Optimization of Fuel Requirement of a Vehicle

[1]Subhadip Das, [2]Dr.S.Mukherjee

[1]Post Graduate Scholar, [2]Professor, Department of Mechanical Engineering, Jalpaiguri Govt. Engineering College, India,

[1]subhadipd3@gmail.com, [2]sudipmukherjee_63@rediffmail.com

Abstract: Fuel is one of the most crucial requirement for everybody in their daily life. As fuel is a non-renewable source of energy and it is not abundantly available in nature, it must be used as less as possible and the recent survey suggests that in the near future fuel is going to be one of the most concerned topic. India has a vast transportation network as a result India uses up a lot of fuel so, if the fuel consumption can be reduced without influencing almost nothing, this can be achieved by optimizing the fuel economy of the transportation we are using. In this work our main area of focus is on the fuel economy of the vehicle by optimizing the influencing factors speed, load and air pressure of the tyre. By varying the dependable factors according to our need and analyzing the data by s/n ratio (signal to noise) ratio and regression analysis a step is being taken forward to use the fuel in a more effective way so that the use of fuel is minimized by keeping our desired requirements unaltered and also a step to feel the less pinch in our pockets.

Keywords: Dependable factors, Fuel, Fuel requirement, Fuel consumption, Fuel economy, non-renewable energy, regression analysis, S/N ratio.

I. INTRODUCTION

Rising fuel prices and increasing driving distance is taking a heavy toll on the car owner's pocket and much use of any vehicle is also effecting the environment so most of the vehicle users are thinking of switching to the hybrid vehicle concept. [1] Whenever anyone goes to buy any vehicle their most concentration or the thing that bothers them is the mileage of the vehicle. Now days in the market everybody wants to buy a fuel efficient vehicle, but that isn't enough. Making a vehicle fuel efficient in the hands of the person who is on the driving seat of the vehicle. In this work the process for optimizing the fuel requirement of a vehicle is being discussed. For this purpose, a vehicle is being considered i.e. Mahindra Scorpio S2[1] for the experimental purpose and the optimization is reached by running the vehicle at different combination of the influencing parameters. These are noted and analyzed mathematically so as to obtain a general relation involving the parameters. Regression analysis and s/n ratio were the mathematical tools used for the optimization. The Mahindra Scorpio is a four-wheel drive SUV manufactured by Mahindra & Mahindra Limited (M&M), the flagship company of the Indian Mahindra Group.

II. FACTORS MOSTLY INFLUENCING THE FUEL ECONOMY OF THE VEHICLE

- Speed (S) is one of the most influencing factors affecting the fuel economy of the vehicle. Speed should be within a range which is neither very low nor very high for better fuel economy
- Load (L) is another factor which inversely affect the fuel economy.
- Tyre air pressure (P) is another important factor affecting the fuel economy. For better fuel economy tyre air pressure is supposed to stay within a very close range.

III. OTHER FACTORS WHICH AFFECT THE FUEL ECONOMY

- Always keep a check at the tire air pressure as it influences the fuel economy of the vehicle in a greater way by virtue of its ability to withstand the load [2].
- Be as smooth as possible with the car's controls. Treat the accelerator and the brake pedals with ease.
- Keep the windows shut as it reduces the fuel efficiency of the vehicle aerodynamically.

- Try to keep the weight as minimum as possible. Avoid taking extra loads as it can reduce the vehicle's fuel economy [2].
- Do not keep the vehicle idle as the energy is being consumed without any fruitful work as output. Idling is the devil's workshop [3].
- Keep the vehicle internally as well as externally clean as dart in the air filter etc. would result in the decrease of fuel economy [6].

IV. DESIGN OF EXPERIMENT

One of the best way to optimize an experiment is to follow full factorial design of experiment. It is one of the most important setup for an experiment. In the design of experiment, the factors that are being considered are grouped into three ranges or limits, the minimum is given as low the mid-range is given as medium and the maximum range if factor is given as high. All possible combinations of parameters, here 3^3=27, [4] were considered. Table 1 containing the factors and their ranges is given below.

