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Evaluation of Four Stroke Diesel Engine Performance With Ferrocene as Fuel Additive

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ABSTRACT

The main aim of the paper is to evaluate a positive effect of adding the optimal percentage of ferrocene in the diesel. An Anti knocking and soot suppressing property of Ferrocene (Fe(C5H5)2) catalytic action, lightened a method for the manual coke clean up which increase the effective fuel combustion and life time of the combustion parts of the engine without effecting the process but energizing the purpose. Ferrocene is the prototypical metallocene, a type of organometallic chemical compound consisting of two cyclopentadienyl rings bound on opposite sides of a central metal atom. The metastable Ferrocene nucleate enables further burnout of the carbon deposits in the combustion chamber. The performance of the diesel engine is tested and compared with different blends of ferrocene in the diesel. The pinking tendency of the fuel decreases with the addition of aromatic molecules to the fuel. The Experimental results show that the addition of the ferrocene optimal percentage to the fuel will enable to increase the break thermal efficiency, decrease the specific fuel consumption of the engine and pinking tendency.

Index terms: ***Ferrocene, Pinking, Break Thermal Efficiency, Specific fuel consumption.***

I.Introduction

Combustion is the rapid chemical reaction between a combustible substance, the fuel and oxygen. During this process, the chemical energy in the fuel is liberated as heat, which is used to supply the energy necessary to produce work from an engine. The main combustible elements in a fuel are carbon and hydrogen. When there is insufficient oxygen, or inefficient combustion, part of the carbon may combine with oxygen to form carbon monoxide or it may produce carbon deposits in the engine cylinder. Carbon monoxide cause headache, nausea, respiratory problem and carbon deposits tend to accumulate on the surface of the combustion chamber until they reach steady state of thickness which affects compression ratio and combustion chamber heat transfer characteristics. In general the boilers and engines are delivered clean with no soot and slag which is a mixture of solid carbon, ash and molten ash that sticks to the fire side of the chamber and ill effect the process by increasing temperature of the furnace wall, reducing coefficient of heat transfer, increasing exit gas temperature, increasing fans and blowers requirement, high operating and maintenance cost. In order to overcome such an ill effects an organometallic compound ferrocene ($Fe(C_5H_5)_2$) is chosen. It is an organic combustion supporting agent which vaporizes easily under industrial temperature, efficient catalyst, non toxic, non pollutant, stable at high temperatures. These properties made it flexible to use as one of the important fuel additives.

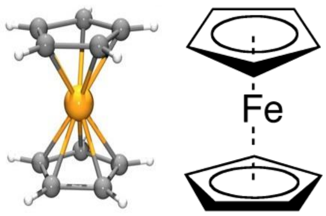

Fig 1: Image of Cyclopentadienyl Iron

II.RELATED WORK:

John J. Kracklauer [1] has observed a method of conditioning diesel engines. The diesel fuel containing dicyclopentadienyl iron thereof for a period of time sufficient to eliminate carbon deposits from the combustion surfaces of the engine and to eliminate carbon deposits from the combustion surfaces of the engine and to deposit a layer of iron oxide on the combustion surfaces, which layer is effective to prevent further buildup of carbon deposits. In Effect of Ferrocene on catalysis combustion [2] experimental results show that ferrocene can increase the combustion rate effectively and reduce kindling temperature by 50^0C. Results [3] obtained with an acetylene diffusion flame show that iron oxide incorporated in the soot particles acts as catalyst to promote soot burnout at the tip of the flame. As per the conclusions the addition of ferrocene to the laminar jet diffusion flame acted as expected by reducing the number and mass of soot particulate. The ferrocene acted as a catalyst in oxidizing the soot and fuel, the more ferrocene added to the flame the more it aided in oxidation to the point that virtually all hydrocarbons and soot had been oxidized.

i) Nucleates before and after soot inception. The catalysis combustion process can be explained as the transition metal ion Fe^{2+} attaches to the surface of the coke particles and the internal surface of the tiny holes at the coke surface, which makes the coke active surface increasing, The transition metal ion Fe^{2+} reacts with the oxygen in the gas flow and forms the meta stable oxidized state. The meta stable oxidized state acts as a oxygen carrier, letting the oxygen travels to the surface of the coke particle by absorption and digression process. The coke particle breaks to nano scale carbon clusters and the coke combustion process can be extremely accelerated and forms CO_2. The deoxidized Fe element reacts with the oxygen in the flew and again repeats the above catalysis process. During this reaction cycle, the transition metal ion Fe^{2+} as the function of oxygen transferring.

