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Artificial Neural Network based Multi-objective Optimization using Genetic Algorithm for Single Cylinder CI Engine Emission and Performance Parameters using Polanga Biodiesel

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Abstract: In view of the limited accessibility and environmental concerns of diesel, biodiesel is one of the promising alternative fuels for CI engine. This research work investigates the influence of engine fuel injection pressure on the emissions and performance of a single cylinder 4-stroke CI engine using blended Polanga biodiesel (10, 20, 30, and 40 %) with diesel as a fuel. Experimental test was carried out using four different fuel injection pressure (160, 180, 200, 220 and 240) bars. The optimization using genetic algorithm in MATLAB software is carried out to optimize the chosen engine input parameters to achieve specified priorities. The study results show that the high fuel injection pressure improves emissions and performance parameters of CI engine, NOx, CO, smoke UBHC emissions, fuel consumption, brake thermal efficiency and exhaust gas temperature respectively.

Keywords: biodiesel, performance, emission, CI engine, Multi-objective optimization.

I. INTRODUCTION

All over the world, there is an increasing interest on the production of biodiesel due to its eco-friendliness and renewability. Biodiesel has a higher flash point that makes it more suitable for transportation and handling. Also, it has a more favourable combustion emission profile than petroleum diesel, such as lower emissions of carbon monoxide, particulate matter and unburned hydrocarbons. Rapidly increasing energy demand due to industrialization has led to a large number of developing countries importing crude oil.

Thus, a major part of their export earnings is spent on purchase of petroleum products. The other problem of concern is the degradation of environment due to fossil fuel combustion besides the fuel crisis. Thus it is essential that low emission alternate fuels must be developed for use in diesel engines. Biodiesel has been widely recognized in the alternative fuel industry due its following attractive features: (i) It is plant-derived, and as such its combustion does not increase current net atmospheric levels of greenhouse gas (ii) It can be domestically produced, offering the possibility of reducing petroleum imports (iii) It is biodegradable.

Relative to conventional diesel fuel, its combustion products have reduced levels of particulates, carbon monoxide, and in some conditions nitrogen oxides Ghobadian et al. [1]. The research and development activities on biodiesel have been mostly on sunflowers, saffola, soyabean, rapeseed and peanut which are considered edible in several countries. However, biodiesel can also be produced from non-edible oil seeds like jatropha, karanja, neem, cotton, rubber and polanga etc by Sahoo et al. [2]. The density and viscosity of Polanga biodiesel after triple stage transesterification process were found to be close to diesel oil.

Sahoo et al. [3] evaluated comparative performance and emission characteristics of jatropha, karanja and polanga based biodiesel as fuel in a tractor engine. Baiju et al. [4] observed that brake specific fuel consumption for all the biodiesel blends with diesel increased with blends and decreased with speed.

Canakci et al.[5] studies however lacks the effect of fuel injection pressure on engine emission and performance parameters. Injection pressure along with blend percentage is also an important parameter that may affect the performance and emission characteristics Shivakumar et al. [6]. Ong et al. [7] optimized biodiesel production from WCO for multiple objectives, using multi-objective differential evolution. Esterification and trans-esterification steps, and three continuous stirred tank reactors (CSTR) in series for trans-esterification, which has obvious advantages Sharma et al. [8].

Fauzi et al. [9] optimized oleic acid esterification catalyzed by ionic liquid. They used RSM based on central composite design for single-objective optimization, while artificial neural network with

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genetic algorithm was employed for simultaneous optimization of responses to the reaction conditions. Rahimi et al. [10] studied the optimization of biodiesel production from soybean oil in a microreactor. They used Box–Behnken method and RSM for the optimization of molar ratio of methanol to oil, catalyst concentration and temperature. Ismail et al. [11] optimized biodiesel production from Calophyllum inophyllum oil containing high free fatty acid.

II. EXPERIMENTAL INVESTIGATION

Kirloskar make single cylinder four stroke water cooled CI engine used for this research work. The detailed specification of the engine is shown in Table 1.

TABLE 1 ENGINE SPECIFICATIONS

Item description	KIRLOSKAR
BHP	5HP
Speed	1500
Number of cylinders	1
Compression ration	16.7:1
Bore	80 mm
Stroke	110 mm
Orifice Diameter	20 mm
Type of ignition	Compression ignition
Method of Loading	Eddy current dyanometer
Method of starting	Manual cranking
Method of cooling	Water

The schematic diagram of the experimental set up is shown in Fig.1. The experimental set up consists of engine, dynamometer, load cell and temperature sensors etc. Eddy current-dynamometer was used for engine loading. A fuel consumption meter, DP transmitter, Range 0-500 mm wc, was used for measuring the specific fuel consumptions of the engine. A Kistler make quartz (piezo-electric) transducer in conjunction with a Kistler charge amplifier was employed to determine the cylinder gas pressure. The pressure transducer had range up to 345 bar pressure measurement.