TABLE 1 factors and their ranges

Factors	Range		
	Low(1)	Medium(2)	High(3)
Speed (S) (m/s)	30	60	90
Load (L) (N)	2	5	8
Air Pressure (P) (N/m^2)	29	31	33

The Mahindra Scorpio vehicle considered for the experiment is made to run at all possible combinations (27) of the designed factors for a specific distance and the results are tabulated. Table 2 shows the combinations of parameters along with their actual values and the corresponding output (fuel economy)

TABLE 2 combinations of parameters

SI NO.	COMBINATIONS			ACTUAL VALUE			OUTPUT
	SPEED (m/s)	LOAD (N)	AIR PRESSURE (N/m^2)	SPEED (m/s) x_1	LOAD (N) x_2	AIR PRESSURE (N/m^2) $x_3 \times 10^5$	FUEL ECONOMY (Km/lit) Y
1	1	1	1	8.333	1177.2	2	10
2	1	1	2	8.333	1177.2	2.13	10.5
3	1	1	3	8.333	1177.2	2.27	11
4	1	2	1	8.333	2943	2	11
5	1	2	2	8.333	2943	2.13	11.5
6	1	2	3	8.333	2943	2.27	12
7	1	3	1	8.333	4708.8	2	9
8	1	3	2	8.333	4708.8	2.13	10
9	1	3	3	8.333	4708.8	2.27	11
10	2	1	1	16.666	1177.2	2	13
11	2	1	2	16.666	1177.2	2.13	13.5
12	2	1	3	16.666	1177.2	2.27	14
13	2	2	1	16.666	2943	2	12
14	2	2	2	16.666	2943	2.13	13
15	2	2	3	16.666	2943	2.27	14
16	2	3	1	16.666	4708.8	2	10
17	2	3	2	16.666	4708.8	2.13	10.5
18	2	3	3	16.666	4708.8	2.27	11
19	3	1	1	25	1177.2	2	11
20	3	1	2	25	1177.2	2.13	11.5
21	3	1	3	25	1177.2	2.27	12
22	3	2	1	25	2943	2	12
23	3	2	2	25	2943	2.13	12.5
24	3	2	3	25	2943	2.27	13
25	3	3	1	25	4708.8	2	9
26	3	3	2	25	4708.8	2.13	10
27	3	3	3	25	4708.8	2.27	10.5

V. TAGUCHI L9 ORTHOGONAL ARRAY

According to the Taguchi's design of experiments [4], among the total sets of combinations the optimal result can be achieved by best 9 combinations obtained from taguchi's orthogonal array. Table 3 below shows the 9 combinations as prescribed by Taguchi [8] taken from table 2 showing all possible combinations.

TABLE 3 9 combinations as prescribed by Taguchi

SI NO.	COMBINATIONS			ACTUAL VALUE			OUTPUT
	SPEED (m/s)	LOAD (N)	AIR PRESSURE (N/m^2)	SPEED (m/s)	LOAD (N)	AIR PRESSURE (N/m^2)	FUEL ECONOMY (Km/lit) Y
1	1	1	1	8.333	1177.2	2	10
2	1	2	2	8.333	2943	2.13	11.5
3	1	3	3	8.333	4708.8	2.27	11
4	2	1	2	16.666	1177.2	2.13	13.5
5	2	2	3	16.666	2943	2.27	14
6	2	3	1	16.666	4708.8	2	10
7	3	1	3	25	1177.2	2.27	12
8	3	2	1	25	2943	2	12
9	3	3	2	25	4708.8	2.13	10

VI. DEVELOPMENT OF MATHEMATICAL MODEL

Generalized regression equation [2]

$Y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ii} x_i^2 + \sum_{i \neq j}^{k} b_{ij} x_i x_j \rightarrow 1$

Here → j = number of parameters = 3
i = number of levels = 3
i,j = 1,2,……,k
here k = 3

