# OPTIMIZATION OF EXHAUST EMISSIONS OF DIESEL ENGINE USING 1-D WAVE SIMULATION

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**Abstract— The environmental legislations are much improved and are challenging the engine manufacturers to redesign their products in order to attend the new emission and performance requirements. A variety of solutions are being implemented to achieve cleaner emissions and reduce the fuel consumption by engine. In this project simulation tool WAVE (a one-dimensional engine modeling software package) is employed to study the efficiency, performance, and emissions impacts of changing physical parameters on engine operation. These simulations indicate that adjusting the parameters like valve timing, injection pressure, injection timing and duration, combustion volume, injector type have noticeable, positive effects on fuel economy and NOX (NO and NO2) and hydrocarbons (HC) emissions. In this WAVE' sability to model an actual engine was c by checked comparing WAVE output to this experimentally measured data. The scope of this work is to discuss and simulate the influence of adjusting these parameters on the emissions and engine performance. Future work will focus on increasing the amount of empirical data on engines, and on improving the engine models more reliable predict NOX and HC emissions. And using more reliable model optimizes the emissions adjusting physical parameters.**

***Keywords***- Emission, NOx, HC, CO, Diesel Engine, Injection System, Combustion Chamber**.**

## I. INTRODUCTION

The strict environmental restriction is challenge to Diesel engine manufacturers are facing. The demand of cleaner emissions (both for NOx and soot) and the fuel consumption reduction are required for improved engine performances. And emissionsof engine are the parameters that should be matched to attend the legislation and customer requirements. The search for solution of these problems is a target that needs to be continuously reached, as the standards for emissions are year-by-year being updated. Also, the saving of fossil fuel is a must for the future due to the limited sources of its global reserves, the high cost required for new fuel sources research and the greenhouse effect. Along with this the external demands, the automotive industry is on a process to reduce costs and improve its efficiency. On this way, theuse of numerical simulationis a significant tool. In order to reduceemission levels, some external engine features can beapplied. Theoptimization of the piston bowl and injector designmay also bring significant improvements on NOx, HC and CO reduction. Piston bowl profile, injector nozzlediameter and angle, injector position or inclination on combustionchamber, and various calibration variables (injection start,fuel mass, etc.) are some of the parameters that canbe set for this purpose.In this paper, the some engine parameters were parameterizedand analyzed. A systematic approach was adopted for the investigations, through acombination of WAVE 1-D simulations and the statisticaloptimization method, Design of Experiment (DoE). The ability of DoE in modeling influences of parameters overa large range with proper accuracy, while reducingcomputation time and effort has been demonstrated.

The geometric parameters of the engine chosen for the analysis were the piston bowldiameter and Compression ratio. The nozzleparameters chosen were the number of holes, hydraulic through flowrate (HTFR) and cone angle. In addition, the start of injection(SOI) and nozzle tip protrusion (NTP) are having widescope for optimization for the combustion system.

Inaddition, a variety of engine thermodynamic and emissions relatedparameters were incorporated in the analysis. And the primary goal of this paper is to reduce NOx, HC and CO to meet CPCB-II Emission Norms.

## II. LITERATURE REVIEW-

The research in emission reduction has been done on high level, here are some literature reviews to demonstrate and support the report.

VinodKarthikRajamani, SaschaSchoenfeld and AvnishDhongde*[1]*explain about various injector nozzle configurations as well as piston bowl geometry with the help of 3D CFD and DoE.

ViniciusPeixoto, CelsoArgachoy, Ivan Trindade, Marcelo Airoldi*[2]* discuss about EGR system of diesel engine its effect on combustion and its optimization for improvement in combustion

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Heywood, J .B. *[3]* explains the details of internal combustion engines and their combustion emission systems as well as factors affecting on it.

