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To Study Performance of Two Stroke SI Engine Using Optimization Techniques

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Abstract: The two stroke engine was developed to obtain a greater output from the same size of engine. The engine mechanism eliminates the valve arrangement making it mechanically simpler. Theoretically a two stroke engine develops twice the power of a comparable four stroke engine, thus making it more compact. Getting air into an engine is the key to making power and there are many ways to increase the air flow into the engine. There are such forced induction, nitrous system, better port and valve shapes to improve flow. But for this study the technique that has been selected were the better port size. The claims that this where the harnessing the inertia of the airs velocity to better fill the cylinders Modification in replacing the variable carburetor system to the existing carburetor system is made. At various throttle positions and with torque and speed as input, and with porting done performance parameters of engine are calculated. Based on the results various curves are plotted. The objective of the project is to determine how much improvement in fuel economy with the modification in replacing the variable carburetor system in compared to the existing carburetor system. Modification to the engine without additional system attach to the engine operation were the best solution to have an optimum engine operation in term of torque and horsepower. To optimize the power and intake port flow produce by the engine modification were through a very limited value. The value is limited due to the restricted area of the engine production by the manufacturer. Hence modification must be planned carefully as over modification of the inlet port can end up with a device slower than its stock counterpart. It was found out experimentally that mechanical thermal efficiency was improved after modification. In other words Fuel economy was improved after using the variable carburetor system.

Key Words: **Air Fuel ratio, Total Fuel Consumption, Brake Thermal Efficiency, Brake Specific fuel Consumption and spring load.**

I. INTRODUCTION

For the present situation the cost of the fossil fuels are increasing day by day and at the same time fuel abundance may exhaust in another 30 – 40 years. The emissions caused by the present automotive engines which led the air pollution. Along with the population growth the vehicle population growth is also increased. The above problems have made the engineers to think of to over come the above problems. The many researchers have conducted experiments on the existing two stoke petrol engines on to improve its performance and to reduce their emissions. From the earlier studies it is known that the demand for small capacity engines with high power to weight ratio and emissions, two Stroke Engines are predominant as such they are being used in large number of two wheeler vehicles. Though the four stroke engines has replaced its counterpart two stroke engines being used in mopeds, scooters, snow mobiles and hand held power tools. Apart from several advantages that these engines claim there are certain draw backs such as high scavenging losses, low thermal efficiency relatively higher emissions. These defects are due to short circuiting of the fuel supply during the scavenging phase and to the dilution of fresh charge by the exhaust gases. Any investigation towards the improvement of performance of these engines simultaneously reducing their emissions will be a great help to the automotive industries and to protect the environment.

As such developments made by C. Ramesh Kumar et al [1] conducted experiment on Performance and emission characteristics of low heat rejection spark ignited SI engine fueled with E20 concluded that partially insulated SI engine when fueled with E20 improves performance and reduce emission. S. Kumarappa et al [2] conducted experiment on Improving the performance of two stroke SI engine by direct electronic CNG injection concluded that improvement in brake thermal efficiency mainly due to significant reduction in short circuit loss of fresh charge and precise control of air fuel ratio. M. Ayaz Afsar et al [3] conducted experiment on Experimental investigation of Direct Air injection Scavenged two stroke engine concluded that improvement in performance and emission charcterstics of engine with scavenging. M. Loganathan et al [4] conducted experiment on

