iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** VII **Month of publication:** July 2017

DOI:

www.ijraset.com

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Numerical Modeling and Comparative Analysis with Experimental Study of Four Stoke CI Engine using Preheated Neem Bio Diesel

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Abstract: Compression ignition engines are used in many areas to support the logistical activities associated with industry. Diesel powered locomotives and heavy-duty trucks move unprocessed commodities, chemicals, intermediate materials between manufacturing processes, and finished goods to the places in which they are all needed. Diesel also plays a considerable role mitigating the problems of waste management. Heavy mobile equipment moves wastes such as plastics, metals, and wastes to large bailing and compacting machines and other processing equipment. Different type of fuels are used for many applications in industry especially the alternate fuels are more popular now a days because they are cheaper and easily available as compare to conventional fuels. Maximum EGT is reached at brake power of 25.42 kW for all fuels. In experimental results the Maximum EGT found with highest preheating temp. (105 °C) is 425 °C, 414 °C, 420 °C and 434 °C for diesel, B20, B40 and B100 fuels respectively.B20, B40 and B100 fuel with different preheating temperature show reduction in exhaust gas temperature by 2.5%, 1.1% and 1.8% respectively compared to diesel fuel. CFD simulation results show excellent comparison with experimental Results which are the motive main goal of the present work.
Kew words: CFD, Alternate fuels, Bio diesel, Neem oil, CI Engine, Ansys (Fluent)

I. INTRODUCTION

An enormous increase in the number of automobiles in recent years has resulted in greater demand for petroleum products. With crude oil reserves estimated to ast only for a few decades, therefore efforts are made on way to research on alternative to diesel. Depletion of crude oil would cause a major impact on the transport sector. Fossil fuels play the significant role in development of country. Continuous supply of fuel with increasing rate should be ensured to sustain and further development of country. Recently, significant problems associated with fossil fuel like short supply, drastically increasing price, non-renewability, contamination of environment, adverse effect on bio systems compiles researcher to search for an alternative fuel, which promises a harmonious correlation with sustainable development, energy conservation, management, efficiency, and environmental preservation has become highly pronounced in the present context. Energy conservation is important for most of the developing countries, including rest of world. The rapid depletion in petroleum reserves and uncertainty in petroleum supply due to political and economic reasons, as well as, the sharp escalations in the petroleum prices have stimulated in search for alternatives to petroleum fuels. The situation is very grave in developing countries like India which import 70% of the required fuel, spending 30% of her total foreign exchange on oil imports.[1] In view of this, researcher found and analyze many energy sources like CNG, LNG, LPG, ethanol, methanol, hydrogen, bio-diesel and many more. Among these alternative fuels, India is having significant scope for development of bio fuel. Diesel engines are major source of transportation, power generation, marine application, agriculture vehicles etc. Bio-diesel is widely accepted as comparable fuel to diesel in compression ignition engine. It offers advantages like higher certain number, reduced emissions of particulates. Moreover, transportation and agriculture sector depends on diesel fuel therefore, it is essential that alternatives to diesel fuels must be developed. In the view of these, vegetable oils like palm oil, cotton seed oil, Neem oil, panama oil are considered as alternative fuels to diesel which are promising alternatives.

A. Alternative Fuels

Compressed Natural Gas: Natural gas is a mixture of hydrocarbons-mainly methane and is produced either from gas wells or in conjunction with crude oil production. Due to its lower energy density, for use as a vehicular fuel, it is compressed to a pressure of 200 to 250 bar to facilitate storage in cylinders mounted in vehicle and so it is called Compressed Natural Gas. [1] Gross production of natural gas in India at 47.51 billion cubic meters' during 2009-10 is 44.63% higher than the production of 32.85 billion cubic meters' during 2008-09. India has total reserves (proved & indicated) of 1437 billion cubic meters' of natural gas as on 1.4.2010 This enormous reserve of natural gas makes it a long-term substitute fuel for use in petrol & diesel engines. Low exhaust emissions, low noise, less maintenance, not prone to adulteration, driver's comfort etc. are some of the attractive features of CNG as an automotive fuel. CNG is used in automobile as bio fuel in case of a gasoline engine and dual or single fuel mode with diesel engine with addition of gas kit to the current engine technology. CNG is widely accepted by vehicle owner as alternative fuel because of low prices, low exhaust emission, low noise, less maintenance and less modification cost of vehicle throughout the world. In spite of these advantages, in India its utilization is limited to very few cities (mainly metro or mega) due to problems of infrastructure, onboard storage & issues on safety.

Liquefied Natural Gas**:** LNG is a hydrocarbon mixture contains mainly methane, ethane, propane, butane and pentane. LNG is produced by cooling natural gas to its boiling temperature of -161.5˚C to eliminate low calorific value, storage and safety problem of natural gas. Very high volumes of natural gas can be transported from one country to another (long distance) with low cost in form of LNG. Scarcity of LNG and complication associated to produce and stores LNG restricted its use in automobile. During 2009-10 India has imported 8.83 Million tones of LNG.

