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Thermal Load Effect on Bimetal Valve by Using Conventional and Blended Fuels

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Abstract: ***The valves used in the IC engines are of three types: Poppet or mushroom valve or Sleeve valve or Rotary valve. Of these three types, Poppet valve is most commonly used. Since both the inlet and exhaust valves are subjected to high temperatures of 1930°C to 2200°C during the power stroke, therefore, it is necessary that the materials of the valves should withstand these temperatures. The temperature at the inlet valve is less compared to exhaust valve. Thus the inlet valve is generally made of nickel chromium alloy steel and exhaust valve is made of silchrome steel. Automobile engines are usually petrol, diesel or gasoline engines. Petrol engines are Spark Ignition engines and diesel engines are Compression Ignition engines. Blended fuels are mixtures of traditional and alternative fuels in varying percentages. In this thesis, the effect of, diesel and blended fuels on valve is studied by mathematical correlations applying thermal loads produced during combustion. Blended fuels are usually Ethanol fuels blended in different percentages. Percentages vary from 5%, 12% and 18%. Internal combustion engines produce exhaust gases at extremely high temperatures and pressures. As these hot gases pass through the exhaust valve, temperatures of the valve, valve seat, and stem increase. To avoid any damage to the exhaust valve assembly, heat is transferred from the exhaust valve through different parts, especially the valve seat insert during the opening and closing cycle as they come into contact with each other. In this thesis, a finite-element method is used for modeling the thermal analysis of an exhaust valve. The temperature distribution and resultant thermal stresses are evaluated. Detailed analyses are performed to estimate the boundary conditions of an internal combustion engine. In this thesis, Pro/Engineer is employed for modeling and Ansys is used for analysis of the exhaust valve.***

Keywords: Rotary valve. inlet valve, exhaust valve, Blended fuels

1. Introduction

Normally a fossil fuel occurs with an oxidizer (usually air) in a chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine (ICE) the expansion of the high-temperature and high-pressure gases produced by combustion apply direct force to some component of the engine. The force is applied typically to pistons, turbine blades, or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy. The first commercially successful internal combustion engine was created by Etienne Lenoir. The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar four and two-stroke piston engines, along with variants, such as the six-stroke piston engine and the Winkle rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same principle as previously described. The ICE is quite different from external combustion engines, such as steam or Stirling engines, in which the energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products. Working fluids can be air, hot water, pressurized or even liquid sodium, heated in some kind of boiler. ICEs are usually powered by energy-dense fuels such as gasoline or diesel, liquids derived from fossil fuels. While there are many stationary applications, most ICEs are used in mobile applications and are the dominant power supply for cars, aircraft, and boats.

2. Literature Review

Many Numerical and experimental investigations were presented with regard to homogeneous- charge compression-ignition for different fuels. In one of the dual fuel approach, N-heptane and n-butane were considered for covering an appropriate range of ignition behavior typical for higher hydrocarbons[Barroso.G et,al.,2005].Starting from detailed chemical mechanisms for both fuels, reaction path analysis was used to derive reduced mechanisms, which were validated in homogeneous reactors and showed a good agreement with the detailed mechanism. The reduced chemistry was coupled with multi zone models (reactors network) and 3D-CFD through the Conditional Moment Closure (CMC) approach. In 2002 a study introduces a modeling approach for investigating the effects of valve events In a model based control strategy, to adapt the injection settings according to the air path dynamics on a Diesel HCCI engine, researcher complements existing air path and fuel path controllers, and aims at accurately controlling the start of combustion [M.Hillion et,al,2011]. For that purpose, start of injection is adjusted based on a Knock Integral Model and intake manifold conditions Experimental results were presented, which stress the relevance of the approach.

