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An Experimental Study of Variable Compression Ratio Engine Using Diesel Blend - A Computing Approach

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Abstract— *Increase in the scarcity of the fossil fuels, prices and global warming have generated an interest in developing alternate fuel for engine. Technologies now focusing on development of plant based fuel, plant oils and plant fats as alternative fuel. The present work deals with finding the better compression ratio for the honne oil diesel blend fueled C.I engine at variable load and constant speed operation. In order to find out optimum compression ratio, experiments are carried out on a single cylinder four stroke variable compression ratio diesel engine. Engine performance tests are carried out at different compression ratio values. The optimum compression ratio that gives better engine performance is found from the experimental results. Using experimental data Artificial Neural Network (ANN) model was developed and the values were predicted using ANN. Finally the predicted values were validated with the experimentally.*

Keywords— ***biofuel, ANN, feed forward back propagation, variable compression ratio diesel engine, optimization.***

I. INTRODUCTION

Predicting and analysis of chemical reactions of fuels are important tasks because they can unlock insights into the complicated dynamics of systems which are difficult or expensive to test experimentally. Optimisation of the compression ratio of diesel fuelled with variable compression ratio C.I engine at various compression ratios and concluded that at compression ratio 14.8 improvements in performance and emission characteristics were attained [9]. Investigation of the performance and emission parameters of methyl ester of cottonseed oil blended with diesel in a single cylinder variable compression ratio diesel engine at a constant speed of 1500rpm and concluded that the highest brake thermal efficiency and lowest specific fuel consumption were observed for 5% biodiesel blend for compression ratio of 15and 17and 20% biodiesel blend for compression ratio of 19 and also the maximum NO_x emission were observed for 20% biodiesel blend at a compression ratio of 17and also observed CO emissions and smoke in the full range of compression ratio and loads [8]. The Variable Compression Ratio SI engine performance and emission using pure petrol, pure LPG, Ethanol blends and kerosene blends and observed that the LPG is a promising fuel at all loads lesser carbon monoxide emission compared with other fuels tested and also found that petrol mixed with ethanol at 10% by volume is better at all loads and compression ratios [8]. Investigation of the performance parameters and exhaust emission parameters using different percentage of blends of Honne oil with diesel at various compression ratios. The experimental results were used to train the Artificial Neural Networks (ANNs) which is used to predict the Engine performance and emission characteristics of the engine. ANN results shows good correlation between the ANN predicted values and the experimental values for various engine performance values and the exhaust emissions [7]. Investigation of the output parameters of CI engine using diesel and sunflower oil blends and experimentally calculated values can be used for training several neural networks using MATLAB. They calculated the trained error values by comparing the output values given by these trained networks with experimental values. The Maximum percentage error between experimental and theoretical values is 0.1691 and suggested that the ANN can be used as a powerful tool to optimize the input parameters in the C.I engine [3]. Biodiesel (palm oil methyl ester) blends in a direct injection diesel engine study shows that the lower blends of biodiesel increases the brake thermal efficiency, reduces the fuel consumption and produce lower engine emissions than neat diesel [4]. The performance and emission characteristics of neat diesel (ND) and neat honne oil (H100) as fuel in DI diesel engine and result shows, at maximum load, brake thermal efficiency and NOx emission decreased whereas emissions like CO, HC increased [5]. The performance characteristics of variable compression ratio diesel engine using ethanol blends with diesel [1]. The artificial neural network modelling of a

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diesel engine using nakthamala oil biodiesel fuel to predict the exhaust emissions of C.I.engine. The experimental results reveals that blends of nakthamala oil methyl ester (NOME) provide improved emission characteristics and ANN results showed good correlation between the ANN predicted values and the desired values for various engine exhaust emissions [2].

From the above studies it is clear that biodiesel can be used as an alternate for diesel without modifications in the C. I Engine and ANN can be used as a prediction algorithm to get better correlation with the experimental values.

