Performance Evaluation of Diesel Engine using Genetic Algorithm

Agil Lukose, AVN Krishna

Abstract*: *Engine analysis and optimization is not a new approach to the field of automobiles. It has always been a keen focus in the research of experts domestically as well as internationally, the control of Air-Fuel Ratio (AFR) in transient operating conditions of engine. For the last few decades, the industry and economic expansion of developed countries has showed a clean increase in the vehicle production as well as transport volume. Global warming, acid rain, greenhouse effect and air pollution problems related to emission of CO2, NOx, PM, CO and unburned HC, together with the consumption of fossil fuels, unite to create serious problems at a global level. Therefore it is a research study considering all these current issues and taking it to a new level of optimization for the output of a better efficiency, better economy and less pollution. Performance of Diesel Engine is evaluated by parameters like Power, Torque and Specific Fuel Consumption.

Index Terms*: *Diesel Engine, Exhaust Gas, Genetic Algorithm,. Performance Evaluation

I. INTRODUCTION

In 80s and 90s, Indirect Injection (IDI) was used but now-a-days Direct Injection (DI) is used mostly in vehicles. In Direct Injection engines, injectors inject fuel directly into the main combustion chamber, which is a gap between cylinder and piston, where it pierce into the hot mass of compressed air. Indirect Injection (IDI) has mainly two designs are used viz. pre- combustion chamber and air cell. Pre-Combustion Chamber: In this, total fuel is injected into pre-combustion chamber and initial combustion take place here only. Due to the combustion, pressure in the pre-combustion chamber increases because of which fuel present in this chamber comes out at a high velocity through a wee orifice into the main combustion chamber. This high velocity of fuel helps the fuel atomize automatically and mix with air present in main combustion chamber and the combustion take place here. Air Cell: A small chamber provided inside the piston in some design is called Air cell. The piston compresses the air during compression stroke and pushes it into this air cell. As the piston retracts the pressure in the cylinder falls down resulting in the flow of hot air from the cell into the combustion chamber. These actions provide turbulence which mix the air and the fuel furthermore and complete the combustion.

II. LITERATURE SURVEY

1) Data Analysis to Predictive Modeling of Marine Engine Performance using Machine Learning: In this paper, predictive analysis of the marine engine performance is analyzed and subjected to multiple machine learning and clustering algorithms. Variables analyzed are shaft power, shaft rpm and shaft torque. Neural network performed as a good model predictor here. Fuzzy C-Means is combined with above mentioned techniques to reduce the prediction error. Gap identified by the narrator says that predictive model needs human intervention for data analysis & clustering. Future work of the paper includes the decision making strategy to reduce human intervention and improving power management system.
2) Improving Performance of Evolutionary Engine Cali-bration Algorithms with Principal Component Analysis: This paper put forth an idea to improve the speed and the performance of engine. Challenge includes expen-sive engine evaluation and time consumption. Method implemented in this paper is a PCA based optimization algorithm, resulted in minimizing fuel consumption & gas and particle emission in a Jaguar XF.
3) An identification method of characteristic parameters for single-cylinder engine fuel film based on genetic algorithm: Test to find the Air-Fuel Ratio of single cylinder engine. Method of perturbation is performed in this test. Genetic algorithm used as to the performed to analyze. Implementation of the test is perturbation test performed keeping the throttle position same but changing fuel injection quantity. Finally the test results in improvement of AFR and the overall performance of engine. Genetic algorithm is used to conduct the characteristics parameter identification.
4) Simulation study of optimization of genetic algorithm for vehicle power train: To improve performance of the car, work mainly focuses the use of Genetic Algorithm for the best match of automotive power train parameters. Computer simulation is used for the automotive power system parameters optimization. Practical approach: VW Jetta; Parameters considered for optimizing and matching: Max speed, fuel consumptions, size of car, ground clearance, engine type, no. of cylinder, max power & max torque. Result shows that all the aspects of original and optimized performance and the rate of change of indicators through optimization of transmission param-eters, fuel consumption of six conditions reduced by 16.159% and acceleration time decreased as well.
5) Combining neural networks and GA to predict and reduce diesel engine emissions: Objective of the paper is to find best way to set the engine as the emission rate is reduced and the reduced rate of fuel consumption.

Revised Manuscript Received on 25 December 2018.

Agil Lukose, M.Tech, 4 Sem. Student, Department of Information Technology, Faculty of Engineering, Christ University (Deemed), Bengaluru (Karnataka), India.