Experimental on low pressure semi-direct fuel injection in a two stroke spark ignition engine has shown that injection timing was found to be most important factor and a balance between reduction in short circuited fuel by late injection.V'yacheslav Ackermann et al [5] in their Study Turbulent flow produced by piston motion in SI engine, the turbulent flow is investigated for a wide range of engine speed using both zero and non-zero initial turbulence. H. Kwon et al [6] conducted experiment on Modified one-step reaction equation for modeling the oxidation of unburned HC in engine conditions had shown a new one – step model was applied to three dimensional computational meshes the modeled 3D engine geometry and piston – valve motions to simulate the oxidation of unburned HC in real engine conditions. Wojceiech Marek et al [7] conducted experiment on Two Stroke SI Engine with pneumatic Fuel Injector shown that it is possible to reach a high repeatability dose per cycle used for liquid fuels with very different fractional and group composition. Jayanth Kumar.T et al [8] in their work on Modification of Two Stroke I. C. Engine to reduce emission and fuel consumption resulted in appreciable decrease in SFC and in HC/CO emissions. M. loganathan et al [9] conducted Investigations on performance and emissions of Two Stroke SI Engine fitted with a manifold injection system shown that the engine can work well with leaner mixtures as compared to carbureted engines. From the literature survey and from the experimental studies of the earlier researchers on these two stroke engines are found some improvements in the performance and reduction in emissions. But still it requires modifications in the existing two stroke engines to the optimum performance with minimum scavenging losses. It also requires reducing the emissions from these engines.

II. EXPERIMENTAL DETAILS

A single cylinder two stroke air cooled and electrical loading to be tested for the performance is coupled to AC generator with swinging field with spring balance. The rate of fuel consumption measured by using volumetric pipette and air flow measured by manometer connected to air bar. The torque on the engine is measured by spring balance with torque arm and engine speed is measured by clearance digital indicator with thermocouple. The whole instrumentation is mounted on a self contained unit ready for operation. Testing procedure of experiment follows:-

1. Initially experiments were done on existing carburetor system and readings are taken by varying the loads on the engine using the electrical dynamometer and calculations are done for the engine performances such as Air Fuel ratio, Total fuel Consumption, Brake thermal efficiency ,Brake Specific Fuel Consumption and Brake power, etc., (Table no: 4.)
2. Later changing the existing carburetor system by the variable Carburetor system readings were taken by varying the loads on the engine using the electrical dynamometer and calculations are done for the engine performances such as Air Fuel ratio, Total fuel Consumption, Brake thermal efficiency ,Brake Specific Fuel Consumption and Brake power, etc., (Table no: 5.)
3. Experiments were also conducted to find the emission characteristics of exhaust gas for the existing and new carburetor system by attaching the gas analyzer to the engine and reading are plotted as graphs. (Fig 5 and 6)[1][8].
4. Select the parameter levels (Table2 and 3) and construct the orthogonal array (Table4 and 5) to find the better optimal values for the existing and new carburetor systems to improve the performance characteristics of the engine and better quality of emission.[1][8][9]
5. Later plotted the response curves for the Means and Signal to Noise ratio for Brake thermal Efficiency for the existing and new carburetor systems.(Fig 1, 2,3 and 4)

III. TAGUCHI METHOD OF OPTIMIZATION

Taguchi method is a simplest method of optimizing experimental parameters in less number of trials. The number of parameters involved in the experiment determines the number of trials required for the experiment. More number of parameters led to more number of trials and consumes more time to complete the experiment. Hence, this was tried in the experiment to optimize the levels of the parameter involved in the experiment. This method uses an orthogonal array to study the entire parameter space with only a small number of experiments .To select an appropriate orthogonal array for the experiments, the total degrees of freedom need to be computed. The degrees of freedom are defined as the number of comparisons between design parameters that need to be made. The present study uses three factors at three levels and hence, an L9 orthogonal array was used for the construction of experimental layout (Table 2,3, column -1,2,3). The L9 has the parameters such as compression ratio, injection pressure and load arranged in column 1, 2 and 3. (Table -4,5).

According to this layout, nine (09) experiments were designed and trials were selected at random, to avoid systematic error creeping into the experimental procedure. For each trial the mechanical efficiency was calculated and used as a response parameter. Taguchi method uses a parameter called signal to noise ratio (S/N) for measuring the quality characteristics. There are three kinds of signal to noise ratios are in practice. Of which, the higher-the-better S/N ratio was used in this experiment because this optimization is based on brake thermal efficiency. The taguchi method used in the investigation was designed by statistical software called “Minitab 16” to simplify the taguchi procedure and results. A confirmation experiment for the optimum set of parameters was also conducted for validation of the predicated value obtained by minitab software. This is mainly to compare the mechanical efficiency of predicated value and experimental value of optimum set of parameters.

