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Biodiesel Fueled Engine Vibration Studies by Taguchi Method and Results Validation by ANN

Satish A. Patil[1], Amit R. Patil[2], Bhupendra S. Patil[3], Dipak S. Patil[4], R. R. Arakerimath[5]

[1]Mechanical Engineering Department, PDEA's College of Engineering, Manjari (Bk), Savitribai Phule Pune University, Pune, (MS), India.

[2] Mechanical Engineering Deparment, MES College of Engineering, Savitribai Phule Pune University, Pune, India.

[3]Mechanical Engineering Deparment, Government Engineering College, Bharuch, Gujarat, India 392002

[4]Mechanical Engineering Deparment, G. H. Raisoni College of Engineeering and Management, Pune, MH, India

[5]Mechanical Engineering Deparment, JSPM's RSCOE, Thatawade, Savitribai Phule Pune University, Pune, India.

*Corresponding Author

Abstract – *Renewable and environmentally friendly biodiesel is a fuel that can provide comparative engine performance. The diesel engine performance, noise, and vibration parameters were studied. Vibration and noise production due to the combustion of fuel in engines have a direct effect on engine performance. Therefore, in this paper, the study of three different vibration parameters are mainly displacement, velocity, and acceleration was carried out with both diesel and biodiesel blends. Kirloskar makes single-cylinder, 4 strokes, water-cooled, 3.5 KW at 1500 rpm, diesel engine with water-cooled eddy current dynamometer was used. The output vibration parameters were measured using vibrometer, engine noise by noise meter, and also other measuring instruments. The testing of the engine was carried out at different loads as per the orthogonal array obtained by Minitab from the input parameters. The orthogonal array selection was based on three parameters and the four levels for each parameter. The experimental output conditions with optimal input parameters blend B15, applied load 7 kg, compression ratio18 are vibration parameters such as Displacement 0.458 mm, Velocity 23.68 mm/s, and Acceleration 345.5m/s2. The regression plot for acceleration obtained by Taguchi is compared with the ANN regression plot. There is a similarity in these plots. Hence results are validated by ANN.*

Keywords*: Biodiesel, Karanja oil, Velocity, Acceleration, Vibration.*

I. Introduction

Utilization of diesel fuels in various zones and having importance for the national economy, the alternative to diesel fuel must be comparable, technically, and economically acceptable. Biodiesel is obtained by the transesterification process from different oils of vegetable and animal fats which are renewable sources with alcohol [1]. Due to the environmentally friendly properties of biodiesel, it has an internationally focused substitute for diesel fuel. Biodiesel may be used in the existing C I engine without any alterations [1].

Engine body vibrations give information about its operating parameters and the physical condition of the engine. It could be measured by attaching a vibrometer on the top of the engine head. Some researchers are working on the engine vibrations using biodiesel blends in comparison with petrodiesel over the world [2]. The study is focused differently to extract useful information about diesel engine operating conditions. Here the diesel engine vibration parameters were studied with given input parameters to the engine. The three parameters used in vibration measurement are mainly displacement, velocity, and acceleration. Velocity and acceleration are much important depending on the frequency range. An accelerometer was mounted vertically on the engine head using a powerful magnet supplied [3].

Excess vibrations wear out different engine components, loosening affect the alignment of foundation, damage of supporting structure. The maintenance cost increases because of more component failures and unplanned operations [4]. It can also affect the balance, risk of fatigue components, decreased engine efficiency, and finally engine life. So, it's essential to search the effect of different biodiesel blends on engine life. The study of different parameters of vibrations is more important because they affect engine performance as well as engine life [4]. It's a necessity to enhance engine life by optimal use of blends by analysis of vibrations of the engine. And to find out the best biodiesel blends for better performance and enhanced engine life.

II. Experimental Setup

In this experimental setup a Kirloskar made, variable compression ratio engine has used. The detailed engine specifications have as below. The computer controlled system test bed has equipped with eddy current dynamometer, thermocouples, tachometer, flow meters, and all other required measuring instruments.

Engine Specifications:-

Make: Kirloskar Engines

No. of Cylinders : One

No. of Strokes : Four

Type of Cooling: Water cooled.

