ANALYSIS OF EXHAUST GAS EMISSIONS AND PERFORMANCE PARAMETERS ON NON- ROAD SPARK IGNITION ENGINES

A.A. Aderibigbe[*a], A. D Ogunsola[a] and W. O Sanusi[a]

[a]Department of Mechanical Engineering,
Ladoke Akintola University of Technology,Ogbomoso, Nigeria
[*] Corresponding Author E-mail Address : aaaderibigbe@lautech.edu.ng

ABSTRACT

Air pollution continues to be a serious threat to the health and well-being of the population. Worldwide, tens of millions of spark ignition (S.I) engines are used for non-road applications such as electric generators, compressors, pumps hand held and non-hand held devices. This work investigated the effects of equivalence ratio, engine speed and engine load on exhaust gas emissions and performance parameters of non-road spark ignition engines. Three input parameters which are engine design/operating parameters and eight output parameters which are exhaust gas emissions and performance parameters were considered in this work. The effect of variation in the input parameters on the output parameters were simulated using software implemented in MATLAB 7.9 neural network toolbox environment developed by the authors. The results show that engine speed of 3000rpm gave the maximum values for several parameters considered. The results also show that exhaust gas emission and several performance parameters increased with increased in engine load. Equivalence ratio of 0.9 gave the least values for exhaust gas emission and specific fuel consumption. It can be concluded that for low exhaust gas emission and improved performance, non-road S.I engines should be operated at low engine loads engine speed of about 3000rpm and equivalence ratio of between 0.9 and 1.0

Keywords: Performance, Emissions, Non-road, Equivalence Ratio and S.I Engines.

1. INTRODUCTION

Air pollution continues to be a serious threat to the health and well-being of the population. Ongoing global tightening and enforcement of regulations, mainly in the transportation sector such as the automotive and heavy truck markets, have been extremely successful in significantly reducing hydrocarbon (HC), Carbon monoxide(CO) and Oxides of Nitrogen (NO_X) emissions from the mobile sources (kojima and Lovei ,2001) As a result of these, transportation sectors are becoming cleaner. Hence, more of the emission burden has been falling on adjacent market segments such as the small non-road spark ignition engines. (Udayraj, 2011, Gwillametal, 2004). Spark ignition engines rated at less than 19 kW are used in both hand held and non-hand held devices used for several applications. Worldwide, tens of millions of spark ignition engines are used for non-road application such as electric generators, chain source, string trimmers, blowers, compressors, pumps, industrial equipment, Law and garden equipment. (Stone, 1992).

With ever increasing cost of fuel use in spark ignition engines, fuel economy has become a critical factor in the design of new spark ignition engines. Specific fuel consumption (SFC) which is the fuel rate per unit power output is a very important parameter. According to Heywood (1988), depending on the operating condition of S.I engine, power control method, type of fuel air mixing, and combustion conditions, each mass or volume unit of fuel require a certain amount of air that may be greater than, equal to or less than the theoretical air requirement needed for complete combustion of fuel. According to Anderson (2002), Blazek (2004) and Newman *et al* (2002), Cylinder pressure which is a measure of break mean effective pressure (BMEP), changes with crank angle as a result of cylinder volume change and combustion.

This work is set to study the effects of engine speed, engine load and equivalence ratio on the performance and exhaust gas emissions of non-road spark ignition engines.

2. Research Methodology

This research work investigated the effect of varying three engine parameters on engine performance and exhaust gas emissions of non-road spark ignition engines. The engine parameters that were varied are termed as input parameters while engine performance parameters and exhaust gas emissions are termed as output parameters.

2.1 Input Parameters.

These are made up of one engine design parameters and two engine operational parameters. The parameters considered are:
(i) Engine load (operational parameter)
(ii) Engine speed (operational parameter)
(iii) Equivalence ratio (design parameter)

(i) Engine Load

The engine load was varied at five levels from 0% loading condition to 100% loading condition. 300kN represents 100% loading condition. The engine loads that were considered are 0%, 25%, 50%, 75%, and 100%.

(ii) Engine Speed.

The range of engine speed for S.I engine is usual between 1000 rpm to 5000 rpm. The engine speeds considered which were at five levels were: 1000 rpm, 2000 rpm, 3000 rpm, 4000 rpm and 5000 rpm.

(iii) Equivalence Ratio.

According to Heywood (1988) equivalence ratio of about 1.0 is usually set for S.I engines (Stoichiometric Air/Fuel ratio). This work investigated the effect of reducing and increasing this ratio at two levels each on engine performance and exhaust gas emission of non-road S.I engines. The equivalence ratios considered in this work were 0.8, 0.9, 1.0, 1.1 and 1.2.