Therefore, equation 1 becomes: -

$Y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_{11} x_1^2 + b_{22} x_2^2 + b_{33} x_3^2 + b_{12} x_1 x_2 + b_{23} x_2 x_3 + b_{13} x_3 x_1 \rightarrow 2$

Here → x_1 = Speed (S)
x_2 = Load (L)
x_3 =Air Pressure (P)
Y = Output
b_0 = Constant

The equations obtained using taguchi's orthogonal array [8] were solved in computer and the values of the parameters found to be: -

b_0= 1.8200 b_1= 1.0126 b_2= 1.6916
b_3= -1.8702 b_{11}= -0.0012 b_{22}= -0.1111
b_{33}= 0.0682 b_{12}= 0.0049 b_{23}= -0.0454 b_{13}= -0.0285

Thus the final regression equation can be written as: -

$Y = 1.8200 + 1.0126\,S + 1.6916\,L - 1.8702\,P - 0.0012\,S^2 - 0.1111\,L^2 + 0.0682\,P^2 + 0.0049\,SL - 0.0454\,LP - 0.0285\,SP$

VII. RESULTS AND DISCUSSION

The regression equation [5] developed earlier was simulated in computer to find out the effect of one factor against fuel economy within the prescribed ranges [10] [5]. For every variation graphs are plotted. The obtained graphs are given below.

Effect of speed on fuel economy at mean levels of load and tyre air pressure

In this the speed is varied between 8.333m/sec to 25m/sec, the load and the tyre air pressure both are kept fixed at their mean values i.e. load at 2943N and tyre air pressure at $2.13\times10^5 N/m^2$.

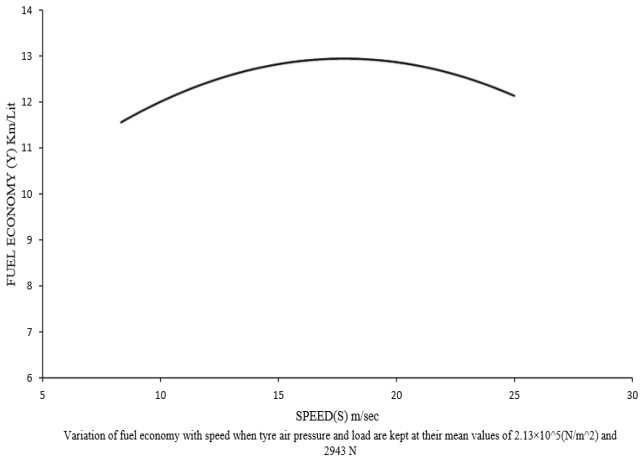

Fig 1 Effect of speed on fuel economy at mean levels of load and tyre air pressure

From the above graph it can be seen that at mean levels of load and tyre air pressure as speed increases fuel economy increases at the start and after a while it starts to decrease and with further increase in speed the fuel economy decreases.

Effect of load on fuel economy at mean levels of speed and tyre air pressure

In this the load is varied between 1177.2N to 4708.8N, the speed and the tyre air pressure both are kept fixed at their mean values which is speed at 60Km/hr. (16.666m/sec) and tyre air pressure at 31Psi($2.13\times10^5 N/m^2$).

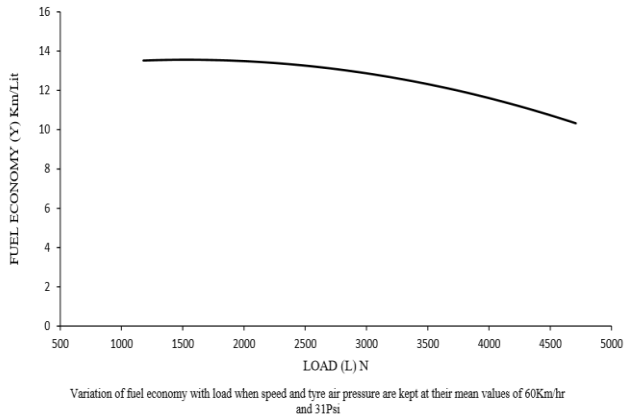

Fig 2 Effect of load on fuel economy at mean levels of speed and tyre air pressure

From the graph it can be seen that with the increase of load fuel economy of the vehicle decreases but till a certain point even though the speed and tyre air pressure are kept at their mean values.