II. TRANSESTERIFICATION

Transestrification if the process of using alcohol(e.g. Methanol, ethanol or butanol),in the presence of a catalyst, such a sodium hydroxide or potassium hydroxide, to break the molecule of the renewable oil chemically into methyl or ethyl ester of the renewable oil, with glycerol as a by product. Biodiesel, defined as the mono-alkyl esters of fatty acids derived from vegetable oil or animal fat, in application ass an extender for combustion in diesel engines, has demonstrated a number of promising characteristics, including reduction of exhaust emissions. Transesterified, renewable oils have proven to be a viable altemative diesel engine fuel with characteristics similar to those of diesel fuel. The transesterification reaction proceeds with or without catalyst by using primary or secondary monohydric aliphatic alcohols having 1-8carbon atoms as follows:

III. OF A DIESEL ENGINE USING NAKTHAMALA OIL BIODIESEL FUEL TO PREDICT THE EXHAUST EMISSIONS OF C.I. ENGINE.

Triglycerides + Monohydric alcohol = Glycerine + Mono-alkyl esters.

A. Properties of Calophylluminophyllum oil

In this present work the calophylluminophyllum oil methyl ester is produced by transesterification process. Transesterification is a chemical reaction between triglyceride and alcohol in the presence of catalyst.Transesterification makes the viscosity lowered.

The purified calophylluminophyllum oil methyl ester was then blended with petroleum diesel in various concentrations for preparing biodiesel blends to be used in CI engine for conducting experiments. The properties of calophyllum inophylum oil are listed in Table I

Table I: Properties of Calophylluminophyllum oil

Properties	Units	HSD	Honne Oil
Density At 30°C	kg/m^3	830	910
Kinematic Viscosity At 40°C	mm^2/s	3.12	(32.48±2)
Flash Point	°C	56	120
Fire Point	°C	75	160
Pour Point	°C	(-16±1)	(-08±1)
Heating Value	kJ/kg	43 000	39 100

IV. EXPERIMENTAL INVESTIGATIONS

Variable compression ratio diesel engine test rig was shown in the Fig.1 and its specifications are given bellow.

Bore in mm - 80
Stroke in mm - 110
Rated speed in rpm - 1500
Rated power output in KW - 5
Method of Loading -Eddy current
Compression ratio - 13:1 to 20:1
Diameter of orifice in mm - 20
Type of ignition -compression ignition
Method of starting - manual cranking
Method of cooling - water cooling
No of cylinder - 1

Fig. 1: Variable compression ratio diesel engine test rig experimental setup

A. Experimental procedure

The experiment is carried out on a single cylinder four stroke variable compression ratio vertical diesel engine test rig which has coupled to eddy current dynamometer.

- Initially the engine was started by manual cranking in proper direction and the decompression lever is used for easy cranking.
- The engine is allowed to run to attain the steady state.
- Set the engine to a particular compression ratio.
- Apply various load and note down the time taken for 10CC fuel consumption.

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- Repeat the experiment for various compression ratios and corresponding readings are noted.

The following engine tests were performed in single cylinder variable compression ratio diesel engine test rig with diesel, and calophylluminophyllum methyl ester blended with diesel for various concentrations and finds the performance and Emission characteristic is studied.

The best performance was obtained for IC engine using diesel blend at 25% of bio-diesel and 75% of diesel.

Thus the tests are carried out for varying the compression ratios (14:1 to 18:1) and various blend concentrations as follows.

25% of calophylluminophyllum methyl ester +75% of diesel.

B. Performance curves

The following performance curves were plotted using the values obtained

- Load VsSpecific Fuel Consumptions (SFC)
- Load Vs Brake Thermal Efficiency
- Load Vs Mechanical Efficiency

V. EXPERIMENTAL RESULTS AND DISCUSSION

The performance tests are carried out on variable compression ratio (VCR) engine under different compression ratio (C.R) and loads using Diesel as fuel and the results are tabulated in the Table II.