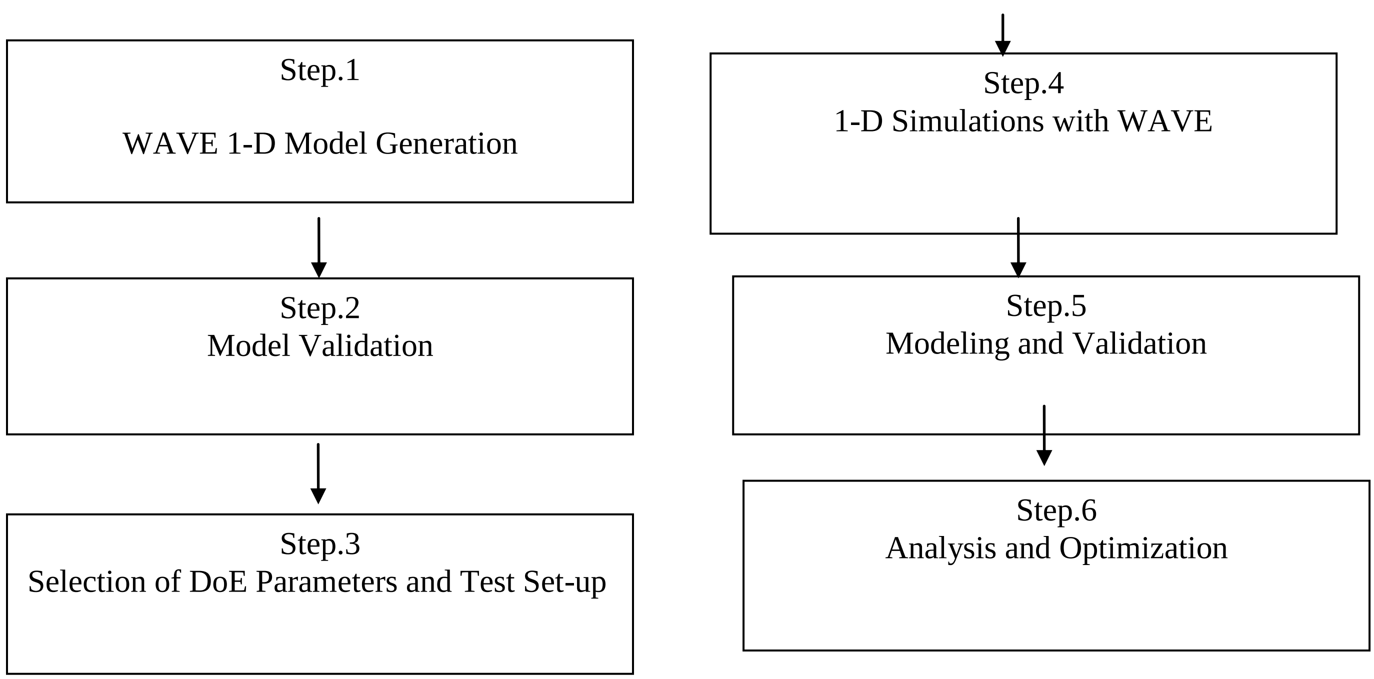
EranSher*[4]* explains the causes of emission, formation and control of pollutants and their effects on environment.

The paper of Ricardo *[5]* discusses the proper methodology of modeling emission model for proper vehicle simulation to study Efficiency, Performance, andEmission Impacts of Advanced Engine Operation.

Gu¨nter P. Merker _ Christian Schwarz
Ru¨digerTeichmann*[6]* discusses about development of combustion engines, their emissions and control strategies.

## III. METHODOLOGY-

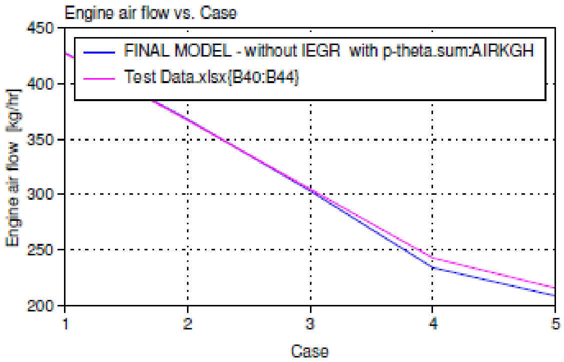
In this paper, diesel engine has beeninvestigated on analysis basis Figure 1 shows theinteraction between the tools. In the first step, the system,including the engine specification and allconditions for the simulations was defined.Then, the 1D WAVE model was tuned and validated with the help ofexperimental data from an engine test bench.