IV. THE TAGUCHI DESIGN APPROACH

The Taguchi method defines two types of factors: control factors and noise factors. An inner design constructed over the control factors finds optimum settings. An outer design over the noise factors looks at how the response behaves for a wide range of noise conditions. The experiment is performed on all combinations of the inner and outer design runs. A performance statistic is calculated across the outer runs for each inner run. This becomes the response for a fit across the inner design runs. The table below lists the recommended performance statistics.

Goal	**S/N Ratio Formula**
nominal is best	$\frac{S}{N} = 10\log\left(\frac{\bar{Y}^2}{s^2}\right)$
larger-is-better (maximize)	$\frac{S}{N} = -10\log\left(\frac{1}{n}\sum_i \frac{1}{Y_i^2}\right)$
smaller-is-better (minimize)	$\frac{S}{N} = -10\log\left(\frac{1}{n}\sum_i Y_i^2\right)$

Table 1: Goal and S/N ratio formula

SELECTION OF FACTOR LEVELS AND ORTHOGONAL ARRAY

In this experiment, three parameters for three levels were considered (table-2,3). Control parameter and their level are given in table.L9 single orthogonal array shown in table-4,5(column-1,2 & 3) was selected for the experimental investigation. “Bigger-the-better” is being taken as quality characteristics, since the objective function is to maximize performance.

Parameters	A/F	TFC (Kg/hr)	Spring Load (Kg)
Level 1	2.936	0.9054	6.5
Level 2	2.395	1.11	8.2
Level 3	2.395	1.11	8.9

Table 2: Process parameter and their level (Old carburetor)

Parameters	A/F	TFC (Kg/hr)	Spring Load (Kg)
Level 1	4.555	0.822	6.3
Level 2	5.213	0.773	7.5
Level 3	5.684	0.724	8.9

Table3: Process parameter and their level (New carburetor)

V. RESULT AND DISCUSSION

Experiment was done for selected sets of parameters by Minitab software and find brake thermal efficiency for those sets of parameters. Brake thermal efficiency for those sets are given in the table.

Sl. No.	**A/F**	**TFC kg/hr**	**Load Kg**	**η Bthe %**	**BSFC Kg/Kw-hr**	**BP KW**
1	2.936	0.9054	6.5	14.871	0.605	1.5
2	2.936	1.1100	8.2	14.424	0.624	1.78
3	2.936	1.1100	8.9	13.816	0.651	1.7
4	2.395	0.9054	8.2	17.684	0.509	1.78
5	2.395	1.1100	8.9	13.816	0.651	1.7
6	2.395	1.1100	6.5	12.130	0.742	1.5
7	2.395	0.9054	8.9	16.938	0.531	1.7
8	2.395	1.1100	6.5	12.130	0.742	1.5
9	2.395	1.1100	8.2	14.424	0.624	1.78

Table 4: Result table for Brake Thermal efficiency and BSFC (Old carburetor)

Sl. No.	**A/F**	**TFC kg/hr**	**Load Kg**	**η Bthe %**	**BSFC Kg/Kw-hr**	**BP KW**
1	4.555	0.822	6.3	14.781	0.609	1.350
2	4.555	0.773	7.5	17.697	0.509	1.520
3	4.555	0.724	8.9	18.646	0.483	1.500
4	5.213	0.822	7.5	16.642	0.541	1.520
5	5.213	0.773	8.9	17.464	0.515	1.500
6	5.213	0.724	6.3	16.782	0.536	1.350
7	5.684	0.822	8.9	16.423	0.548	1.500
8	5.684	0.773	6.3	15.718	0.573	1.350
9	5.684	0.724	7.5	18.895	0.476	1.520

Table 5: Result table for Brake Thermal efficiency and BSFC (New carburetor)

ANALYSIS FOR RESPONSE CURVE

Response curve analysis is aimed at determining influential parameters and their optimum levels. It is graphical representations of change in performance characteristics with the variation in process parameter. The curve gives a pictorial view of variation of each factor and describe what the effect on the system performance would be when a parameter shifts from one level to another. Fig 1 shows significant effects for each factor for three levels. The S/N ratio for the performance curve were calculated at each factor level and average effects were determined by taking the total of each factor level and dividing by the number of data points in the total. The greater difference between levels, the parametric level having the highest S/N ratio corresponds to the parameters setting indicates highest performance.