Power Developing Capacity: 3.5 kW @ 1500 rpm.

C. R. ranges: 12-18

Length of Stroke: 110 mm

Bore dia. 87.5 mm

Vibration Measurement: A vibrometer with given specifications has used for measurement of vibration parameters.

Fig.1. Vibrometer

Specifications

Display = 0.5" (13mm) 4-drgit LCD

Transducer = piezoelectric accelerometer

Vibration analysis has used to find the operating and mechanical condition of engine. Vibration analysis can indicate the developing problems before they become too serious and causes unscheduled downtime.

III. Operating Conditions

Study the effect of following parameters. [6]

1) Biodiesel Blend

2) Load on Engine

3) Compression Ratio

The operating range with levels of factors for study of optimization

TABLE I: OPERATING FACTORS AND LEVELS

A: Blend	B: Load	C:Compression Ratio
A1 = 0	B1 = 0	C1 = 16
A2 = 15	B2 = 4	C2 = 17
A3 = 20	B3 = 7	C3 = 17.5

A4 = 25	B4 = 10	C4 = 18

IV. Analysis

Analysis of Displacement, Velocity, and Acceleration for Vertical Measurement of Vibration on Engine Head:

Orthogonal array: [5] [6] Orthogonal array indicate the number of combinations of input parameters for the experiments. This orthogonal array selection is based on three parameters and the four levels for each parameter.

Orthogonal Taguchi array obtained by Minitab

Design Summary

Taguchi ArrayL16 (4^3)

No. of Factors: 3

No of Runs: 16

Columns of L16 (4^5) array: 1 2 3

TABLE II SAMPLE READINGS OF TAGUCHI ARRAY FOR OPTIMIZATION OF PARAMETERS [7]

Blend	Load	C.R.	DISPL_V	VELO_V	ACCL_V	SNR_ DISP_V	SNR_ VElO_V	SNR_ ACC_V
0	10	18	0.393	19.9	366.8	8.112149	-25.9771	-51.2886
15	4	16	0.437	22.06	317.5	7.190371	-26.8721	-50.0349
15	7	18	0.458	23.68	345.5	6.78269	-27.4876	-50.769
20	0	17.5	0.296	14.77	332.85	10.57417	-23.3876	-50.445

IV.1. Analysis of Displacement

Taguchi Analysis [5,6]: DISPLACEMENT_V versus Blend, Load, C.R.

Model Summary

S		R-Squ.	R-Squ.(adju)
0.8274		86.65%	66.62%

Regression Equation

DISP_V=0.345 + 0.00041 Blend + 0.00987 Load -
0.0008 C.R …… (1).

IV.2. Analysis for Velocity

Taguchi Analysis: VELOCITY_V versus Blend, Load, C.R.

Model Summary

S	R-Squ.	R-Squ.(adju.)
0.9614	79.50%	48.76%

Regression Equation

VELO_V = 10.2 + 0.0526 Blend + 0.450 Load + 0.396 C.R …… (2)

IV.3. Analysis for Acceleration

Taguchi Analysis: ACCLERATION_V versus Blend, Load, C.R.

Model Summary

S	R-Squ.	R-Sq (adju)
0.5464	76.89%	42.23%

10.2 + 0.0526 Blend + 0.450 Load + 0.396 C.R

ACCL_V = 238 - 0.692 Blend + 5.35 Load + 4.59 C.R. (3)

V. Validation of Results

Validation of Experimental Results for Acceleration on Engine Head by Artificial Neural Network (ANN):

Here, the results of only acceleration i.e. one of the parameters of vibration have validated by ANN (Artificial Neural Network).

ANN Script:

Script has written for obtaining the output by putting the values of input parameters

TABLE III: ANN SCRIPT

```
clc; close all; clear all;
x = xlsread('Input1');
y = xlsread('Output2');
net =
newff(minmax(x),[20,1],{'logsig','purelin','trainlm'});
net.trainparam.epochs = 1000;
net.trainparam.goal = 1e-15;
net.trainparam.lr = 0.01;
net = train(net, x, y);
y_net = net(x);
plot(y);hold on; plot(y_net, 'r');
error = (y - y_net);
```

Experimental values of acceleration and values calculated by ANN, error between them and % error have in this table.