2.2 Output Parameters.

The output parameters are made up of five engine performance parameters and three exhaust gas emission parameters.
The parameters considered are:

1. Specific fuel consumption (SFC) - Performance parameters
2. Brake power (BP) - Performance parameters
3. Brake mean effective pressure (BMEP) Performance parameters
4. Thermal efficiency (η_{th}) - Performances parameters
5. Exhaust gas temperature (T_{eG}) - Performance parameters
6. Unburnt Hydrocarbon (HC) – Exhaust gas emission
7. Carbon monoxide (CO) - Exhaust gas emission
8. Oxides of Nitrogen (NO_X) - Exhaust gas emission

2.3 Simulation Procedure

The effect of the variations in the input parameters on output parameters were simulated using artificial neural network software implemented in MATLAB 7.9 environment developed by the author. Fig 1 shows the flow chart for the simulation procedure.

The ANN model used is:

$$y_k = \sum_{l=1}^{N_H} W_i \, \varphi \left(\sum_{j=1}^{N} W_{ij} \, I_l \right) ---------- (1)$$

Where
y_k = outputs of the ANN model
K = number of output
N_H = number of neurons in the hidden layers
H = number of hidden layers
W_i = synaptic weights connecting the hidden layers with output
W_{ij} = synaptic weights connecting the inputs to the hidden layers
N = number of inputs
φ = activation / transfer function I_j = Inputs to the ANN model

3. Results and Discussion

The effects of variation in the input parameters on the output parameters were simulated using artificial neural network software developed by the author. The results were presented below from Fig.1 to Fig.8 and table 1. From the figures, it can be shown that as the value of equivalence ratio increases, the values of BSFC, BP, BMEP, exhaust gas temperature, HC emission and CO emission increase at all engine speeds and at all engine loads. For HC and CO emissions, an increase in the value of equivalence ratio from 0.8 to 0.9 has marginal effect on the value of their emissions. Thermal efficiency has the highest value at equivalence ratio of 0.8 and it decreases as equivalence ratio increases. NO_X emission has the highest value at equivalence ratio of 0.9 and this value of emission decreases as equivalence ratio either increase from 0.9 or decrease from 0.9 at all engine speeds and at all engine loads.