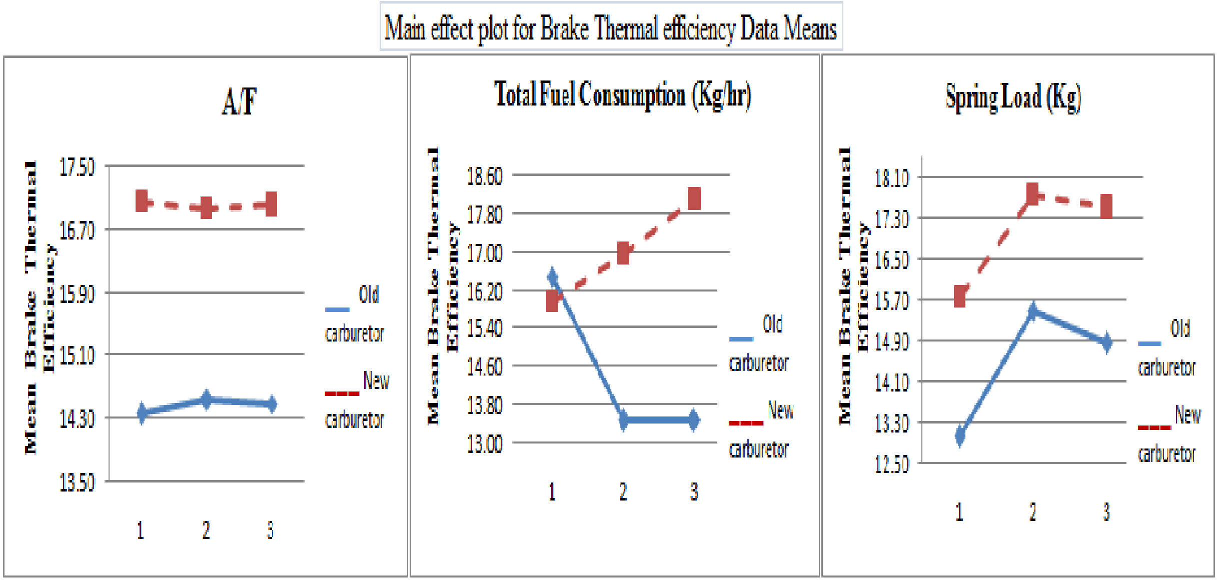

Fig 1: Main effect plot for Means of Brake Thermal Efficiency (Old Carburetor and New carburetor)

From the fig1: **Old carburetor result**s: the mean value is the maximum (14.543) for 2.395 Air Fuel Ratio & minimum (14.370) for 2.936 Ratio. The mean value is the maximum (16.498) for 0.9054 TFC and minimum (13.457) for 1.11 TFC. The mean value is the maximum (15.511) for 8.2 kg engine load and minimum (13.043) for 6.5 kg engine load,

From the fig1: **New carburetor results** : the mean value is the maximum (17.042) for 4.555 Air Fuel Ratio & minimum (16.963) for 5.213 Ratio. The mean value is the maximum (18.108) for 0.724 TFC and minimum (15.949) for 0.822 TFC. The mean value is the maximum (17.745) for 7.5 kg engine load and minimum (15.760) for 6.3 kg engine load

From the fig 1 : **Old carburetor results**: Delta is difference of maximum value and minimum value. Delta value is maximum for TFC parameter (3.041) and minimum (0.173) for the A/F Ratio parameter. The Delta value of load is between other two parameters and it is (2.467). So that effect of TFC is a maximum and effect of A/F Ratio is minimum on Brake Thermal Efficiency.

From the fig 1 **: New carburetor results:** Delta is difference of maximum value and minimum value. Delta value is maximum for TFC parameter (2.159) and minimum (0.079) for the A/F Ratio parameter. The Delta value of load is between other two parameters and it is (1.985). So that effect of TFC is a maximum and effect of A/F Ratio is minimum on Brake Thermal Efficiency.