Dr. AVN Krishna, Professor, Department of Computer Science and Engineering, Faculty of Engineering, Christ University (Deemed), Bengaluru (Karnataka), India.

III. METHODOLOGY & DESIGN

As a new level of optimization and as a technique of finding an effective and efficient way for running a diesel engine, certain factors viz. NOx, PM, AFR, EGR and PIP are observed and analyzed. The analyzed factors are observed under the transient condition of diesel engine. The observed values are tabled against the pre-decided values on the x axis. These tabled values are used to find the Lagrange's interpolation equation using an online Lagrange's interpolation polynomial calculator. As a result, a polynomial is generated and this polynomial is used in the Genetic Algorithm for optimization. Genetic Algorithm is performed using the tool RStudio and the optimized values are generated for the tabular values. These optimized values are the key of the research study here and further analysis is made according to that. Apart from this, the tabled values are plotted to graphs, in order to make sure and partly verify the basic trend in the diesel engine and to know the variations in the readings.

IV. COMPARISON AND MONITORING OF DIFFERENT FACTORS IN EMISSION GAS

AFR-N O_x

DI		IDI	
AFR	NOx	AFR	NOx
0.1	80	0.1	200
0.15	100	0.15	220
0.2	200	0.2	250
0.25	350	0.25	300
0.3	450	0.3	450
0.35	600	0.35	570
0.4	750	0.4	580
0.45	950	0.45	575
0.5	1100	0.5	520
0.55	1225	0.55	500
0.6	1380	0.6	500
0.65	1400	0.65	485
0.7	1440	0.7	430
0.75	1450	0.75	425
0.8	1420	0.8	420
0.85	1380	0.85	410
0.9	1350	0.9	400
0.95	1260	0.95	370
1	1225	1	320

PM-N O_x (2-valve engine)

PM	NO_x1	NO_x2	NO_x3	NO_x4
0.1	22.4	22.6	22.8	22
0.15	18.4	18	18.2	17
0.2	15.6	14.5	15.9	10
0.25	12.6	7.8	14.2	25
0.3	10.4	8.2	10.8	21
0.35	8.2	8	10.4	2
0.4	7.2	7.6	10.3	23
0.45	6.2	7.4	9.9	13
0.5	5.5	7.2	9.6	11
0.55	5.4	6.9	8.8	16

PM-N O_x (4-valve engine)

PM	NO_x1	NO_x2	NO_x3	NO_x4
0.03	21.6	21.9	20.5	23
0.04	18	21.5	17.6	12
0.05	15	20.1	14.6	7
0.052	12.6	15.6	11.3	9
0.053	10.6	10.2	9.6	16
0.055	8.6	7.6	7	20
0.058	7.8	7.4	6.5	17
0.1	7	7.2	5.1	25
0.15	6	6.6	5.5	3
0.2	5	6.2	5.6	5

PM-PIP

PM	PIP1	PIP2	PIP3	PIP4
0.1	1675	1716	1677	1716
0.2	1500	1659	1637	1057
0.3	1275	1370	1553	1276
0.4	1075	1027	1358	951
0.5	900	883	1020	760
0.6	675	837	841	717
0.7	475	458	778	332
0.8	300	224	692	434
0.9	75	78	670	265
1.0	40	10	339	177

EGR-N O_x

EGR	NO_x1	NO_x2	NO_x3	NO_x4
0	3	3.9	2.2	2.5
10	1.5	3.5	2	1.5
20	0.7	3.1	1.7	1.7
30	0.3	2.4	1.2	1.6
40	0.05	2.2	0.6	1.4
50	0.05	1.55	0.2	0.9
60	0	1.1	0	0.4

The same factors were considered for the further research using neural networks and found manual combinations like which each considered factors interrelate. The following table shows that:

PM	NO_x	EGR	Peak	CASE
0.01	.05	40	3000	1
0.01	.3	30	2300	1
0.02	.7	20	2050	1
0.03	1.5	10	1950	1
0.05	3	0	1800	1
0.1	5	0	1675	1
0.2	6	0	1500	1
0.3	7.4	0	1275	1
0.4	8.6	0	1075	1
0.5	10.6	0	900	1

V. FITTING FUNCTION IN GA USING LAGRANGES EQUATION

To identify the optimal AFR for the maximum NOx emission in exhaust gas, fitting function for the DI engine has to be calculated.

To calculate the Fitting function, a Lagrange's fitting function polynomial is used.

