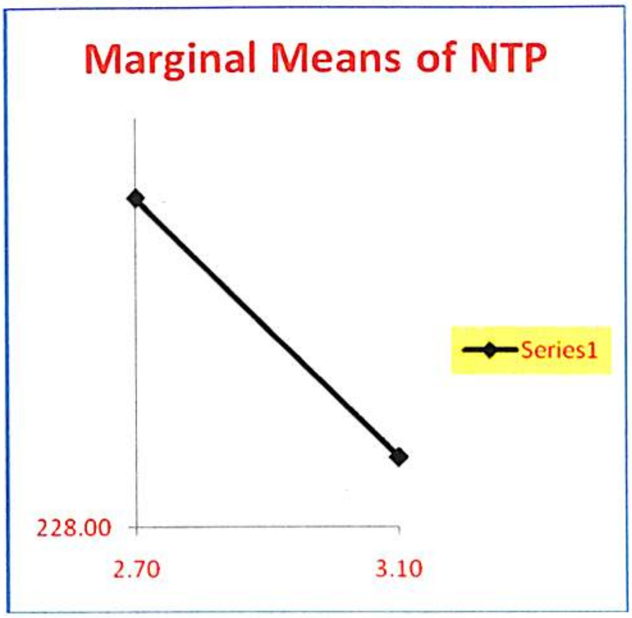
By taking the input of SFC which is shown in the table its generate the multiple plots with the help of software in which its shown the effect of two factor levels on its response, as well as the interaction effect plot

Factor	A	B	C	D=-AC		SFC		
Row #	INJECTIOI	NTP	DELEVERY	TIMER TRAVEL		Y1		Y bar
1	1.29	2.7	73	1.9		235.2		235.2
2	1.29	2.7	75	2.4		232.8		232.8
3	1.29	3.1	73	1.9		229.8		229.8
4	1.29	3.1	75	2.4		230.6		230.6
5	1.34	2.7	73	2.4		229.2		229.2
6	1.34	2.7	75	1.9		229.283		229.283
7	1.34	3.1	73	2.4		226.1		226.1
8	1.34	3.1	75	1.9		228.5		228.5

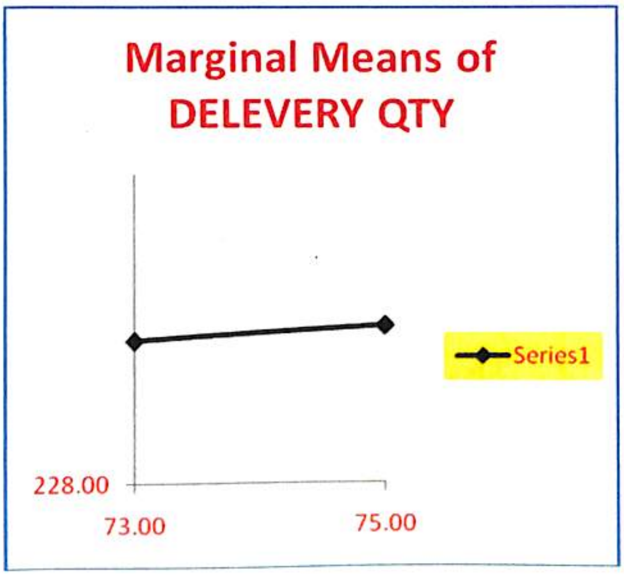
Minitab &Doe Pro XL was used here to draw these plots to analyze the main as well as interaction effects between the parameters on the every output that was measured. In figure1 the main effect plots for different factors at different levels has been shown .The response Interpretation is that higher the slope, higher the effect of that parameter on output Response. Here the injection timing &Nozzle through Flow has effecting more mean it has highly substantial effect, where as delivery quantity and timer trave has substantial effect.

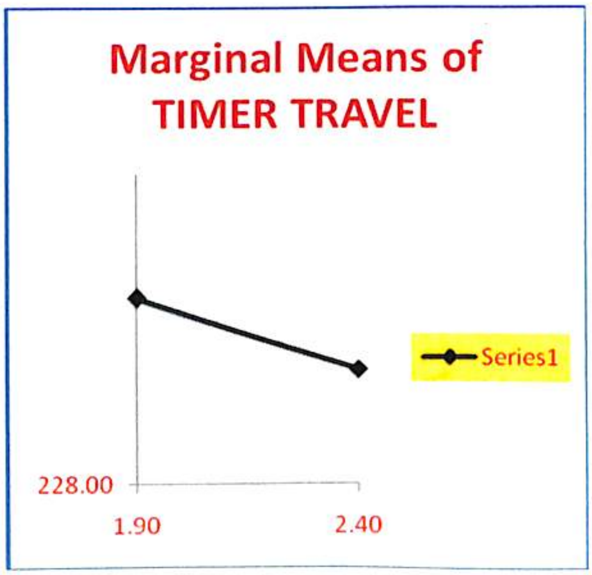
MULTIPLE PLOT OF SFC



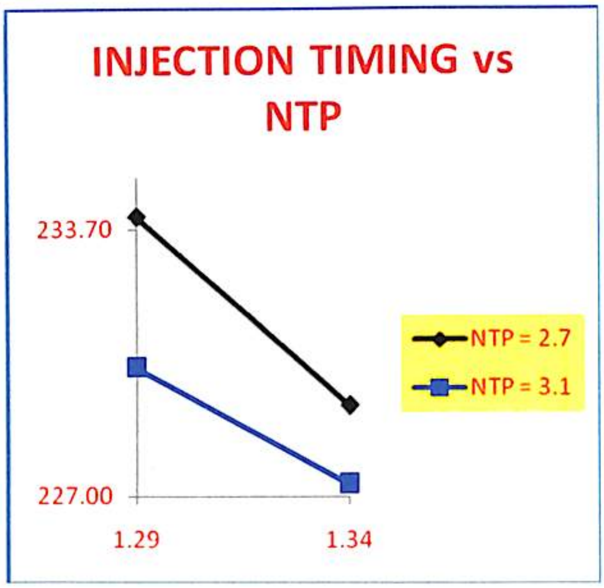


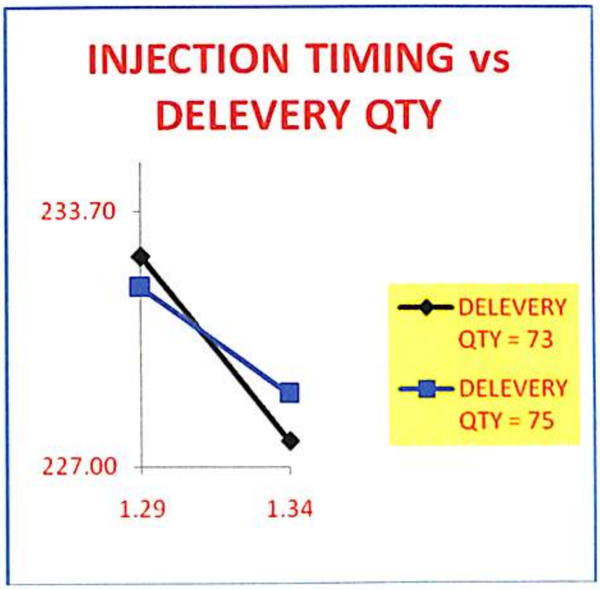
Effect plots show the change in response from one level to another level for each factor. Higher the slope of the effect plot, stronger the influence of the factor on the response. The effect plot can have a positive or a negative slope depending on the direct or inverse relationship the factor has with the response.

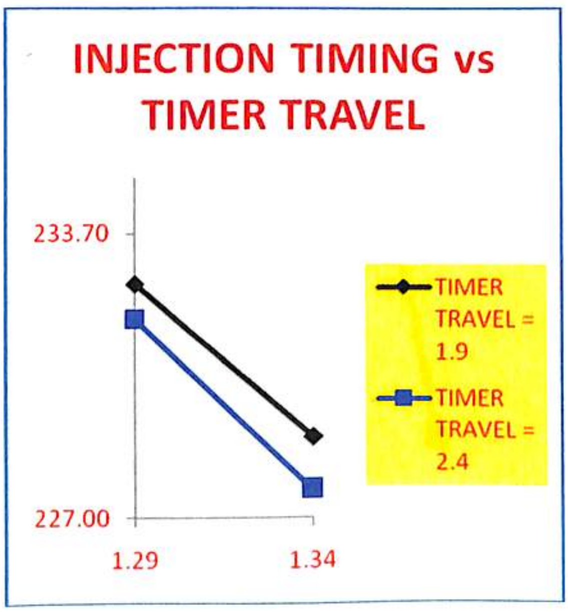


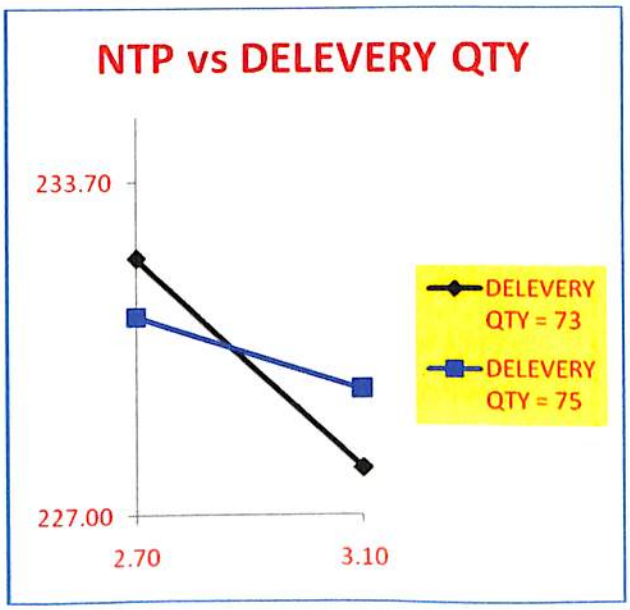


Interactions can also be judged from the effects plots by plotting one factor at first level as well as at second level of the other factor. For choosing the best combination, the response value for that parameter has to be checked at all levels and the highest one will be the best. But this method is applied when no interaction effect is taken into consideration. When the interaction effect is considered in the experimentation matrix, similar type of graph is to be drawn to check whether any combination is dominant. If so, then the main affect level has to be overridden to new level with maximum response value.

