

# Data Optimization Technique for Tuning NO<sub>x</sub> Predictors

[1] Divyata Khachane, [2] Prof. Ashok Suryawanshi, [3] Durvesh Pathak  
[1] PG Student, Pimpri Chinchwad College of Engineering, Pune, [2] Senior Professor, Pimpri Chinchwad College of Engineering, Pune, [3] Electronics Engineer, Cummins India Ltd., Kothrud, Pune  
[1]divyatakachane999@gmail.com, [2] ashok.suryawanshi@pccoepune.org,  
[3]durvesh.pathak@cummins.com

**Abstract**— Exhaust system is one of the important part of engine. Many gases are exhausted from an engine, one of them is NO<sub>x</sub> which has adverse effects on environment and human health. To reduce these effects government has developed emission regulatory standards (BSIII/ BSIV). According to regulatory standards, exhaust gases must be emitted within a specified range, to fulfil this condition some tools are available in automobile industry for checking and regulating exhaust gas. These tools are generally excel based and lots of manual work has to be done till final result. As well it requires more time to complete whole process. To overcome these disadvantages we have proposed MATLAB tool. Proposed MATLAB tool will filter test cell data and calculate the regression coefficients. These coefficients will be given to Simulink model and response will be observed.

**Index Terms**— NO<sub>x</sub> (Oxides of Nitrogen), NO<sub>x</sub> estimator tuning tool, Selective catalyst reduction.

## I. INTRODUCTION

Now a day's transportation is an increasing demand to move people and goods further and faster. These both are a cause and an effect of India's rapid economic growth. The growth in transportation leads to the corresponding surge in fuel use. The increase in mobility enriched the standard of living but there were some unpleasant consequences associated with it. These include growing reliance on imported fossil fuels, which are responsible for climate change, and increasing emissions of pollutants responsible for adverse human health effects. [2]

Diesel engines are used in many areas such as automobiles, locomotives, marine engines, power generations etc., due to its high power output and efficiency. Even though the diesel engines have more benefits, the human discomfort caused by pollutant emission of these engines has to be considered. [2] Diesel engines provide important fuel economy and durability advantages for large heavy-duty trucks and buses, while diesel engine has disadvantage of emitting significant amounts of oxides of nitrogen (NO<sub>x</sub>), particulate matter, hydrocarbon (HC) and carbon monoxide (CO). Hence to control these emissions becomes crucial part of automotive industry.

## II. EXHAUST SYSTEM

Exhaust system is an important part of engine. All exhaust gases are emitted through exhaust system. Out of these gases, NO<sub>x</sub> is very harmful gas. NO<sub>x</sub> is the generic term for a group of highly reactive gases, which contain nitrogen and oxygen in various proportion. Many of the

nitrogen oxides are colourless and odourless. However, one common pollutant is nitrogen dioxide (NO<sub>2</sub>). [4]

The main sources of NO<sub>x</sub> emission are the combustion of fuel in motor vehicles, commercial furnaces, industrial boilers and engines, and other equipment. Out of these all sources industrial sources contribution is comparatively more.

### A. Industrial Sources (Anthropogenic Sources)

There are three primary sources of NO<sub>x</sub> in combustion process. They are as follows:

- Thermal NO<sub>x</sub>
- Fuel NO<sub>x</sub>
- Prompt NO<sub>x</sub>

Thermal NO<sub>x</sub> is highly temperature dependent and it is mostly exhausted during combustion of natural gas. Fuel NO<sub>x</sub> is generated during the combustion of fuels, such as coal, which has a significant nitrogen content, particularly when burned in combustors designed to minimize thermal NO<sub>x</sub>. The prompt NO<sub>x</sub> is normally considered as negligible. [7]

Nitrogen oxides formed during the combustion of coal, are commonly referred as NO<sub>x</sub>. It formed during combustion contains nitrogen monoxide (90-95%), nitrogen dioxide (5-10%) and a very small percentage of nitrous oxides (N<sub>2</sub>O). Formation of nitrogen oxide is accelerated and reactive organic compounds are formed. These cause adverse effect on environment and human body. So government has set some regulatory standards for emission of such polluting gases. Every engine manufacturer has to follow these government norms. [6]

To reduce concentration of NO<sub>x</sub> emission, selective catalytic reduction and selective non-catalytic reduction systems are available in industry. SCR is being used in on-highway and off-highway application. The use of catalytic

converters in motor vehicle engines have reduced vehicular emissions significantly. This NO<sub>x</sub> reduction method is based on physical implementation. [3] [8]

For keeping emissions within range manufacturer has developed some virtual tools. Virtual implementation of tool is as follows.

### III. METHODOLOGY

As projects problem statement is originated from exhaust gas system. There is one standard range of emission of gases specified. So all exhaust gases of engine are supposed to be emitted within that specified range. To control this emission of gases following tool is available which is excel based tool.

#### A. Existing Tool: NO<sub>x</sub> Estimator Tuning Tool

NO<sub>x</sub> Estimator Tuning Tool follows the following procedure,

- Data collection
- Data redundancy check (Sanity check)
- Data Selection for regression
- Regression coefficients
- Validation
- Fine tuning

This process is time consuming because lot of work is done manually. So there is need to develop a tool which will reduce manual work, time and errors.

