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Design and Fabrication of Apparatus to Find Adulteration of petroleum Fuels

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Abstract

The importance of petrol and diesel in the present world is well known to everyone. Thus, their quality plays an important role in functioning of appliances viz; vehicles, airplanes etc. Hence it becomes necessary to check their adulteration as it may affect the performance and also may damage the appliances in the worst possible case. Petrol is generally adulterated with kerosene, as the price of kerosene, distributed through public distribution system is kept low due to social and economic considerations. Petroleum fuels are similar in structure but kinematic viscosity is different. In this method, a spring-mass system guided inside a container like a damped vibration system to find adulteration. Hence damping vibration index number will vary for different fuel samples with same set of oscillations.

1. Introduction

Petrol and Diesel are commonly available fuel for automobiles. Since the cost of petrol is high comparing with other petroleum products, which introduces adulteration. Adulteration is defined as the illegal or unauthorized addition of foreign substance into petroleum substance, with the result that the product does not conform to the requirements and specifications of the product. The foreign substances are also called adulterants, normally kerosene, which introduces alteration and degradation of quality of base transport fuels. Due to adulteration of petrol with kerosene causes incomplete burning, releasing carbon monoxide, oxides of nitrogen and carcinogenic hydrocarbons. Since kerosene, being the domestic fuel for very large poorer section in our society, easily accessible at a price much cheaper than that of petrol and diesel by our government. According to report released by the central pollution control board, Delhi in 2001 our country is losing at least Rs. 10,000 crores annually because of fuel adulteration, but lately, this figure has been estimated over Rs. 30,000 crores which included diversion of PDS kerosene and damages to vehicle. Many previous studies were carried out to determine quality of petroleum fuels.

Now we are looking for a new method in which vibration damping and kinematic viscosity are the factors to determine fuel adulteration. Vibration means periodic motion of particle or a body or a system of connected bodies displaced from a position of equilibrium. Vibration occurs when a system is displaced from a position of stable equilibrium. The system tends to return to this equilibrium position under the action of restoring forces. The system keeps on moving back and forth across its position of equilibrium. A vibratory system basically consists of three elements, namely the mass, spring and damper. In a vibrating body there is exchange of energy from one form to another. Energy is stored by mass in the form of kinetic energy ($\frac{1}{2}mv^2$), in the spring in the form of potential energy ($\frac{1}{2}kx^2$) and dissipated in the damper in the form of heat energy which opposed the motion of the system.

From previous studies, one of well-known technique is fiber optic technique to determine adulteration in petrol. In this method, An LED placed at one end of the fiber produce sufficient radiant energy over the wavelength region where absorption to be measured by considering internal reflection. Optical fiber cladding was removed over a small length. Hence, evanescent wave may able to interact with the measurand, introducing basis for sensing. The light received at the other end of the fiber is converted into a proportional current using a photodiode. It can be observed that the absorbance increases with increase in kerosene adulteration as obtained by AnwerSadat[1]. In another method, the attempt was made to address the problem using concept of kinematic viscosity. The kinematic viscosity different for petroleum fuels even structure may similar. Kinematic viscosity depends on molecular size (length in particular) and magnitude of intermolecular forces as reported by B.P. More., M.K. Malave., and R.B. Toche D.B. Shinde., [2]. Measurement of viscosity and density is one of good method for determining fuel adulteration. But for viscosity testing, we have increase the temperature of fuel which results property change in petroleum fuels was observed by Sh.R. Yadav., K.Murthy., D.Mishra., and B. Baral[3].