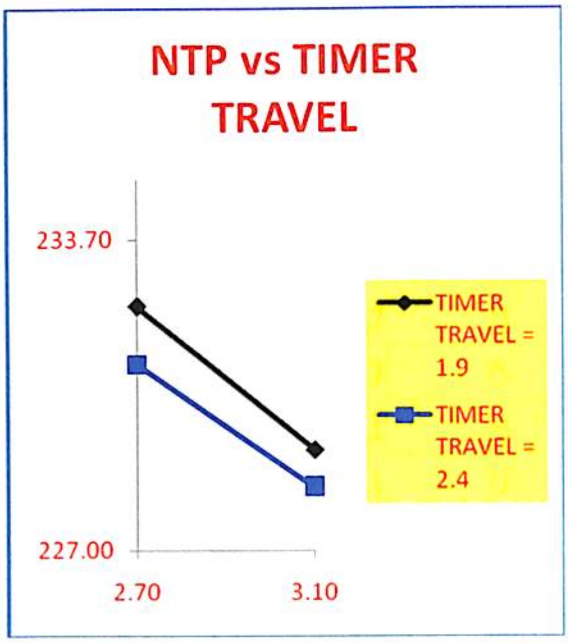


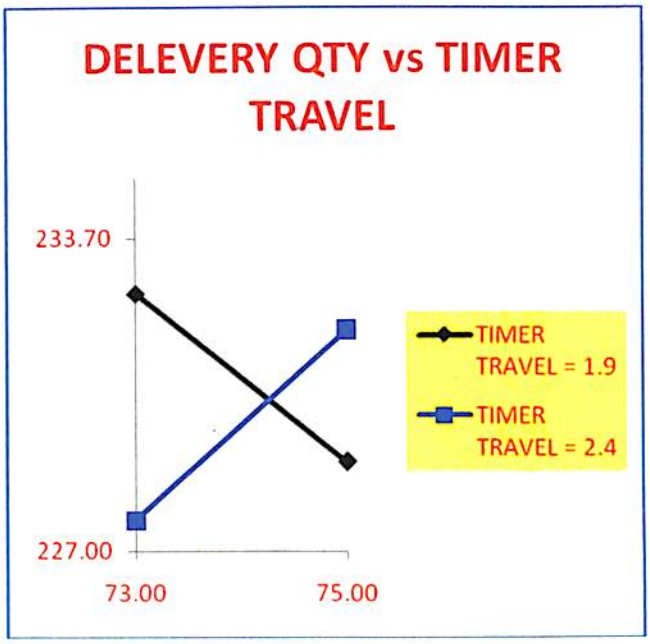




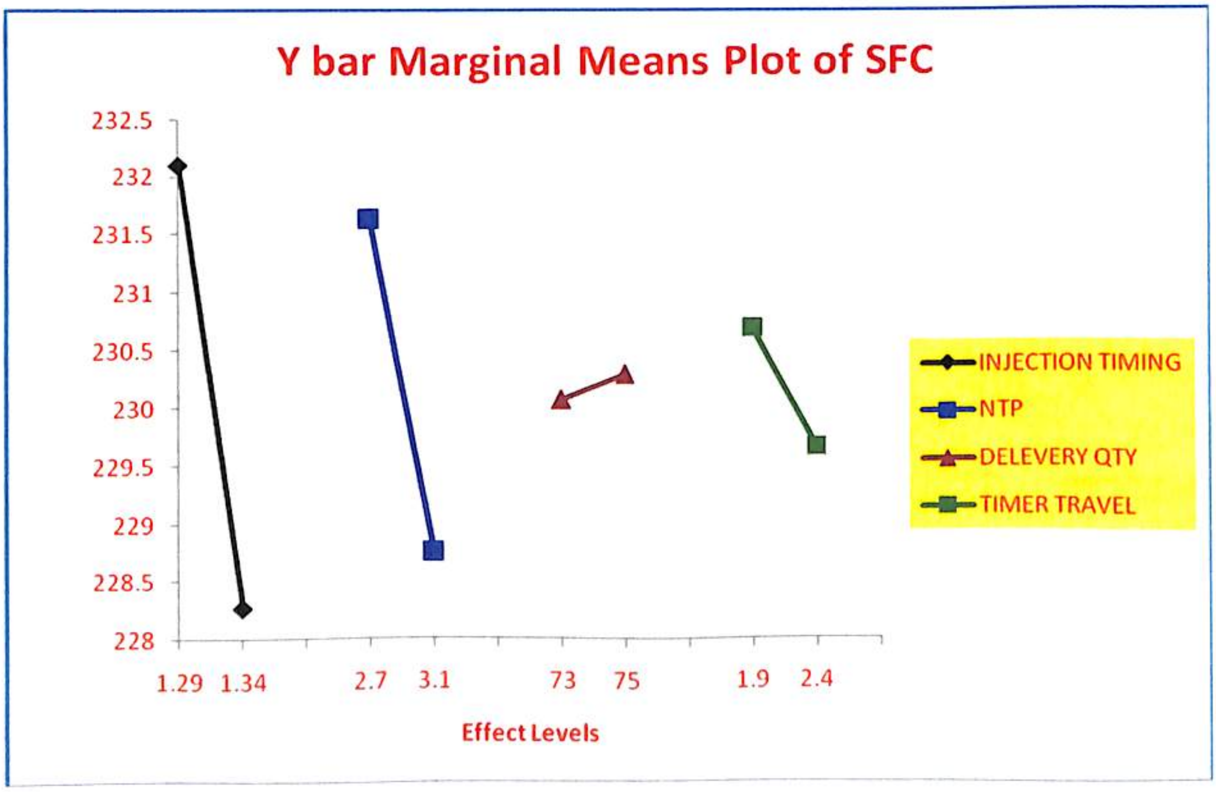


In these graphs the interaction effect of intjection timing vs timer travel ,NTP vs DQ ,NTPvs TT ,DQ vs T.T has been shown with respect to SFC value .its basically tell how much they are effecting sfc value.





Y Axis Is SFC Output Value



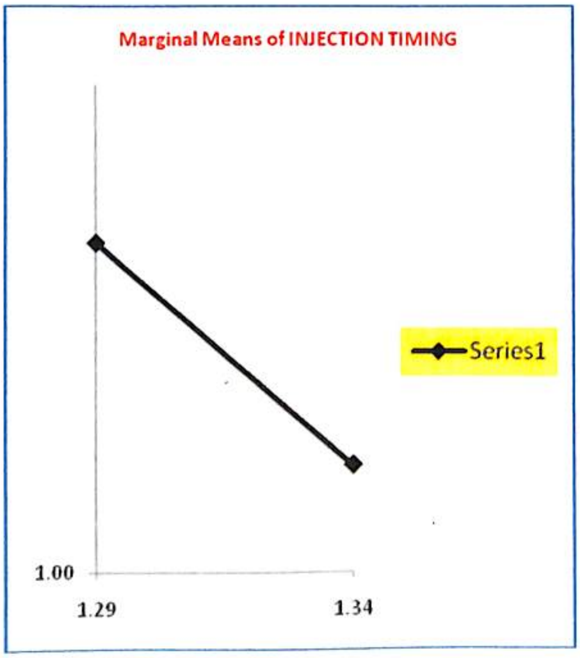
In this y marginal graphs its tells injection timing and nozzle through flow is effecting more on SFC Value. as we see the deviation is more with these parameters.

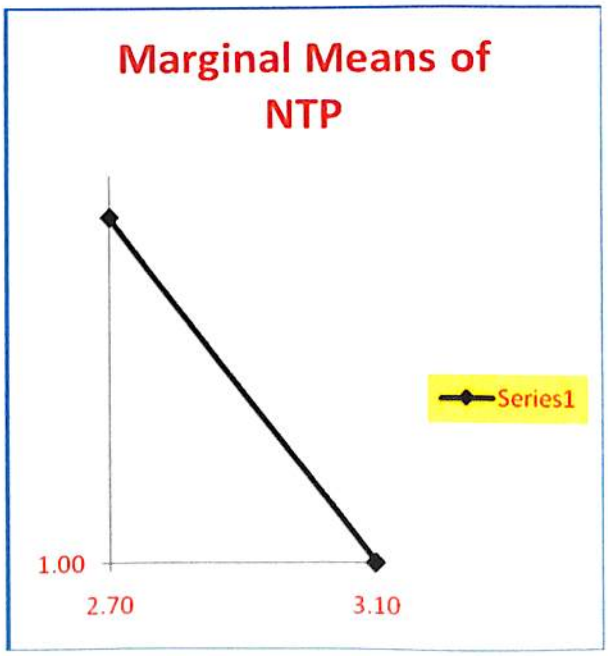
Now in this co design sheet the experimental value of carbon monoxide has been given as a input. so with the input it generate the effect plot of each parameters and there interaction effect on carbon monoxide value.

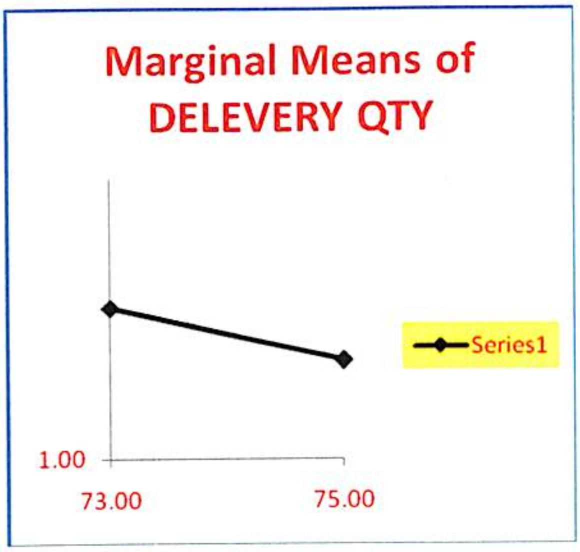
CO DESIGN SHEET

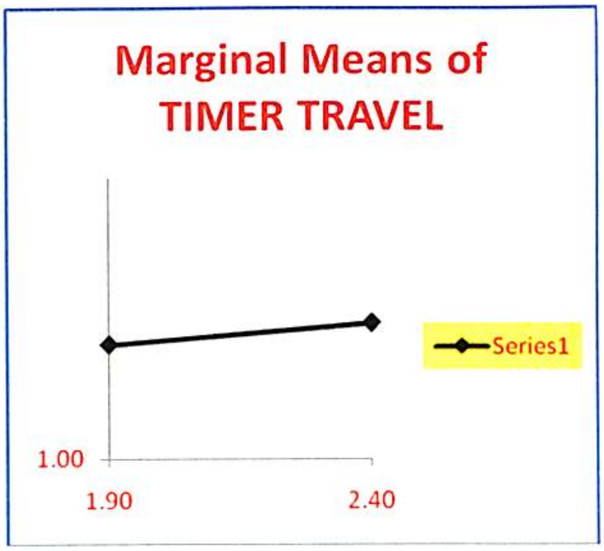
Factor	A	B	C	D=-AC	CO	
Row #	INJECTION	NTP	DELEVERY TIMER	TRAVEL	Y1	Y bar
1	1.29	2.7	73	1.9	1.51	1.51
2	1.29	2.7	75	2.4	1.11	1.11
3	1.29	3.1	73	1.9	0.93	0.93
4	1.29	3.1	75	2.4	1.26	1.26
5	1.34	2.7	73	2.4	1.09	1.09
6	1.34	2.7	75	1.9	1.36	1.36
7	1.34	3.1	73	2.4	1.12	1.12
8	1.34	3.1	75	1.9	0.69	0.69