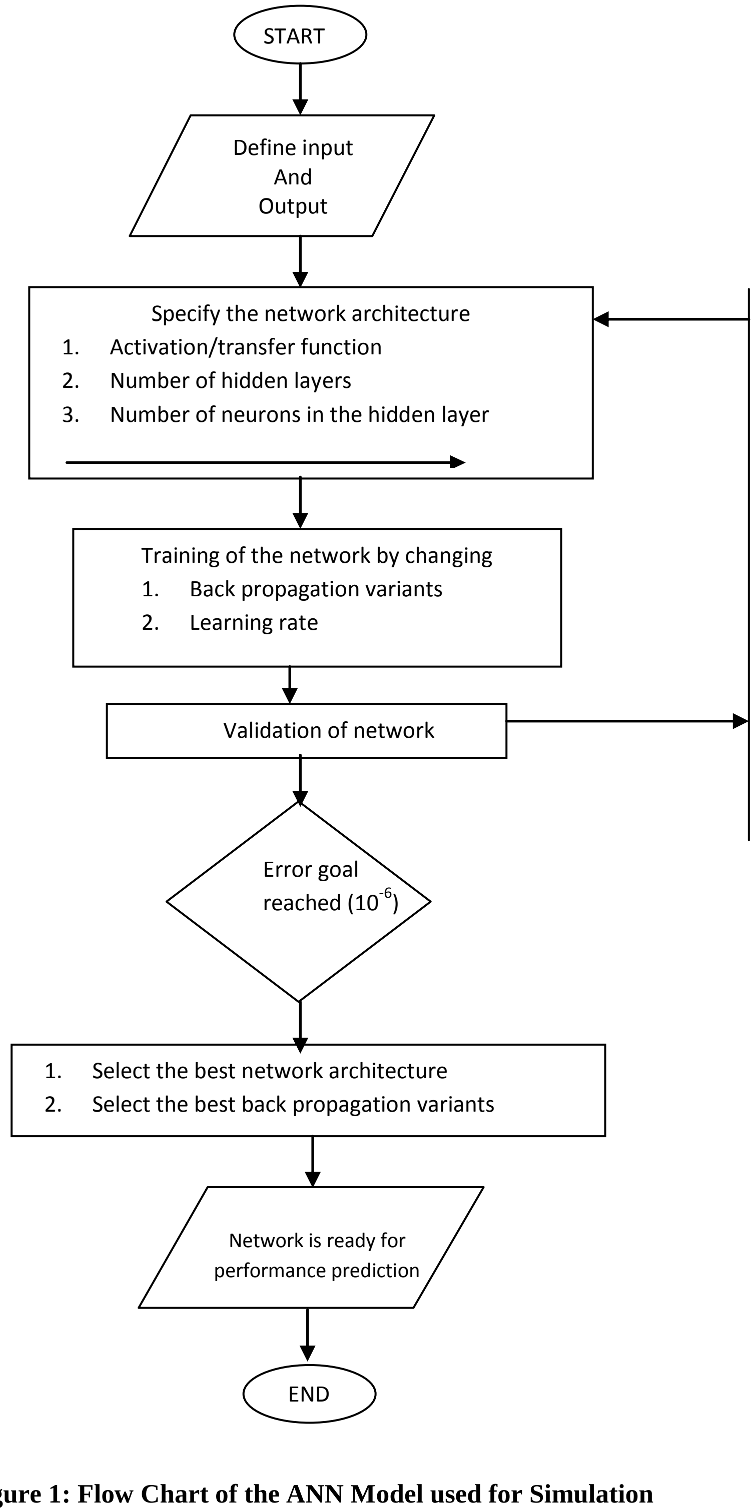

Figure 1: Flow Chart of the ANN Model used for Simulation

It can be shown from table 1 that thermal efficiency decreases with increase in engine load at all equivalence ratios while all the other parameters increase with increase in engine load at all equivalence ratios. Engine speed of 3000 rpm gives the minimum value for BSFC, maximum value for BP, maximum value for BMEP, maximum value for thermal efficiency and maximum value for NO_X emission at all equivalence ratios. Engine speed of 5000 rpm gives the maximum value for exhaust gas temperature. CO and HC emissions increase significantly with increase in engine speed with maximum value at 5000 rpm at all equivalence ratios.

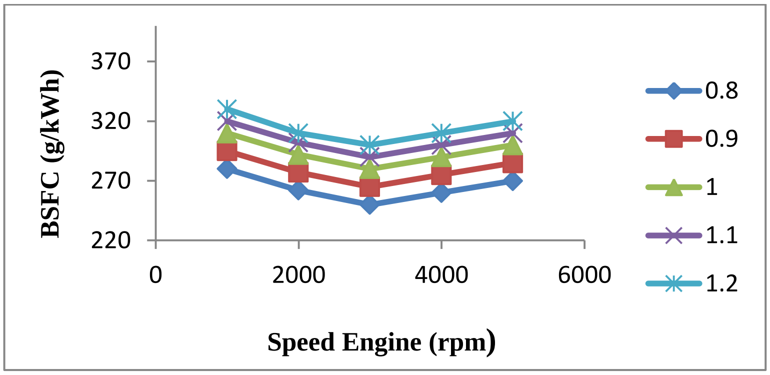

Figure 4.1: Effect of Equivalence Ratio on BSFC.

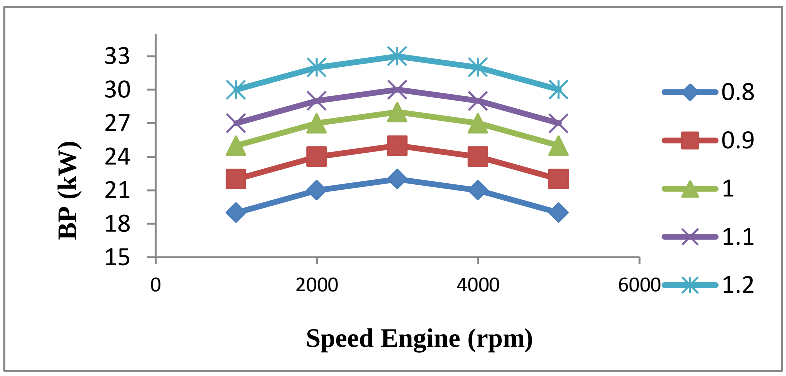

Figure 4.2: Effect of Equivalence Ratio on Brake Power (BP)

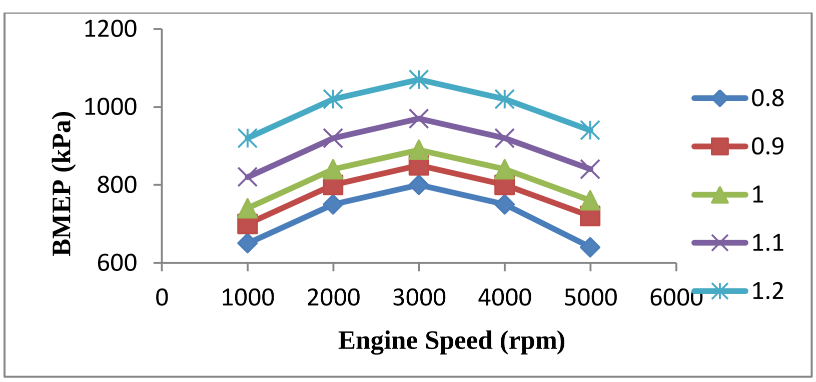

Figure 4.3: Effect of Equivalence Ratio on BMEP.