The performance tests are carried out on variable compression ratio (VCR) engine under different compression ratio (C.R) and loads using 25% honne oil diesel blend as fuel and the results are tabulated in the Table III.

Table II: Performance observations for 100% diesel

C.R	LOA	B.P	TFC	SFC	Meff	ITE	BTE	IP
	Kg	KW	Kg/hr	Kg/KW-hr	%	%	%	KW
14:1	1	0.3151	0.4788	1.5194	22.270	24.059	5.3580	1.4151
14:1	2	0.6238	0.6156	0.9868	36.190	22.794	8.2495	1.7238
14:1	4	1.2276	0.7358	0.5993	52.741	25.753	13.582	2.3271
14:1	6	1.8365	1.005	0.5475	62.54	23.774	14.868	2.9365
15:1	1	0.3173	0.464	1.4624	19.382	28.720	5.5669	1.6373
15:1	2	0.6238	0.5801	0.9299	32.094	27.277	8.7545	1.9438
15:1	4	1.2356	0.7358	0.5954	48.350	28.276	13.671	2.5556
15:1	6	1.8378	0.9427	0.5129	58.198	27.269	15.870	3.1578
16:1	1	0.3183	0.4713	1.4805	19.794	27.778	5.4986	1.6083
16:1	2	0.6254	0.5915	0.9457	32.654	26.362	8.6083	1.9154
16:1	4	1.2316	0.7735	0.6280	48.842	26.539	12.962	2.5216
16:1	6	1.8414	0.9731	0.5284	58.804	26.196	15.404	3.1314
17:1	1	0.3173	0.4132	1.3021	22.711	27.527	6.2520	1.3973
17:1	2	0.6254	0.5801	0.9275	36.674	23.932	8.7771	1.7054
17:1	4	1.2372	0.7938	0.6416	53.393	23.762	12.687	2.3172
17:1	6	1.8390	1.0056	0.5468	63.001	23.631	14.888	2.9190
18:1	1	0.3183	0.4022	1.2634	22.931	28.099	6.4437	1.3883
18:1	2	0.6278	0.5485	0.8735	36.980	25.200	9.3194	1.6978
18:1	4	1.2396	0.7182	0.5794	53.673	26.178	14.050	2.3096
18:1	6	1.8378	0.9141	0.4974	63.202	25.895	16.36	2.9078

Table III: Performance observations for 25% of Calophylluminophyllum + 75% diesel

C.R	LOAD	B.P	TFC	SFC	Meff	ITE	BTE	IP
	Kg	KW	Kg/hr	Kg/KW-hr	%	%	%	KW
14:1	1	0.3149	0.4502	1.4296	23.4174	27.4106	6.4188	1.3449
14:1	2	0.6254	0.5746	0.9186	37.7824	26.4375	9.9887	1.6554
14:1	4	1.2235	0.7015	0.5733	54.2952	29.476	16.004	2.2535
14:1	6	1.830	0.9577	0.5231	63.9930	27.4093	17.5401	2.860
15:1	1	0.3163	0.4404	1.3920	24.7863	26.5951	6.5919	1.2763
15:1	2	0.6198	0.5485	0.8849	39.2346	26.4311	10.370	1.5798
15:1	4	1.2343	0.7015	0.5681	56.2610	28.7087	16.151	2.1948
15:1	6	1.840	0.942	0.5123	65.7169	27.2571	17.912	2.800
16:1	1	0.3171	0.4372	1.3785	25.4310	26.176	6.6569	1.2471