Liquefied Petroleum Gas: LPG is composed primarily of propane and butane with smaller amounts of propylene and butylenes. LPG is produced by crude oil refining. LPG is also produced during natural gas refining as by product. In India, production of LPG during 2009-10 was 6.51 and 2.21 million tones by refining of oil and from natural gas. Due to high calorific value of the LPG it is filled in cylinder with moderate pressure of 10-15 bar. Reduction in emissions, very less carbon build-up increases life of engine parts like spark plugs, little or no damage to soil or water if it is spilled, rapid evaporation, higher octane number are some of the advantages of LPG fuel. It is generally used in gasoline fuel vehicle with addition of gas kit to engine. Short supply of LPG, due to main use as cooking gas, inhibits use of LPG as alternative fuel.

Methanol: Methanol is produced mainly from natural gas and fermentation and distillation of bio mass. Methanol contains oxygen in structure which reduces calorific value to 18500kJ/kg. This oxygenated fuel reduces problems of emission and misfires. The biological problems occurred by spilling and mixing of water is less prominent as methanol decomposes within 2-3 weeks. Another advantage of higher octane allows use of higher compression ratio engines results in to higher efficiency. Main problems associated with methanol as fuel are corrosion, moisture absorption, low calorific value, availability, high price, new or modified infrastructure for transportation and storage. The drivability is inferior during warm up. Methanol burns well in lean mixtures and produces low NOx emissions, but typically it yields high emission of unburned fuel and troublesome aldehydes. Trying to mix methanol with petrol brings problems like they are not entirely compatible and the slightest amount of water absorbed by the fuel causes the alcohol to separate out in the bottom of the tank. Additives are commercially available, but this adds to the fuel cost. Presently, methanol can be better used in industrial process rather than as fuel in automobile.

Ethanol : India is the largest producer of sugar in the world. In terms of sugarcane production, India and Brazil are almost equally placed. India is currently producing stocks of over 10 million tonnes since 1999-2000. Correspondingly, molasses production has also increased. According to MPNG, 5% ethanol blends on all India bases would require 500 million litres. The current production of molasses and alcohol would be adequate to meet this requirement after fully meeting the requirement of chemical industries. It is estimated that about 300 million litre capacity would have been created for the production of anhydrous alcohol.[20] Ethanol is used as an automotive fuel by itself and can be mixed with gasoline to form what has been called "gasohol" or can be mixed with diesel to form diesohol or E-diesel. Because the ethanol molecule contains oxygen, it allows the engine to more completely combust the fuel, resulting in fewer emissions. Since ethanol is produced from plants that harness the power of the Sun, ethanol is also considered a renewable fuel. The principal interest in ethanol as motor vehicle fuel lies in its use as blends with gasoline. It is very high octane rating makes it an effective knock suppressor like TEL with an additional advantage of being a fuel in itself with no hazardous component like lead in TEL, which causes lead pollution. Its blends can permit higher compression operation of the engine without knock. Its higher latent heat of vaporization, uniform composition, stoichio-metric air requirements, higher flash point etc. impart to its blends certain useful properties which not only improve engine performance but also reduce engine emissions and make the blends safer as compared to gasoline. Its lower calorific value, higher surface tension, greater solvent power etc. restrict its use as a complete motor vehicle fuel. It can be best utilized as a blend constituent with up to around 30% ethanol-gasoline blends useable in the present day automobiles without requiring any major engine modifications; and giving reduced levels of exhaust CO and HC emissions.

Hydrogen: Otto, the German scientist, in 1870, used hydrogen gas as a fuel for his IC engine. Since then, researchers have tried to use hydrogen as automotive fuel. Till date all attempts to commercialize IC engines running on pure hydrogen have failed due to problems of storage, transportation, safety and production. Hydrogen is produced from water, which is abundantly available. Moreover, hydrogen is clean fuel with less emission compared to LPG and CNG. Vehicle running on hydrogen can meet stringent emission norms. Hydrogen can also be used as fuel for fuel cell vehicles. IIT Delhi is on forefront of R & D work on hydrogen engines. Attempts are also made to use hydrogen in form of blends with conventional fuel.