Real time data acquisition was done with the help of Engine test Express V5.76 which was Lab view based software package. Exhaust gas analyzer of AVL make (AVL DiGas 444) was used for measuring the emissions of HC, and NOx from the engine.

A Smoke meter, model 437C, made by AVL Gurgaon, was used for measuring the engine smoke emission. Exhaust gas emissions recorded were: unburned hydrocarbons (UBHC) in parts per million (ppm), and oxides of nitrogen (NOx) in ppm and CO in % vol. by using AVL DiGas 444 gas analyzer.

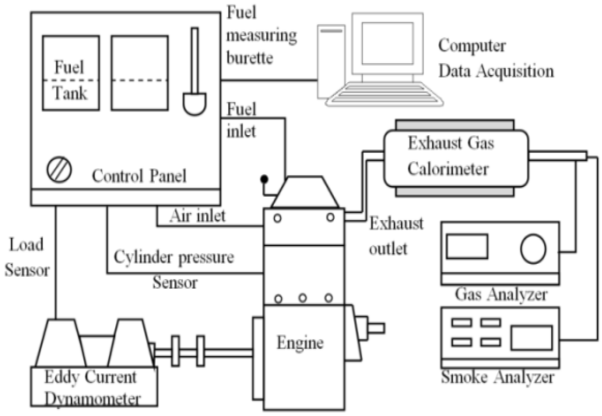

Fig 1 Experimental Setup

Opacity of the smoke in the exhaust was measured in % by using AVL 437C smoke meter. K-type thermocouples were employed to assess the exhaust gas, cooling water inlet and outlet temperatures. The percentage uncertainties of various instruments are given in Table 2.

TABLE 2: % UNCERTAINTIES OF VARIOUS INSTRUMENTS

Instruments	Measuring range	Accuracy	Percentage
AVL DiGas 444 Gas Analyser			
Hydrocarbon(HC)	0-20000 ppm vol	<200 ppm	±0.3
Nitric oxide(NO)	0-5000 ppm vol	<500 ppm	±0.2
AVL-437C Smoke meter			
Smoke opacity	0-100%	±1%	±1
Exhaust gas	0-1250°C	±1°C	±0.2
Burette for fuel measurement		±1cc	±1
Pressure	0-100 bar	±0.01b	±0.1

The performance test of the engine included fuel consumption and rating test. In order to carry out fuel consumption test, initially the engine was started and warmed up on zero loads. After that the engine was gradually loaded up to 100 percent load to stabilize its operation.

The experiment with each selected fuel type was replicated three times and the average value of different performance and emission parameters measured was taken for analysis. The experimental data obtained has been summarized in Table 3.

TABLE 3 EXPERIMENTAL RESULTS OF BIODIESEL UNDER DIFFERENT INJECTION PRESSURES AND BLENDS

IP(bar)	BD(%)	BSFC(kg/kWh)	BTE(%)	EGT(^{o}C)	CO(%vol)	UBHC (ppm vol)	NOx (pp vol)m	Smok(%)e
160	10	0.24	38	257	0.077	41	1796	39.6
160	20	0.247	36.21	258	0.07	40	1747	39.12
160	30	0.258	35.1	263	0.058	38	1671	38.72
160	40	0.267	34.02	265	0.0466	37	1624	38.12
180	10	0.2268	40.23	260	0.0712	40	1763	39.44
180	20	0.24	38.45	264	0.062	38	1702	39.2
180	30	0.25	37.25	267	0.052	36	1647	38.52
180	40	0.2614	36.66	270	0.039	35	1593	37.6
200	10	0.2268	40.6	266	0.0637	36	1744	39.2
200	20	0.238	39.31	271	0.05	34	1687	38.56
200	30	0.243	38.27	275	0.043	34	1636	38
200	40	0.2522	37.9	278	0.0254	31	1567	37.36
220	10	0.2535	35.77	269	0.0502	33	1789	38.8
220	20	0.247	36.63	273	0.04	32	1737	38.28
220	30	0.241	37.84	277	0.029	31	1687	37.68
220	40	0.2394	38.7	282	0.019	29	1632	37
240	10	0.262	34.56	272	0.0366	32	1812	38.44
240	20	0.2495	37.18	280	0.027	30	1787	37.96
240	30	0.238	39.34	282	0.022	29	1711	37.24
240	40	0.23	41.18	288	0.016	28	1694	36.8