16:1	2	0.6250	0.5485	0.8775	40.1959	26.0167	10.457	1.5550
16:1	4	1.2340	0.7015	0.5685	57.0251	28.3057	16.141	2.1640
16:1	6	1.8359	0.9282	0.5054	66.3700	27.3386	18.1446	2.765
17:1	1	0.3171	0.4249	1.3396	26.0578	26.2873	6.8492	1.2171
17:1	2	0.6238	0.5485	0.8792	40.9399	25.4946	10.437	1.5238
17:1	4	1.2364	0.6935	0.5603	57.8744	28.2699	16.3610	2.1364
17:1	6	1.8378	0.942	0.51297	67.1269	26.6495	17.8890	2.7378
18:1	1	0.3165	0.3969	1.2539	21.5854	33.9041	7.31835	1.4665
18:1	2	0.6254	0.5535	0.8849	36.4609	28.4393	10.3692	1.7154
18:1	4	1.2316	0.6935	0.5630	53.0504	30.7200	16.2974	2.3216
18:1	6	1.8358	0.8619	0.4696	62.7400	31.1450	19.5404	2.9253

A. Performance curves for 25% honne oil and 75% diesel blend.

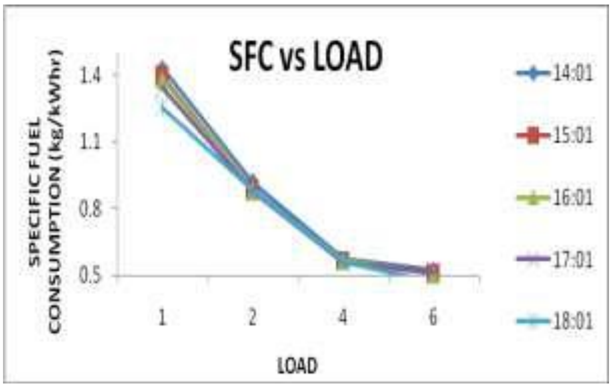

Fig. 2: Specific fuel consumption Vs Load

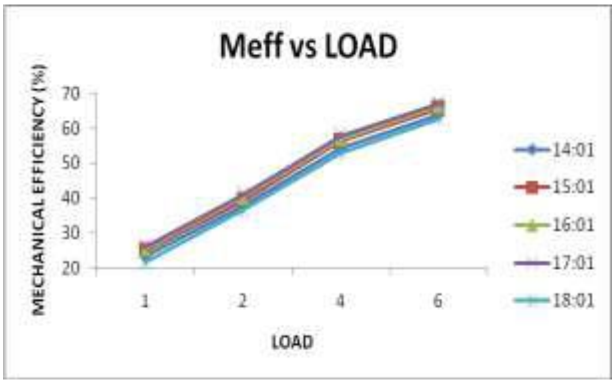

Fig. 3: Mechanical Efficiency Vs Load

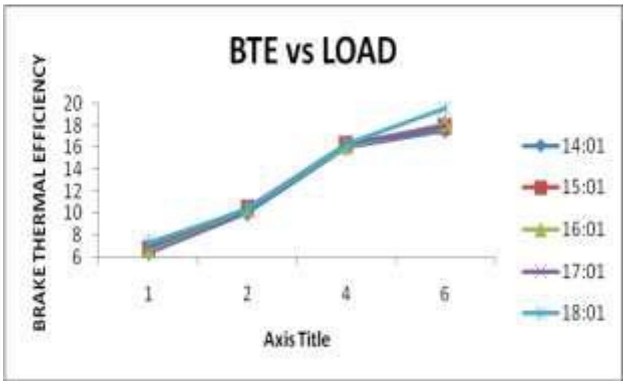

Fig. 4: Brake Thermal Efficiency Vs Load

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B. Summary

Based on the experimental data and the graphs were drawn for the different compression ratio and load with SFC, mechanical efficiency and brake thermal efficiency.The Fig 2, 3 and 4 shows that the SFC is almostequal for all the compression ratio. But the mechanical and brake thermal efficiency are more for the compression ratio of 18:1 than other values.