A paper by Aradhana Dutta., Bidyut Deka., Partha P Sahu.[4], Evanescent optical waveguide sensor was a new technology to determine fuel adulteration rapidly. Here, using Silicon oxynitride (SiON) as the core layer on silica-silicon wafer incorporating composite planar waveguide geometry and its implementation for rapid detection of adulterant traces in pure petrol, using standard Plasma Enhanced Chemical Vapour Deposition (PECVD) technologies and Reactive Ion Etching (RIE) technique. It is found that the sensor structure is polarization independent and advantages include high sensitivity, easy fabrication and more importantly, requirement of very minimal amount of sample volume for detecting adulteration. Finally, refractive indices of petrol, kerosene and diesel as measured using an Abbe refractometer. There were difference in values of refractive indices of pure and adulterated fuels. As per investigation of R.K.Sharma., Anil Kumar Gupta.[5], using ultrasonic, since kinematic viscosity changes when adulterant adding to fuel, the speed of sound also vary. The speed of ultrasound in non-adulterated and intentionally adulterated gasoline and diesel has been determined using pulse echo method. It was made as a low cost equipment, adulteration results in the change in the measured speed of ultrasound which can be calibrated in terms of percentage adulteration determined by R.K.Sharma., Anil Kumar Gupta[6]. A paper prepared by Mukesh Kumar., Derick Engles., Shivendu Prashar., Amit Singh.[7], use Etched Fiber Bragg Grating (FBG) as chemical sensor to determine fuel adulteration. The performance of the resulting grating is demonstrated by developing a fuel adulteration sensor based on refractive index changes, which can determine fuel adulteration upto 10%.

Anil Kumar Gupta., and R.K. Sharma.[8], presented a short note on ASTM proposed tests for fuel adulteration were (a) Evaporation Test, (b) Distillation Test, (c) Gas Chromatography (GC) is powerful laboratory tool which can be used to detect hydrocarbon based adulterants. Long period fiber grating (LPFG) sensor also used to determine fuel adulteration. Besides offering all advantages of fiber optic sensors, LPFG also offers important key features like wave length coded information, low back reflection, relatively simple and cost effective fabrication, core cladding coupling which makes LPFGs extremely sensitive to variation in refractive index of material surrounding the cladding field is strongly attenuated by it which presented by Vandana Mishra., Subash C Jain., Nahar Singh, G C Poddar., Pawan Kumar[9].

2. Theory

Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. These

motions were opposed by forces like friction, damping, etc. damping influences the system by restricting or preventing its oscillations. In physical systems, damping is produced by processes that dissipate the energy stored in the oscillation. Viscous damping, coulomb damping, and structural damping were common types of damping. Viscous damping was the basic of this paper to determine adulteration of petroleum fuels.

To study the vibration of viscous damped system, the following assumptions are made: (1) The mass is rigid and has no damping, (2) The spring is massless and has no damping (linear elastic), (3) The damper had neither mass nor elasticity. The basic equation can write as:

$$m\ddot{x} + c\dot{x} + kx = 0 \quad (1)$$

Where, $m\ddot{x}$ - inertia force, $c\dot{x}$ - damping force, kx - spring force, 'c' is damping coefficient.

The damping force given by, $F_d = \alpha 2Av$ (2)

From equation (1), $F_d = c\dot{x} = cv$

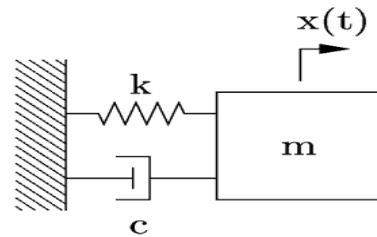
(3)

Comparing both equation (2) and (3) results

$$c = \alpha 2A$$

(4)

where F_d -Damping force, v - velocity of mass



Frequency of undamped vibration

$$f_1 = \frac{\omega_1}{2\pi} = \frac{\omega_n}{2\pi}$$

(5)

Frequency of damped vibration

$$f_2 = \frac{\omega_{d2}}{\pi} = \frac{\omega_n \sqrt{1-\zeta^2}}{2\pi}$$

(6)

Dividing equation (5), (6) and hence solving ζ^2

$$\zeta^2 = 1 - \left(\frac{f_2}{f_1}\right)^2$$

(7)