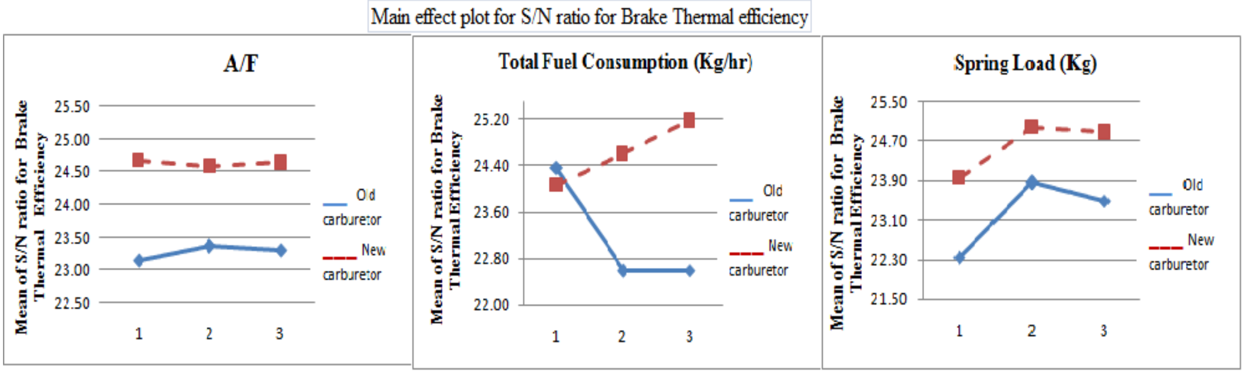

Fig 2 : Main effect plot for S/N Ratio of Brake Thermal Efficiency (Old Carburetor and New carburetor).

Referring to Fig 2 for **Old carburetor results**:, the response curve for S/N ratio, the highest S/N ratio was observed at 2.395 A/F ratio (23.360), 0.9054 TFC Kg/hr (24.370) and 8.2 Spring load Kg (23.850), which are optimum parameter setting for highest brake thermal efficiency. From delta values as mention above, maximum of TFC is 1.77 and the minimum for A/F is 0.21. The parameter TFC is the most significant parameter and A/F ratio is less significant for brake thermal efficiency.

Referring to Fig 2 for **New carburetor results**, the response curve for S/N ratio, the highest S/N ratio was observed at 4.555 A/F ratio (24.670), 0.724 TFC Kg/hr (25.170) and 7.5 Spring load Kg (24.990), which are optimum parameter setting for highest brake thermal efficiency. From delta values as mention above, maximum of TFC is 1.11 and the minimum for A/F ratio is 0.08. The parameter engine load is the most significant parameter and blend ratio is less significant for brake thermal efficiency.

OPTIMUM SET OF PARAMETER

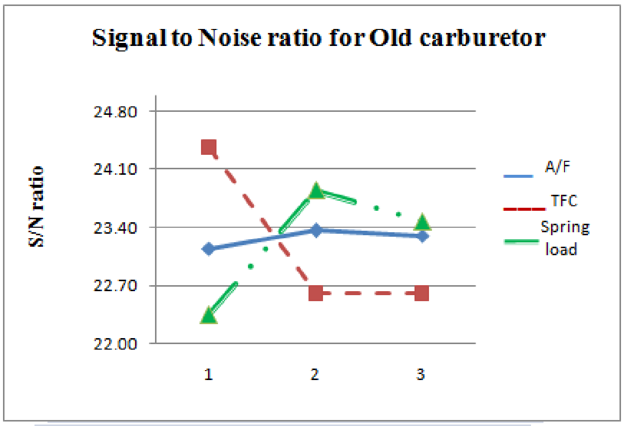

Fig 3: Response table for signal to noise ratio (Old carburetor)