It is investigated; Mahua Oil Biodiesel (MOB) and its blend with diesel were used as fuel in a single cylinder, direct injection and compression ignition engine [07]. The MOB was prepared from MO by transesterification using methanol and potassium hydroxide. The fuel properties of MOB are close to the diesel and confirm to the ASTM standards. From the engine test analysis, it was observed that the MOB, B5 and B20 blend results in lower CO, HC and smoke emissions as compared to diesel. But the B5 and B20 blends results in higher efficiency as compared to MOB. Hence MOB or blends of MOB and diesel (B5 or B20) can be used as a substitute for diesel in diesel engines used in transportation as well as in the agriculture sector. The biodiesel was produced from MO by transesterification. The fuel properties of MOB are closer to the diesel and satisfy the American, European, German, Austria and Sweden standards. When MOB was used as sole fuel in diesel engine, it results in lower thermal efficiency due to its higher viscosity and poor volatility. But it results in lower CO, HC and smoke emission. The B5 and B20 blends results in higher thermal efficiency and higher exhaust emissions as compared to the MOB. The B5 blend results in higher efficiency than the B20 blend. Based on the engine tests, it can be concluded that the MOB or its blends can be adopted as an alternative fuel for application in agricultural diesel engine as a renewable fuel replacement for diesel. Use of MOB as fuel in agricultural diesel engine will improve rural economy, sustainability and increase the environmental benefits of India.

Author has carried an experimental investigation on the application of the blends of ethanol with diesel to a diesel engine [03]. First, the solubility of ethanol and diesel was conducted with and without the additive of normal butanol (n-butanol). Furthermore, experimental tests were carried out to study the performance and emissions of the engine fuelled with the blends compared with those fuelled by diesel. The test results show that it is feasible and applicable for the blends with n-butanol to replace pure diesel as the fuel for diesel engine; the thermal efficiencies of the engine fuelled by the blends were comparable with that fuelled by diesel, with some increase of fuel consumptions, which is due to the lower heating value of ethanol. The characteristics of the emissions were also studied. Fuelled by the blends, it is found that the smoke emissions from the engine fuelled by the blends were all lower than that fuelled by diesel; the carbon monoxide (CO) were reduced when the engine ran at and above its half loads, but were increased at low loads and low speed; the hydrocarbon (HC) emissions were all higher except for the top loads at high speed; the nitrogen oxides (NOx) emissions were different for different speeds, loads and blends. Ethanol cannot be blended with diesel without the assistance of additive such as normal butanol. With the blends tested, the blends of 10%, 20%, 25% and 30% ethanol (by volume) with diesel were all separated into two layers; when 5% butanol were added into the above blends, they were all lasted longer and no less than 11 days without the phase separation problem. Further investigations are recommended to find out the optimized percentage of the additive to the blends to solve the problem of the stability. For example, 8% or 10% solvent addition may be used for further tests. The study showed that the n-butanol is a good additive for mixing diesel with ethanol, although the price of nbutanol was higher than that of diesel when the tests were carrying on. From long term point of view, fossil fuels including diesel will be less and less due to the limited sources; more and more biofuels will be used gradually as the alternatives to replace the fossil fuels. It might not be economical to use n-butanol today but it would be in the future. The fuel consumptions of the engine fuelled by the blends were higher compared with those fuelled by pure diesel. The more ethanol was added in, the higher fuel consumptions were. The differences were from 5.2% to 31.5% for different blends at different loads and speeds. The thermal efficiencies of the engine fuelled by the blends were comparable with those fuelled by pure diesel, with some extent increases or decreases at different loads and speeds. The carbon monoxide (CO) emissions from the engine fuelled by the blends were divided into two parts: when the engine ran above half loads, the CO emissions from the engine fuelled by the blends were lower than those fuelled by diesel; when the engine ran under half loads, the CO emissions of blends were higher than those of diesel. The unburned Hydrocarbon (HC) emissions from the engine fuelled by the blends were all higher when the engine ran at the speed of 1500 r/min; but the HC emissions became less as the loads increased. Similar results can be seen for 2000 r/min,

Except for the point of top power output, which shows lower HC emissions from the blends.The nitrogen oxides (NOx) emissions from the engine were reduced at the low speed of the engine fuelled by the blends; the NOx emissions were decreased for the blends of Z5E20D75, Z5E25D70 and Z5E30D65 at 1500 r/min. But at the high speed of 2000 r/min, the NOx emissions were increased or decreased some extent, there was not a stable trend for the NOx emissions. The smoke emissions from the engine fuelled by the blends were all lower than that fuelled by diesel; the reductions are from 16.7% to 87.5%.