VI. ARTIFICIAL NEURAL NETWORK

The first and arguably most simple type of artificial neural network is the feed neural network. Information are moves in only one direction forwards in this network: Data goes through the hidden nodes (if any) and to the output nodes from the input nodes. There are no cycles and loops in this network. Feed forward networks can be constructed from different types of units, e.g. binary McCulloch-Pitts neurons, the simplest example being the preception. Continuous neurons, frequently with sigmoidal activation, are used in the context of the back propagation of error.

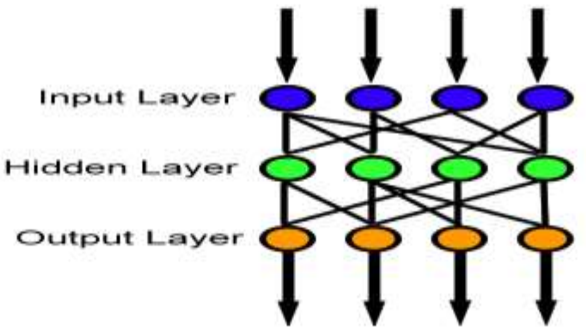


Fig.5: Simple feed forward back propagation network

In the model, 80%of the data set was randomly assigned as the training set, while the remaining 20%of the data are put aside for prediction and validation. From all of the trained networks, any ones could provide this condition, from which the simplest network was chosen to have a more precise investigation into the model. The correlation between the predicted values by the ANN model and the measured values resulted from experimental tests are very high.

A. Prediction output responses using ANN

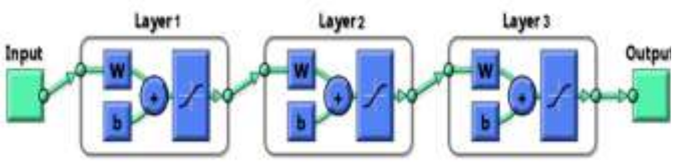


Table IV: Artificial Neural Network

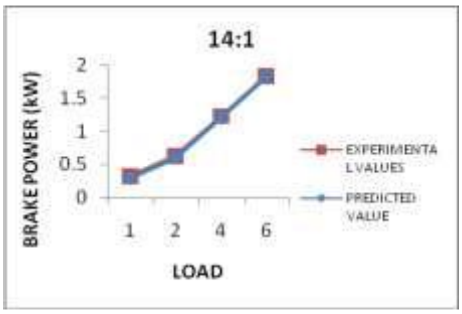
Output responses	**ANN**
Brake power	2-3-2-1
SFC	2-2-3-1
Mechanical efficiency	2-2-2-1

The training algorithm of Feed Forward Back-Propagation isselected for predicting engine parameters. The input response is selected as Compression Ratio and Load also Speed and volume of fuel consumed are taken as constant and the outputs are tabulated in Table V

Table.V: Comparison experimental and predicted values of Brake Power

C.R	LOAD	BRAKE POWER (KW)		% of error
	Kg	EXPERIMENTAL VALUES	PREDICTED VALUE	
14:01	1	0.3149	0.2952	6.26
14:01	2	0.6254	0.6056	3.17
14:01	4	1.2235	1.2041	1.59
14:01	6	1.83	1.8102	1.08
15:01	1	0.3163	0.2965	6.26
15:01	2	0.6198	0.6005	3.11
15:01	4	1.2343	1.2145	1.60
15:01	6	1.84	1.8202	1.08
16:01	1	0.3171	0.2973	6.24
16:01	2	0.625	0.6052	3.17
16:01	4	1.234	1.2142	1.60
16:01	6	1.8359	1.8161	1.08
17:01	1	0.3171	0.2973	6.24
17:01	2	0.6238	0.604	3.17
17:01	4	1.2364	1.2166	1.60
17:01	6	1.8378	1.818	1.08
18:01	1	0.3165	0.2967	6.26
18:01	2	0.6254	0.6056	3.17
18:01	4	1.2316	1.2118	1.61
18:01	6	1.8358	1.816	1.08

The below Fig. 6 (a), (b), (c), (d), (e) shows that the predicted neural network (2-3-2-1) for brake power. It is seen that the predicted values are very close to the experimental results and the maximum error is 6.26%.