Bio-diesel is fatty acid methyl or ethyl ester made from virgin or used vegetable oils (both edible & non-edible) and animal fats. The main commodity sources for bio- diesel in India can be non-edible oils obtained from plant species such as Jatropha Curcas, Karanj, Neem, Mahua etc. Bio-diesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a bio-diesel blend or can be used in its pure form. Just like petroleum diesel, bio-diesel operates in compression ignition engine; which essentially require very little or no engine modifications because bio- diesel has properties similar to petroleum diesel fuels. It can be stored just like the petroleum diesel fuel and hence does not require separate infrastructure. The use of bio-diesel in conventional diesel engines results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particulate matters. Bio-diesel is considered clean fuel since it has almost no sulphur, no aromatics and has about 10% built-in oxygen, which helps it to burn fully. Its higher cetane number improves the ignition quality even when blended in the petroleum diesel.

B. Advantages of Bio-Diesel

Successful alternative fuels fulfill environmental and energy security needs without sacrificing operating performance. Operationally, bio-diesel performs very similar to low sulphur diesel in terms of power, torque and fuel without major modification of engines or infrastructure. Bio-diesel offers similar power to diesel fuel. One of the major advantages of bio-diesel is the fact that it can be used in existing engines and fuel injection equipment with little impact to operating performance. Bio-diesel has a higher cetane number than diesel fuel. In over 15 million miles of in-field demonstrations bio-diesel showed similar fuel consumption, horsepower, torque and haulage rates as conventional diesel fuel [6]. It provides significant lubricity improvement over petroleum diesel fuel. Lubricity results of bio-diesel and petroleum diesel using industry test methods indicate that there is a marked improvement in lubricity when bio-diesel is added to conventional diesel fuel. Even bio-diesel level as low as 1% can provide up to 65% increase in lubricity in distillate fuels.[6] Using high % blends fuel system components (primarily fuel hoses and fuel pump seals) that contain elastomers compounds incompatible with bio-diesel. Manufacturers recommend that natural rubber not be allowed to come in contact with pure bio-diesel. Bio-diesel will lead to degradation of these materials over time, although effect will lessen with bio-diesel blends.

C. Disadvantages of Bio-Diesel

Cold weather can cloud and even gel any diesel fuel, including bio-diesel. Users of 20% bio-diesel blend will experience an increase of the cold flow properties (cold filter plugging point, cloud point, pour point) of approximately 3 to 5 Fahrenheit.[6] Precautions employed for petroleum diesel are needed for fuelling with 20% blends.[6] Same solutions work well with bio-diesel blends, as do the use of cold flow improvement additives

II. LITERATURE REVIEW

Prbakaran *, Dinoop Viswanathan (2016) The study presents the experimental evaluations of performance, combustion and emission characteristics of blends containing non-edible cotton seed oil methyl ester and anhydrous ethanol in a diesel engine at various loads. Blends are made from bio-diesel from cotton seed oil by transesterification and anhydrous ethanol (200 proof) in various proportions ranging from10% to 50%. The results of the investigation are compared with diesel as base fuel. It is observed from the results that the brake thermal efficiency of the blends is similar to that of diesel. There is decrease of emissions of oxides of nitrogen and smoke, there is a decrease of emissions of carbon monoxide and hydrocarbon at higher loads and increase at lower loads. Also there is increase of maximum heat release rate and maximum pressure for the blends at higher loads. However, there is a decrease of maximum heat release rate and maximum pressure at lower load. This study gives a direction of renewable fuel blends to replace diesel for fuelling diesel engine thereby reducing the dependency of fossil fuels An experimental investigation of performance, combustion and emission characteristics of blends of biodiesel from cottonseed oil and ethanol has been performed in a diesel engine for three proportions at five different loads at 1500 rpm .S V Channapattanaa*,Kantharaj Cb,(2015) The present work investigates the emission and thermal performance of DI CI variable compression ratio engine using blends of biodiesel and standard diesel as a fuel at compression ratios of 15,16,17 and 18. The biodiesel derived from non edible Calophyllum Inophyllum linn oil is used on the engine. The blends of biodiesel and diesel used were B20, B40, B60, B80 and100% biodiesel. At 18 CR the brake thermal efficiency of the engine operated with 100% biodiesel is 8.9% less than Diesel and the brake specific fuel consumption for biodiesel found to be more than that of diesel. There is major reduction in Carbon monoxide and Hydrocarbon emissions with 100% biodiesel as a fuel compared to diesel at compression ratio of 18.The change in CR does not have much effect on the H Gas of the engine. However, at most of the CRs it is less for Hanne biodiesel than Diesel. The performance study reveals that the blend B20 operates very close to Diesel with respect to thermal performance. However the performance of Hanne biodiesel approaches that of Diesel fuel at higher CRs. Therefore it can be concluded that higher CR should be the mode of operation when engine is fuelled with Hanne biodiesel. At higher compression ratios (16 to 18), combustion of fuel is efficient due to high temperature of compressed air. Due to which, the exhaust emissions are found to reduce at higher CRs. Also at higher CRs, smoke is less due to complete combustion of fuel. However, the NOx emissions are found to increase at higher CRs with Hanne biodiesel as compared to Diesel. There is need to trade off between NOx and smoke emission. So the selection of CR can be based on the combined effect on thermal performance and emission characteristics. It is preferable to operate the engine at CR of 18 for optimum thermal performance. If NOx is considered then it is better to operate at CR 16.But it causes decrease in BTE of about 13% and increase of BSFC of about 13% which are not recommendable just to reduce NOx emissions. It is found that CO2 emissions are more for Honne biodiesel than that of diesel. Higher CO2 emissions reduce harmful CO emissions. The percentage reduction in HC emissions for Honne biodiesel is about 60% as compared to that of Diesel. Due to higher NOx emissions with pure Honne biodiesel, suitable blends can become a striking balance between NOx emissions on one end and all other emissions along with performance onthe other hand. The emission characteristics show that the Hanne biodiesel gives minimum harmful emissions as compared to all other blends. Further, at a higher CR of 18 the fairly reduced exhaust emissions are observed irrespective of the fuel. Therefore, in operating the diesel engine with Hanne biodiesel at a CR of 18 results in minimum emissions but more NOx emissions.

