International Journal of
I.C. Engines and Gas Turbines

ISSN: 2582-290X
Volume 9, Issue 1, 2023
DOI (Journal): 10.37628/IJICEGT

http://mechanical.journalspub.info/index.php?journal=JIEGT&page=index

Review IJICEGT

Enhancement in Fuel Efficiency with Magnetised Nano Ferro Particles in Internal Combustion Engines

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Abstract

The purpose of the research is to reduce the fuel consumption and increase the material life of an IC engine. The performance of an internal combustion engine can be evaluated in terms of fuel consumption by addition of nano sized ferro particles into cooling water system at varying percentage and magnetizing it with varying magnetic intensity. The experiment was undertaken in a 796 cc, 3 Cylinder petrol engine with a rated power of 34 bhp at 5000 rpm whose cooling water capacity is three liters. The test was undertaken with water alone as cooling media, water with varying percentage of ferro particles and water with varying concentration of ferro particles and magnetic intensity. The percentage of ferro fluid used for testing is 1-6%. The performance measures evaluated are calculated with respect to fuel consumption per minute. The experiment shows that the fuel consumption per minute for using water alone as cooling media is 9.276 g/min (556.56 g/hr). By addition of 4% ferro particles in to the base fluid the fuel consumption per minute reduced to 8.106 g/min (486.36 g/hr). The fuel consumption further reduced to 7.892g/min (473.52) by addition of 4% ferro particle with magnetic intensity of 300 gauss. The difference in fuel consumption between water alone as cooling media and with 4 percentage magnetized ferro particles having magnetic intensity of 300 gausses is 1.384 g/min (83.04 g/hr).

Keywords: ANOVA, Cooling media, fuel efficiency, magnetized ferroparticles, Matlab, performance, spikes

INTRODUCTION

When magnetic field is applied on ferrofluid, the fluid converts to pseudo solids and this can absorb more heat than liquids. The main attention is to improve the performance of heat exchange devices, minimize energy costs and obtain maximum compactness with use of minimum materials. The most suitable solutions to the problem of heat transfer performance enhancement could be the use of nano fluids, which are fluids containing nano particles of various composition [7, 9]. Heat carrying property of ferrofluid increases by magnetization upto a threshold value of magnetic intensity. With further advancement in ferromagnetic materials and manufacturing better magnetic nano fluids with improved magnetization and higher pyromagnetic coefficient, magnetic nano fluids can be applied considerably in a wide variety of engineering fields, especially in the field where there is a critical requirement of reducing the energy consumption [8]. Beyond that value, bifurcation occurs and particles forms different shapes which reduces the surface area [3]. Ferrofluids posses more heat carrying capacity than conventional fluids used in heat exchangers. Nanofluid refers to fluids by suspending nano particles in the base fluid [1, 2]. Heat carrying capacity of liquid is less compared to solids. Ferrofluids have superior properties which includes variable viscosity, improved thermal conductivity and formation of spike like structure in the presence

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Received Date: November 07, 2023
Accepted Date: November 20, 2023
Published Date: December 05, 2023

Citation: Rajesh Kocheril. Enhancement in Fuel Efficiency with Magnetised Nano Ferro Particles in Internal Combustion Engines. International Journal of I.C. Engines and Gas Turbines. 2023; 9(1): 40–46p.

of an external magnetic field [4]. Addition of ferro particles or nano particles into cooling water of IC Engines increases the heat transfer which results in the size reduction of heat exchanger and fuel consumption [10]. The micro-magnets in a ferro fluid also react to a magnetic field by aligning along the field resulting in strong exertion of forces on the fluid, radically altering its shape as the fluid passes to maximally fill its volume with magnetic field [6]. Drinking water scarcity is a major challenge faced by the world now. Larger capacity diesel power plants and the engines used on board ships consume large quantity of water for cooling the jacket. By addition of nano particles along with base fluid, the quantity of water used may be reduced because of the increased heat transfer rate.

METHODOLOGY FOR FERROFLUID SAMPLE PREPARATION

Nanofluids should meet the important properties such as suspension stability, limited agglomeration of particles and without any change in chemical properties of the particles [5]. Nanofluids are produced by dispersing nano meter scale solid particles into the base liquids such as water, ethylene glycol, oil etc. [4]. There are mainly two techniques used to produce nanofluids: the single-step and the two- step methods [5].

The Properties and Its Values of Ferro Particles Used for the Experiment

The properties and its values of ferro particles used for the experiment is given in Table 1.