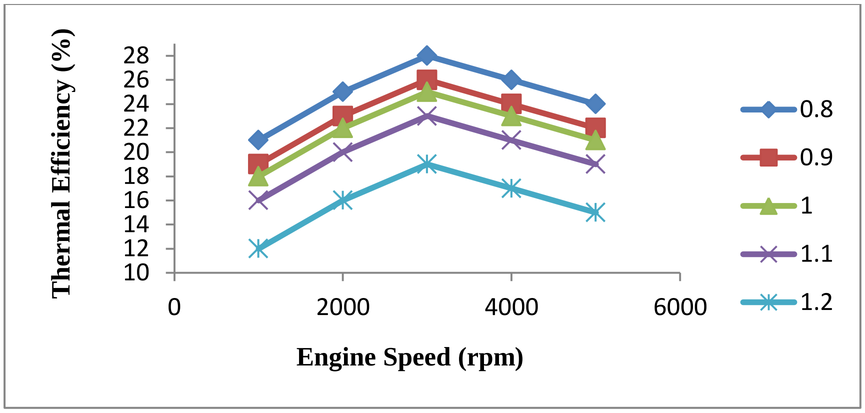

Figure 4.4: Effect of Equivalence Ratio on Thermal Efficiency.

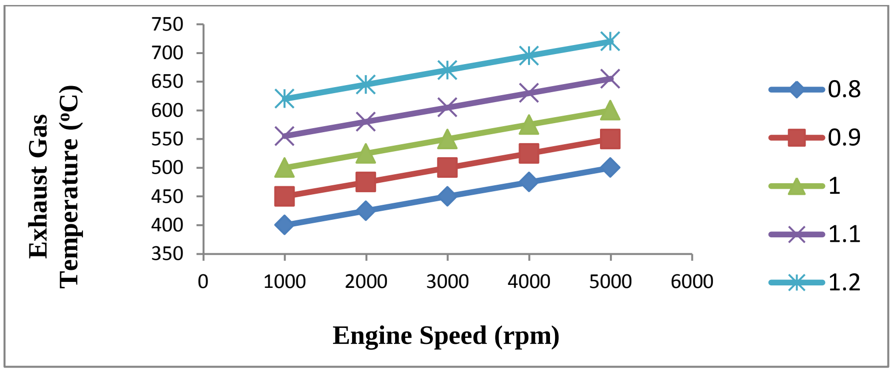

Figure 4.5: Effect of Equivalence Ratio on Exhaust Gas Temperature.

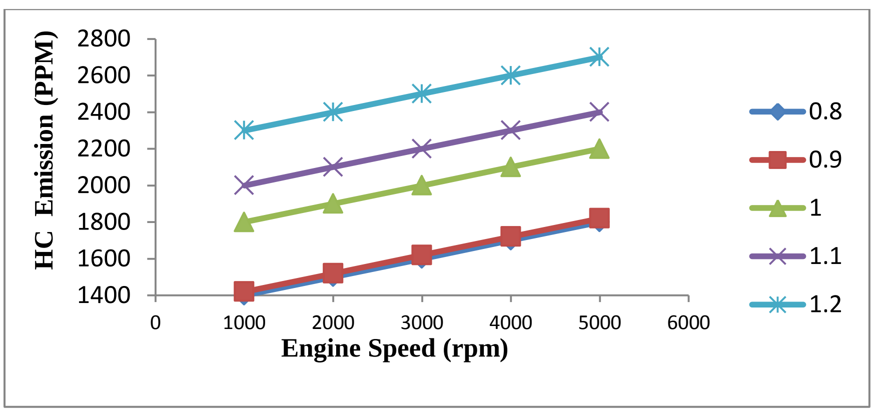

Figure 4.6: Effect of Equivalence Ratio on HC Emission.