III. OBJECTIVE OF THE STUDY

In current study our main objective is to compare the experimental results with the Numerical analysis by using CFD. Experimental studies on the effect of Neem bio-diesel blending with fuel preheating on performance and emission of multi cylinder, four stroke, water cooled, direct injection has been performed in previous work, now we want to compare these results with simulation. Determining the relationship between diesel engine performance and the percentage of Neem bio-diesel in fuel blends with using different preheating blend. Determining the relationship between diesel engine performance and the percentage of Neem biodiesel in fuel blends with using different preheating blend.

A. CFD (Computational Fluid Dynamics)

Computational fluid dynamics, sometimes abbreviated as CFD, could be a branch of mechanics that uses numerical analysis and algorithms to unravel and analyze issues that involve fluid flows. Computers ar accustomed perform the calculations needed to simulate the interaction of liquids and gases with surfaces outlined by boundary conditions. With high-speed supercomputers, higher solutions may be achieved. Current analysis yields software system that improves the accuracy and speed of complicated simulation situations like sonic or turbulent flows. Initial experimental validation of such software system is performed employing a structure with the ultimate validation coming back in complete testing, e.g. flight tests To run a simulation, 3 main parts are needed:

1) *Pre-processor:* A pre-processor is employed to outline the pure mathematics for the process domain of interest and generate the mesh of management volumes (for calculations). Generally, the finer the mesh within the areas of enormous changes, the a lot of correct the answer. Fineness of the grid additionally determines the pc hardware and calculation time required. The ASCII text file pre-processor used for this project is termed Salomé.
2) *Solver:* The convergent thinker makes the calculations employing a numerical answer technique, which may use finite distinction, finite component, or spectral ways. Most CFD codes use finite volumes that could be a special finite distinction

methodology. Initial the fluid flow equations ar integrated over the management volumes (resulting within the actual conservation of relevant properties for every finite volume), then these integral equations are discretised (producing algebraically equations through changing of the integral fluid flow equations), and at last an repetitious methodology is employed to resolve the algebraically equations. (The finite volume methodology and discretisation techniques are delineated a lot of within the next sections. Open FOAM CFD code is employed for finding the simulations during this project.

3) *Post-Processor:* The post-processor provides for visualization of the results, and includes the aptitude to show the geometry/mesh, produce vector, contour, and second and 3D surface plots. Particles is caterpillar-tracked throughout a simulation, and therefore the model is manipulated (i.e. modified by scaling, rotating, etc.), and every one fully colour animated graphics. Para read is that the ASCII text file post-processor used for this project.

IV. METHODOLOGY

A. Basic Steps To Perform CFD Analysis

1) *Pre-Processing: CAD Modeling:* Creation of CAD Model by using CAD modeling tools for creating the geometry of the part/assembly of which you want to perform FEA.CAD model may be 2D or 3d.
2) *Meshing:* Meshing is a critical operation in CFD. In this operation, the CAD geometry is discretized into large numbers of small Element and nodes. The arrangement of nodes and element in space in a proper manner is called mesh. The analysis accuracy and duration depends on the mesh size and orientations. With the increase in mesh size (increasing no. of element), the CFD analysis speed decrease but the accuracy increases.
3) *Type of Solver:* Choose the solver for the problem from Pressure Based and density based solver.
4) *Physical Model:* Choose the required physical model for the problem i.e. laminar, turbulent, energy, multi-phase, etc.
5) *Material Property:* Choose the Material property of flowing fluid.
6) *Boundary Condition:* Define the desired boundary condition for the problem i.e. temperature, velocity, mass flow rate, heat flux etc.