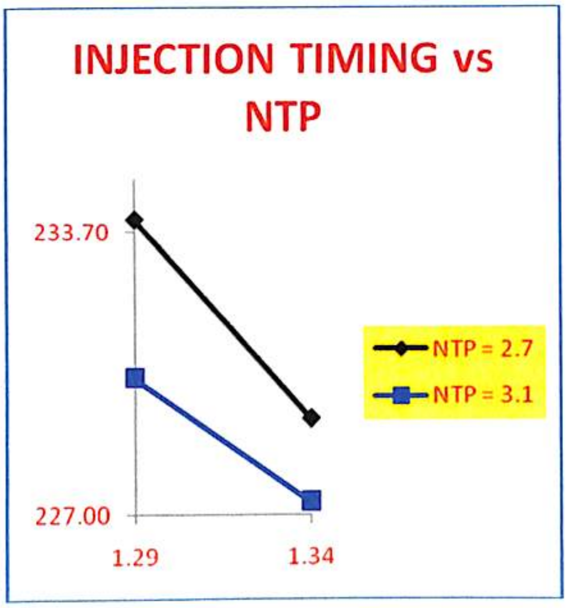
MULTIPLE PLOT OF CO

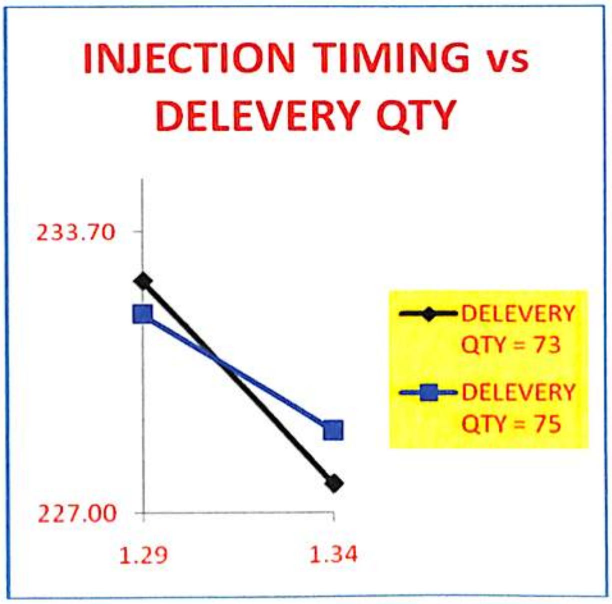




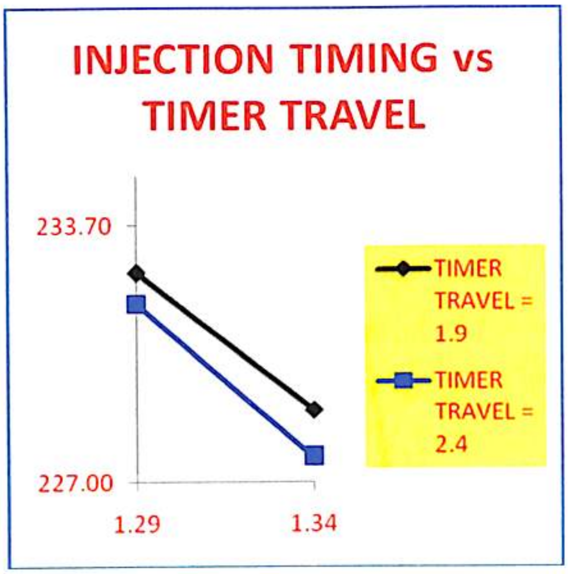


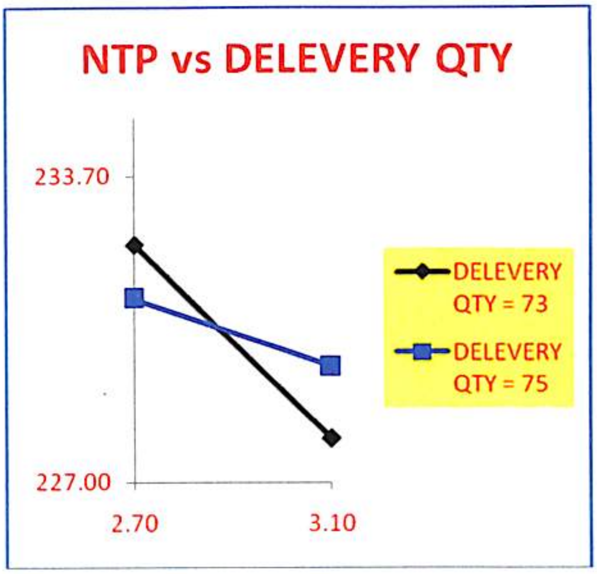


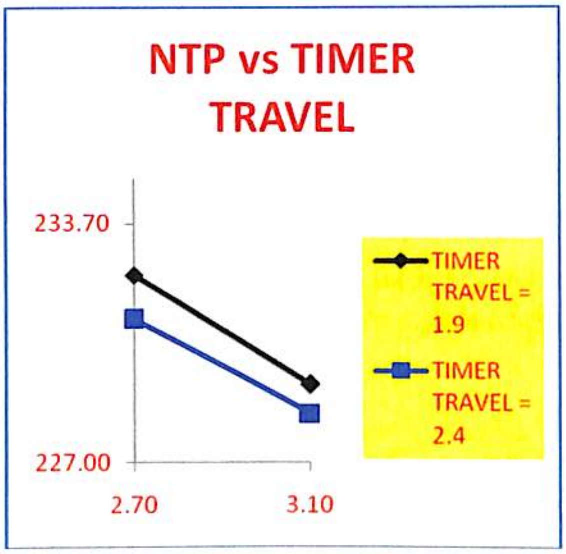


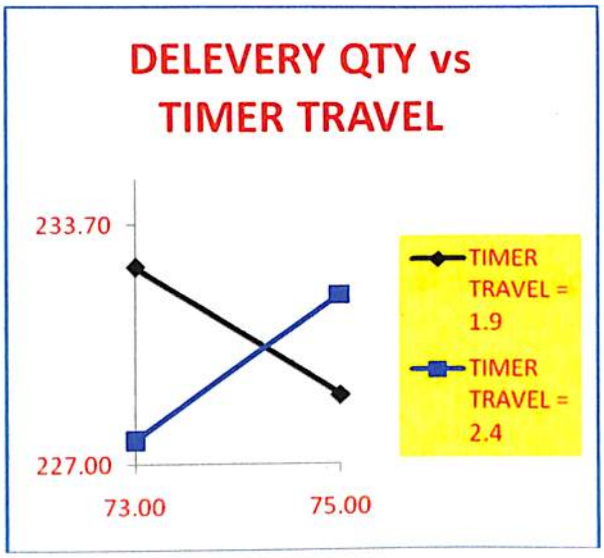


These graphs show the interaction effect on response carbon monoxide.



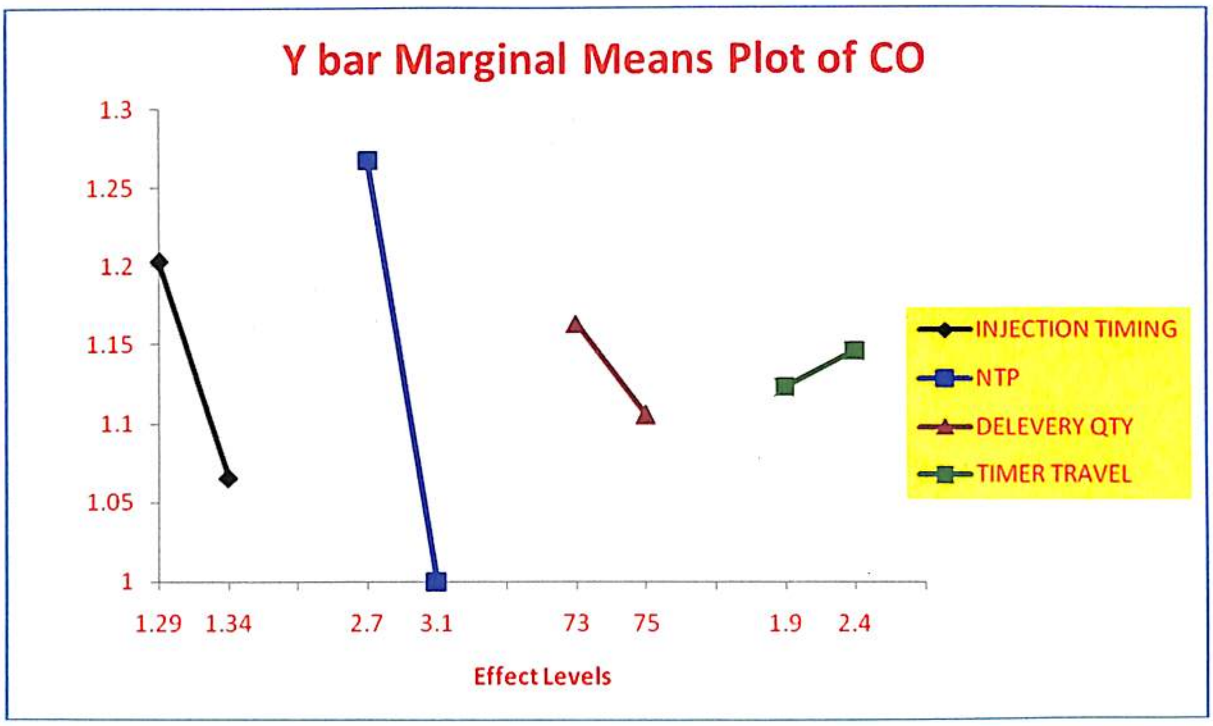






Y Axis Is CO Output Value

In this y marginal effect plots **nozzle through flow** is affecting more on output response carbon monoxide



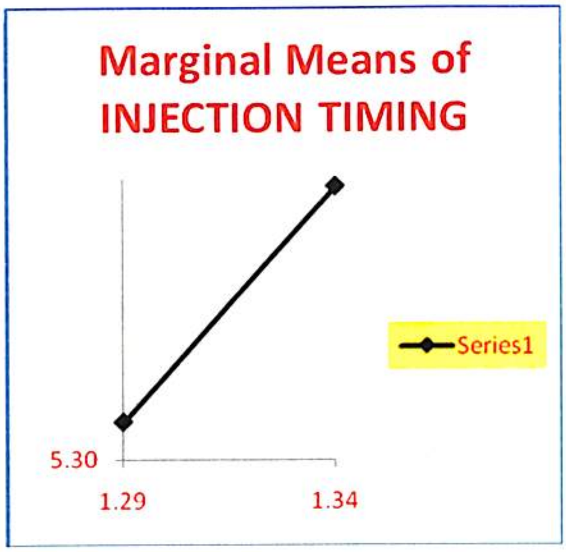
NOX DESIGN SHEET

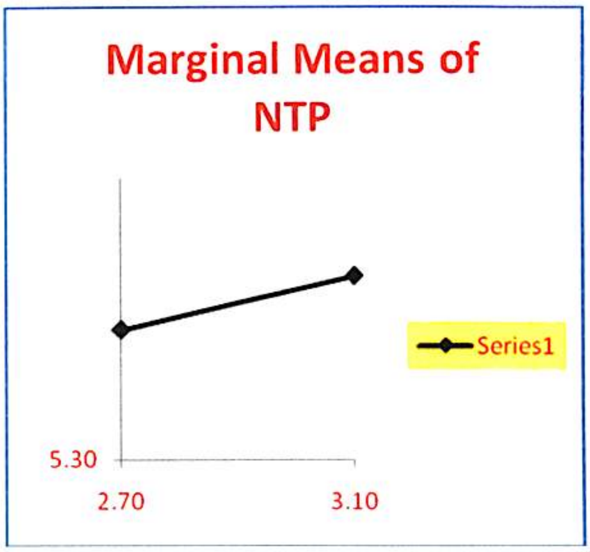
in this nox design sheet the experimental values of nitrous oxide has been used as a input to generate effect plot &interaction plots on output response of NOX.

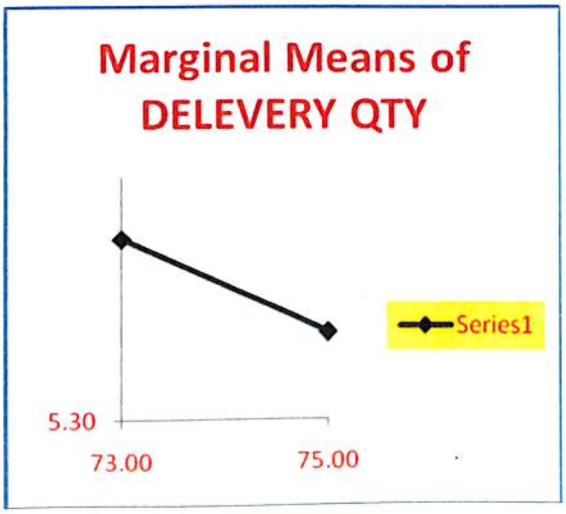
Factor	A	B	C	D=-AC	NOX		
Row #	INJECTION	NTP	DELEVERY	TIMER TRAVEL	Y1		Y bar
1	1.29	2.7	73	1.9	4.837		4.837
2	1.29	2.7	75	2.4	5.786		5.786
3	1.29	3.1	73	1.9	5.956		5.956
4	1.29	3.1	75	2.4	4.779		4.779
5	1.34	2.7	73	2.4	6.071		6.071
6	1.34	2.7	75	1.9	5.054		5.054
7	1.34	3.1	73	2.4	5.228		5.228
8	1.34	3.1	75	1.9	6.012		6.012

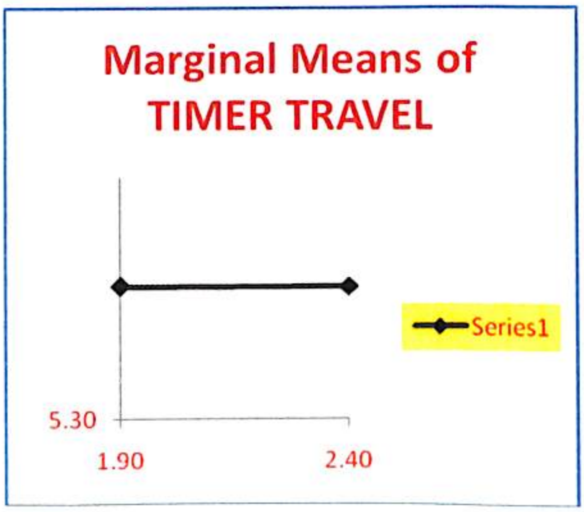
In this graphs the individual effect has been shown of injection timing ,NTP, delivery qty,timer travel.