(a)

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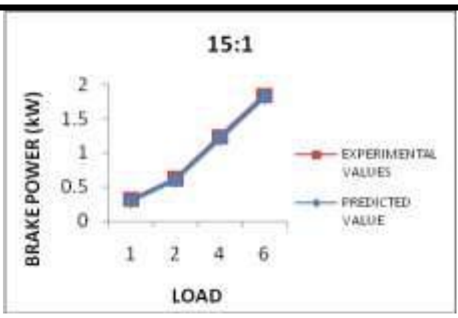

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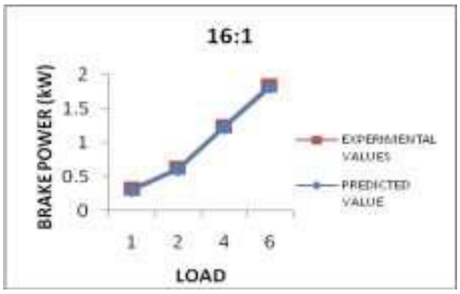

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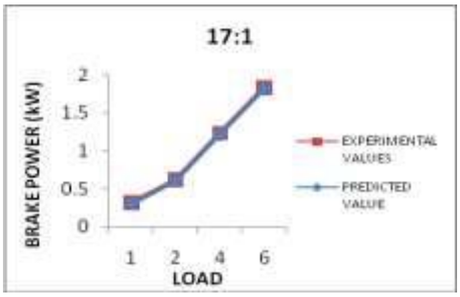

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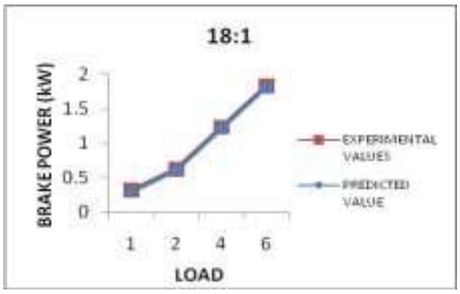


(e)

Fig. 6: Comparison of Predicted and Experimental Values of brake power

Then again the input response is selected as Compression Ratio and Load also Speed and volume of fuel consumed are taken as constant. Output response is Specific fuel consumption and it is tabulated in Table VI

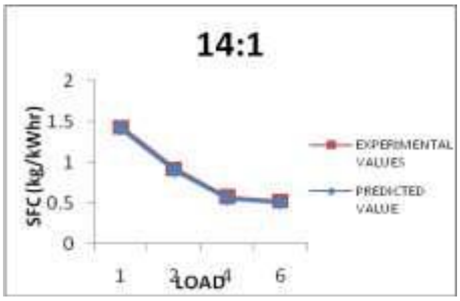
Table VI: Comparison experimental and predicted values of Specific Fuel Consumption

C.R	LOAD	SPECIFIC FUEL CONSUMPTION (kg/kWhr)		% of error
	Kg	EXPERIMENTAL VALUES	PREDICTED VALUE	
14:01	1	1.4296	1.4093	1.42
14:01	2	0.9186	0.8988	2.16
14:01	4	0.5733	0.5539	3.38
14:01	6	0.5231	0.5033	3.79
15:01	1	1.392	1.3722	1.42
15:01	2	0.8849	0.8656	2.18
15:01	4	0.5681	0.5483	3.49
15:01	6	0.5123	0.4925	3.86
16:01	1	1.3785	1.3587	1.44
16:01	2	0.8775	0.8577	2.26
16:01	4	0.5685	0.5487	3.48

Table VI contd.: Comparison experimental and predicted values of Specific Fuel Consumption