B. Solution

1) *Solution Method :* Choose the Solution method to solve the problem i.e. First order, second order
2) *Solution Initialization:* Initialized the solution to get the initial solution for the problem.
3) *Run Solution:* Run the solution by giving no of iteration for solution to converge.
4) *Post Processing:* For viewing and interpretation of Result. The result can be viewed in various formats: graph, value, animation etc.

C. CFD Method Applied

The model was simulated and the required geometry configurations were pre-processed in ANSYS 14.5. This following section illustrates the method used in the CFD simulations in this particular study.

1) *STEP 2*

a) *Mesh File:* To Be Meshed

.Generated Mesh Model In The Ansys Shows In Figure 4.2 And 4.3

2). Step 3 Checks The Mesh: Various checks on the mesh and reports the progress in the console. Also check the minimum volume reported and make sure this is a positive number select mesh to mm.

a) Methods:

i) Pressure based
ii) 2d ax symmetry Model is used.
iii) Gravity is enabling

b) *Model:*

i) Energy equation is enabled.
ii) K-Epsilon turbulence model used.

iii) P-1 radiation model is used, since it is quicker to run. However DO radiation model can be used for more accurate results in typical models.

iv) Finite rate / eddy dissipation in turbulence chemistry. Interactions are used for species model.

3) Step 4 Simulation Set Up:

a) Boundary Conditions:

i) Mass Flow inlet

ii) Outlet – pressure based, pressure is 1 bar.

b) Material:

i) Fluid:-Diesel oil and B20, B40 , B60, B100 Fuels

ii) Thermal conductivity: **-** Define two polynomial coefficients

iii) (a) 0.0076736 (b) $5.8837*10^{-5}$

iv) Polynomial coefficient for viscosity
(a) 7.6181e-06 (b) 3.2623e-

v) For absorption coefficient take wags domain.

vi) Scattering coefficient is 1e-9.

4) Step 5 Solutions:

a) Method:

i) Coupled

ii) Presto model is used:-

Presto model is often used for buoyant flows where velocity vector near walls may not align with the wall due to assumption of uniform pressure in the boundary layer so presto can only be used with quadrilateral.

b) Meshes:

Pseudo transient is enabled

i) 0.1 time scale factor of turbulent kinetic energy and turbulent dissipation rate

ii) Time scale factor of species and energy is 1

iii) Note: Higher time scale size is used for the energy and species equation to converge the solution in less number of iteration

iv) Solution Initialisation: The solution is initialize

v) Run Calculation: Start the calculation for 1000 iterations.