A study introduced in 2002 which introduced a modeling approach for investigating the effects of valve events HCCI engine simulation and gas exchange processes in the framework of a full-cycle HCCI engine simulation [Aristotelis Babajimopoulos et al., 2002]. A multi-dimensional fluid mechanics code, KIVA-3V, was used to simulate exhaust, intake and compression up to a transition point, before which chemical reactions become important. The results are then used to initialize the zones of a multi-zone, thermo-kinetic code, which computes the combustion event and part of the expansion. After the description and the validation of the model against experimental data, the Application of the method was illustrated in the context of variable valve actuation. It has been shown that early exhaust valve closing, accompanied by late intake valve opening, has the potential to provide effective control of HCCI combustion. With appropriate extensions, that modeling approach can account for mixture in homogeneities in both temperature and composition, resulting from gas exchange, heat transfer and insufficient mixing.

Present-day gasoline fuel as such cannot obtain the potential advantages of lean combustion because of the rapid decrease in flame speed with leaner mixtures and its narrow flammability limits. Methanol has been found to be a more suitable fuel, with relatively good lean combustion characteristics, compared to gasoline and other hydrocarbon fuels. There has been sufficient evidence katoh et al [05] to show that methanol has wider flammability limits and higher flame speed sunder lean conditions than doe's gasoline. Nevertheless, many technical difficulties associated with the use of methanol for commercial application in vehicles are yet to be overcome. Until then, these of gasoline-methanol blends are one alternative available for immediate use. such blends have improved octane quality, lean limits, knock-limited compression ratio, thermal efficiency, power output, and no, emissions. However, some undesirable effects result from blending methanol into gasoline, namely phase-separation, increased vapor pressure, and emissions of unburned methanol, particularly at higher methanol concentrations. Besides methanol and ethanol, some reports talked et al [23] suggest that eucalyptus oil and orange oil possess high octane values and are also good potential alternative fuels for si engines. Eucalyptus oil is extracted from eucalyptus leaves. The main ingredient is 1.8 cineol (c10h18o). Orange oil can be extracted from the peel of orange fruits. The main ingredient of orange oil is limonene (c10hi6).the high octane values of eucalyptus and orange oils increase the octane value of the blend when added to low-octane gasoline. Their physical and chemical properties are similar, and they are easily miscible with gasoline. Eucalyptus oil is also an effective co-solvent to minimize the phase-separation problems of alcohol-gasoline blends

Simulations of combustion of direct injection gasoline sprays in a conventional diesel engine were presented and emissions of gasoline fueled engine operation were compared with those of diesel fuel [Young chul R et, al., 2012]. A multi-dimensional CFD code, KIVA-ERC-Chemkin, that is coupled with Engine Research Center (ERC)-developed sub-models and the Chemkin library, was employed. The oxidation chemistry of the fuels was calculated using a reduced mechanism for primary reference fuel, which was developed at the ERC. The results show that the combustion behavior of DI gasoline sprays and their emission characteristics are successfully predicted and are in good agreement with available experimental measurements for a range of operating conditions. It is seen that gasoline has much longer ignition delay than diesel for the same combustion phasing, thus NOx and particulate emissions are significantly reduced compared to the corresponding diesel cases. The results of parametric study indicate that expansion of the operating conditions of DI compression ignition combustion is possible. Further investigation of gasoline application to compression ignition engines is recommended.

Author [07] conducted an experimental study on the performance and exhaust emissions of a turbocharged indirect injection diesel engine fuelled with tobacco seed oil methyl ester, which was performed at full and partial loads. the results showed that the addition of tobacco seed oil methyl ester to diesel fuel reduced co and so2 emissions while causing slightly higher nox emissions. Mean while, it was found that the power and the efficiency increased slightly with the addition of tobacco seed oil methyl ester

Author [08] used diesel, bio-diesel mixed with diesel used in diesel engine for the investigation of combustion and emission parameters. it was observed that biodiesel blends with diesel showed lower co, smoke and increase nox emissions. nox emission is to be reduced slightly whenever egr was applied.

Author [09] studied the combustion and emissions characteristics of a four-cylinder turbocharged di diesel engine using soyabean oil and diesel. it was observed that biodiesel reduced pm, co, and unburned hc emissions and slight increase in nox. The engine does not require any modifications.

Authors [10] conducted an experimental work using biodiesel as an alternate fuel in diesel engine. the experimental results showed that the o/w/o emulsion had the lowest carbon dioxide (co2) emissions, exhaust gas temperature, and heating value, and the largest brake specific fuel consumption, fuel consumption rate, and kinematic viscosity of four tested fuels. The increase of engine speed caused the increase of equivalence ratio, exhaust gas temperature, co2 emissions, fuel consumption rate, brake specific fuel consumption, but a decrease of nox emissions. Mo reover, the existence of aqueous ammonia in the o/w/o biodiesel emulsion curtailed nox formation, thus resulting in the lowest nox emissions among the four tested fuels in burning the o/w/o biodiesel emulsion that contained aqueous ammonia.