MULTIPLE PLOT OF NOX

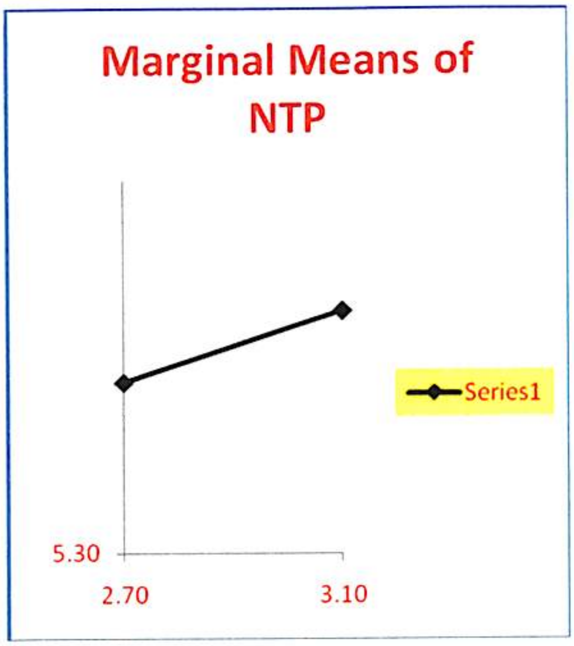


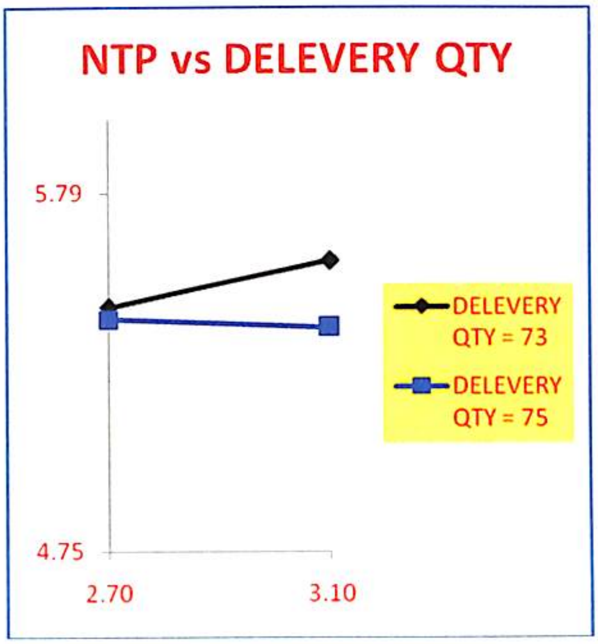


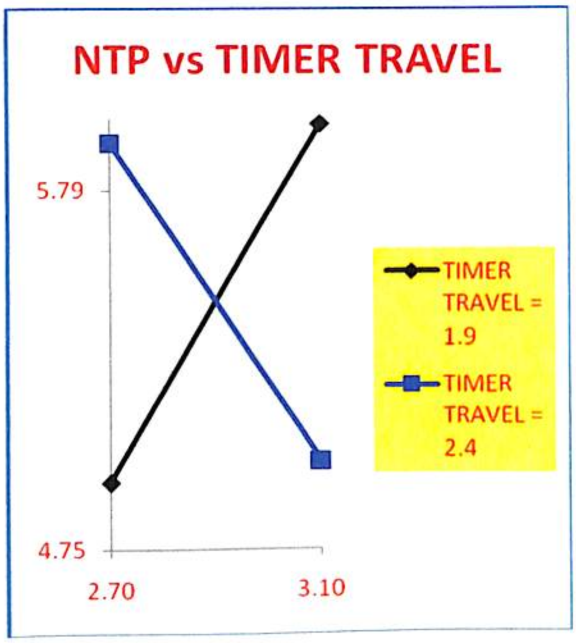


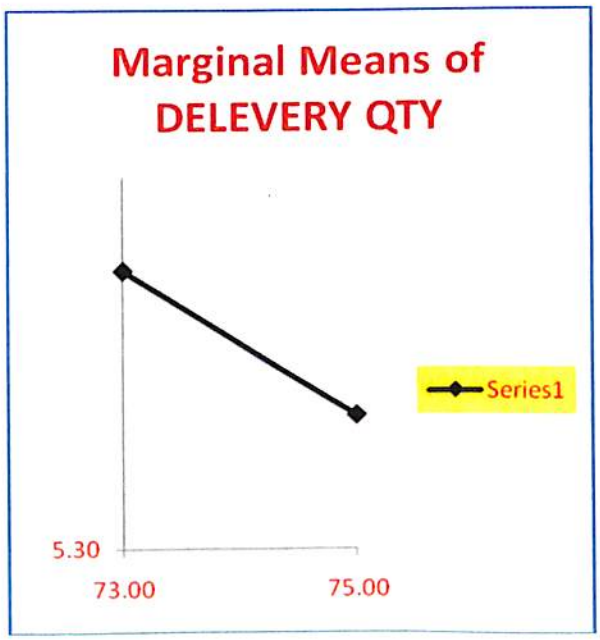


Y Axis Is NOX Output Value

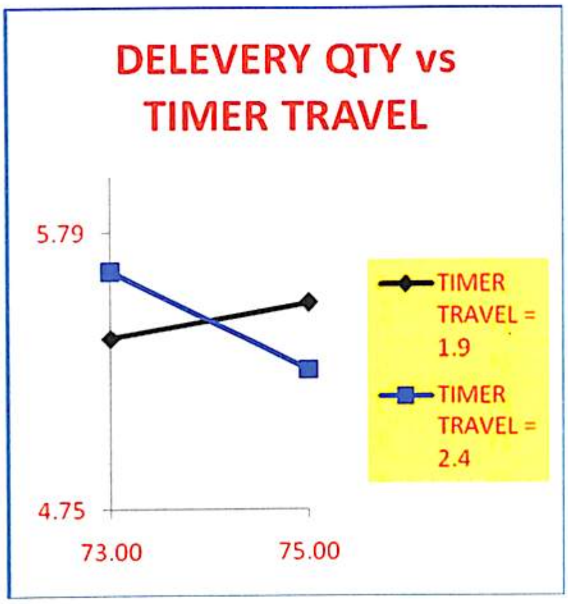


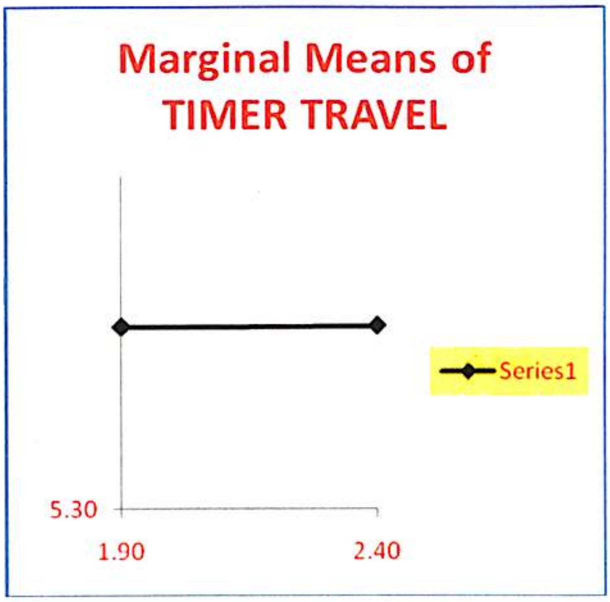


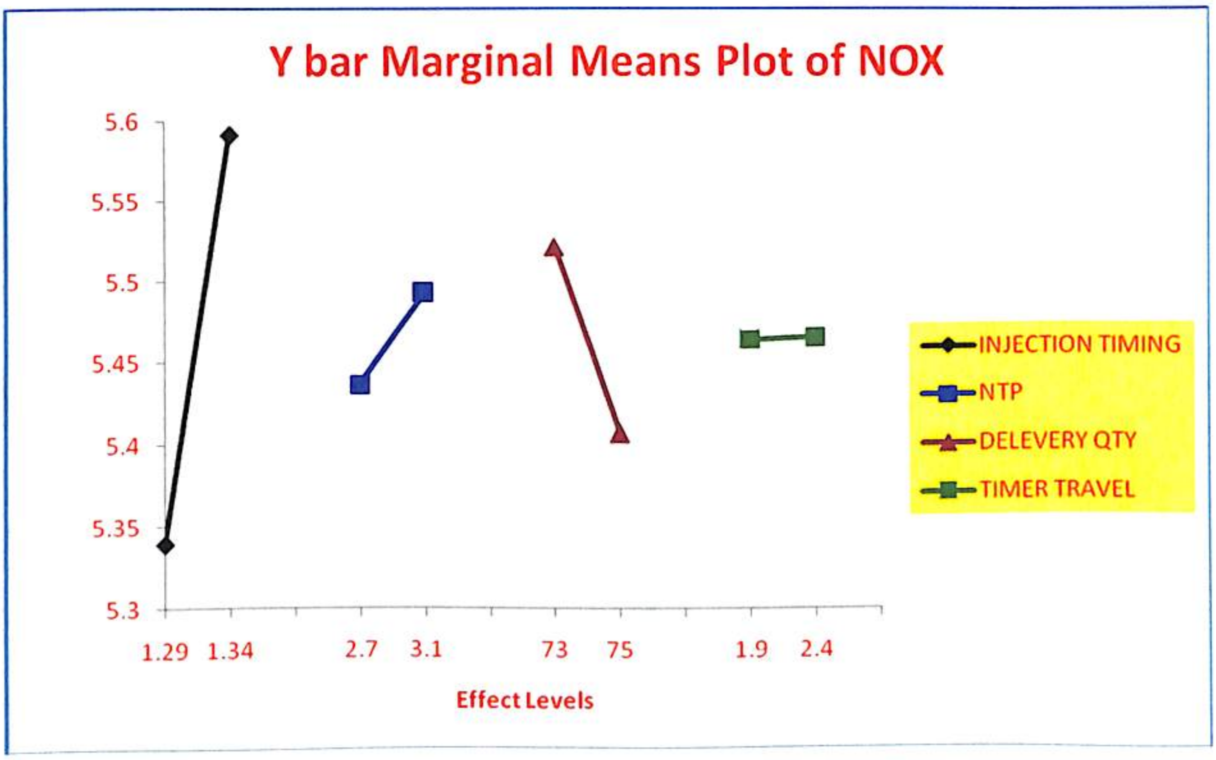




Y Axis Is NOX Output Value


DELEVERY QTY vs TIMER TRAVEL
5.79
4.75
73.00
75.00
TIMER TRAVEL = 1.9
TIMER TRAVEL = 2.4


Marginal Means of TIMER TRAVEL
5.30
1.90
2.40
Series1


Y bar Marginal Means Plot of NOX
5.6
5.55
5.5
5.45
5.4
5.35
5.3
1.29
1.34
2.7
3.1
73
75
1.9
2.4
Effect Levels
INJECTION TIMING
NTP
DELEVERY QTY
TIMER TRAVEL

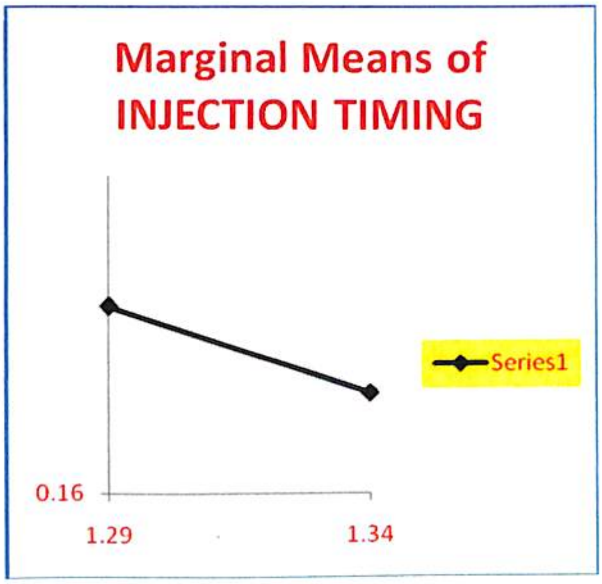
PM DESIGN SHEET

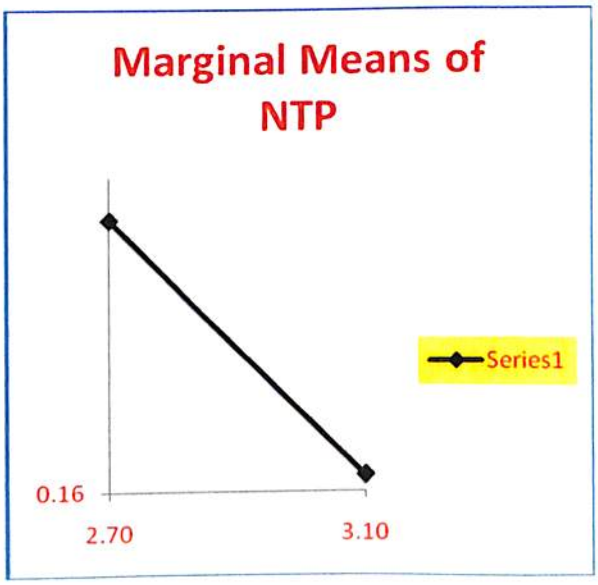
in this table the experimental value of particulate matter has been given has input to generate multiple plots on the response particulate matter.