C.R	LOAD	SPECIFIC FUEL CONSUMPTION (kg/kWhr)	LOAD	% of error
	kg	EXPERIMENTAL VALUES	kg	
16:01	6	0.5054	0.4856	3.92
17:01	1	1.3396	1.3198	1.48
17:01	2	0.8792	0.8594	2.25
17:01	4	0.5603	0.5405	3.53
17:01	6	0.51297	0.49317	3.86
18:01	1	1.2539	1.2341	1.58
18:01	2	0.8849	0.8651	2.24
18:01	4	0.563	0.5432	3.52
18:01	6	0.4696	0.4498	4.22

The below Fig. 7 (a), (b), (c), (d), (e) shows that the predicted neural network (2-3-2-1) for SFC.It is seen that the predicted values are very close to the experimental results and the maximum error is 3.86%.



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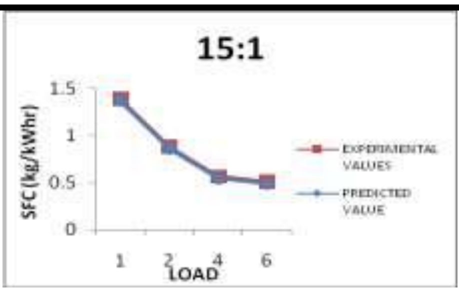

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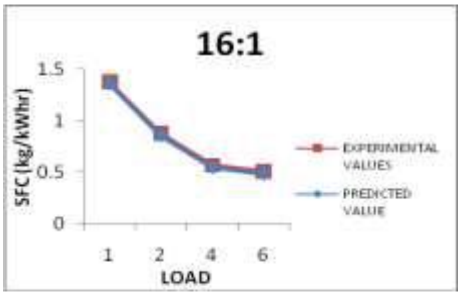

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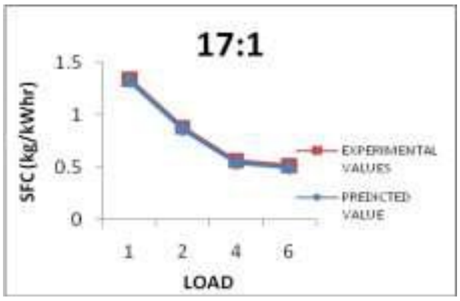

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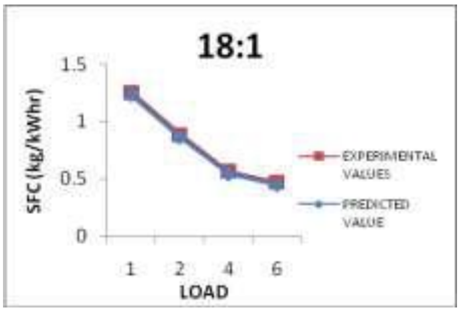


(e)

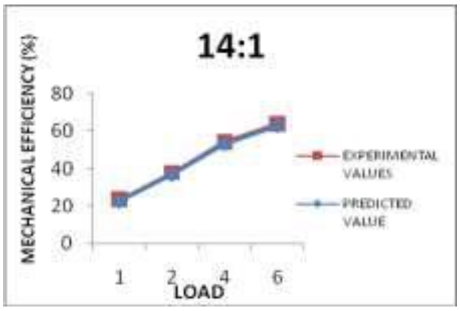
Fig. 7: Comparison of Predicted and Experimental Values of SFC

Then again input response is selected as Compression Ratio and Load also Speed and volume of fuel consumed are taken as constant. Output response is Mechanical Efficiency and the outputs are tabulated in Table VII

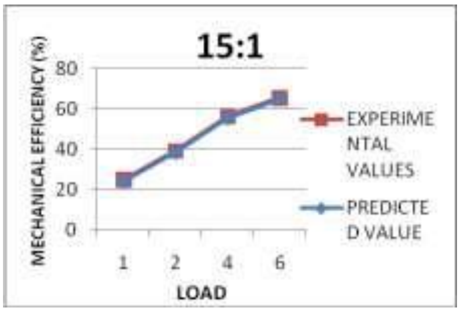
Table VII: Comparison experimental and predicted values of brake thermal efficiency