Authors [11] reported that hc emissions reduced with the biodiesel application. Hot MME (mahua methyl ester) injected entailed lesser heat transfer from the compressed air mass after injection resulting in more co formation. Second reason could be assigned to higher specific gravity of the mme oil. Shorter ignition delay period at full load in the case of MME and MME 55 entailed lower no emissions. MME 55 possesses lower density because of which the injection distance gets reduced and lesser air entrainment in the premixed combustion period. This may lead to more smoke formation. Lower spectrum average levels in the case of the MME indicated smoother combustion than the baseline oil. MME 55, it may be recommended as a viable non edible oil alternative to the diesel fuel because of low injection problems and low emissions. Preheating of the ester was recommended in the context of several advantages enumerated above.

Authors [12] showed the test results indicating that the performance of 30 % orange oil blends was much better than 10 % and 50 % orange oil blends and diesel. The specific fuel consumption was increased with the increase in orange oil blends due to lower calorific value of orange oil. The emissions of hydrocarbon (hc), carbon monoxide (co) and smoke were reduced but nitric oxide (nox) increased compared to diesel. it was concluded from the results of the experimental investigation that 30 % orange oil blends could be used as diesel fuel substitute in diesel engine.

Authors [13] used coconut oil. The results were compared with diesel fuel baseline data. the effect of injection pressure on the performance and emission characteristics of biodiesel blends of b20, b30 and b100 at four different injection pressures of 180, 200, 220 and 160 bar were studied. From the investigations it was found that 200 bar was the optimum injection pressure with b20 and b30 blends, which resulted in better performance and emission characteristics with biodiesel blends as fuel.

Author [14] investigated the effect of karanja methyl ester and its blends on a single cylinder direct injection diesel engine. it was found that karanja methyl ester with diesel up to 40% by volume could replace diesel for running the engine without sacrificing the power output. Reduced co, smoke, nox was 80%, 50%, 26% respectively compared to diesel.

Authors [15] main objective of the work was to study the effect of bio diesel blends on particulate emissions, measured in terms of mass, optical effect (smoke opacity) and size distributions. a sharp decrease was observed in both smoke and particulate matter emissions as the bio diesel concentration was increased. the mean particle size was also reduced with the bio diesel concentration, but no significant increases were found in the range of the smallest particles. No important differences in emissions were found between the two tested bio diesel fuels.

Authors [16] in this study, usage of methyl ester obtained from waste frying oil (wfo) are examined as an experimental material. a reactor was designed and installed for production of methyl ester from this kind of oil. Physical and chemical properties of methyl ester were determined in the laboratory. The methyl ester was tested in a diesel engine with turbocharged, four cylinders and direct injection. Gathered results were compared with no. 2 diesel fuel. Engine tests results obtained with the aim of comparison from the measures of torque, power; specific fuel consumptions are nearly the same. in addition, amount of emission such as co, co2, nox, and smoke darkness of waste frying oils are less than no. 2 diesel fuel.

Authors [17] of this paper presents the results of investigations carried out on a single cylinder, four-stroke, direct-injection, ci engine operated with methyl esters of honge oil, jatropha oil and sesame oil. Bio diesel can be used in its pure form or can be blended with diesel to form different blends. It can be used in ci engines with very little or no engine modifications. Engine performance in terms of higher brake thermal efficiency and lower emissions (hc, co, nox) with sesame oil methyl ester operation was observed compared to methyl esters of honge and jatropha oil operation.

Author [18] in this study the performance, emission and economic evaluation of using the clove stem oil (cso)–diesel blended fuels as alternative fuels for diesel engine have been carried out. Experiments were performed to evaluate the impact of the cso–diesel blended fuels on the engine performance and emissions. The societal life cycle cost (lcc) was chosen as an important indicator for comparing alternative fuel operating modes. The lcc using the pure diesel fuel, 25% cso and 50% cso–diesel blended fuels in diesel engine are analysed. Emissions of co and hc are low for the cso–diesel blended fuels. nox emissions were increased remarkably when the engine was fuelled with the 50% cso–diesel blended fuel operation mode.