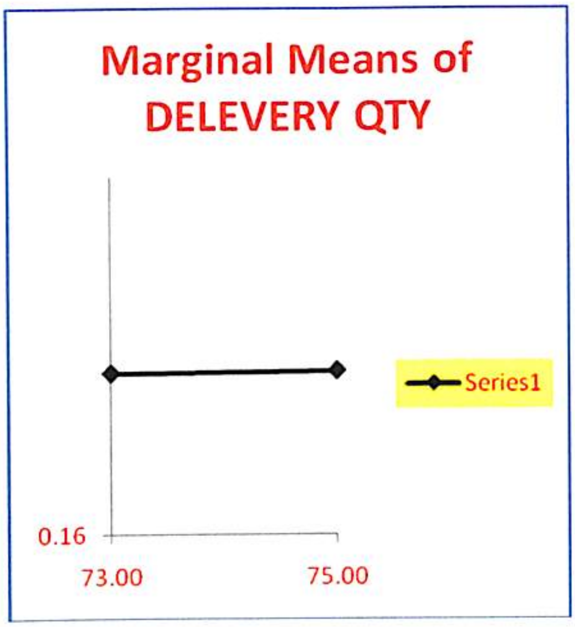
Factor	A	B	C	D=-AC	PM		
Row #	INJECTIO NTP		DELEVERY TIMER TRAVEL		Y1		Y bar
1	1.29	2.7	73	1.9	0.285		0.285
2	1.29	2.7	75	2.4	0.193		0.193
3	1.29	3.1	73	1.9	0.136		0.136
4	1.29	3.1	75	2.4	0.192		0.192
5	1.34	2.7	73	2.4	0.168		0.168
6	1.34	2.7	75	1.9	0.236		0.236
7	1.34	3.1	73	2.4	0.178		0.178
8	1.34	3.1	75	1.9	0.148		0.148

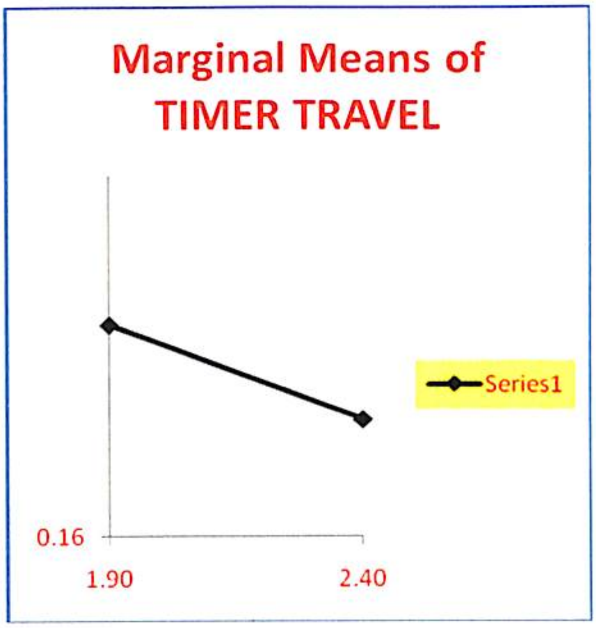
In this graphs given below it has been shown that nozzle through flow is affecting more to the particulate meter, whereas all the other parameters effecting less.

MULTIPL PLOT OF PM

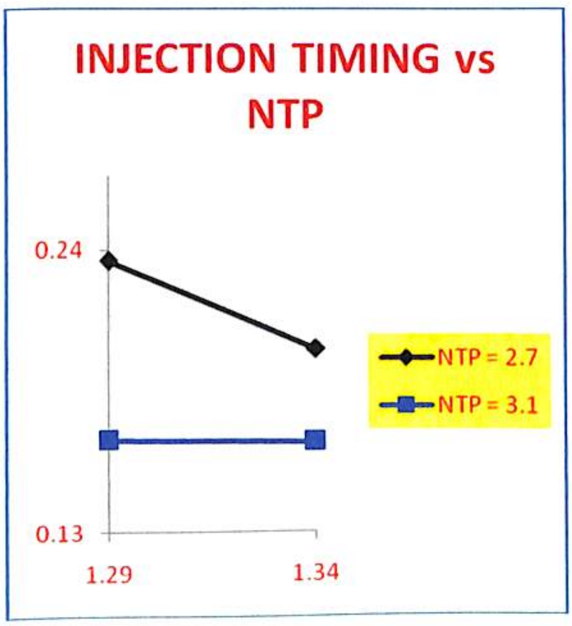


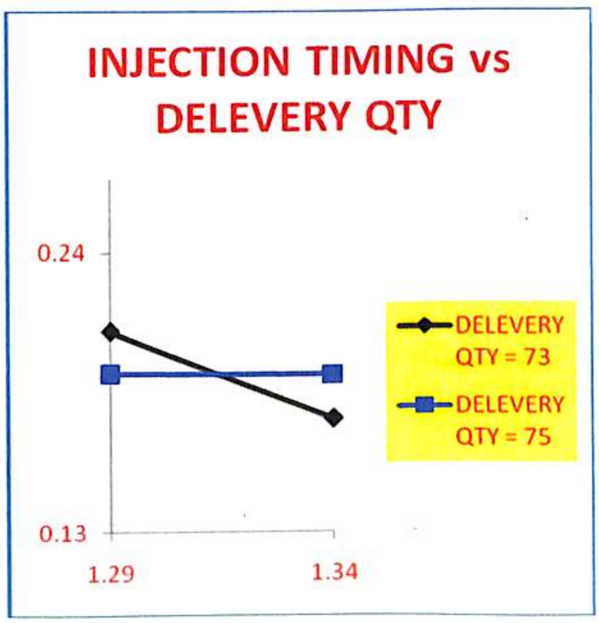




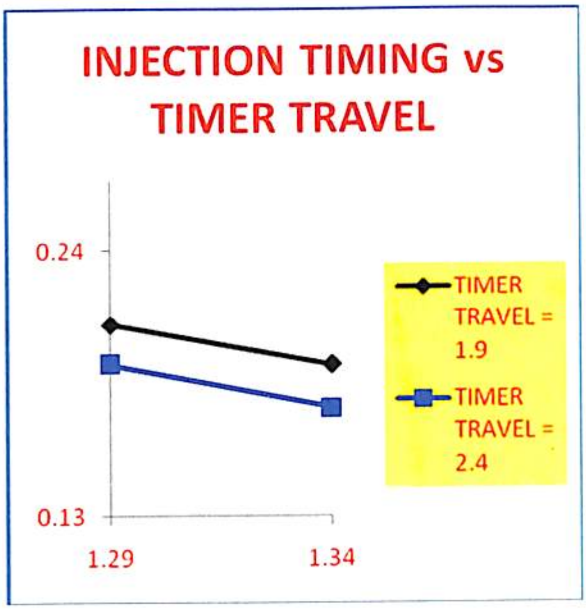


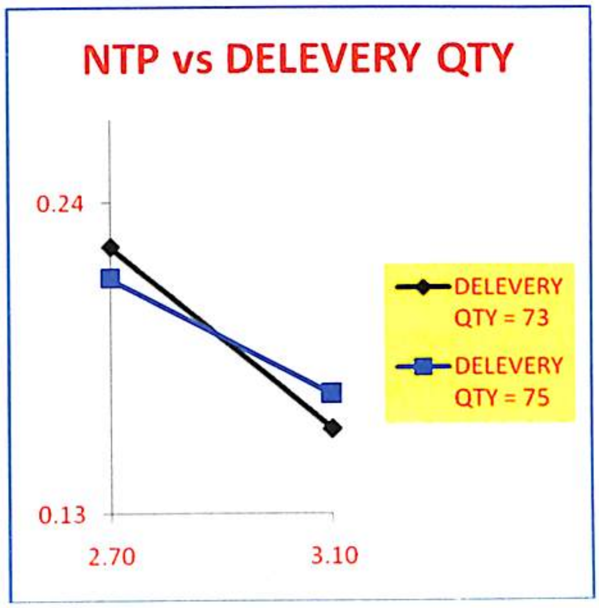
In these graphs the interaction effect of injection timing vs. timer travel, NTP vs. DQ, NTPvs TT, DQ vs. T.T has been shown with respect to particulate meter.



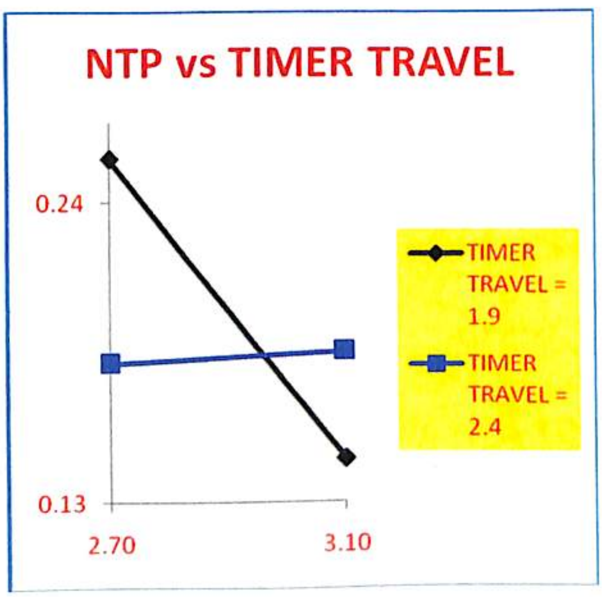


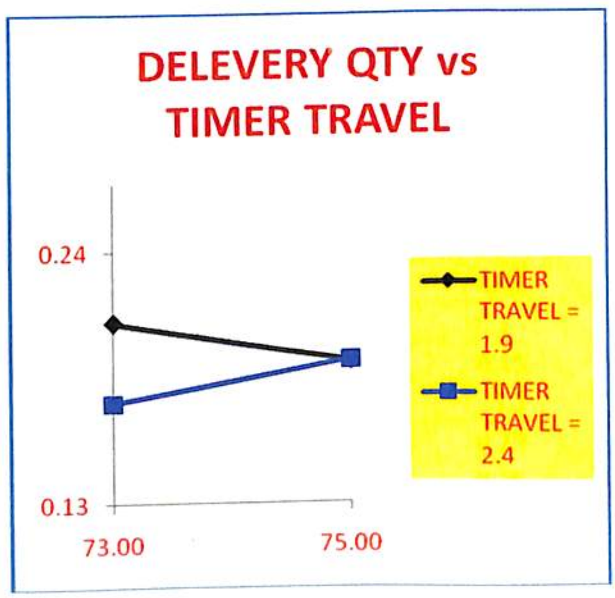
Y Axis Is PM Output Value



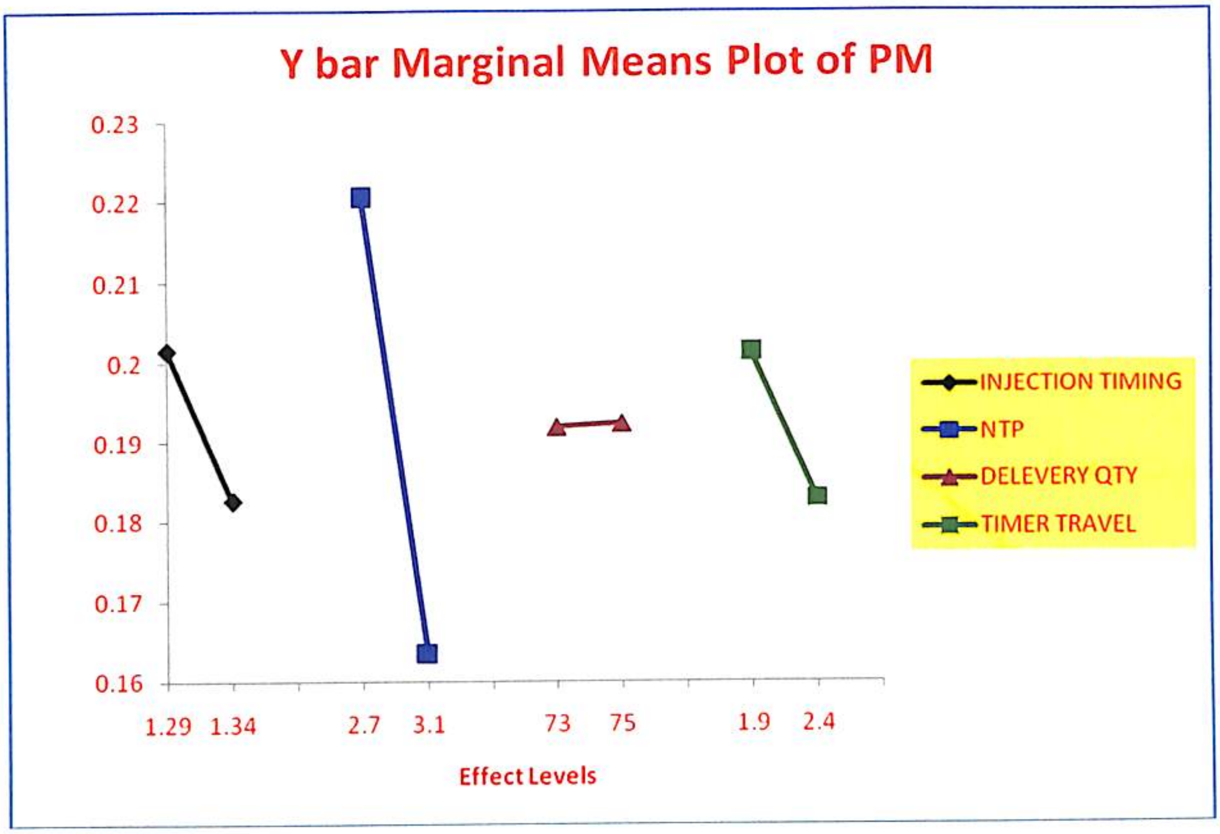


In these graphs the interaction effect of NTP vs. Timer Travel has to be studied. As it's shown that the timer travel at the factor level of 2.7 its effecting more to the PM than at the factor level 2.4