Effect of tyre air pressure on fuel economy at mean levels of speed and load

In this the tyre air pressure is varied between 2×10^5 N/m^2 to $2.27 10^5$ N/m^2, the speed and the load both are kept fixed at their mean values i.e. speed at 60Km/hr and load at 2943N.

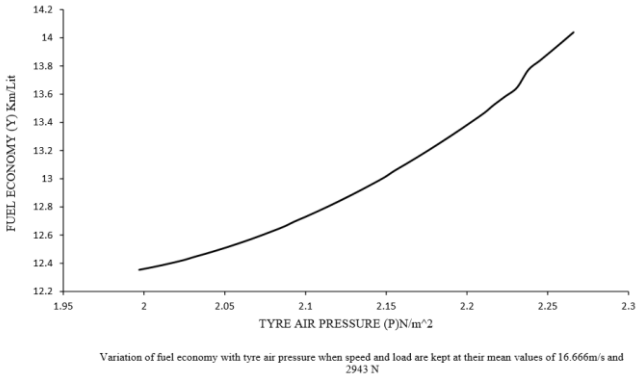

Fig 3 Effect of tyre air pressure on fuel economy at mean levels of speed and load

From the graph it is seen that at mean values of load and speed, tyre air pressure is directly proportional to the fuel economy. The fuel economy goes on increasing as the tyre air pressure is increased.

From the graphs it can be clearly seen that the fuel economy is maximum at the combination of speed at 17m/s, load at 1177.2N and tyre air pressure at 2.27×10^5 N/m^2.

VIII. CONCLUSION

From the above research work it can be concluded that the fuel economy of a vehicle can be improved when operated under optimum combination of the influencing parameters. Here the optimum combination of the parameters for best fuel economy is speed = 17m/s, load= 1177.2N and tyre air pressure = 2.17×10^5N/m^2. Regression equation obtained here can be used to find one parameter when the other two are known so as to get the best fuel economy within the range.

REFERENCE

[1] Yiyong Xiao, Quihong Zhao, development of a fuel consumption optimization model for the capacitated vehicle routing problem, volume 39, issue 7, july 2012

[2] Development and Optimization of PCM Based Technology for Cooling Applications for Improvement of Fuel Efficiency in Commercial Vehicle by Shukla, A., Dhami, R., Bhargava, A., and Tiwari, S., "Development and Optimization of PCM Based Technology for Cooling Applications for Improvement of Fuel Efficiency in Commercial Vehicle," SAE Technical Paper 2017-01-0150, 2017, doi:10.4271/2017-01-0150.

[3] David Brownstone, Thomas F Golob, the impact of residential density on vehicle usage and energy consumption, journal of urban economics, volume 65, issue 1, jan 2009

[4] Journal on Model-Based Fuel Economy Technology Assessment by Lee, H., Lee, B., Kim, S., Kim, N. et al., "Model-Based Fuel Economy Technology Assessment," SAE Technical Paper 2017-01-0532, 2017, doi:10.4271/2017-01-0532

[5] Regression Analysis by Example, 5th Edition by Samprit Chatterjee, Ali S. Hadi

[6] Fuel economy of the gasoline engine by D.R. Blackmore

[7] Fuel economy of the gasoline engine: fuel, lubricant, and other effects by David Richard Blackmore, Alun Thomas, W. S. Affleck

[8] A prime on the taguchi method by ranjit k roy

[9] Power-To-Gas: Study of the Conversion Efficiency & Process Integration, by Lamberts Oliver

[10] design of experiment by ranjit k roy, arahant publications.