V. RESULTS AND CONCLUSION

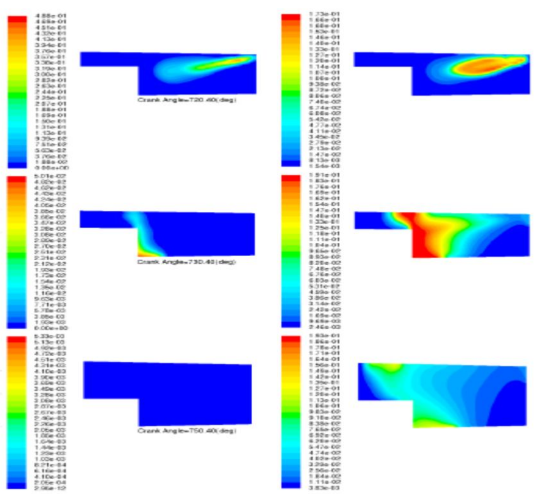

Figure1: Mass fraction of oxo carbons for diesel oil

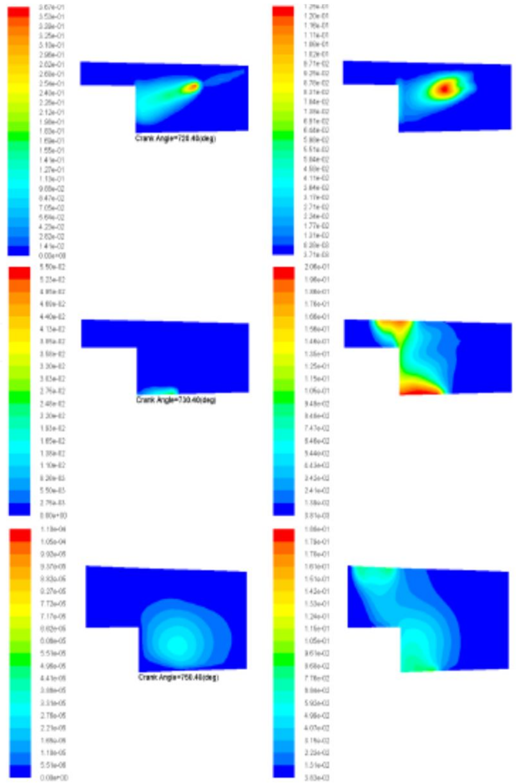

Figure2: Mass fraction of oxo carbons for B20

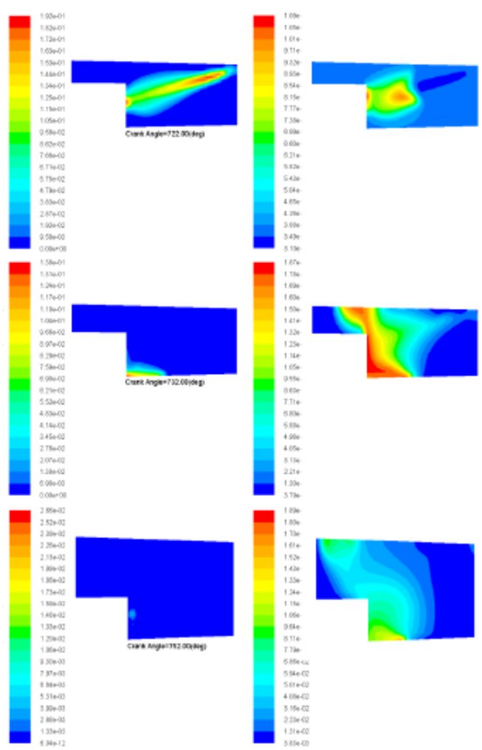

Figure3: Mass fraction of oxo carbons for B40

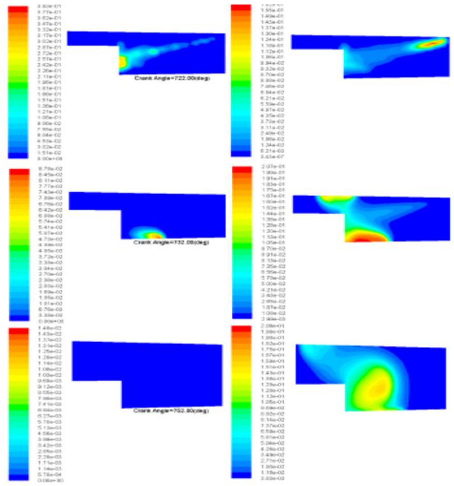

Figure4: Mass fraction of oxo carbons for B60

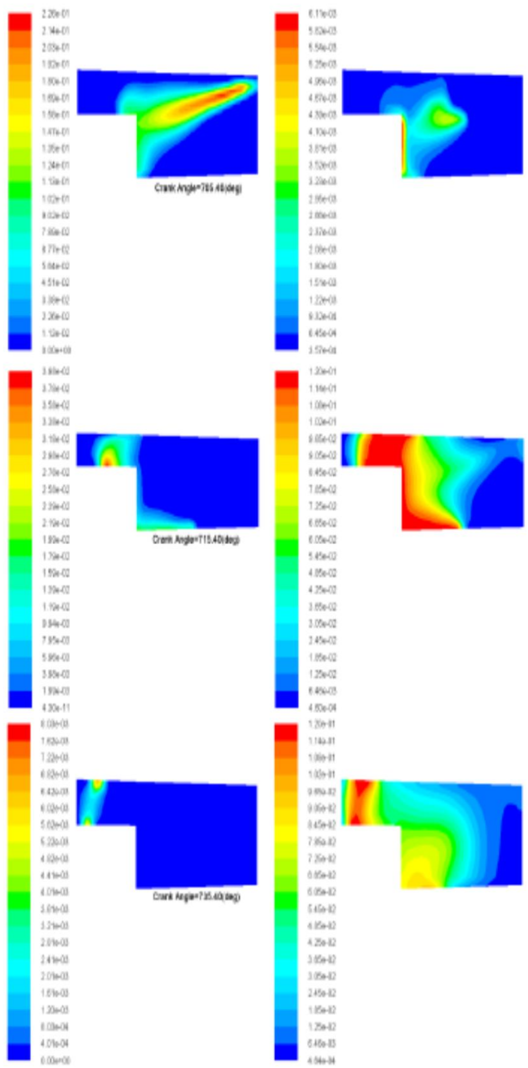

Figure5: Mass fraction of oxo carbons for B100

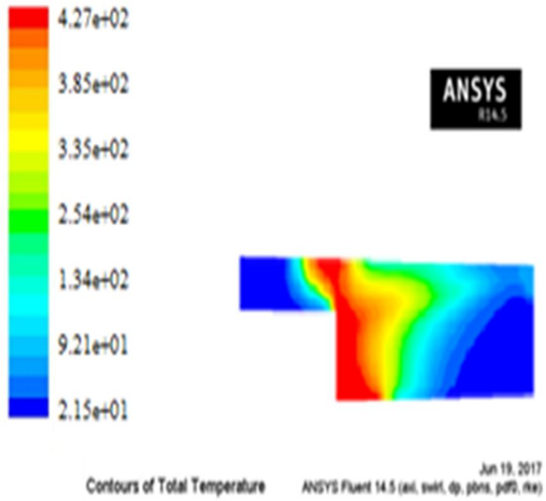