From another relation, we can form:

$$\zeta = \frac{c}{c_c} = \frac{\alpha 2A}{2\sqrt{km}}$$

(8)

The LHS of both equations (7) and (8) was damping ratio. Hence solving equations to find value of 'α'

$$\alpha = \frac{2\pi f_1 W \sqrt{(f_1^2 - f_2^2)}}{g A f_1}$$

(9)

But frequency, $f = \frac{1}{\tau}$

Hence finally equation can be,

$$\alpha = \frac{2\pi W}{gA\tau_1\tau_2} \sqrt{(\tau_2^2 - \tau_1^2)}$$

(10)

Where, α is constant.

This vibration constant can be related with petroleum fuels by taking as damping fluid. Hence from the above relation we can use this for finding fuel adulteration. For this, we can refer ' α ' as purity index number. ' W ' weight of mass which is oscillating, τ_2 is time required for damped oscillation, τ_1 is time required for free vibration. ' A ' circumferential area of mass, and ' g ' is acceleration due to gravity. When adulterant added to fuel, the kinematic viscosity changes and hence time required for vibration will change (τ_2).

3. Experiment method

3.1. Equipment description

The main elements of experimental setup were,

- (1) Spring- mass system
- (2) A Plastic Container
- (3) A microcontroller circuit with light sensors.
- (4) Excitation rod for giving initial displacement for the mass.



Fig: 3.1 Experimental Setup

The figure shows the experimental setup determining adulteration of fuel using vibration. The experiment placed over a stand to avoid external vibrations. The plastic container carries spring-mass system. The mass kept between infrared light emitter and infrared light receiver sensors. The sensors were provided to measure the time for fixed number of oscillations of vibrating mass inside the container. The light emitted from LED will be cut by the mass during oscillations. Hence the microcontroller executes the program to solve the equation for ' α '.



Fig: 3.2 Mass Samples

Different weighted masses were made for determine influence of mass in value of purity index number.

3.2. Equipment Specification

Diameter of container	= 160mm
Height of container	= 200mm
Length of excitation rod	= 260mm
Weight of masses	= 0.45/0.5/0.55/0.6
Kg	
Diameter of masses	=58/62/66/68 mm
Height of masses	=20/20/20/20 mm

3.3. Sample Preparation

Admixtures of kerosene in diesel, kerosene in petrol, diesel in petrol were prepared in the ratio 10:90 (10%), 15:85 (15%), 20:80 (20%), and 25:75 (25%) for conducting experiment. All samples were of quantity one litre. Pure samples of petrol and diesel took for conducting experiment.

3.4. Procedure

1. Allow the spring-mass system to oscillate inside the container without petrol to determine the time required for ' n ' number of oscillations (undamped system)
2. Pour petrol or diesel without adulterant into container, with mass fully damped inside the fuel sample. Hence determine the time required for ' n ' number of oscillations. (Damped system)
3. Using the formulae determine the purity index number for pure petrol from data available from step 1&2
4. Pour the different samples of fuels, i.e., kerosene mixed with petrol, or diesel mixed with petrol, or kerosene mixed with diesel and each case determine the time required for ' n ' oscillations of spring mass system. (Damped system)
5. Determine purity index number for each case
6. In all the cases excitation is made by pushing the mass to bottom of container

4. Result and Discussion

The method here used for determining petroleum fuel adulteration is a new idea. The factors affecting were kinematic viscosity and vibration damping. Since petrol has less kinematic viscosity compared with kerosene and diesel, the purity index number will increase with adulteration of petrol increases. But kinematic viscosity of diesel is high comparing with kerosene. Hence purity index number of diesel will decrease with increase in adulteration. This adulteration determining technique can be installed at petrol bunks. If the added adulterant has same kinematic viscosity as base fuel this technique cannot be useful.

The time of oscillation of different masses in container without damping were shown in Table:4.1.