$$Fe(tr)L = [Fe(tr)]^+ + L^-$$
$$[Fe(tr)]^+ + O_2 = [Fe(tr)_mO_n]$$

ii)further oxidation of coke/soot [Fe(tr)mOn]- +C(coke/soot) = [CmOn]+ +Fe(tr)
[CmOn]+ + O2 = CO2

iii)Addition of aromatic rings the remained part of ferrocene $(C_2H_5)^-_2$ let the engine to decrease the knocking tendency. Decreasing knocking tendency order is paraffins, napthenes, and aromatic hydrocarbons.

Ignition quality is a measure of the ability of fuel to ignite promptly after injection. A fuel which ignites slowly causes diesel knock. The Chemical structure desired in petroleum fuels for C

I engines is opposite to that of desirable for spark ignition engines. The best fuels for the CI engine are highly paraffinic with average molecular weights greater than those of gasolines. The antiknock quality and ignition quality are opposed to each other. There seems to exist a simple, linear relation between the characteristic numbers, octane number (ON) and cetane number(CN) is given

ON=120-2CN
ON=150-2.5CN

and it varies around 5%. Gasoline has got antiknock qualities, but does not ignite readily. As such, gasoline is not suitable for use in diesel engines. Sharp oscillations of pressure are noted during combustion. With the addition of ferrocene the calculated cetane index is getting decreased with the increase in percentage of ferrocene.

Therefore a number of additives are added to improve its combustion characters prevents engine knocking by increasing octane number, reacts with carbon and sulpher residue and removes from the cylinder, as an antioxidant prevents gum formation, overcomes catalytic effects of dissolved copper, prevents corrosion , impart color for identification.

The addition of ferrocene will increase the combustion rate, decrease the knocking tendency. It is vapourised above 100^0C and hence can be easily added into

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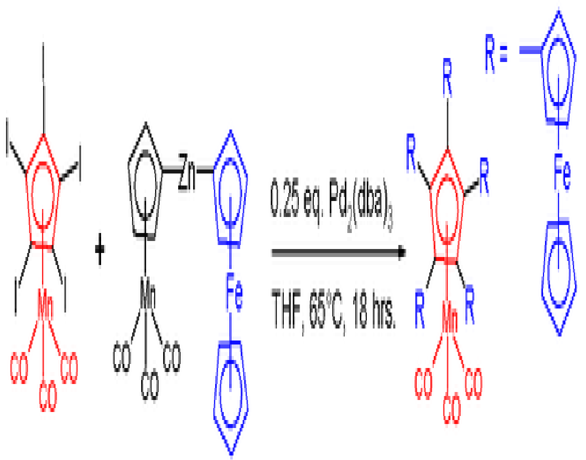
industrial installations. It is one of the most stable stable organic metal complexes at high temperatures, which will not be decomposed till 400^0 C. According to some previous report [2], ferrocene and derivatives are very effective in catalysis of liquid and solid fuel. It is non-toxic, Which is not common in most organic metal complexes. Compared to other organic metal complexes, it is relatively cheaper.

Preparation of Ferrocene

Ferrocene, (C5H5)2Fe, was first discovered in 1951. Until this time organometallic compounds containing Metal-Carbon bonds were restricted to Grignard Reagents (R-MgBr), Zeise's Salt and a few miscellaneous others. Attempting to prepare Fulvalene via a Grignard Reagent, T.J. Kealy and P.L. Paulson formed Dicyclopentadienyl Iron, or Ferrocene, instead:

2 (C5H5)-MgBr + FeCl2 (C5H5)-Fe-(C5H5) + MgBr2 + MgCl2

Ferrocene and it's numerous derivatives have no large-scale applications, but have many niche uses that exploit the unusual structure (ligand scaffolds, pharmaceutical candidates), robustness (anti-knock formulations, precursors to materials), and redox (reagents and redox standards). Ferrocene analogues can be prepared with variants of cyclopentadienyl. For example, bisindenyliron and bisfluorenyliron.



Carbon atoms can be replaced by heteroatom as illustrated by Fe(η5- C5Me5)(η5-P5) and Fe(η5-C5H5)(η5- C4H4N) ("azaferrocene"). Azaferrocene arises from decarbonylation of Fe(η5-C5H5)(CO)2(η1-pyrrole) in cyclohexane. This compound on boiling under reflux in benzene is converted to ferrocene. Because of the ease of substitution, many structurally unusual ferrocene derivatives have been prepared. For example, the penta (ferrocenyl) cyclopentadienyl ligand, features a cyclopentadienyl anion derivatised with five ferrocene substituents.