3. Theoretical Calculations

3.1 Renault Duster

The Duster is an entry level SUV from Renault that seeks to revolutionize the segment. The Duster comes equipped with a choice of petrol and diesel engines, decent fit and finish and good ride quality, on and off the road.

3.2 Technical Specifications Of Rx E Diesel 85 Ps

- **Engine Type K9K Diesel Engine**

Engine Description :1.5-litre 83.8bhp 4Cylinder K9K Diesel Engine
Displacement (cc) : 1948cc
Power (PS@rpm) :83.8bhp@3750rpm
Torque (Nm@rpm) :200Nm@1900rpm
No. of Cylinders : 4
Valves per Cylinder : 4
Fuel Type : Diesel
Fuel System : CRDI
Turbo Charger : Yes

- **Transmission**

Transmission Type : Manual
Gears : 5
Gear Box Type : 5 Speeds
Drive Type : FWD

- **Fuel Economy**

Mileage Highway (km/liter) :20.46
Mileage City (km/liter) :18.0

- **Dimensions and Weights**

Overall Length (mm) : 4315
Overall Width (mm) :1822
Overall Height (mm) :1695
Wheel Base (mm) :2673
Ground Clearance (mm) :205
Front Track (mm) :1560
Rear Track (mm) :1567
Gross Vehicle Weight (kg) :1758
No of Doors : 5

- **Capacities**
- **Suspensions**

Front Suspension : : Independent McPherson Strut with Coil Springs & Anti-Roll Bar
Rear Suspension: Torsion Beam Axle with Coil Springs & Anti Roll Bar

- **Steering**

Steering Type : Power
Power Assisted Steering : Electro Hydraulic Power Assisted
Minimum Turning Radius (meter):5.2

- **Brakes**

Front Brakes : Ventilated Disc
Rear Brakes : Drum

- Wheels and Tires

Wheel Type	: Alloy
Wheel Size	: R16
Tire Type	: Tubeless Tires
Tire Size	: 215/65 R16

Power (W) =83.8hp
=83.8"×" 746=62514.8W
Displacement (V d) =1948cc
=1.948×〖10〗^(-3) m^3
Speed (N) =3750 rpm
Capacity=1.5L
=1.5/1000=1.5〖×10〗^(-3) m^3
Density of Diesel = 821.31Kg/m3
Mass =Volume* Density =1.948×〖10〗^(-3)×821.31=1.5kg
Molecular mass (m) =223gr/mol
P b mean = (n W)/(Vd N)
=(2"×"62514.8)/(1.948×〖10〗^(-3)"×"750/60)
=1026937.166N/m^2
P b mean=break mean effective pressure in N/m^2
n= no. of power cycles
N=speed in rev/sec
V d= Displacement in m^3
PV=MRT
T=PV/MR (From Universal Gas Constant Equation)
V=induced volume= (capacity* speed)/2
=1.948〖×10〗^(-3)*(3750/60×2)
=0.060875m^3/sec
T= temperature in Kelvin
M =mass
R = universal gas constant = 8.314 J/K mol
T= (1026937.166×0.060875)/(1.5/0.223×8.314)
=1117.8574 K

3.3 Blended Fuels

Molecular weight of oxygenated blended fuel = 292.2g/mol
Oxygenated=5% Diesel =95%
Md=1.5×95/100 =1.425 Kg
Mo=1.5×5/100=0.075Kg
T=PV/MR=(1026937.166×0.060875)/((1.425/0.223+0.075/0.292)×8.314)
=1131.47 K

Oxygenated =12% Diesel =88%
Md=1.5×88/100=1.32kg
Mo=1.5×12/100=0.18kg
T=PV/MR
=(1026937.166×0.0608)/((1.32/0.223+(0.18)/(0.292))×8.314)
=1149.063K
Oxygenated =18% Diesel =82%
Md=1.5×82/100=1.23kg
Mo=1.5×18/100=0.27kg
T=PV/MR
=(1026937.166×0.060875)/((1.23/0.223+(0.27)/(0.292))×8.314)
= 1166.07 K