Table 1. Properties of ferro particles used for experiment.

Property	Values
Hydro dynamic size(DLS)(nm)	29.2
Carrier	Water
Particle magnetization Md(emu/cc)	320
Surfactant	Tetra layer coated LA
Size distribution, σ	0.244
Type of binding	Chemical coating
% Binding of surfactant	33%
Particle density	5g/cc

Specifications of the Test Engine

The specification of engine used to undertake the performance and fuel consumption is given in Table 2.

Table 2. Specification of engine used for testing.

Characteristics	Limits
Capacity of engine	796 cc
Fuel type	Petrol
BHP	34bhp @5000 rpm
Cooling water capacity	3 liters
No of cylinders	3

EXPERIMENTAL ANALYSIS

The test was undertaken with water alone as cooling media, water with varying percentage of ferro particles and water with varying concentration of ferro particles and magnetic intensity. The percentage of ferro particles used for testing is 1-6%. The performance measures are obtained and calculated with respect to fuel consumption per minute.

Cooling Medium as Water Alone

The performance test was undertaken on a 796 cc, 3 Cylinder petrol engine with a rated power of 34 bhp at 5000 rpm. The experiment shows that the fuel consumption per minute for using water alone as cooling media is 9.276 g/min (556.56 g/hr).

Cooling Medium as Water With Ferro Fluid

The cooling medium used for the testing vehicle is water with various percentage of ferro fluid. The percentage of ferro fluid used for testing is 1-6%. The performance measures evaluated are calculated with respect to consumption per minute. The optimum fuel consumption is obtained when 4% of ferro fluid is added and the fuel consumption is found to be 8.106 g/min (486.36 g/hr). The difference in fuel consumption between water alone as cooling media and with 4 % addition of ferro particles is 2.082 g/min (83.04 g/hr). The result obtained from the experiment with varying percentage of ferro particle is shown in Figure 1.