TABLE IV: SAMPLE READINGS FOR EXPERIMENTAL RESULTS VALIDATION FOR ACCELERATION

Blend	Load	C.R.	ACCL_V	ANN ACCL	Error	Error %
0	0	16	318	318.00	0.00	0%
0	7	17.5	379.5	373.15	6.35	2%
15	0	17	298.5	305.81	-7.31	-2%
15	10	17.5	353.1	360.09	-6.99	-2%
20	0	17.5	332.85	332.85	0.00	0%

VI. Comparison of Acceleration

Comparison of Acceleration values obtained by Experimentation and ANN:

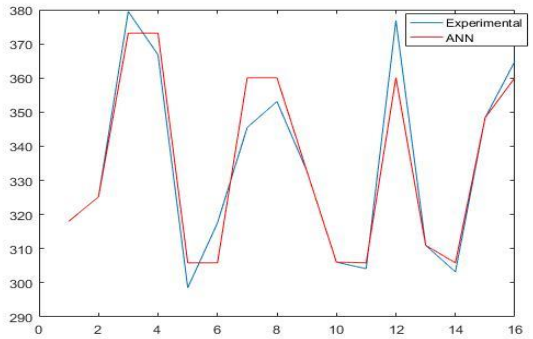

Fig. 2.Comparison of Acceleration obtained by Experimentation and ANN

The comparative study of Acceleration obtained by experimentation and ANN has as shown in Figure Fig. (2). There has a small error in between these two values of Acceleration.so results are validated.

VII. Residual Plots

Residual plots for Acceleration for Vertical Measurement of Vibration on Engine Head

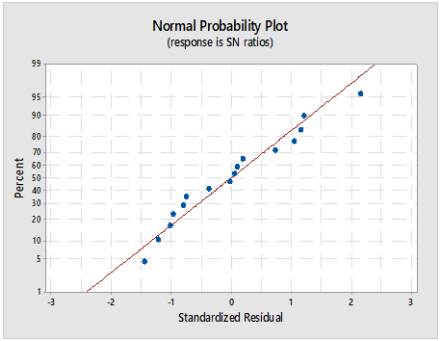

Fig.3. Residual plot for Acceleration

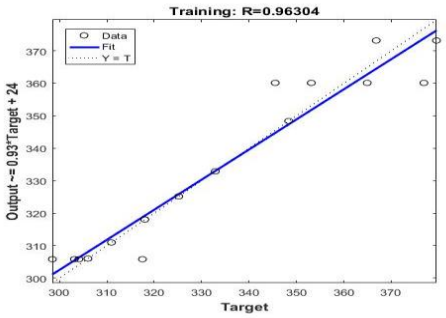

Fig.4. Regression residual plot for Acceleration

The R-square value for this regression has around 80% [6][8] [9].The regression plot obtained by Taguchi has compared with the ANN regression plot. The low residuals are there and all residual values are along the line, shown in both plots. There has a similarity in these plots. Hence results are validated.

VIII. Conclusion

This work has carried out for optimization of inputs namely different biodiesel blends, loads on engine and CR for output parameters of vibration such as Displacement, Velocity, and also Acceleration. The analysis on SNR basis using Taguchi method has done for optimization of these parameters. The results obtained by experimentation with Minitab are validated by ANN (Artificial Neural Network), the conclusions are;

1) Experimental optimal input parameters are blending B15, applied load 7 kg, compression ratio 18. The optimal output vibration parameters are displacement 0.458mm, Velocity 23.68 mm/s and Acceleration 345.5m/s2.
2) From main effect plots blend and load affect more on the vibration so effects of remaining one i.e. CR has neglected.
3) Interaction plots have shown the vibration parameters have minimum values for blend15 and load 7 kg.
4) The R square values obtained by analysis are around 80% shows the obtained model has actual data fitted.
5) There has a small difference in the values of acceleration obtained by experimentation and by ANN % error is also small.
6) The regression plot obtained by Taguchi is compared with the ANN regression plot. There are similarities in these plots. Hence results are validated.

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