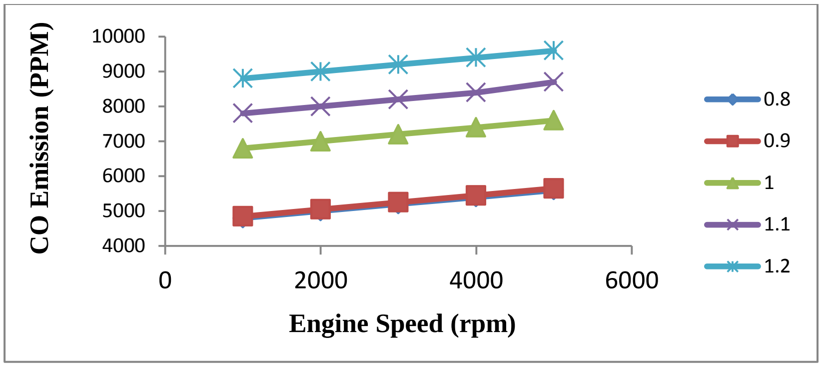

Figure 4.7: Effect of Equivalence Ratio on CO Emission.

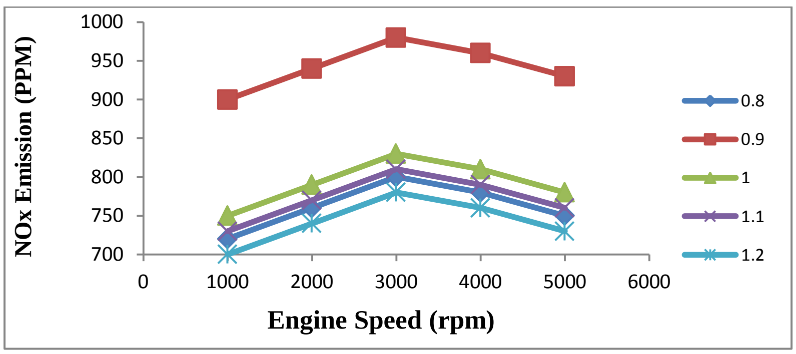

Figure 4.8: Effect of Equivalence Ratio on NO_x Emission

Table 1: Effects of Equivalence Ratio and Engine Load on S.I Engine Operation

S/N	Engine Load (%)	Equivalence Ratio	BSFC (g/kWh)	BP (kW)	BMEP (kPa)	η_{TH} (%)	T_{EG} (^oC)	HC (PPM)	CO (PPM)	NO_X (PPM)
1	0	0.8	210	15	320	28	380	1200	4600	550
2	25	0.8	225	16	420	27	410	1350	4850	600
3	50	0.8	240	17	490	26	440	1500	5100	650
4	75	0.8	255	18	580	25	470	1650	5350	700
5	100	0.8	270	19	670	24	500	1800	5600	750
6	0	0.9	225	18	370	26	430	1220	4650	730
7	25	0.9	240	19	420	25	460	1370	4900	780
8	50	0.9	255	20	540	24	490	1520	5150	830
9	75	0.9	270	21	630	23	520	1670	5400	880
10	100	0.9	285	22	720	22	550	1820	5650	930
11	0	1.0	240	21	410	25	480	1600	6600	580
12	25	1.0	255	22	510	24	510	1750	6850	630
13	50	1.0	270	23	580	23	540	1900	7100	680
14	75	1.0	285	24	670	22	570	2050	7350	730
15	100	1.0	300	25	760	21	600	2200	7600	780
16	0	1.1	250	23	490	23	535	1800	7600	560
17	25	1.1	265	24	590	22	565	1950	7850	610
18	50	1.1	280	25	660	21	595	2100	8100	660
19	75	1.1	295	26	750	20	625	2250	8350	710
20	100	1.1	310	27	840	19	655	2400	8700	760
21	0	1.2	260	26	590	19	600	2100	8600	530
22	25	1.2	275	27	690	18	630	2250	8850	580
23	50	1.2	290	29	760	17	660	2400	9100	630
24	75	1.2	305	29	850	16	690	2550	9350	680
25	100	1.2	320	30	940	19	720	2700	9600	730

4. Conclusions

In this work performance analysis of non-road S.I engine has been carried out. The analysis was with a view to study the effects of three design/operating parameters of S.I engines on performances and exhaust gas emission of non-road S.I engines. Our results showed that engine speed of about 3000 rpm gave maximum values for several parameters considered. The result also showed that the higher the engine load, the higher the exhaust gas emissions Equivalence ratio of about of about 0.9 gave the least values for exhaust gas emissions and specific fuel consumption. This ratio also gave the highest values for several performance parameters considered. We conclude that for improved fuel economy higher engine efficiency and low exhaust emissions, the non-road S.I engine should be operated at low engine loads, engine speed of about 300rpm and equivalence ratio of between 0.9 to 1.0.

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