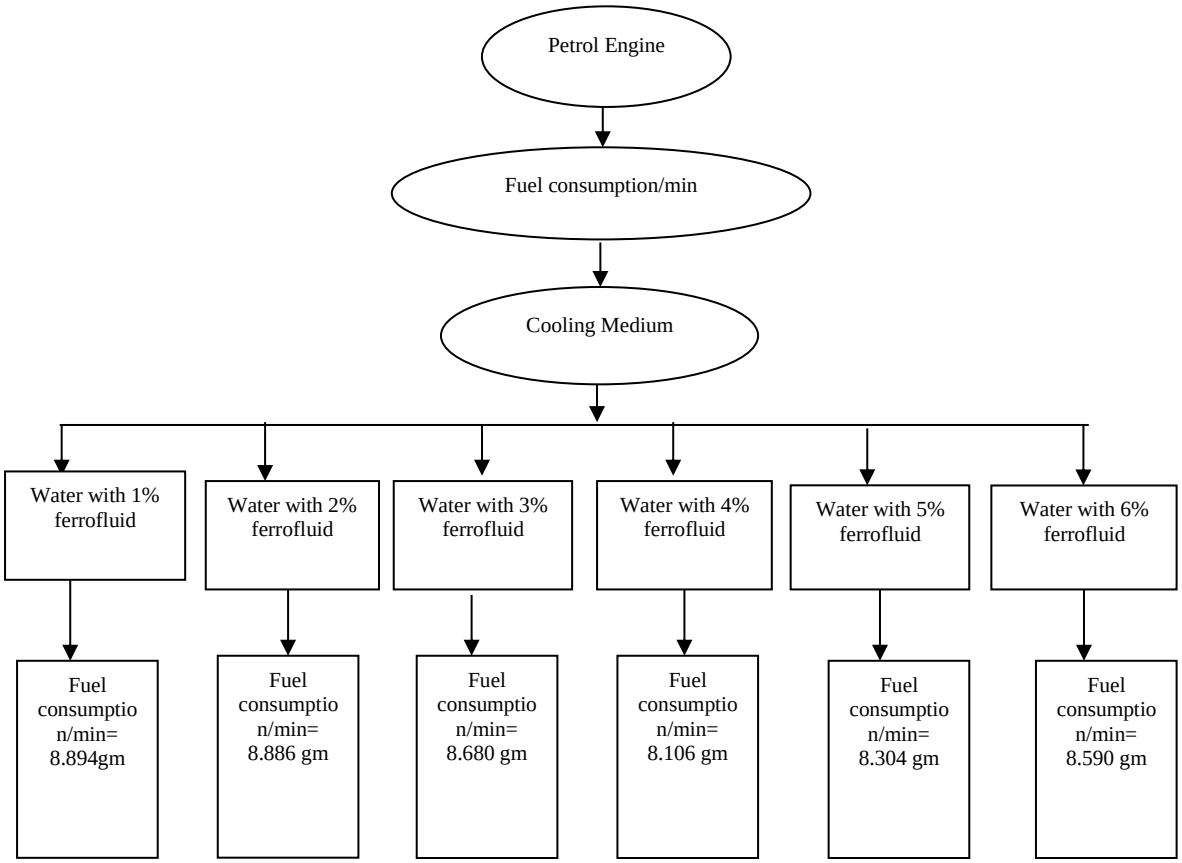

Figure 1. Experiment results with varying percentage of ferro particle.

From the experiment, fuel consumption per litre for different percentages of ferro fluid is calculated. Based on these data a regression equation of fuel consumption per litre and percentage of ferro fluid is developed with the help of the statistical software package MINITAB 18. This equation gives an optimum percentage of ferro fluid that gives optimum fuel consumption per litre.

The regression equation of fuel consumption (y) against percentage of ferro fluid (x) is

$$y = 7.668 + 0.4125\, x_1 - 0.5075\, x_1^2 \quad (1)$$

The equation mentioned gives an optimum percentage of ferro fluid that gives optimum fuel consumption. The regression equation of fuel consumption (y) against % of ferro fluid (x) is

$$y = 7.668 + 0.4125x_1 - 0.5075{x_1}^2 \quad (2)$$

where y is the fuel consumed and x_1 is the percentage of ferrofluid used for the testing engine. The fitted regression equation is graphically shown in Figure 2.

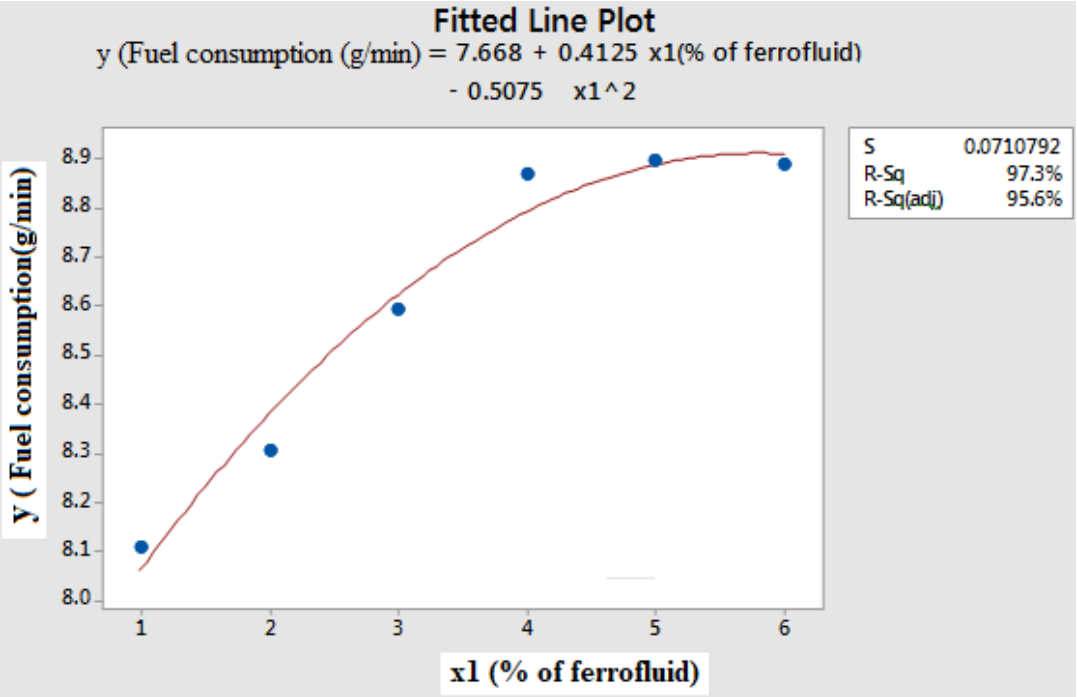

Figure 2. Graphical representation of fitted mathematical model.

The statistical tool used for checking the validity of the regression equation is the analysis of variance and is given in Table 3.