Y Axis Is PM Output Value

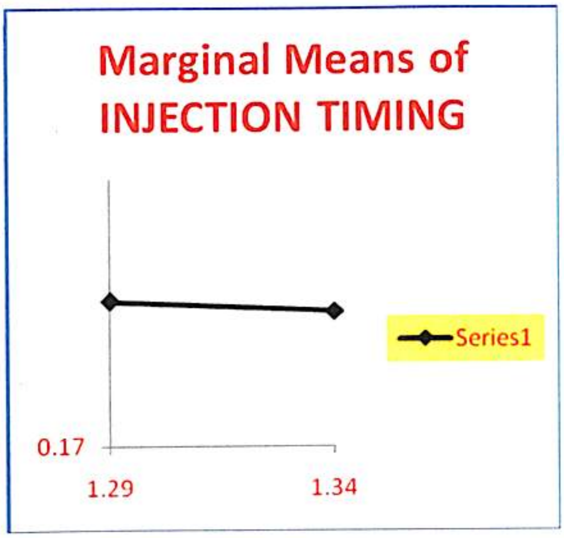


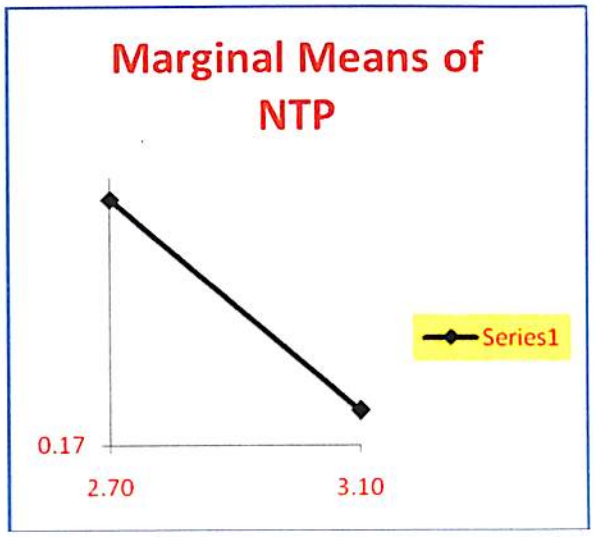
In this it has been shown that NTP is affecting more too particulate matter as the deviation is more in that.

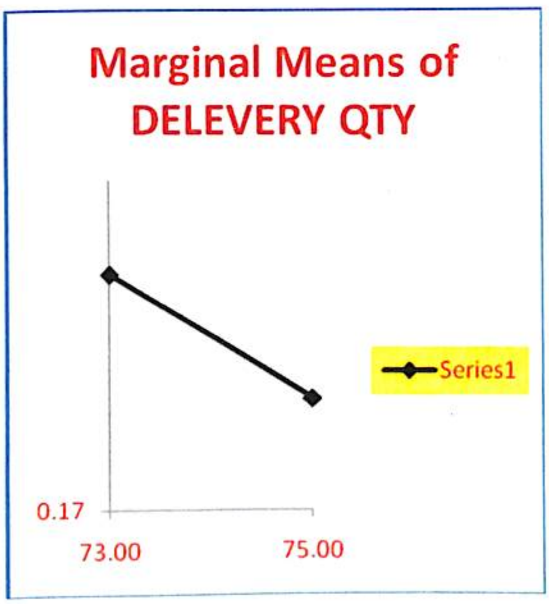
HC DESIGN SHEET

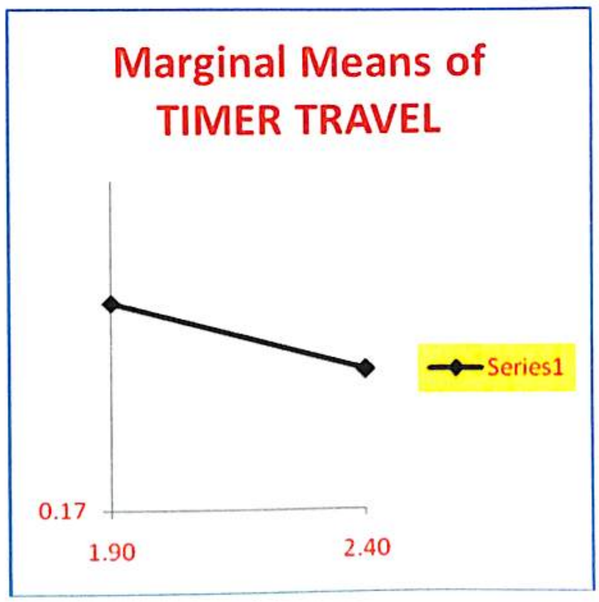
Factor	A	B	C	D=-AC	HC	Y bar
Row #	INJECTIOI	NTP	DELEVERY	TIMER TRAVEL	Y1	Y bar
1	1.29	2.7	73	1.9	0.29	0.29
2	1.29	2.7	75	2.4	0.17	0.17
3	1.29	3.1	73	1.9	0.15	0.15
4	1.29	3.1	75	2.4	0.2	0.2
5	1.34	2.7	73	2.4	0.19	0.19
6	1.34	2.7	75	1.9	0.25	0.25
7	1.34	3.1	73	2.4	0.22	0.22
8	1.34	3.1	75	1.9	0.14	0.14