Fuel additives

Ferrocene and its derivatives are antiknock agents used in the fuel for petrol engines; they are safer than tetraethyllead, previously used. It is possible to buy at Halfords in the UK, a petrol additive solution which contains ferrocene which can be added to unleaded petrol to enable it to be used in vintage cars which were designed to run on leaded petrol. The iron-containing deposits formed from ferrocene can form a conductive coating on the spark plug surfaces.

Iii. Analysis Of Proposed Methodology:

A Kirloskar made single cylinder four stroke diesel engine (5HP, 1500 rpm) was run with different blends of ferrocene from 0% to 3% by weight. The performance of the engine is observed. The calculated Break thermal efficiency, specific fuel consumption and brake power are compared with each blend including diesel.

i) Maximum percentage of solubility diesel.

The weighed in grams, samples of ferrocene are 0.15, 0.20, 0.25, 0.30, 0.40, 0.50 are mixed to 10ml diesel individually. The mixture is stirred and left for a day. It is observed at atmospheric temperature the diesel dissolves till 3% of ferrocene completely, precipitates for 4% and above is observed. Hence the saturated dissolving percentage of ferrocene in diesel is in between 3-4% only.

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Fig 2: Image of Solubility levels of Ferrocene

Fig 3: Image of Saturated dissolving

percentage of Ferrocene in diesel

i) The calorific values for the blends were known for the samples from Lucid Laboratories pvt.Lt d and the Gross calorific values were observed to be decreasing from 1% of ferrocene blend to 3% of ferrocene blend in diesel which does not affect the engine performance.

Fig 4: Tabular form of calorific values for the blends from Lucid

S.No	Test Pattern	Diesel Oil	1%ferrocene	2%ferrocene	3%ferrocene
1	Density at 15°C (g/cc)	0.8264	0.8319	0.8354	0.8387
2	Gross Calorific value (K.cal/Kg)	10430	10190	10060	9950
3	Calculated Cetane Index	55.5	54.0	53.5	52.5

on observing LUCID report there is a slight increase in density , decrease in the gross calorific and calculated cetane index. It indicates clearly that the blends with the higher percentages of ferrocene is not suitable because there is a much decrease in the calorific value that of from diesel.

iii) Experiment is conducted for diesel, 1%, 2% and 3% of ferrocene blends. The Load (KW), speed (rpm), time taken for 10cc of fuel consumption were taken at the variation of the loads from 0 to 10kg and the Break Thermal Efficiency, Specific fuel consumption and break power are calculated and tabled.

1) $BP = \frac{2*3.14*N*w*(D+d)/2}{60000}$

D= dia of break drum=0.246m
d= dia of rope =0.02m
W= 9.81*mass
N=speed (rpm)

2) SFC= Mfc/BP

3) Break thermal efficiency= BP/heat input

IV.Results and Discussion

i) Break Power (KW) Vs Load (Kg)
The break power of the diesel and 1%ferrocene blend are competitive whereas that of 2 and 3% are having lower power because the calorific value of the