Table 4: Properties of Polanga biodiesel and its blends

Fuel	Calorific value (KJ/kg)	Viscosity (cSt) at 15 ^{o}C	Density (gm/cc)	Flash point (^{o}C)	Cloud point (^{o}C)
Diesel	43990.3	2.93	0.831	74	6.5
BD10	40095.2	3.3	0.849	84	7.3
BD20	39195.73	3.31	0.849	89	8.0
BD30	38395.3	3.33	0.857	95	8.3
BD40	37796.98	3.8	0.867	100	8.9

Polanga biodiesel preparation through transesterification process has already been reported in previous studies (Sahoo et al. 2007; Sahoo et al. 2009). Four biodiesel blends of Polanga were used viz., BD10, BD20, BD30, BD40. The physical and chemical properties of biodiesel were determined as per ASTM standard test methods as shown in Table 4. The fuel injection pressure of the engine was kept at 180 bars (as set by the manufacturer) for diesel as a fuel. The emissions and performance characteristics of diesel engine were recorded at a constant engine speed of 1500 rpm. Similar procedures were repeated for other biodiesel blends at the different fuel injection pressure. To visualize the effect of fuel injection pressure, the entire procedure was repeated for different fuel injection pressure of 160 bar, 200 bar, 220 bar and 240 bar with combination of different polanga biodiesel blends.

III. RESULTS AND DISCUSSION

A. Biodiesel fuel characteristics and properties

Biodiesel is produced by the three stage transesterification process. The first stage removes the organic matters and other impurities present in the unrefined filtered polanga oil using reagent. The second stage reduces the acid value of the oil about 4 mg KOH/gm corresponding to a FFA level of 2%. The product of the second stage (pure triglycerides) is transesterified to mono-esters of fatty acids (biodiesel) using alkali catalyst. It was observed that the bio-diesel produced from polanga oil by above three stages, has the physico-chemical properties close to those of conventional diesel fuel.

B. Performance parameters

Table 3 shows BSFC results for different polanga biodiesel-blended diesel fuels with different fuel injection pressures at constant full load condition. A decrease in fuel injection pressure increased the BSFC values compared to original injection pressure of 180 bar for all the polanga biodiesel blends. With decreasing fuel injection pressure, fuel particle diameters will enlarge and ignition delay period during the combustion will increase. This situation causes an increase in the BSFC. On the other hand, increasing fuel injection pressure from the original pressure decreases the BSFC values for BD30 and BD40 polanga biodiesel blends. The decrease in BSFC can be attributed to the more efficient utilization of the fuel at higher fuel injection pressure because of better atomization of fuel associated with slight delay in admission due to high needle lift pressure with same period and hence lesser fuel going to cylinder. For blends BD10 and BD20, an increase in injection pressure increases the BSFC values due to a shorter ignition delay period. The BTE points to the ability of the combustion system to accept the experimental fuel and provides comparable means of assessing how efficient the energy in the fuel was converted to mechanical output. From the previous discussion, it could be concluded that as the biodiesel amount increases in the fuel blend at the given injection pressure, the BSFC increases, since the LHV value of the blend decreases. BTE is a function of BSFC and LHV of the blend for a constant effective power. It is clear that LHV is more effective than BSFC with regard to increasing BTE. Therefore, the BTE generally increased as the biodiesel content increased in the blended fuel for all injection pressures. As demonstrated in Table 3, the maximum BTE was acquired as 41.18% with the BD40 for 240 bar fuel injection pressure.

C. Exhaust emissions

Reduction in CO was observed with increasing fuel injection pressure for all polanga biodiesel blends. Minimum CO emission of 0.16% by vol. was observed at the injection pressure of 240 bar with polanga BD40. This is due to the lower carbon content of biodiesel and also better combustion caused by the improved atomization, better mixing process at higher fuel injection pressure of 240 bar. UBHC emission of biodiesel decreased with increasing fuel injection pressure from 160 bar to 240 bar. Lowest UBHC emission of 28 ppm was observed at 240 bar, which is 9 ppm lower than that of UBHC emission at 160 bar for the same biodiesel blend BD40. The reduction in UBHC emission of biodiesel is mainly due to the higher oxygen content and cetane number. Further, the increasing of fuel injection pressure improved the spray characteristics which led to better combustion. The NOx emission level decreased with increasing fuel injection pressure; this was because of faster combustion and higher cylinder gas temperature. Maximum NO emission is 1796 ppm at 160 bars. The lowest smoke opacity of 36.8% was obtained with 240 bar biodiesel operation compared to other injection pressures. Reduction in smoke level of biodiesel is may be due to its oxygen content and small particle diameter of injected fuel with high fuel injection pressure.