Figure 6 Temperature (^{0}C) contour for Diesel Oil

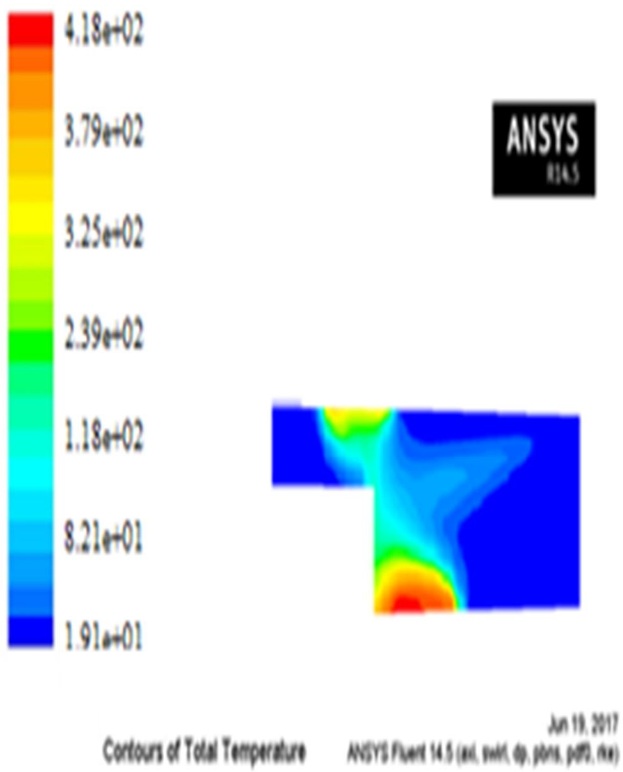

Figure 7 Temperature (^{0}C) contour for B20

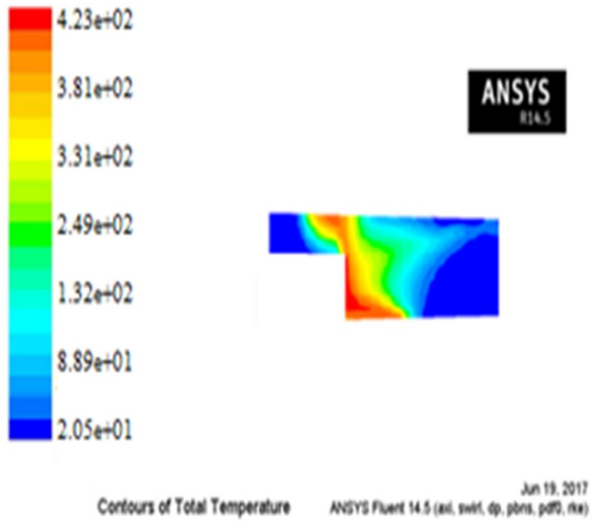

Figure 8 Temperature (^{0}C) contour for B40

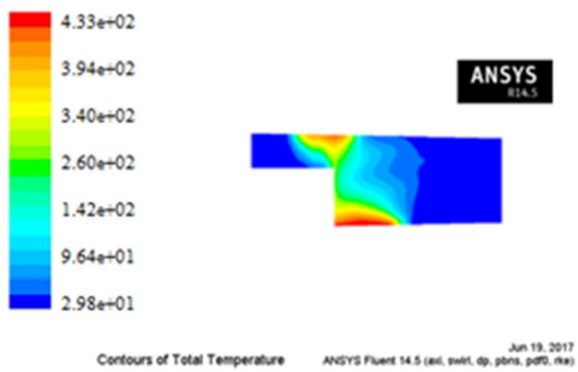

Figure 9 Temperature (^{0}C) contour for B60

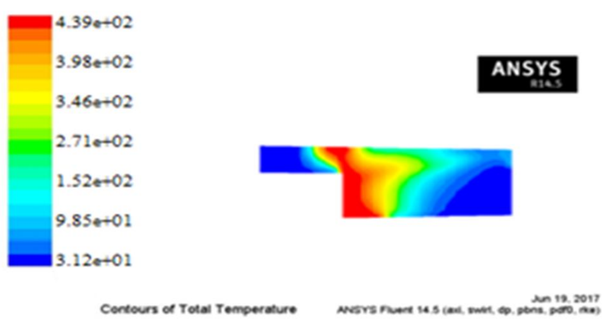

Figure 10 Temperature (^{0}C) contour for B100

RESULTS TABLE 1

fuel	EGT(°C) (EXPERIMENTAL)	EGT(°C) SIMULATION
Diesel oil	425	427
B20	414	418
B40	420	423
B60	428	433
B100	434	439