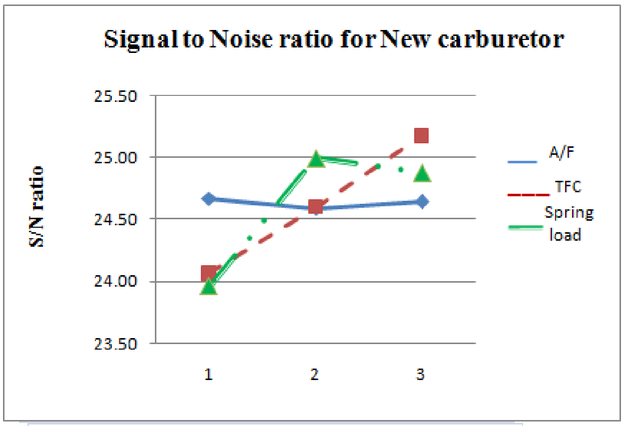

Fig 4: Response table for signal to noise ratio (New carburetor)

Percentage of CO and ppm of HC

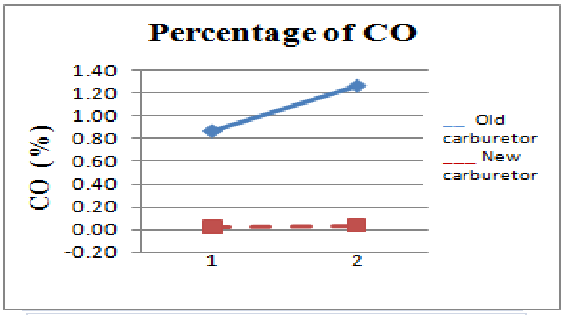

Fig5:Percentage of CO (Old and New carburetor)

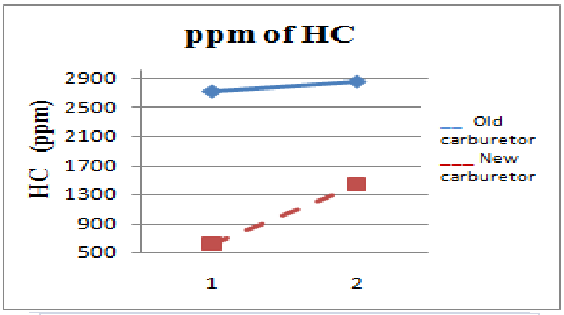

Fig6:ppm of HC (Old and New carburetor)

The term optimum set of parameters reflects only optimal combination of the parameters defined by this experiment for highest brake thermal efficiency. The optimum setting is determined by choosing the level with the highest S/N ratio. Referring Fig 3 , and Table-2, the response curve for S/N ratio, the highest performance at set 2.395 A/F ratio, 0.9054 TFC Kg/hr , and engine load 8.2 Kg, which is optimum parameter setting for highest brake thermal efficiency.

The term optimum set of parameters reflects only optimal combination of the parameters defined by this experiment for highest brake thermal efficiency. The optimum setting is determined by choosing the level with the highest S/N ratio. Referring Fig 4 , and Table-3, the response curve for S/N ratio, the highest performance at set 4.555 A/F ratio, 0.724 TFC Kg/hr , and engine load 7.5 Kg, which is optimum parameter setting for highest brake thermal efficiency.

VI. CONCLUSION

The Taguchi method was found to be an efficient technique for quantifying the effect of control parameters. The highest performance at set 4.555 A/F ratio, engine load 7.5kg, and 0.724 Kg/hr TFC for new carburetor where as for old carburetor results are 2.395 A/F ratio, 8.2 Kg and 0.9054 Kg /hr TFC, which are optimum parameter setting for highest brake thermal efficiency. And % CO and ppm of HC is reduced by using variable carburetor system in both optimization and without optimization technique. Engine performance is mostly influenced by A/F ratio and is least influenced by load. It was found out experimentally that brake thermal efficiency and Air Fuel ratio was improved after modification. In other words Fuel economy was improved after using the variable carburetor system.

VII.FUTURE SCOPE

Using variable carburetor system and adopting the Taguchi optimization technique results in estimating the best carburetion system for achieving maximum fuel economy. This procedure also helps us to assess preliminary viable and non viable procedures so as to get maximum efficiency from the existing system without changing any component of the system and can also be applied for any heat transfer applications.

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