In above process first we get data from test cell. Then data redundancy check and data selection is done manually. This selected data is used as input to MINITAB which calculates regression coefficients. This process is manual and requires more time. [1]

Hence there is need to develop a tool in MATLAB which is generally used for automation will help to automate this process. So this tool will automates four steps i.e. Data check (sanity check), Data selection for regression, Regression coefficient calculation and validation. These steps are divided into three parts

- Data optimization
- Regression coefficient calculation
- Validation

#### B. Data Optimization

Data Optimization process includes preparation of the logical schema from the data view schema. It replicates the functionality of data de-optimization. Data optimization has an importance in database management. Data optimization is commonly known as a non-specific technique used for several applications in fetching data from a sources. [5]

Data optimization also achieved by data mapping, which is an essential aspect in data integration. The process of optimizing data includes data transformation or mediation between a source and its destination. In this case, the data sources could refer as the logical schema whereas the destination could refer as data view schema. Data mapping also translate data between different kinds of data types as well as presentation formats translate into a unified format which is used in different reporting tools.

Following block diagram gives overview of data optimization process which is used in automation

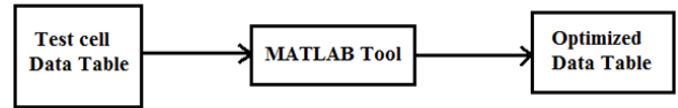


Figure 2: Block diagram of Data Optimization

This block diagram shows automation in data optimization. Test cell data is given as input to the MATLAB Tool. Optimization operation will perform by tool and it will generate the useful data which is used for further process.

#### C. Regression Coefficients Calculation

Regression analysis is a statistical process. It is used for estimating the relationships among variables. Regression analysis includes many techniques for modelling number of variables. It focuses on analysing the relationship between a dependent variable and independent variables. Regression is based on prediction and causal inference. It shows the relationship between independent variable (X) and a dependent variable (Y), as in the formula below:

$$Y = \beta_0 + \sum \beta_n X_n + \alpha$$

Where,

$\beta_n$  is the slope parameter,

$\beta_0$  is constant, it is the status of the dependent variable when the independent variable is absent.

$\alpha$  is an error term, which captures the amount of variation not predicted by the slope and intercept terms.

Hence regression shows how variation in one variable co-occurs with variation in another.

Following block diagram gives overview of regression coefficient calculation process which is used in automation.

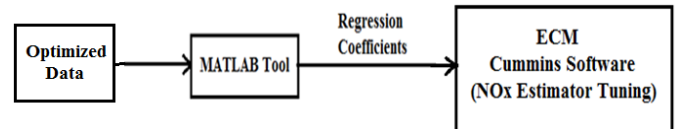


Figure 3: Block diagram of Generation of Regression Coefficients

Above block diagram shows automation in generation of regression coefficients, in which test cell data is given as input to the MATLAB Tool. After performing operations this tool will generate proper regression coefficients which will be used for further validation.

#### D. Validation

In validation process, regression coefficients will be given to Simulink model and from output graph we will check whether emissions are within range or not.

### IV. ADVANTAGES

This MATLAB tool has following advantages over existing tool

- Regression coefficient tool will help to remove manual work from coefficient calculation process.
- Data optimization tool will remove unwanted data from test cell data tables and will provides useful

data which reduces manual work as well as saves time.

#### V. CONCLUSION

A robust concept of NOx predictor tuning will be developed to overcome disadvantages of existing tool. Proposed MATLAB tool filters test cell data, calculates regression coefficients, and further by feeding these coefficients to Simulink model, validation will be done. This tool will reduce manual work, time to calculate regression coefficients.

#### REFERENCES

- [1] Durvesh Pathak, Vishal Halale, "An Introductory Approach to virtual sensor and its modelling technique", International journal of scientific & Engineering Research March 2016.
- [2] Gaurav Bansal, Anup Bandivadekar, "Overview of India's Emission Control program: Past success and Future prospects" 2013 International Council on Clean Transportation.
- [3] R. Praveen and S. Natarajan, "Experimental Study of Selective Catalytic Reduction System On CI Engine Fuelled with Diesel-Ethanol Blend for NOx Reduction with Injection of Urea Solutions" International Journal of Engineering and Technology (IJET), ISSN: 0975-4024 Vol 6 No 2 Apr-May 2014.
- [4] "Air pollution control technology: Fact sheet", EPA-CICA Fact Sheet.
- [5] John A. Stratton, Christopher Rodrigues, I-Jui (Ray) Sung, Li-Wen Chang, Nasser Anssari, Geng (Daniel) Liu, and Wen-mei W. Hwu, "Algorithm and Data Optimization Techniques for Scaling to Massively Threaded Systems ", IEEE 2012.
- [6] Kenan Muri, "Modeling of NOx formation in heavy duty engines", Department of Automatic Control, Lund University, September 2011.
- [7] "Internal Combustion Engine Fundamentals", John B. Heywood.
- [8] L. Muzio, R. Smith, D. Shore, G. Quartucy, Q. Qader, "Recent Experiences Tuning SCR Systems", Fossil Energy Research Corp., 23342C South Pointe, Laguna Hills, CA 92653.