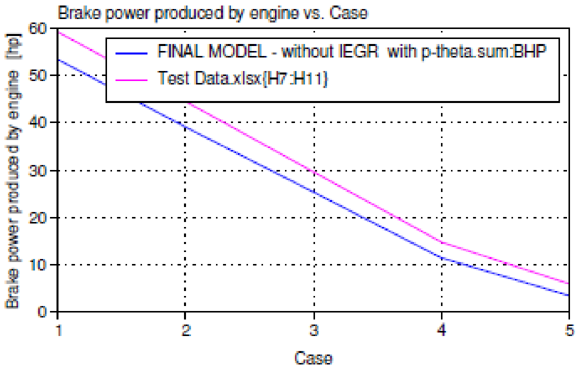
Numerical valueswhich parameterize the pollutant formation and combustionprocess in engine were chosen. Based on the results of this DoE, some parameters were chosen, in order to satisfy CPCB –II final emission limits at acceptable fuel consumption (FC). The parameters chosen were theNTP, HTFR per nozzle hole, spray cone angle, CR, injection duration and pressure, SOI,valve opening closing time and number of nozzle holes.

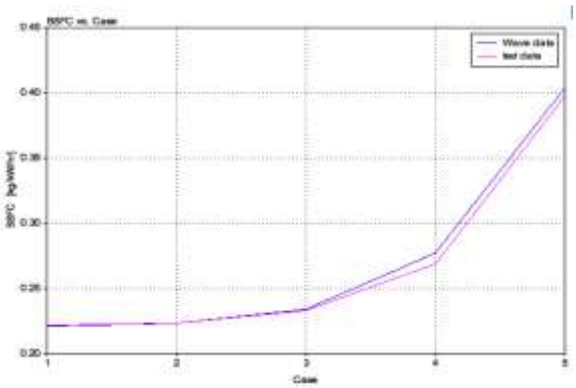
## IV. VALIDATION OF 1-D MODEL

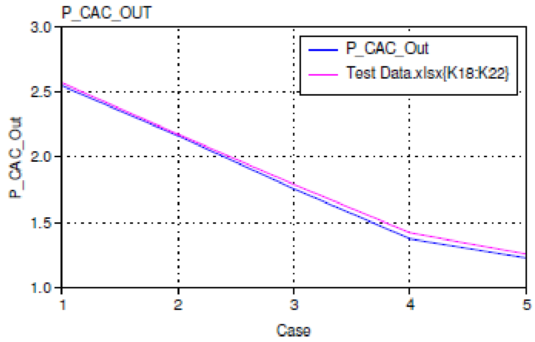
The validation is done for 5 cases according to standard D2 test cycle i.e. at 100%, 75%, 50%, 25% and 10% Load.



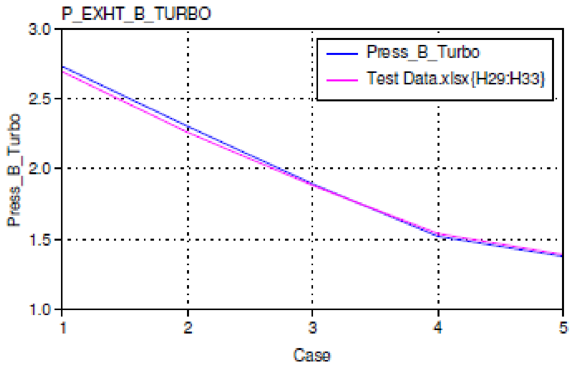

Engine air flow indicates the air mass flow (kg/hr) going in cylinder. The air flow in the model is compared with air flow measured on test bed.






P_CAC_OUT is the pressure of air coming out from Charged Air Cooler and going into intake manifold.




P_EXHT_B_TURBO is pressure of exhaust measured at just after exhaust manifold.

The first optimization step is to check the injection strategy. And then optimization of the combustion chamber, by simulating different compression ratio. The main objective is to use a 1D tool looking at the resulting combustion and the products/parameters of this combustion. The use of software allows more accurate predictions related to emission and fuel consumption of engine.

The optimization is achieved from a Design of Experiment (DoE), which allows the definition of a range of values for each significant variable that will be simulated. DoE is used to obtain the most appropriated result with the intention of using the solution in the engine being designed. The range of value has some restrictions, mainly because of the construction and design necessities.