Masses, Kg	0.45	0.5	0.55	0.6
Periodic time for '5' number of oscillation ' τ_1 ', sec.	3.3	3.01	2.96	2.8

Table: 4.1 Time required Undamped Vibration

The Table:4.2 shows time required for oscillations under damping and purity index number of different samples, i.e. kerosene in petrol, diesel in petrol. Table:4.3 shows time required for oscillations under damping and purity index number of kerosene in diesel.

Masses, Kg	0.45		0.5		0.55		0.6	
Time, sec /Purity index number	τ_2	α	τ_2	α	τ_2	α	τ_2	α
Pure petrol	3.50	7.35	3.45	12.35	3.38	12.87	3.29	15.70
Adulteration of Kerosene in petrol								
10% kerosene in Petrol	3.54	7.99	3.47	12.57	3.43	13.47	3.35	16.42
15% kerosene in petrol	3.57	8.42	3.51	13.00	3.46	13.81	3.38	16.75
20% kerosene in petrol	3.62	9.07	3.57	13.58	3.49	14.13	3.43	17.27
25% kerosene in petrol	3.65	9.43	3.60	14.12	3.51	14.63	3.47	17.67
Adulteration of diesel in petrol								
10% diesel in petrol	3.55	8.13	3.50	12.89	3.46	13.81	3.38	16.75
15% diesel in petrol	3.59	8.69	3.54	13.68	3.50	14.31	3.41	17.37
20% diesel in petrol	3.64	9.31	3.60	14.12	3.55	14.72	3.48	17.76
25% diesel in petrol	3.67	9.66	3.63	14.29	3.58	15.14	3.51	18.30

Table: 4.2 Purity Index number for different samples of petrol

Masses, Kg	0.45		0.5		0.55		0.6	
Time, sec /Purity index number	τ_2	α	τ_2	α	τ_2	α	τ_2	α
Pure diesel	3.78	10.76	3.75	15.07	3.68	15.84	3.60	18.80
Adulteration of Kerosene in diesel								
10% kerosene in diesel	3.74	10.38	3.72	14.85	3.65	15.60	3.58	18.64
15% kerosene in diesel	3.71	10.08	3.67	14.45	3.62	15.35	3.56	18.47
20% kerosene in diesel	3.68	9.77	3.63	14.12	3.59	15.09	3.54	18.30
25% kerosene in diesel	3.64	9.31	3.60	13.86	3.56	14.81	3.51	18.04

Table: 4.3 Purity Index number for different samples of diesel

The following graphs shows change in purity index number in addition of adulterant with petrol and diesel samples for different sets of oscillating masses.

