Fuel Requirement Optimization of a Vehicle by using Taguchi

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Abstract - The requirement of fuel is essential for everybody to maintain their daily lifestyle. Petrol being a major area of concern in recent times due to its scarcity soon, it is the responsibility of all to use this in an optimized manner. A broad transport network within India results in huge demand for petrol due to which optimizing the use of petrol without giving up on the need is the goal. This goal can be brought through this fuel optimization technique. The main aim of this research was to find out the fuel economy of a vehicle by optimizing the factors influencing the fuel economy. Factors that were considered were the speed at which the vehicle will move, the load that is the number of people on the vehicle, and the tire air pressure of the vehicle. By differing the factors according to the requirement and investigating with the help of S/N ratio signal to noise ratio and regression analysis we have tried to optimize the fuel requirement without sacrificing any of our needs which in turn will also help us economically in a long run.

Keywords - Fuel economy, Fuel requirement, regression analysis, S/N ratio, Fule consumption.

INTRODUCTION

With the significant increase in fuel prices and transportation being a pivotal area of a country, every transport owner is experiencing a pinch in their savings which in turn is felt by the common people [1]. It is obvious that more the fuel is burnt up more the harmful gasses are freed in the atmosphere and the atmosphere gets polluted which in turn degrades our standard of living. It is quite frequently observed that if someone decides to buy a car then their main area of concerns is the milage of the car. It's a quiet common question they ask that for a 1 litre of fuel how much distance the car would cover. In the present scenario everybody is concerned in buying a fuel-efficient car, but the fact is that it's not enough. A company can not completely make a fuel-efficient car as the fuel efficiency depends on the person on the driving seat. Here we have tried to optimize the fuel efficiency by using some technique that will be discussed later. For the experiment purpose the vehicle that is used is Mahindra Scorpio S2 [1]. The fuel efficiency is optimized by varying the input parameters according to our need. By conducting the experiment, the data are noted and mathematically analysed to put forward an equation that will have all the input parameters and the co relation between them. The tools that are being used here are s/n ratio regression ratio. Mahindra Scorpio is a four-wheel drive SUV, product of Mahindra and Mahindra limited and a prime product of the company.

MOST COMMON FUEL EFFICIENCY INFLUENCERS

1)Speed (S) one of the important factors that can manipulate the fuel economy. For a better fuel economy, the speed of the vehicle must not be too high or too low.
2)Load (L) being another factor that is inversely proportional to the fuel economy.
3)Tyre air pressure (P) another factor that can influence the fuel economy. The tyre air pressure should have a very close range.

ADDITIONAL FACTORS THAT EFFECT FUEL ECONOMY

1)Quiet often one should keep tracking the tyre air pressure as it has a great effect on the fuel economy of the vehicle as it withstands the load [2].
2) Smoothly control the vehicle rather than with hazards.
3) Keeping the window open can decrease the fuel economy aerodynamically so keep the window shut if possible.
4) Try to keep the load under check as taking extra load may result in decreased fuel economy [2].
5) Keeping the vehicle idle for long hours decreases fuel economy as one doesn't get any output though the energy gets wasted [3].
6) Maintain the vehicle at regular intervals as fuel economy may decrease due to poor maintenance [6].

DESIGN OF EXPERIMENT

As optimization of fuel economy is our primary goal of the experiment full factorial design of the experiment is being applied. In this the input parameters of the experiment which means the speed, load and tyre air pressure are grouped into three

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ranges of limits. The minimum is named as low, the mid-range is named medium and the maximum range is named as high. After this, all the possible combinations of the influencing parameters are considered and shown in table 1. This means that as there are three influencing parameters and there are three ranges so the total numbers of combinations that are possiis are $3^3 = 27$ [4].

Table 1. Different Factors and Their Range.

Factors	Range		
	Minimum (1)	**Moderate (2)**	**Maximum (3)**
Speed(S)(m/s)	30	60	90
Load(L)(N)	2	5	8
AirPressure(P)(N/m^2)	29	31	33

For the experimentation purpose Mahindra vehicle have chosen to run at all possible combinations (27) of the designed factors for a specific distance. Results are shown in table format. Table 2 shows the experimental result by combination of different parameters along with their actual value and related output (fuel economy).