C.R	LOAD	MECHANICAL EFFICIENCY (%)		% of error
	kg	EXPERIMENTAL VALUES	PREDICTED VALUE	
14:01	1	23.4174	22.4644	4.07
14:01	2	37.7824	36.8294	2.52
14:01	4	54.2952	53.3422	1.76
14:01	6	63.993	63.04	1.49
15:01	1	24.7863	23.8333	3.84
15:01	2	39.2346	38.2816	2.43
15:01	4	56.261	55.308	1.69
15:01	6	65.7169	64.7639	1.45
16:01	1	25.431	24.478	3.75
16:01	2	40.1959	39.2429	2.37
16:01	4	57.0251	56.0721	1.67
16:01	6	66.37	65.417	1.44
17:01	1	26.0578	25.1048	3.66
17:01	2	40.9399	39.9869	2.33
17:01	4	57.8744	56.9214	1.65
17:01	6	67.1269	66.1739	1.42
18:01	1	21.5854	20.6324	4.42
18:01	2	36.4609	35.5079	2.61
18:01	4	53.0504	52.0974	1.80
18:01	6	62.74	61.787	1.52

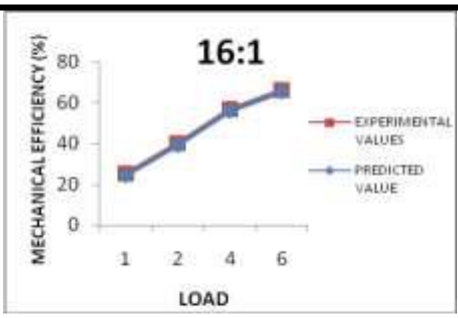
The below Fig. 8 (a), (b), (c), (d), (e) shows that the predicted neural network (2-3-2-1) for mechanical efficiency. The values are more accurate with the maximum error of 3.84%..



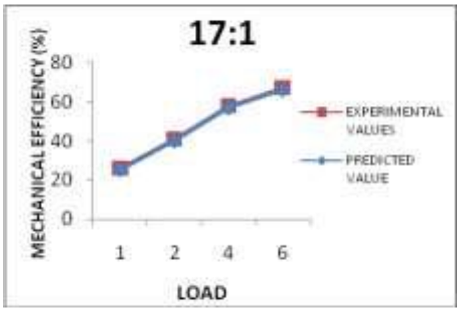
(a)



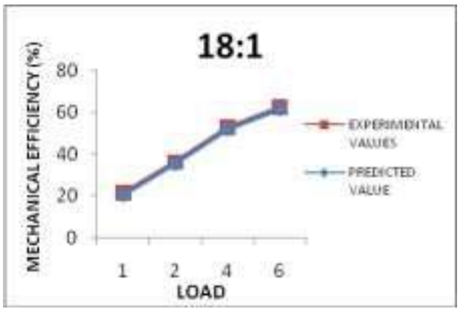
(b)



(c)



(d)



(e)

Fig.8: Comparison of Predicted and Experimental Values of Mechanical Efficiency.

VII. CONCLUSION

The performance test on VCR engine is carried out for the engine fueled with 25% biodiesel blend and neat diesel. The experimental results of both the fuels are compared. Thus it is understood thatthe25 % biodiesel blend produces better performance than base fuel at the compression ratio of 18:1

The training algorithm of Feed Forward Back-Propagation is selected for predicting engine parameters. The input responses selected are Compression Ratio and Load by taking speed as constant. Then, the ANN results are validated with experimental results and found satisfactory. Thus it can be concluded that the training algorithm of feed forward back-propagation is sufficient in predicting engine performance parameters.

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