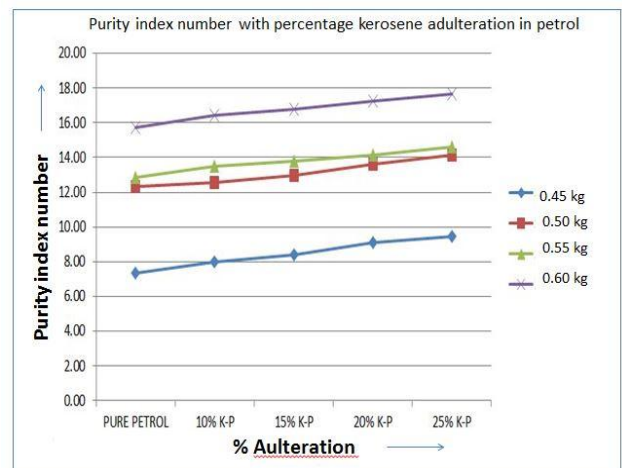


Fig: 4.1 Variation of Purity index number for kerosene adulteration in petrol

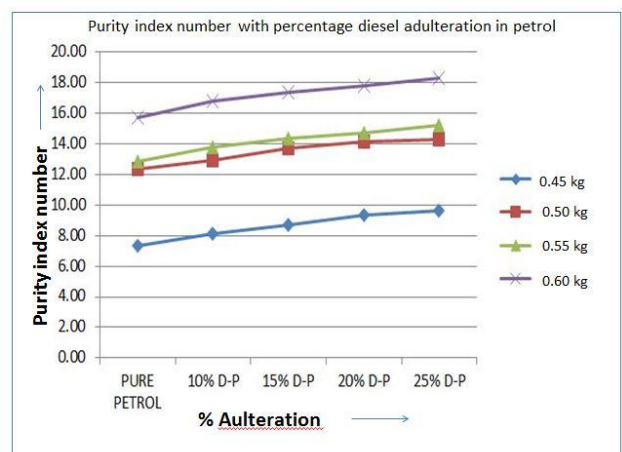


Fig: 4.2 Variation of Purity index number for diesel adulteration in petrol

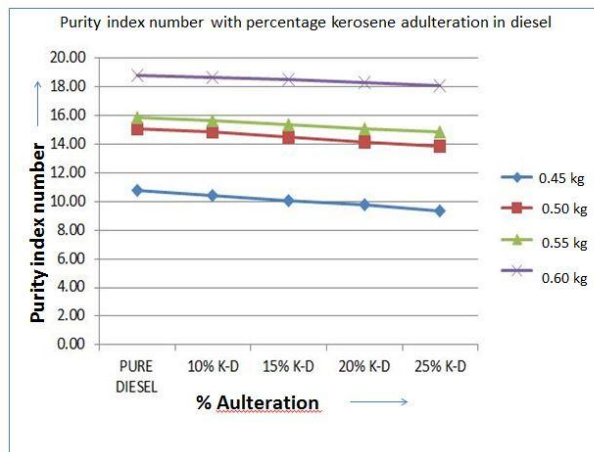


Fig: 4.3 Variation of Purity index number for kerosene adulteration in diesel

From the graphs we can see that purity index number will increase with increase in adulteration of petrol and decrease with increase in adulteration in diesel. The results were satisfied for all masses of the system and almost all results have similar slope for variation in masses. Hence the mass did not affect much for the test experiment.

All samples were tested for viscosity by using Red wood Viscometer at 40⁰C for validation of experimental method. Table:4.4 shows the kinematic viscosity for different samples. At 40⁰C kinematic viscosity of pure Diesel is 2-3 cst and kinematic viscosity of Petrol is 0.5-0.9 cst.

Test Samples	Kinematic viscosity 'v', cst
Pure kerosene	1.103
Pure Petrol	0.735
Adulteration of Kerosene in Petrol	
10% kerosene in Petrol	0.8088
15% kerosene in Petrol	0.882
20% kerosene in Petrol	0.931
25% kerosene in Petrol	1.004
Adulteration of Diesel in Petrol	
10% diesel in Petrol	0.833
15% diesel in Petrol	0.940
20% diesel in Petrol	1.054
25% diesel in Petrol	1.151
Diesel Samples	
Pure Diesel	2.065
Adulteration of Kerosene in Diesel	
10% kerosene in Diesel	1.853
15% kerosene in Diesel	1.715
20% kerosene in Diesel	1.562
25% kerosene in Diesel	1.414

Table: 4.4 Kinematic viscosity of different test samples

5. Conclusion

The setup makes it very easy to determine the quality (purity) of petrol and diesel from kerosene that even a common man feels it easy. Purity index

number is a new term which increases with increase in adulterant in petrol and decreases with increase in adulterant in diesel. The test results were compared with testing same samples in Redwood viscometer. Amount of power required is very small for finding purity index number that makes it use economical and affordable. Cost of making the instrument is very less since it requires only cheap electronic and mechanical parts. The initial excitation should be given manually in the present conditions. The accuracy may be less, since the technique used is purely mechanical. The vibration may cause agitation in the fuel. Any unnecessary jerks may cause vibration in the reading.

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