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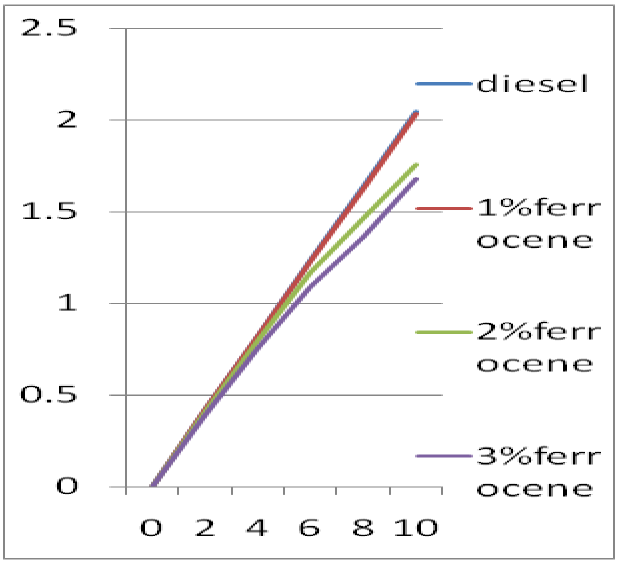
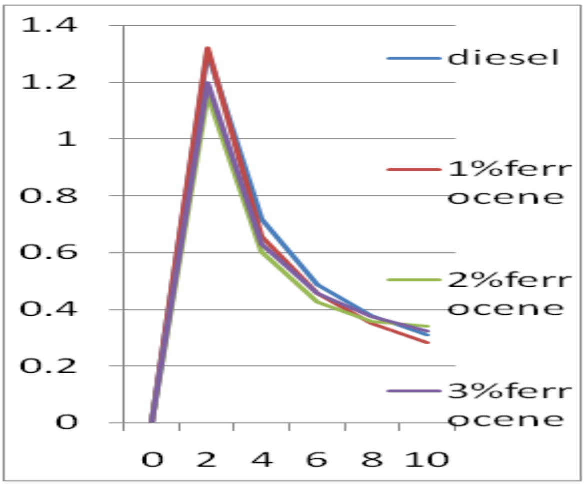
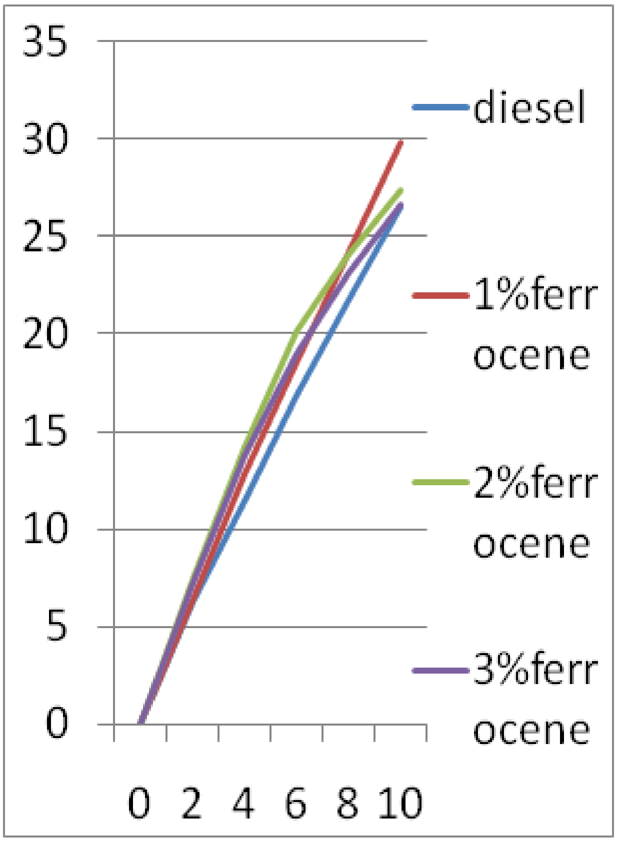
ferrocene blended diesel are decreasing with the increase in ferrocene percentage. And Calculated Cetane Index is also decreasing indicating decrease in ignition quality. As a result 1% ferrocene blend is better and suggestible for use.



ii) SFC-Specific fuel consumption (Kg/Kw-hr) Vs Load(Kg). The order of decreasing specific fuel consumption is observed to be 2%,3%,diesel,1%ferrocene. Due to the catalytic action of Iron oxide improves the effective fuel combustion. But in the case of 2 and 3% blends is having high SFC because the calorific value of the fuel is low that of from diesel. The cetane index is also low which decrease the Ignition Quality of the fuel.



iii)Break Thermal Efficiency Vs Load(Kg) The Break thermal efficiency of 1%ferrocene blend got the highest value near to 30% followed by 2% ,3% blends and diesel. And the input power follows the reverse order.



V.Conclusion

The existing "EVALUATION OF FOUR STROKE DIESEL ENGINE PERFORMANCE WITH FERROCENE AS FUEL ADDITIVE" presented an experimental results and discussions that there is a positive effect of adding the optimal percentage of ferrocene in the diesel. For 1% ferrocene blended diesel has more thermal efficiency(29.77%) and the specific fuel consumption is lower compared to other is 0.283 Kg/KW-hr. Therefore the optimal percentage is in between 1% to 2% that is 10ppm to 20ppm of ferrocene in the fuel. Not only it improves the effective fuel combustion but also decreases the knocking tendency due to the presence of aromatic molecules. The knocking tendency decreases with the increase in the ferrocene percentage. The Break Themal efficiency improves and the specific fuel consumption decrease.

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