Here the null hypothesis used for testing is H_0: There is some variation in the regression model.

Table 3. Analysis of variance.

Source of Variation	Degrees of freedom	Sum of squares	Mean Sum of squares	*F*-ratio	*p*-value
Regression	2	0.556788	0.278394	55.10	0.004
Error	3	0.015157	0.005052		
Total	5	0.571945			

After the analysis, the value of *F*-ratio is greater than *p*-value. Therefore the null hypothesis H_0 is rejected. i.e. there is no variation in the regression model or the model is of good fit. The coefficient of determination of the regression model is computed to be 97.35%.

For finding the optimum fuel consumption rate (y) corresponding to the percentage of ferro fluids (x_1) using equation (5.4.1) is done by designing a software program with the help of package MATLAB 2016a. The program developed is

```
fun = @(x)-7.668 - 0.4125*x(1)- 0.5075*x(1)^2;
x0 = [1, 6];
[x,fval] = fminunc(fun,x0);
```

Using this program, the optimum value of fuel consumption rate corresponding to the percentage of ferro fluids is 8.112.

Cooling Medium as Water with Magnetized Ferro Fluid

The cooling medium used for the testing is water with different percentage of ferro fluid and gauss for magnetization. The composition of ferro fluid used for testing is 1-6% and the magnetic intensity used is 150,300 and 400 Gauss. The fuel consumption for each case is evaluated.

From the experiment, fuel consumption is calculated for different percentages of ferro fluid and magnetic intensity (Gauss). By magnetizing the ferro particles added into the base fluid, the coolant becomes magnetized and its effect is shown in Figure 3.

Figure 3. Spike formation by magnetic effect.

The performance test was undertaken on the same engine with ferro particle addition varied from 1 to 6% and the magnetic intensity applied was 150, 300 and 400 gauss. The results of experiment with magnetized ferro fluid with varying magnetic intensity are shown in Figure 4.

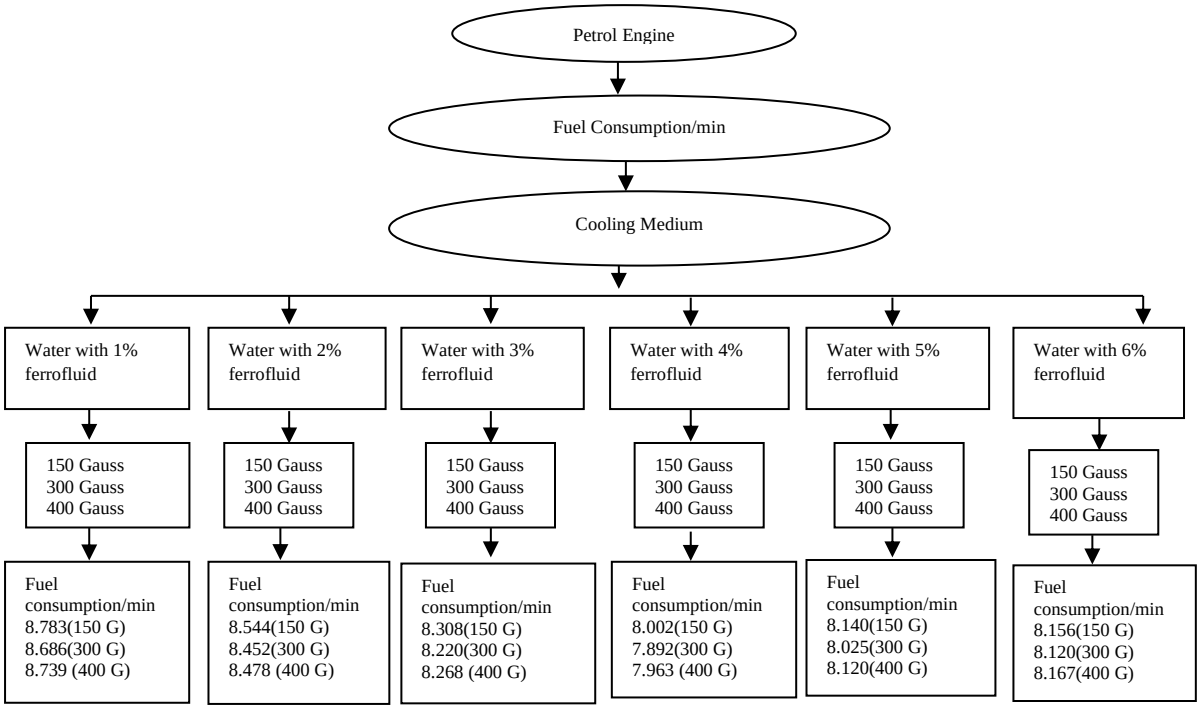

Figure 4. Experiment results with varying magnetic intensity.