DI: Fitting Function= equation (when AFR 0.2-0.8 is given)

Fitting Function: 110395000000 $*x^{12}$+…………

IDI: Fitting Function= equation(when AFR 0.2-0.8 is given)

F(x)= -1572559 000000 * x^{12}+………………………

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

DI: Fitting Function= equation(when AFR 0.1-1.0 is given)

$F(x) = 73258300000000 * x^{18} + \ldots$

IDI: Fitting Function= equation(when AFR 0.2-0.8 is given)

$F(x) = -41502100000000 * x^{18} + \ldots$

PM-N O_X (2-valve engine) Fitting function = equation

$F(x) = -257000000 * x^{9} + \ldots$

PM-N O_X (4-valve engine) Fitting function = equation

$F(x)= 1.0006000*10^{17} * x^{9} + \ldots$

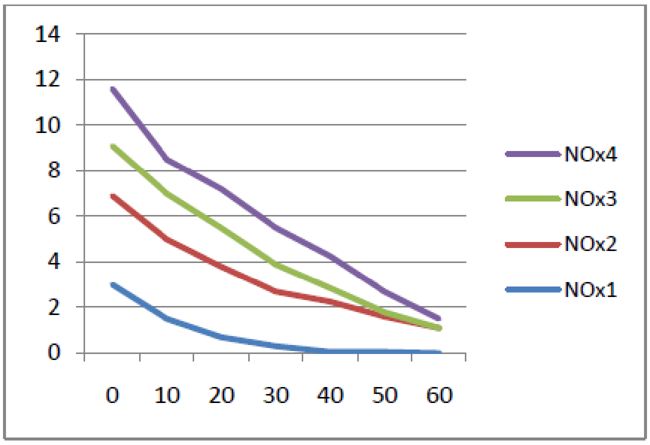
PM-PIP Fitting function = equation

$F(x)= -5125660 * x^{9} + \ldots$

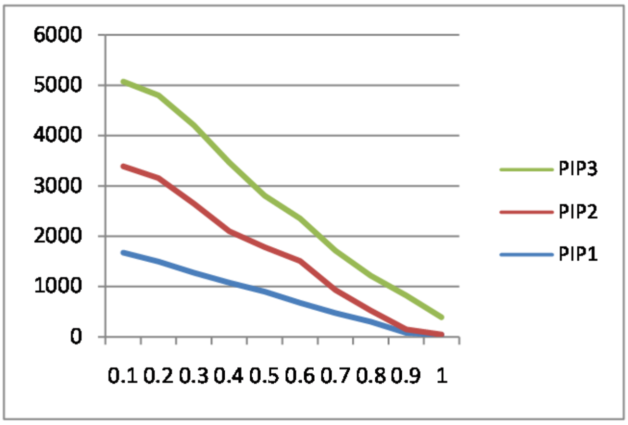
EGR-N O_X Fitting function = equation

$F(x)= 660000000* x^{9} + \ldots$

PM-NOx



PM-PIP



EGR-NOx

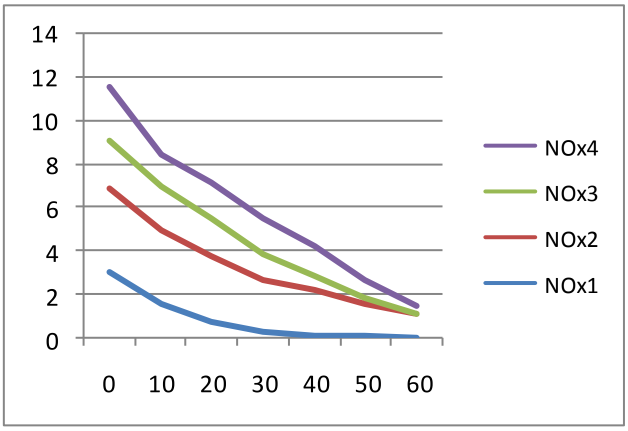


TABLE I. AFR-No$_x$ OPTIMIZED VALUES

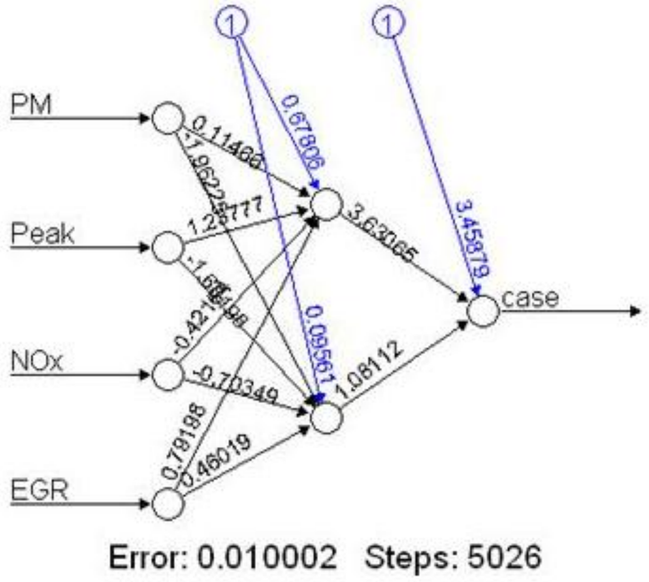
AFR Range (0.2-0.8)		AFR Range (0.1-1.0)	
DI	0.7992883	DI	0.1000205
IDI	0.2160344	IDI	0.43706

TABLE II. OPTIMIZED VALUES

Tables	Optimized Value
PM-NO$_x$(2-valve)	0.1000219 g/kWh
PM-NO$_x$(4-valve)	0.1374515 g/kWh
PM-PIP	0.1056914 bars
EGR-NO$_x$	0.176577 g/kWh

VI. RESULTS & ANALYSIS

Possible weightage of each factors found using neural networks are as shown in the plot below.



VII. CONCLUSION

It has always been a keen focus in the research of experts, the control of Air-Fuel Ratio (AFR) in transient operating conditions of engine. Though as the experts say, the Transient AFR has a deviation from theoretical mixture ratio. DI is best for heavy vehicle (Optimal value of AFR is 0.1892883). IDI is best for light vehicle (Optimal value of AFR is 0.2160344).

As an extension of the work, by considering the other factors in emission gas viz. Nitrogen Oxide (NOx), Particulate Matters (PM) and the standard factors like Peak Injection Pressure (PIP), Exhaust Gas Recirculation (EGR) also paves a new conclusion for the better efficient engine.