Table 2. Parameters Combination Table.

Sl No.	Combination			Actual value			Output Fuel economy (km/lit)
	Speed (m/s)	Load (N)	Tyre air pressure (N/m^2)	Speed (m/s)	Load (N)	Tyre air pressure (N/m^2)	
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

L9 TAGUCHI ORTHOGONAL ARRAY

Taguchi's orthogonal array stated that the optimal result can be achieved by the best nine combinations among the total set-combinationstion. Taguchi's method emphasizes reducing the variations in the process through the vigorous design of experiments [4]. The main motive of this method is to optimize the output of the experiment. Taguchi has produced a method for the design of the experiment which will convey the way various input parameters will affect the variance and mean of the process performance characteristics. The table given below uplifts the nine setsets combinations as suggested by Taguchi [8] that is a part of the combinations from the above table of twenty-seven combinations. Table 3 contains the 9 combinations as suggested by Taguchi for optimizing the output.

Table 3. Combinations Designed By Taguchi.

Sl No.	**Combination**			**Actual value**			**Output Fuel economy (km/lit)**
	Speed (m/s)	Load (N)	Tyre air pressure (N/m^2)	Speed (m/s)	Load (N)	Tyre air pressure (N/m^2)	
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

DEVELOPMENT OF MATHEMATICAL MODEL

Forming of mathematical model
Basic regression equation [2]: -

$$Y= b_0+ \sum_{i=1}^{k}(b_i x_i)+ \sum_{i=1}^{k}(b_{ii} x^2{}_i)+\sum_{i=j}^{k}\left(b_{ij}\, x_i x_j\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Here j is the number of parameters which is 3
i is the number of levels which is 3
I, j = 1, 2…. k, where k =3
Therefore equation 1 becomes

$$Y=b_0+ b_1\, x_1+ b_2\, x_2+ b_3\, x_3+ b_{11}\, x_1^2+ b_{22}\, x_2^2+ b_{33}\, x_3^2+ b_{12}\, x_1x_2+ b_{22}\, x_2x_3+ b_{13}\, x_3x_1 \ldots (2)$$

Here x_1 is Speed (S)
X_2 is Load (L)
X_3 is Tyre air pressure (P)
Y is the output and b_0 is a constant.

The equation acquired by using Taguchi's orthogonal array [8] was calculated in computer and the corresponding values of the parameters are as follows: -

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} = -0.454 b_{13} = 0.0285

Therefore, the final regression equation obtained by substituting the values is: -

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

RESULTS AND DISCUSSIONS

The regression equation [5] developed above was stimulated in computer to understand the relation of one factor with the fuel economy between the predefined ranges [10] [5]. Graphs were plotted for every variation, and it is shown below. Under this condition, the speed is being differed between 8.333 m/s to 25 m/s. And the values of load and tyre air pressure are kept at their mid-levels i.e., load at 2943N and tyre air pressure at 2.13×10^5 N/m^2.

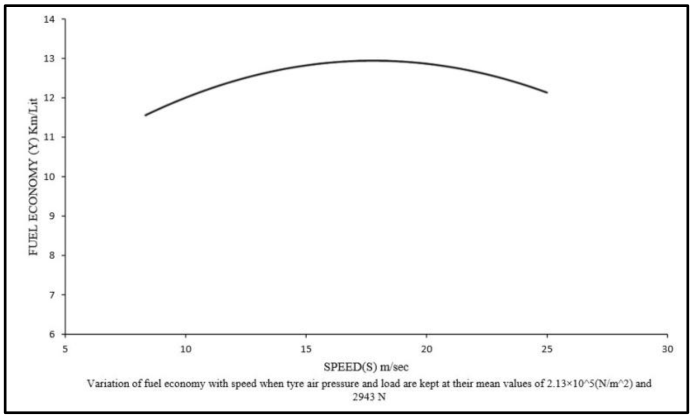

Fig. 1. Outcome of speed on fuel economy at mid-levels of load and tyre air pressure.