## V. RESULT AND DISCUSSION-

The variables that were considered in the studies and their values are described below along with their effect on emission parameters:

1. **Injection Pressure**– It is the pressure with which the fuel is introduced in the combustion chamber.

| INJ_PR: | bar | 470 | 490 | 510 |
|---|---|---|---|---|
| CO | ppm | 46.80 | 46.80 | 46.87 |
| HC | ppm | 30.72 | 30.72 | 30.72 |
| NOx | ppm | 1074.26 | 1074.31 | 1074.25 |

2. **Injection Duration**- It is the duration of injection in terms of crank angle degrees. Increase in duration upto some extent reduces NOx

| INJDUR: | Deg | 20 | 25 | 30 |
|---|---|---|---|---|
| CO | Ppm | 47.4091 | 46.7494 | 46.6728 |
| HC | Ppm | 30.6716 | 30.7213 | 30.83 |
| NOx | Ppm | 1101.91 | 1070.84 | 1013.21 |

3. **Compression Ratio –** The compression ratio decides the volume of combustion chamberand by increasing it CO reduces and NOx increases because of proper combustion and thus increase in temperature.

| CR: | - | 15 | 17 | 19 |
|---|---|---|---|---|
| CO | ppm | 47.91 | 46.80 | 45.76 |
| HC | ppm | 30.58 | 30.72 | 30.83 |
| NOx | ppm | 1065.76 | 1074.31 | 1082.02 |

**4. Start of Injection(crank deg)-**

| SOINJ: | deg | 0 | 0.75 | 1.5 | 2.25 | 3 |
|---|---|---|---|---|---|---|
| CO | ppm | 46.66 | 46.64 | 46.79 | 46.73 | 46.58 |
| HC | ppm | 30.70 | 30.66 | 30.62 | 30.58 | 30.54 |
| NOx | ppm | 1065 | 1048 | 1032 | 1018 | 999 |

5. **Nozzle Diameter**- It is the diameter of the injector nozzle. And it doesn’t have significant effect on emissions.

| NOZZLE | mm | 0.2 | 0.25 | 0.3 |
|---|---|---|---|---|
| CO | ppm | 46.84 | 46.89 | 46.75 |
| HC | ppm | 30.72 | 30.72 | 30.72 |
| NOx | ppm | 1075.08 | 1075.27 | 1075.27 |

6. **Spray Spread Angle**- It is the angle of spray of fuel coming from holes of nozzle.

| SPRAY A. | deg | 122 | 144 | 166 |
|---|---|---|---|---|
| CO | ppm | 46.86 | 46.86 | 46.86 |
| HC | ppm | 30.72 | 30.72 | 30.72 |
| NOx | ppm | 1075.30 | 1075.30 | 1075.30 |

7. **Intake Valve Open Angle Deviation**- Advancement in intake valve open degrees increases NOx, CO as well as HC.

| deviation | deg | -10 | 0 | 10 |
|---|---|---|---|---|
| CO | ppm | 45.05 | 46.86 | 57.17 |
| HC | ppm | 30.49 | 30.72 | 31.61 |
| NOx | ppm | 1062.17 | 1075.30 | 1118.04 |

8. **Exhaust Valve open Angle Deviation**- Advancement in Exhaust valve open degrees reduces NOx and CO.

| deviation | deg | -10 | 0 | 10 |
|---|---|---|---|---|
| CO | ppm | 56.53 | 46.86 | 39.43 |
| HC | ppm | 31.02 | 30.72 | 30.61 |
| NOx | ppm | 1098.62 | 1075.30 | 1062.97 |

Above are the results of the software which shows the co-relation between parameters and emission content. So from these results we can chose parameters to make change on engine to get optimized emission.

## VI. CONCLUSION AND FUTURE WORK

- The use of numerical simulation is apowerful tool for proper understanding thephenomena involved on the combustion.The possibility in visualizing effects that arenot so easy to observe in engine tests can contribute to betterimprovementson engine design.
- The numerical results showed good correlations within the experimental data used to calibrate the model as well as the trends are correct with varying loads.
- With the developed model, it wasnot possible to measure what is the influence of various parameters on emissions and on engine performance results.
- The future work of this project to select best and economical parameters to be changed on engine from analysis.Do the changes and check whether it has positive effect on emissions with proper performance or not if not then go for the further analysis.

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