MULTIPLE PLOT OF HC

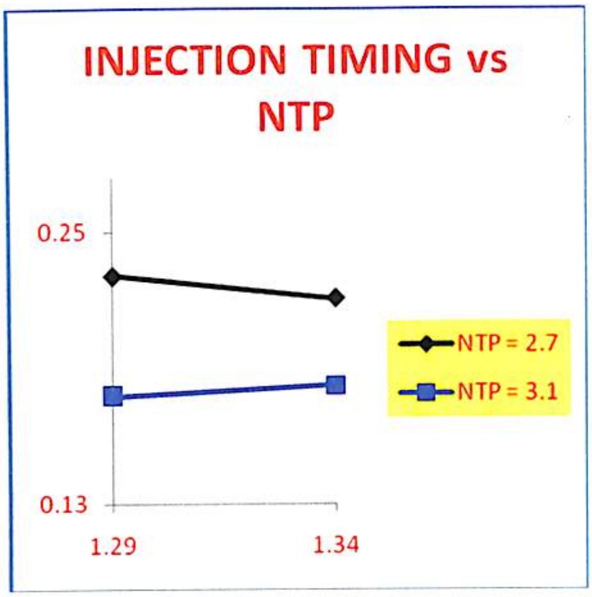


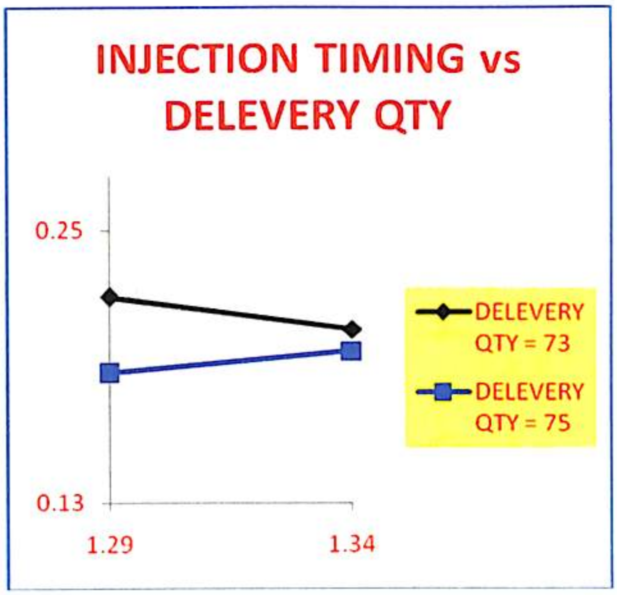


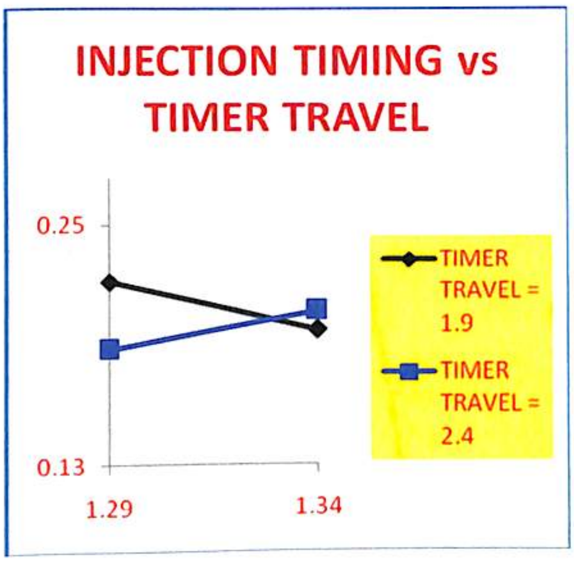


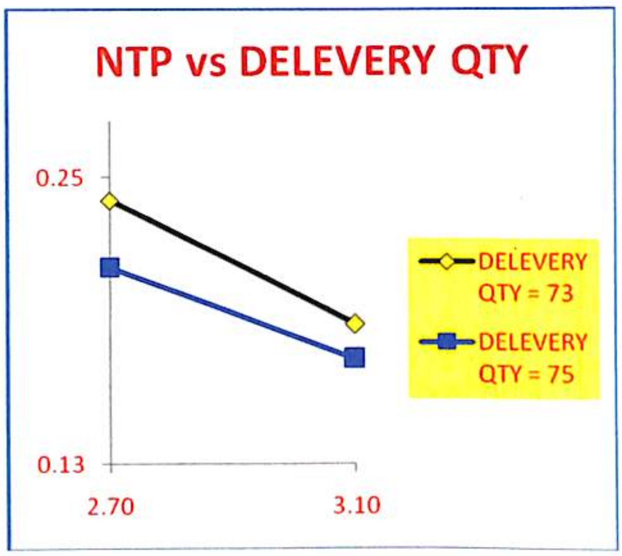


Y Axis Is HC Output Value

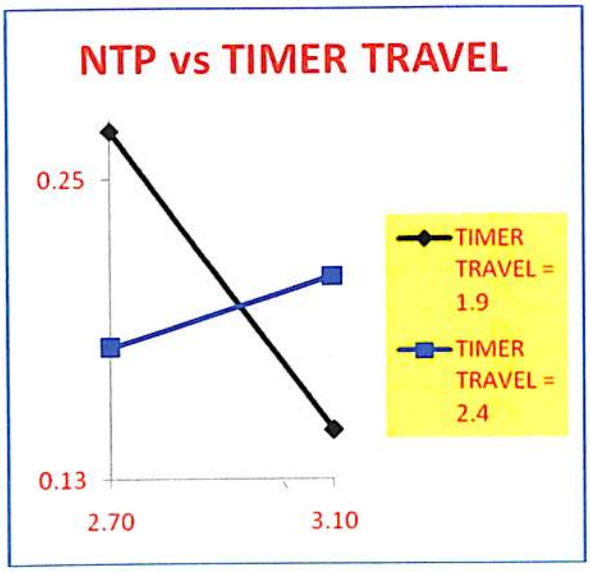


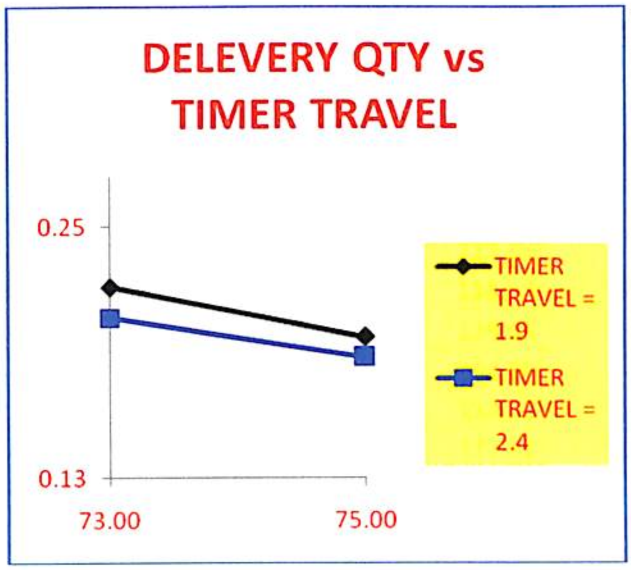


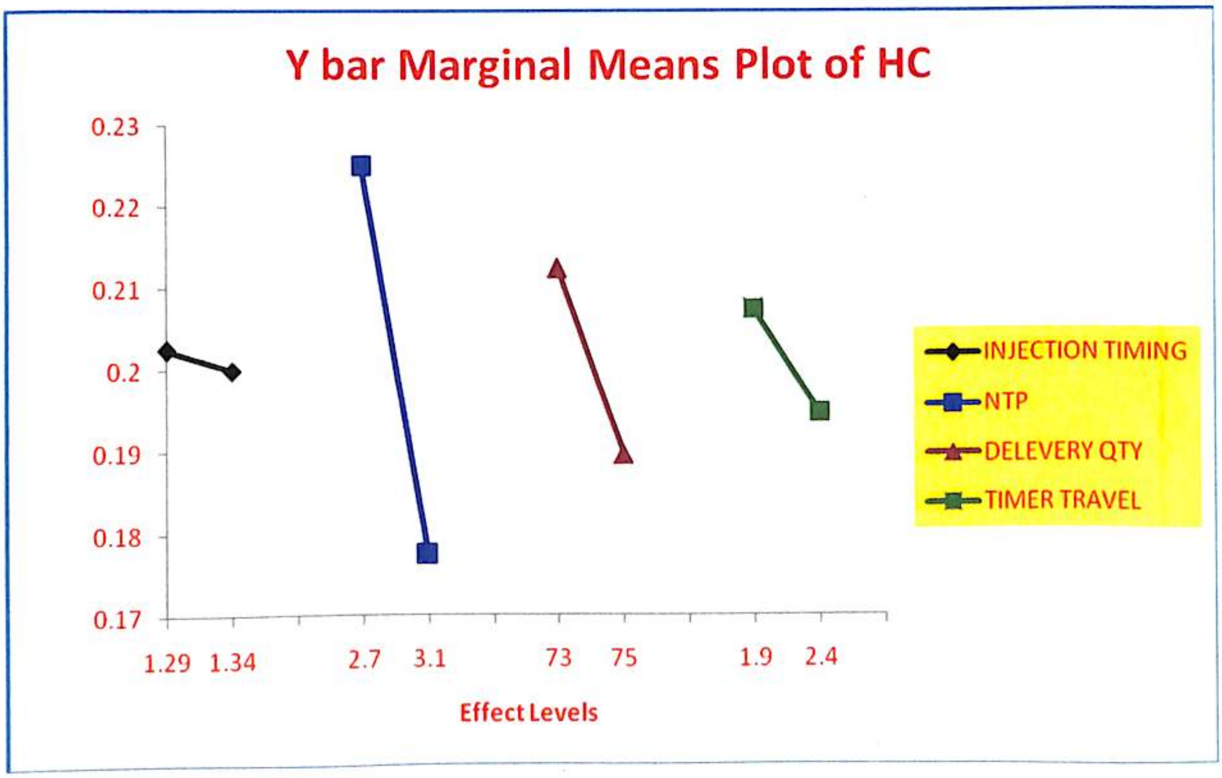




Y Axis Is HC Output Value


NTP vs TIMER TRAVEL
0.25
0.13
2.70
3.10
TIMER TRAVEL = 1.9
TIMER TRAVEL = 2.4


DELEVERY QTY vs TIMER TRAVEL
0.25
0.13
73.00
75.00
TIMER TRAVEL = 1.9
TIMER TRAVEL = 2.4

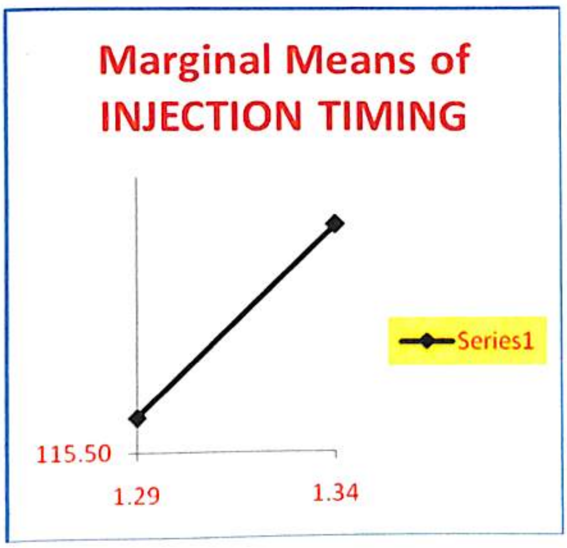

Y bar Marginal Means Plot of HC
0.23
0.22
0.21
0.2
0.19
0.18
0.17
1.29 1.34
2.7 3.1
73 75
1.9 2.4
Effect Levels
INJECTION TIMING
NTP
DELEVERY QTY
TIMER TRAVEL

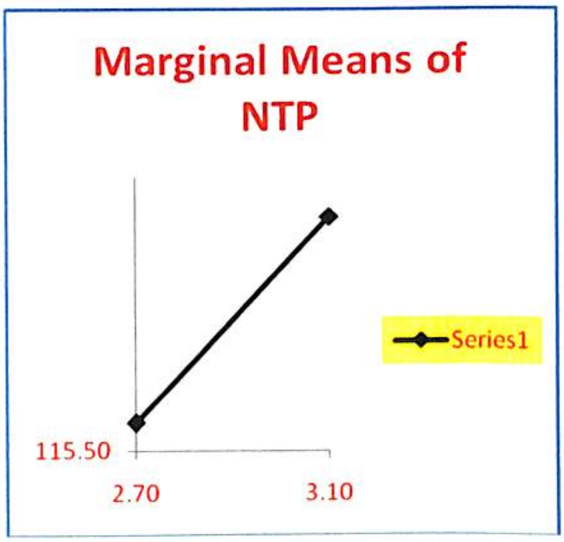
POWER DESIGN SHEET

In this the experimental value of power has been taken as the input to generate the individual as well as interaction effect plots.

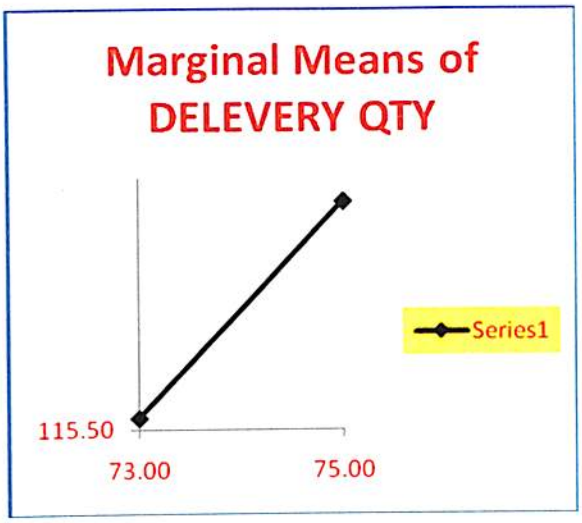
Factor	A	B	C	D=-AC	POWER	
Row #	INJECTIOI NTP		DELEVERY TIMER TRAVEL		Y1	Y bar
1	1.29	2.7	73	1.9	112.34	112.34
2	1.29	2.7	75	2.4	115.66	115.66
3	1.29	3.1	73	1.9	116.62	116.62
4	1.29	3.1	75	2.4	118.63	118.63
5	1.34	2.7	73	2.4	116.36	116.36
6	1.34	2.7	75	1.9	118.63	118.63
7	1.34	3.1	73	2.4	117.12	117.12
8	1.34	3.1	75	1.9	118.12	118.12

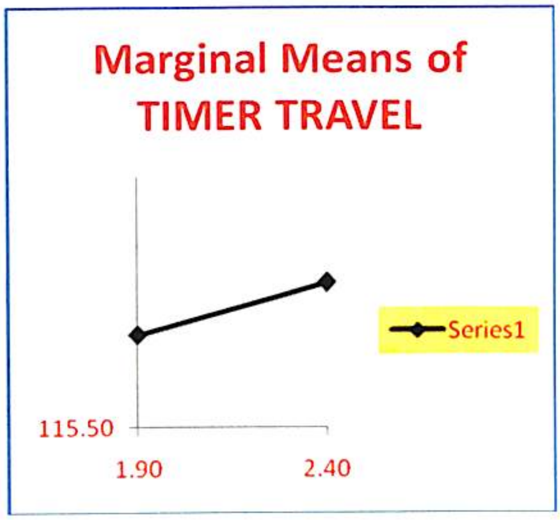
MULTIPLE PLOT OF POWER

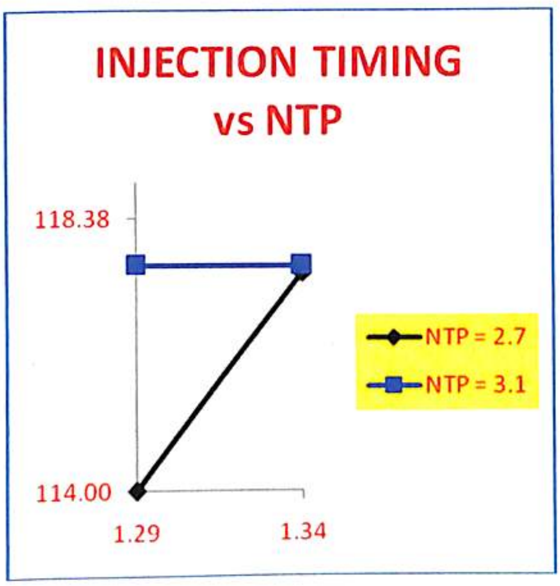


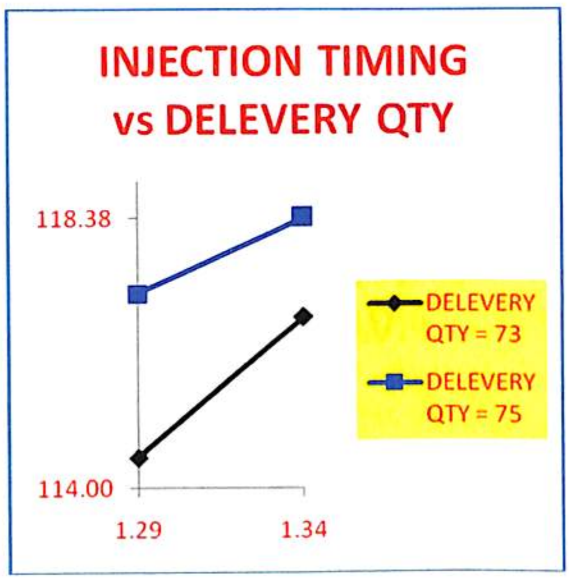


In this the injection timing, delivery quantity and timer travel is affecting almost up to the same extent to the response power, whereas timer travel is affecting less compare to that.