The fuel consumption when water alone is used is 9.974 g/min and that with 4 % ferro particle addition into the base fluid, the fuel consumption reduced to 8.106 g/min. Upon magnetizing the ferro particles, the optimum consumption of fuel aws found to be at 4% with magnetic intensity of 300 gauss. The fuel consumption reduced to 7.892 g/min.

Based on the data, regression equation for fuel consumption with respect to percentage of magnetized ferro fluid and magnetic intensity is modeled with the help of the statistical software package MINITAB 18. This equation gives an optimum combination of the percentage of ferro fluid and magnetic intensity (Gauss) that gives optimum fuel consumption.

The regression equation of fuel consumption (y) with respect to the percentage of ferro fluid, the amount of fuel, the amount of water content and the amount of gauss is

$$y = 37.35 + 0.1344\, x_1 - 0.572\, x_2 - 0.298\, x_3 + 0.000328\, x_4 \quad (3)$$

where y is the fuel consumption, x_1 is the percentage of ferro fluid, x_2 is the time taken, x_3 is the amount of water content and x_4 is the amount of gauss. The statistical tool used for checking the validity of the regression equation is the analysis of variance and is given in Table 4.

Here the null hypothesis used for testing is H_0: There is some variation in the regression model.

Table 4. Statistical tool used for checking the validity of regression equation using ANOVA (Analysis of Variance).

Source of Variation	Degrees of freedom	Sum of squares	Mean Sum of squares	*F*-ratio	*p*-value
Regression	4	0.64266	0.16067	18.55	0.001
x_1	1	0.60951	0.60951	70.36	0.000
x_2	1	0.09094	0.09094	10.50	0.014
x_3	1	0.00395	0.00395	0.67	0.521
x_4	1	0.00708	0.00708	0.82	0.396
Error	7	0.06064	0.00708		
Total	11	0.70330	0.00866		

After the analysis, for all the cases, the value of *F*-ratio is greater than *p*-value. Therefore the null hypothesis H_0 is rejected. i.e there is no variation in the regression model or the model is of good fit. The coefficient of determination of the regression model is computed to be 91.38%.

CONCLUSIONS

Nano fluids exhibits notable thermal properties when compared with fluids generally used for heat transfer. By addition of nano particles into the cooling water system of an internal combustion engine, the heat transfer rate can be increased. The experiment was conducted on 796 cc petrol engine, having three cylinders with cylinder diameter 19.05 mm per cylinder with 59 Nm torque at 2500 rpm and 25.364 kW power at 5000 rpm. The percentage addition of ferro fluid varied between 1% and 6% and the optimum is at 4% addition, the ferro fluid is then magnetised with a magnetic intensity of 150, 300 and 400 Gauss. The experiment shows that the fuel consumption per minute for using water alone as cooling media is 9.276 g/min (556.56 g/hr). When ferro particles were added the optimum consumption is observed to be at 4% addition and the fuel consumption is found to be 8.106 g/min (486.36 g/hr). Further, on magnetization, the optimum fuel consumption noted at 4% with a magnetic intensity of 300 gauss is 7.892 g/min (473.52 g/hr). The difference in fuel consumption between water alone as cooling media and with magnetized ferro fluid having magnetic intensity of 300 gauss is 1.384 g/min (83.04g/hr).

It was observed that the fuel consumption increases when magnetic intensity is increased beyond 300 gauss because of bifurcation in shape from conical spikes. For statistical evidence, the obtained results were analyzed using statistical tool ANOVA and evaluated using MINITAB 18. A program using MATLAB 16a is developed for finding the minimum fuel consumption with optimum combination of ferro particles and magnetic intensity.

Nomenclature

ANOVA: Analysis of Variance
IC Engine: Internal Combustion Engine
g/min: grams/min
g/hr: grams/hour

%: Percentage
°C: Degree Celsius
Rpm: revolutions/min
y: fuel consumption
x_1*:* percentage of ferro fluid
x_2*:* time taken
x_3*:* amount of water content
x_4*:* amount of gauss.

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