For a standard value of PM, 0.1000219 g/kWh NOx is the safest amount in emission in 2-valve engine, where as in 4-valve engine the NOx slightly increases to 0.1374515 g/kWh. Likewise for a unit value of PM, 0.1056914 bars of peak injection pressure is evaluated as the safest amount in emission using Genetic Algorithm as well as for the standard value of EGR, 0.176577 g/kWh NOx is the safest amount in emission. Furthermore the most possible weight age of each factors together in the emission gas is shown in the plot, using neural networks.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

FUTURE WORK

To work on various interpolation techniques to identify the suitability of the fitting function.
To work on different parameters like combustion chamber design, injection system in improving the performance of Diesel engine.
To Build Hybrid vehicle design.
To Study the relevance of Neural Networks in improving the performance of Diesel engine.

REFERENCES

1. T.K.Chan, C.S.Chin, "Data Analysis to Predictive Modeling of Marine Engine Performance using Ma-chine Learning", 2016 IEEE Region 10 Conference (TENCON)-Proceedings of the International Confer-ence, pp. 2076-2080, 2016.
2. Tayarani-N, Mohammad-H and Bennett, Adam Prugel¨ and Xu, Hongming and Yao, Xin, "Improving the performance of evolutionary engine calibration algo-rithms with principal component analysis", 2016 IEEE Congress on Evolutionary Computation (CEC), pp. 5128-5137, 2016.
3. Yang, Yong and Xu, Man and Zhao, Kegang and Zhou, Sijia, "An identification method of characteristic pa-rameters for single-cylinder engine fuel film based on genetic algorithm", Proceedings of the 35th Chinese Control Conference, July 27-29, 2016, Chengdu, China
4. Fangxiao, Cheng and Xudong, Liu and Xiaomei, Lin, "Simulation Study of Optimization of GA for Vehicle Power Train", 2011 International Conference on Internet Computing & Information Services (ICICIS), pp. 330-333, 2011.
5. Shatnawi, Yousef and Al-Khassaweneh, Mahmood, "Fault diagnosis in internal combustion engines using extension neural network", IEEE Transactions on Indus-trial Electronics, vol. 61, no. 3, pp. 1434-1443, 2014.

Mr. Agil Lukose is a student persuing his M.Tech in IT from Faculty of Engineering, CHRIST(Deemed), Bengaluru, India.

Dr. AVN Krishna is Professor in CSE, Faculty of Engineering, CHRIST (Deemed), associated in Academic Field for 25 years, Published work in Journals of National and International repute.