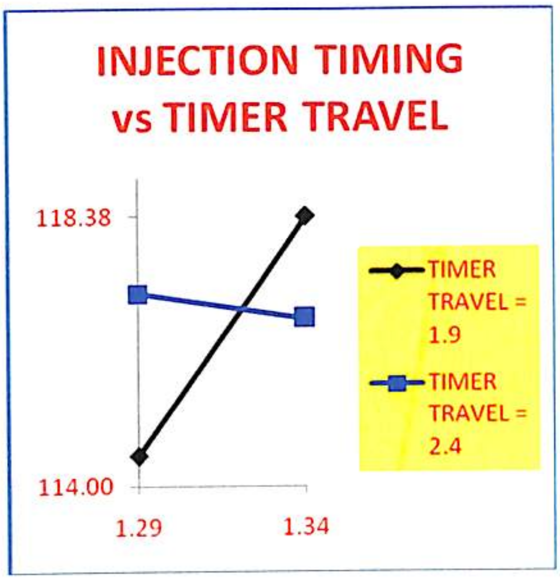


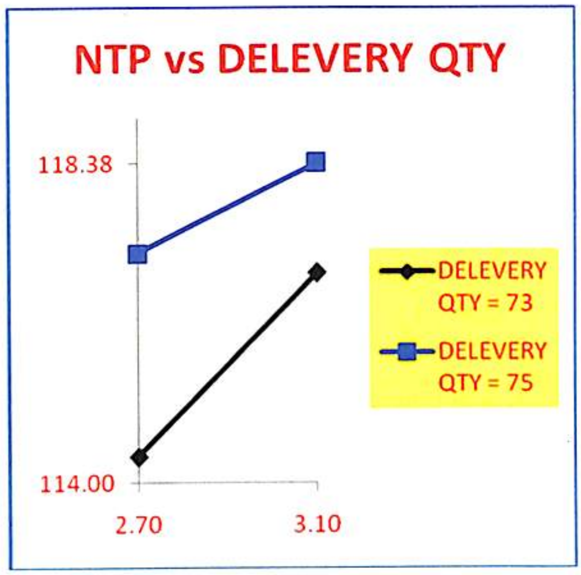




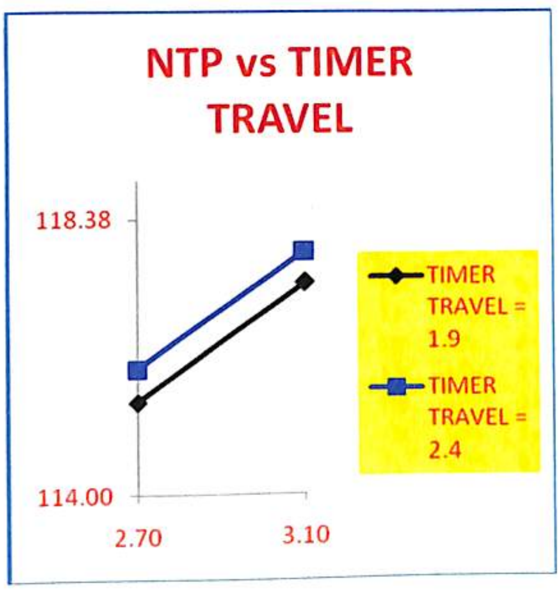


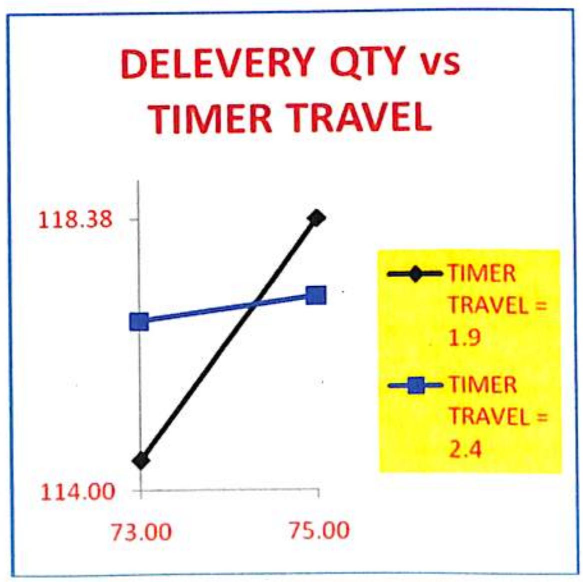
Y Axis Is Power Output Value



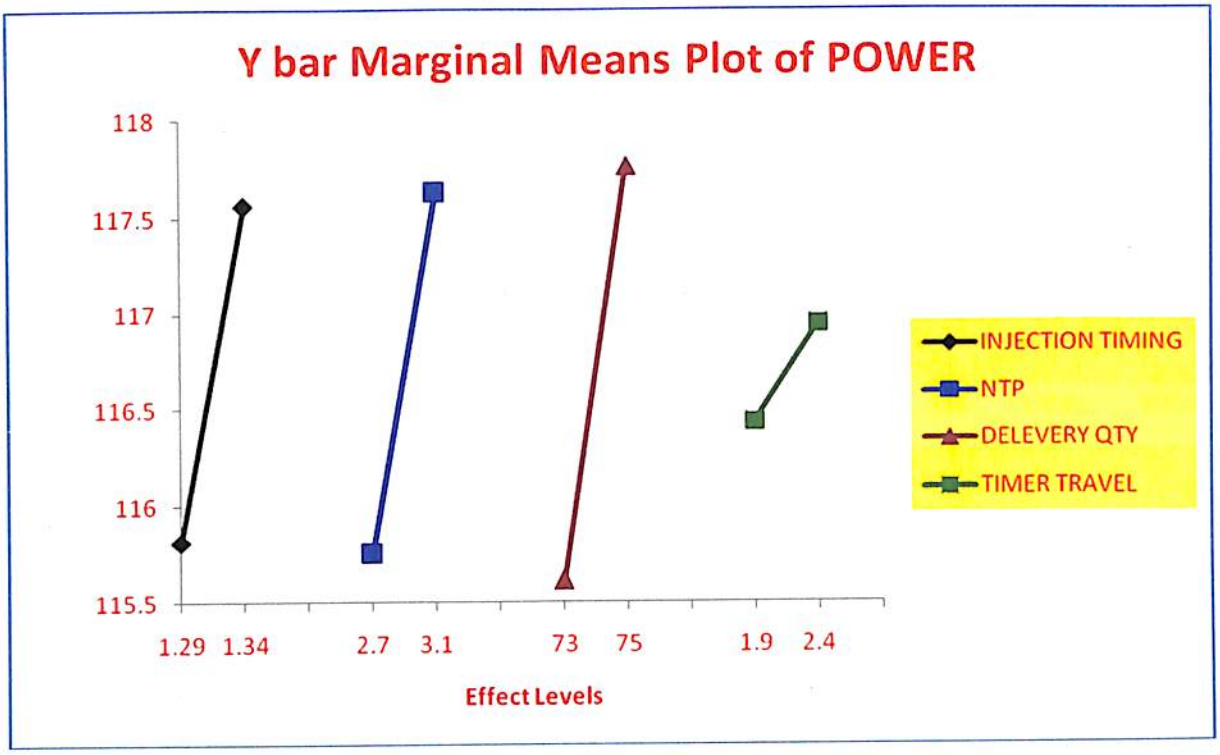


In this the interaction affect plot of injection timing vs. Timer travel , at factor level of 1.34 of injection timing the timer travel is affecting more to response power. And also it affecting more at the factor level of 75 of delivery quantity.



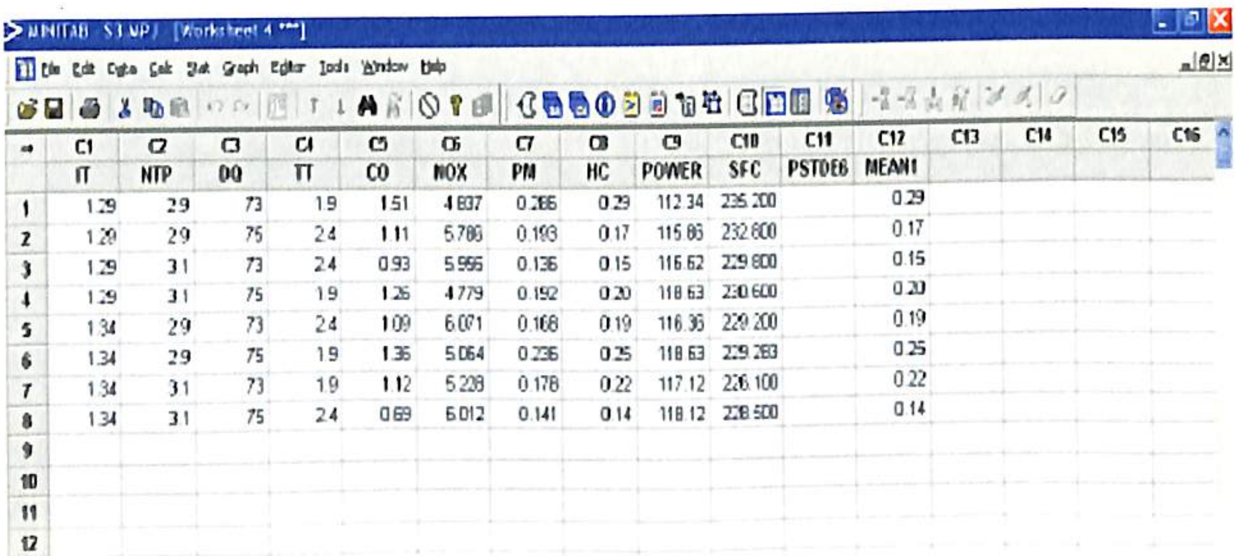


Y Axis Is Power Output Value



Experiment – Output result:

In this minitab worksheet the experimental output value of each response has been shown.



	C1 IT	C2 NTP	C3 DQ	C4 TT	C5 CO	C6 NOX	C7 PM	C8 HC	C9 POWER	C10 SFC	C11 PSTDEB	C12 MEAN1
1	1.29	2.9	73	1.9	1.51	4.837	0.286	0.29	112.34	235.200		0.29
2	1.29	2.9	75	2.4	1.11	5.786	0.193	0.17	115.86	232.800		0.17
3	1.29	3.1	73	2.4	0.93	5.996	0.136	0.15	116.62	229.800		0.15
4	1.29	3.1	75	1.9	1.26	4.779	0.192	0.20	118.63	230.600		0.20
5	1.34	2.9	73	2.4	1.09	6.071	0.168	0.19	116.36	229.200		0.19
6	1.34	2.9	75	1.9	1.36	5.064	0.236	0.25	118.63	229.283		0.25
7	1.34	3.1	73	1.9	1.12	5.228	0.178	0.22	117.12	226.100		0.22
8	1.34	3.1	75	2.4	0.69	6.012	0.141	0.14	118.12	228.500		0.14

So in the below table the experimental value of 3rd run is the best in all the above value which is suitable for the required condition. in this run we are able to achieve the cop limit of particulate matter and power. so we can decide the optimum point with the help of design of experiment.

Experiment - Output

Experiment No	Inj Tim	NTP	DQ	TT	CO	HC	Nox	PM	Power	SFC
1	1.29	2.7	73	1.9	1.51	.29	4.837	.286	112.34	235.2
2	1.29	2.7	75	2.4	1.11	.17	5.786	.193	115.86	232.8
3	**1.29**	**3.1**	**73**	**2.4**	**.93**	**.15**	**5.956**	**.136**	**116.62**	**229.8**
4	1.29	3.1	75	1.9	1.26	.2	4.779	.192	118.63	230.6
5	1.34	2.7	73	2.4	1.09	.19	6.071	.168	116.36	229.2
6	1.34	2.7	75	1.9	1.36	.25	5.064	.236	118.63	229.29
7	1.34	3.1	73	1.9	1.12	0.22	5.228	0.178	117.12	226.1
8	1.34	3.1	75	2.4	0.69	.14	6.012	0.141	118.12	228.5
Limit					4.0	1.1	7	0.150	115.9	

Optimum Settings From the experiment results – Following optimum settings are found .

IMPLEMENTATION In the below table the value of 3rd run has been taken which is the optimum range for this project of required target value of particu8late matter &power output.

S.no	Factor	Optimum Setting
1	Injection Timing	1.29
2	NTP	3.1
3	Delivery Quantity	73
4	Timer Travel	2.4

So finally if we will give this factor value to our four input parameters such as injection timin, NTP, delevery quantity &timer travel then test will clear the COP limit.

Chapter 4

Scope and further studies.

4.1Emission Norms for HDD Engines in India

Norms			Euro I	Euro II	Euro III
Year	1992	1996	2000	2001	2005
Nox	18	14.47	8	7	5
CO	14.5	11.2	4.5	4	2.1
HC	3.5	2.4	1.1	1.1	0.66
PM	----	----	0.36	0.15	0.10

Mechanism for Enforcing Emission Norms in India

As per the CMVR rules , Any new engine developed in India must get the "Type Approval Certificate" from the authorized agencies nominated by MOST. (ARAI, VRDE etc).

• After the type approval certificate only, the engines can be mass produced and sold in the market.

• It is also mandatory as per CMVR that the manufacturers shall prove that their engines are meeting the emission norms at regular intervals to the authorized agencies – This is called **COP** (Conformity of Production) **.So to meet cop standard DESIGN OF EXPERIMENT is used in industry and further improvement is also in progress**, currently in AVL it is in use .Ashok Leyland is also using these technique for its testing purpose.

4.2Global Scenario before Emission Norms

4, 60,000 deaths world over every year due to pollution related causes

Temperature has increased by 0.06 Deg between 1955 and 1995

If countries around the world don't reduce GHG emissions by end of next century

□ Temperature will increase 1-3.5 0c depending upon population and economic growth.

□ Sea level will rise by 15 to 90 cms threatening 92 million people each year with floods by year 2100.

SOURCE; IPCC REPORT 1995.

4.3Global Scenario after EURO 3:

Euro III or Equivalent Standards Implemented in US, Europe and Japan

□ Sulfur Content in Commercial diesel has been decreased to 15 PPM level.

□ 60 % Improvement in visibility compared to 1950 in California

□ 40% Reduction in deaths caused by Air pollution in California

□ Contribution of Automobiles to total emission has been reduced to 46% from 64% in 1950

Source: California Air Research Board

4.4Indian Scenario

□ Vehicles in Major metropolitan cities of India are estimated to account for

□ 70% of CO

□ 50% of HC

□ 30 - 40% of Nox

□ 30% of SPM

□ 10% of SO2

□ Total Estimated pollution load from transport sector has increased from 0.15 million tones in 1947 to 10.3 million tones in 1997, an increase of approximately 68 times!!!

□ 10 - 45% of total deaths in India could be attributed to

Particulate air pollution

□ 7500 people have died of pollution related respiratory and cardio ailments in 1996 in Delhi

□ Breathing Delhi's air is equivalent to smoking 20 cigarettes a day as a result 80% of the people has respiratory complaints respiratory complaints.

Chapter 5

Conclusion

CONCLUSIONS:

- We could get the optimum results only by varying adjustable parameters.
- DOE has been found to be a very useful tool and just by conducting 8 runs, we were able to predict results of all 16 runs for optimizing emissions with minimum BSFC.
- Hence there is no need for any design change.
- The optimum results are well within the limits,
- The number of parameters chosen and their levels are very important as number of factors increases number of experiments exponentially.
- Necessary interaction only has to be considered.
- By DOE techniques, number of engine dynamometer tests can be reduced and hence the number of chassis dynamometer tests.
- Design of experiments technique has been successfully established and within a short period the complete optimization of the engine can be carried out.

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