D. Optimization of CI engine emissions and performance and using MATLAB

The genetic algorithm makes use of the correlations obtained by performing nonlinear regression analysis on the experimental data for all Polanga biodiesel and diesel blends and fuel injection pressures. Curve Expert software is used to obtain the correlations. The different correlations evaluated are,

Square function: y = a×(x1) + b× (x2) + c× (x3) + d× (x1)2 + e× (x2)2 + f× (x3)2+ g× (x1) × (x2) + h× (x2) × (x3) + i× (x3) × (x1)

Cubic function: y= a + b× (x1) + c× (x2) + d× (x3) + e× (x4) + f× (x1)2 + g× (x2)2 + h× (x3)2 + i× (x4)2 + j× (x1) × (x2) + k× (x2) × (x3) + l× (x3) × (x4) + m× (x3) × (x4) + n× (x1)3 + o× (x2)3+ p× (x3)3 + q× (x4)3

Exponential function: y = e[a(x1) + b(x2) + c(x3) + d]

Linear: y= a× (x1) + b× (x2) + c× (x3) + d

where, x1= Load, x2= IT, x3= IP, x4= Blend

The optimization process is carried out after fixing the upper and lower bounds for constraints, defining the fitness function and number of variables. The constraints are load, blend, fuel injection timing and fuel injection pressure.

Table 5 Upper and Lower Bounds for Constraints

Constraints	Lower bound	Upper bound
Load (full load)	10	10
Injection Pressure (bar)	160	240
Blend	10	40

The optimization of engine performance parameters is conducted by considering three important engine parameters viz. BTE, BSFC and EGT. BTE is always preferred to be maximum, BSFC and EGT to be minimum. Hence, this creates a multimodal scenario of optimization. The solution procedure for optimization of engine performance is as follows:

1. Three types of mathematical equations viz. Polynomials, exponentials and power functions are developed from the captured experimental data (Table 3) to form a relation between the input (Load, IP, Blend) and output (BTE, BSFC and EGT) parameters using the Curve expert software.
2. The mathematical equation with best fit is selected based on best value of coefficient of determination (R^2) for all parameters. Cubic polynomial is found to be the best fit on both criterion and for all output parameters. Table 6 shows the cubic polynomials for engine performance parameters, with their respective R^2 values.

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3. The equations thus obtained are defined as a function in MATLAB. This function is called as the fitness function for optimization in MATLAB. The Genetic Algorithm tool box of MATLAB is used for defining and solving the problem. Figure 2 shows optimization problem definition screen.

Figure 2 shows display screen of MATLAB program before optimization of engine performance is carried out. The problem definition screen is where the solver, fitness function and bounds are defined. The options column on the left hand side is used to select pareto front display. After the optimization is done, number of iterations is displayed in the current iteration box. The function values are also displayed suitably.