Outcome of speed on fuel economy at mid-levels of load and tyre air pressure

From the above graph obtained between fuel economy and speed by keeping varying the speed from 8.333 m/s to 25m/s and keeping the other input parameters that is the load and tyre air pressure at mid-level it can be clearly observed that the fuel economy increases till a certain value of speed and after that it starts decreasing on further increase of speed. So, for this condition the vehicle should run at 17.333m/s to achieve its highest fuel economy.

Outcome of load on fuel economy at mid-levels of speed and tyre air pressure

Under this condition the load is being differed between 1177.2N to 4708.8N. And the values of speed and tyre air pressure are kept at their mid-levels i.e., speed at 60Km/hr and tyre air pressure at 31Psi (2.13×10^5 N/m^2).

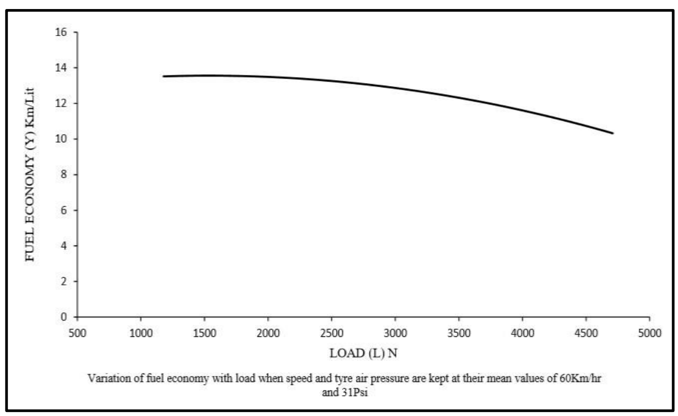

Fig. 2. Outcome of load on fuel economy at mid-levels of speed and tyre air pressure.

From the above graph obtained between fuel economy and load by varying load from 1177.2 N to 4708.8N and keeping speed and tyre air pressure at mid level that is speed at 60Km/he and tyre air pressure at 31Psi (2.13×10^5 N/m^2) it can be clearly observed that the fuel economy of the vehicle decreases as the load increases. The graph starts at its highest point and starts declining after that.

Outcome of tyre ait pressure on fuel economy at mid-levels of speed and load

Under this condition the tyre air pressure is being differed between 2×10^5 N/m^2 to 2.27×10^5 N/m^2 and the values of speed and load are kept at their mid-levels i.e., load at 2943N and speed at 60Km/hr.

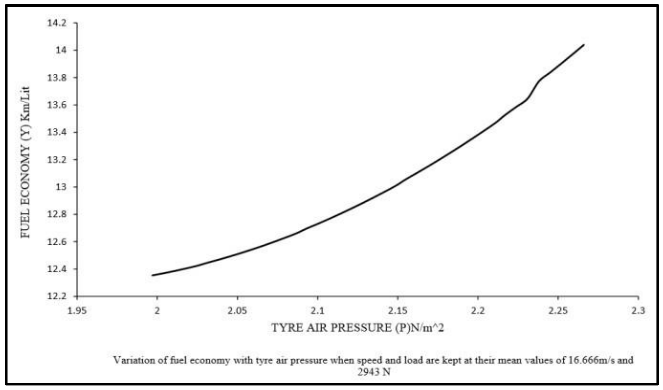

Fig. 3. Outcome of tyre ait pressure on fuel economy at mid-levels of speed and load.

From the above graph obtained between fuel economy and tyre air pressure by varying the tyre air pressure and keeping the speed and load at mid-levels that is speed at 60Km/hr and load at 2943N it can be clearly observed from the graph that as the value of tyre air pressure increases the fuel economy also increases gradually. It can be said that the tyre air pressure and fuel economy is directly proportional till a certain point.

CONCLUSION

From the above all the graphs it can be concluded that the fuel economy is at its peak when the corresponding value of speed is 17m/s, load at 1177.2N and tyre air pressure at 2.27×10^5 N/m^2. After this research work after analysing, it can be easily concluded that the fuel economy of a vehicle can be increased if operated under the optimum condition of the influencing parameters. The optimum combination of the input parameters is speed at 17m/s, load at 1177.2N and tyre air pressure at 2.17×10^5 N/m^2. The equations obtained here can also be used to find out the effect of one input parameters on fuel economy at various levels by keeping the other two input parameters constant.

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