VI. CONCLUSION

Maximum EGT is reached at brake power of 25.42 kW for all fuels. In Results table1 the comparison of different fuel with exp. and simulation results is shown. This shows variations in EGT(Exhaust Gas Temperature) with brake power for diesel, B20, B40 B60 and B100 fuels. In experimental results the Maximum EGT found with highest preheating temp. (105 °C) is 425 °C, 414 °C, 420 °C and 434 °C for diesel, B20, B40 and B100 fuels respectively. B20, B40 and B100 fuel with different preheating temperature show reduction in exhaust gas temperature by 2.5%, 1.1% and 1.8% respectively compared to diesel fuel. CFD results show excellent validation with experimental outcomes. Mass fraction of emission with different fuels which we used in present study is calculated by CFD simulation gives a excellent effect on current research.

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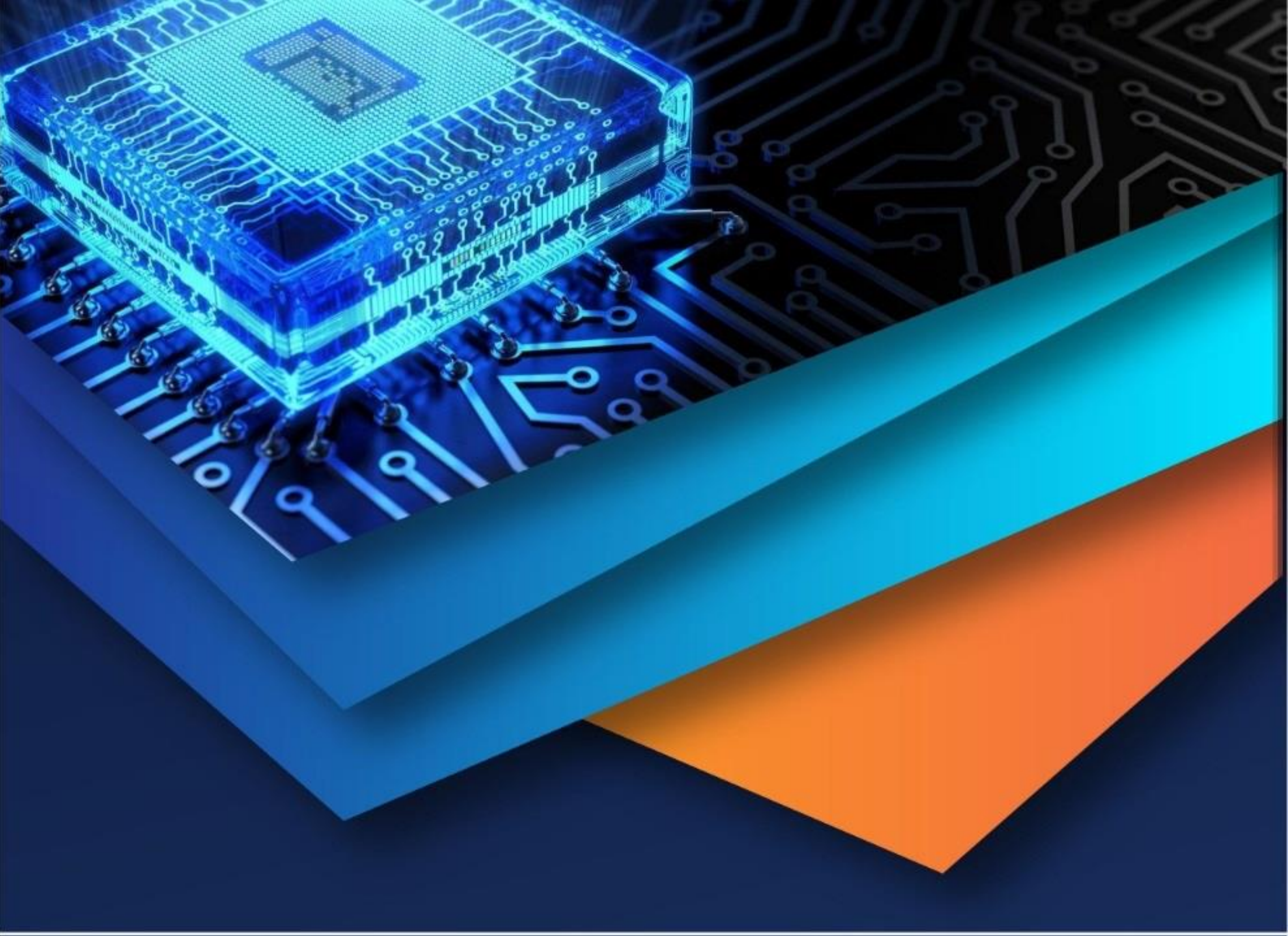

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