3.4 Design Calculations of Exhaust Valve

Design Of Exhaust Valve

a) Size of valve port

a_p*v_p=aV
V = 90m/s = 90000mm/s
a_p= 2550.465X7325/90000=207.579mm
a_p=π/4(〖(d_p)〗^2〖(d_p)〗^2=(207.579×4)/π=163.032
d_p=12.768mm

b) Thickness of valve disc

t = $Kd_p \sqrt{(p/\sigma_b)}$
t = 0.42×12.768√(0.27/100)=0.2784mm

c) Maximum lift of the valve

h = lift of the valve
h =d_p/(4cosα)=12.768/4cos(30^0) =12.768/3.46=3.683mm

d) Valve steam diameter

d_s=12.768/8+6.35 or
ds=1.596+6.35
ds=7.946 mm
tanα=(2(h+t))/((d_v/2))= (2(h+t))/d_v
tan〖30=(4(3.683+0.2784))/d_v〗
d_v=15.8456/tan30=27.462mm

4. Thermal Analysis of Valve with Two Materials

4.1 Valve Seat – En52 Steel

Density = 7860Kg/m 3
Young's modulus =215Gpa
Poisson's ratio= 0.3
Thermal conductivity =30 W/m-K
Specific heat = 506 J/Kg-K

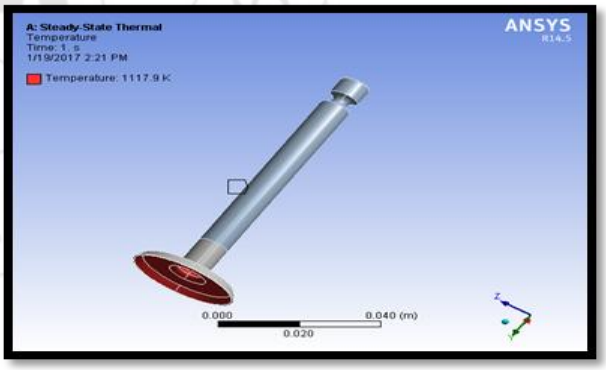

Figure 1: Temperature Analysis

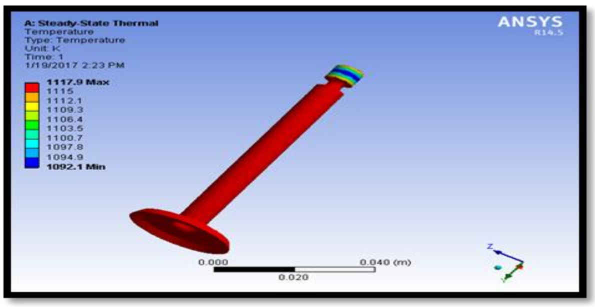

Figure 2: Temperature Analysis

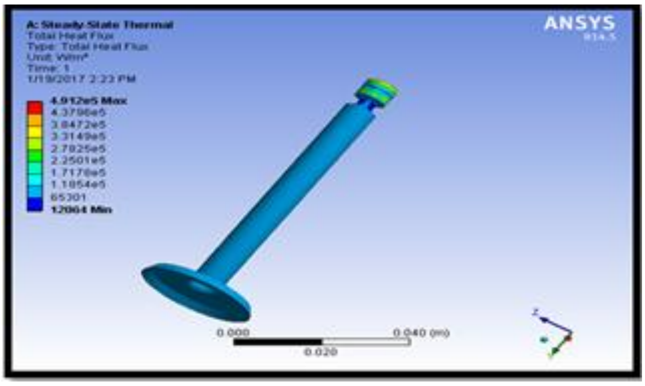

Figure 3: Heat flux Analysis

4.2 Blended Fuel – Diesel – 95% & Oxygenated Biodiesel-5%

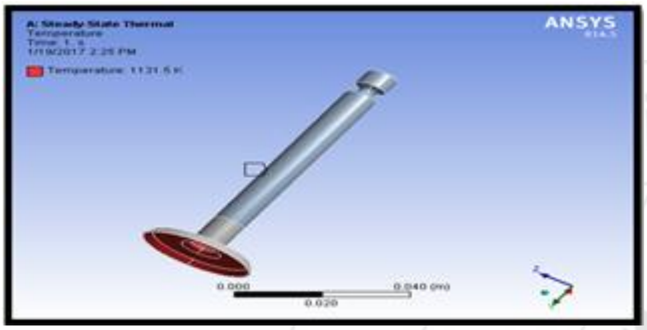

Figure 4: Temperature Analysis

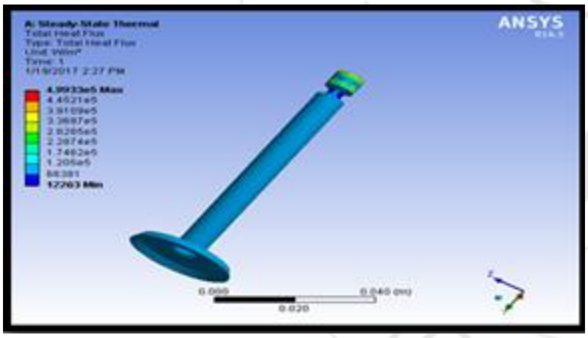

Figure 5: Heat flux Analysis

5. Thermal Analysis With Two Materials

Diesel – % Oxygenated Biodiesel – %	Temperature (K)	Heat flux (W/m2)
Diesel-100%	1117.9	4.912e5
Diesel-95% &Oxygenated biodiesel-5%	1131.1	4.9933e5
Diesel-95% &Oxygenated biodiesel-5%	1149.1	5.0983e5
Diesel-95% &Oxygenated biodiesel-5%	1166.1	5.1998e5

5.1 Graphs