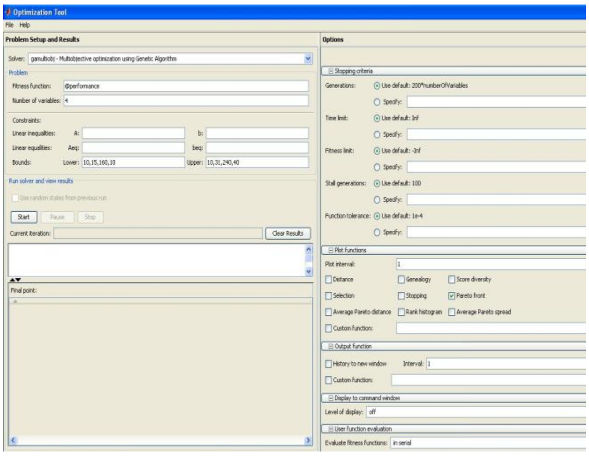

Fig. 2 Optimization tool problem definition screen

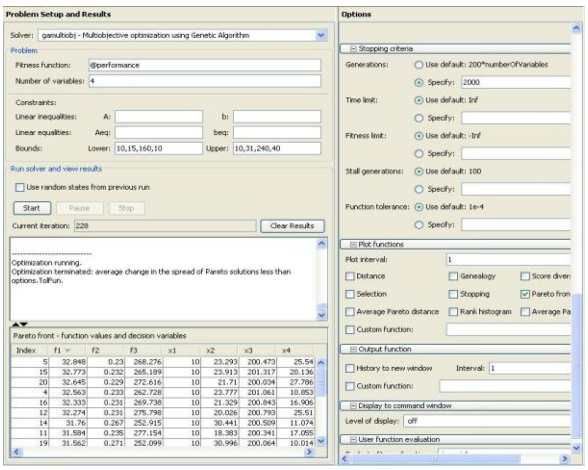

Fig.3 MATLAB program showing optimization of engine performance

Figure 3 shows display screen of MATLAB program after optimization of engine performance is carried out. The problem definition screen is where the solver, fitness function and bounds are defined. The optimization is carried out considering full load condition and hence, both upper and lower bounds for load. The set bounds for the constraints are given in Table 5. The same are entered in the order of engine load, fuel injection pressure and percentage of polanga biodiesel in the software. The options column on the left hand side is used to select pareto front display. After the optimization is done, number of iterations is displayed in the current iteration box. The function values are also displayed suitably.

IV. CONCLUSION

In this research work the different polanga biodiesel blends with diesel used in the single cylinder CI engine without any engine modifications. Experimental investigation showed that the injection pressure of 240 bars was found to be the optimum condition for engine with BD40 biodiesel, based on the reduction in BSFC and improvement in brake thermal efficiency was also observed. Biodiesel blends resulted in the reduction of CO, UBHC and smoke emission at higher fuel injection pressures. However NOx emission increased with increasing fuel injection pressures. Among the various injection pressure, 240 bar exhibited shorter ignition delay with slightly longer combustion. Desirability approach of the MATLAB optimization was found to be the simplest and efficient optimization technique for optimizing the engine variable parameters.

REFERENCES

[1] Ghobadian, B., Rahimi, H., Nikbakht, A. M., Najafi, G., and Yusaf, T. F. 2009. Diesel engine performance and exhaust emission analysis using waste cooking biodiesel fuel with an artificial neural network. Renewable Energy 34 (4):976–982

[2] Sahoo, P. K, Das, L. M, Babu, M. K. G., Naik, S. N. 2007. Biodiesel development from high acid value polanga seed oil and performance evaluation in a CI engine. Fuel 86:448–454.

[3] Sahoo, P. K, Das, L. M, Babu, M. K. G., Arora, P., Singh, V. P., Kumar, N. R., Varyani, T. S. 2009. Comparative evaluation of performance and emission characteristics of jatropha, karanja and polanga based biodiesel as fuel in a tractor engine. Fuel 88:1698–1707.

[4] Baiju, B., Naik, M. K., Das, L. M. 2009. A comparative evaluation of compression ignition engine characteristics using methyl and ethyl esters of Karanja oil. Renewable Energy 34:1616–1621.

[5] Canakci, M., Gerpen, J. V. 2003. Comparison of engine performance and emissions for petroleum diesel fuel, yellow-grease biodiesel and soybean-oil biodiesel. Transactions of the ASAE 46(4):937–944.

[6] Shivakumar, Srinivasa, P., Shrinivasa, B. R. 2011. Artificial Neural Network based prediction of performance and emission characteristics of a variable compression ratio CI engine using WCO as a biodiesel at different injection timings. Applied Energy 88:2344–2354.

[7] Ong HC, Masjuki HH, Mahlia TMI, Silitonga AS, Chong WT, Leong KY 2014. Optimization of biodiesel production and engine performance from high free fatty acid Calophyllum inophyllum oil in CI diesel engine. Energ Convers Manage ;81:30–40.

[8] Sharma S, Rangaiah GP.2013 Multi-objective optimization of a biodiesel production process. Fuel 103:269–77.

[9] Fauzi AHM, Amin 2013. Optimization of oleic acid esterification catalyzed by ionic liquid for green biodiesel synthesis. Energ Convers Manage ;76:818–27.

[10] Rahimi M, Aghel B, Alitabar M, Sepahvand A, Ghasempour HR 2014. Optimization of biodiesel production from soybean oil in a microreactor. Energ Convers Manage 79:599–605.

[11] Ismail, H. M., Kiat, N. H., Queck C. W., Gan S. 2012. Artificial neural networks modelling of engine-out responses for a light-duty diesel engine fuelled with biodiesel blends. Applied Energy 92:769–777.