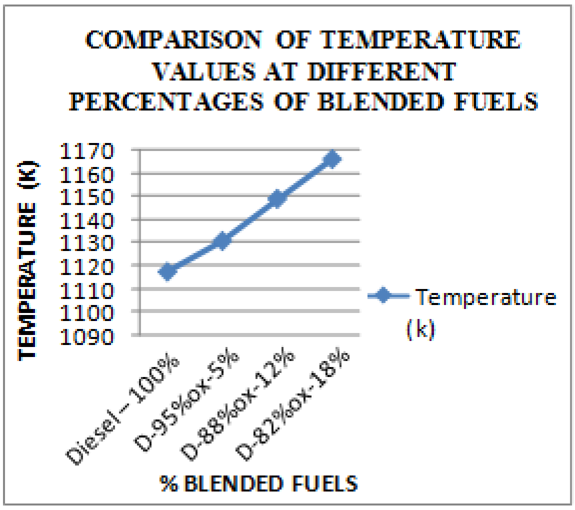

Figure 6: Graph

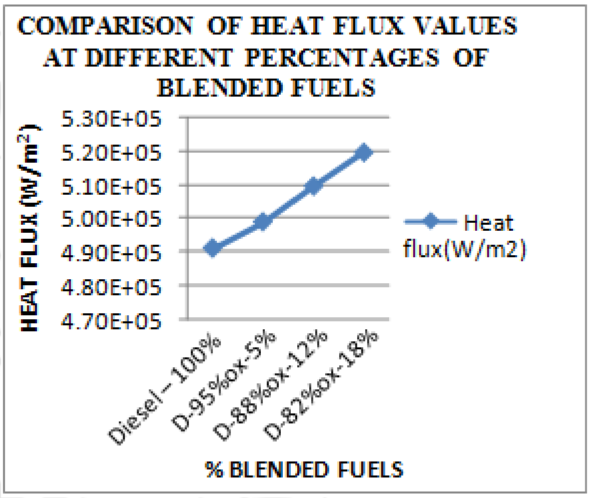

Figure 7: Graph

6. Conclusion

In this thesis, the effect of diesel and blended fuels on exhaust valve is studied by mathematical correlations to calculate thermal loads produced during combustion. Fuels considered are Diesel and Blended fuels. Blended fuels are usually Ethanol fuels blended in different percentages. Percentages vary from 5%, 12% and 18%. Theoretical calculations are done to calculate the temperature produced for combustion when fuel is changed. Thermal analysis is done on the valve applying temperature by changing the fuels used for combustion. The cases considered are Diesel, Diesel + 5% Ethanol, Diesel + 12% Ethanol, Diesel + 18% Ethanol. Thermal analysis is performed on the valve by applying the temperatures on the valve. The materials considered are by taking Austenitic Stainless Steel for valve tip and EN52 Steel for valve seat. By observing the analysis results, the heat flux is increasing by increasing the percentage of ethanol to the diesel. (i.e) the heat transfer rate is more when the percentage of ethanol blended with diesel is more. The heat flux value is more when compared with 100% diesel, by about 1.628% when 5% ethanol is blended with diesel, by about 3.65% when 12% ethanol is blended with diesel and by about 1.628% when 5% ethanol is blended with diesel, by about 5.53% when 12% ethanol is blended with diesel.

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