International Journal of Advanced Research Foundation

Website: www.ijarf.com, Volume 2, Issue 1, January 2015)

A Critical Review of Nusselt Number and Performance Characteristics of I.C. Diesel Engine Using Alternative BioFuels

K Ashok Reddy

Professor, Department of Mechanical Engineering, Guru Nanak Institutions Technical Campus, Ibrahimpatanam, R R Dist-501 506 , Hyderabad, Telangana State

Abstract: **A theoretical heat transfer model have been developed to enhance the heat transfer performance in terms of viscosity (μ) of biofuels and flow behavior index (n) with help of power law relations. Using continuity and energy equations of flow through circular tube , the Nusselt number can be evaluated as Nu= [(280n^3 + 296n^2 + 88n +8)/(31n^3 + 43n^2 + 13n +1)] .The derived equation can be extended to engine cylinder. In this paper , we have discussed the literature review of the research work carried by co workers on performance evaluation of internal diesel engine using biofuels. The heat transfer model which can be applied in a wider range to evaluate entropy generation of the engine cylinder.r**

Keywords: **nusseelt number, biofuels ,heat transfer & viscosity**

1. INTRODUCTION

Consumption of power in all forms has been rising all over the country.. Results show increasing in demand of power leads to the shortage of power and its effect will cease economic development in near by future .Increased use of petroleum products also causes emissions in the atmosphere creating a global warming into depletion of fossil fuels like coal, diesel and petroleum products leads the researchers to investigate the substitute fuel like waste oils, animal and plants seed oils with combination of diesel , which on today use in wide range such as in transport and automobiles vehicles and power generations. The substitution of these fuels is of great importance because it will reduce their dependence on diesel based power. Most of the research was carried using biodiesel as alternative fuels and evaluated the engine performance characteristics like brake thermal efficiency and emissions and pollutants parameters like Nox and Sox in the single cylinder diesel engine.

Efforts have been made to design the thermal systems to overcome the power crises and made indigenous thermal equipments which are now commercially available in the market. These include solar water heaters, biogas generation, wind mills and diesel generators and direct energy conversion devices like hydrogen fuel cell, electric battery operated vehicles were introduce to overcome the power shortage and environmental damage.

Justifiable reason for embracing and promoting the use of biodiesel in India is Global warming. By global warming we mean the increase in the atmosphere temperature ,oceans and landmass of the earth as proposed by Hart [2007].Researchers have reiterated that global warming is humanly induced. Its chief cause includes burning of petroleum products by automobiles which continually releases carbon dioxide into atmosphere. According to Environmental Research Development Report [2012], the world temperature has increased around 1.2^o C since the advent of industrialization and the rate is shocking day by day. It is argued that, biodiesel is free from gas emissions because carbon dioxide release from burning biodiesel is balanced by carbon dioxide intake by growing plants from where biodiesel are made as suggested by I Azih [2007]. In Recent years "Energdiesel", Trade mark of the biofuel research division in Singapore which consists of 28% biofuel that is 20% biodiesel and 8% ethanol which is rich in cetane number with hydrogen and carbon compounds has been giving good results.

II.LITERATURE REVIEW

Increasing the petroleum products prices ,the government agony stated looking alternative for the substitute and even subsides have been allotted to use of the biofuel ,which can be extracted from the animal and plant waste. Union Railway Ministry have deiced to allow 5% use of biofuel in the diesel engines which consumes two billon liters every year and far of reducing the fuel consumption and subsequently savings in the fuel bill.Indian Railways Organization for Alternate fuels(IROAF) has to upgrade the facilities of trans-etherification plant to convert the residues into biodiesl balancing the cost effective methods of production of bio fuels in coming years .The drawbacks have motivated researchers to investigate the problems on percentage of blending of biofuels with petroleum products and engine modification like S K Trividei and Abid Haleem [2012],R Lokanatham and K Ravindernath [2013], H S Sorthia and H J Yadav [2012] and M K Rath et al [2014] and others.

The research has been carried out on single cylinder i.c. diesel engine for performance and combustion characteristics experimentally and the effects of biofuels like calophyllum inophyllum based biodiesel, canola and waste palm oil, soybean and coconut biodiesel, jatropha and ethanol gasoline blend on emissions were investigated [1-14].B Y Buhari et al have studied the biodiesel produced from Jatropha Curcas seeds, using both mechanical and solvent extraction methods. Results obtained from their study showed that solvent extraction produced high quality oil than mechanical extraction. It was also found that parameters such as reaction temperature ,oil temperature and purity of reactants are factors that affect the transesterification process and that the use of KOH instead of NAOH as catalyst gave more quality biodiesel. On other hand using NAOH as catalyst in the production of vegetable oil gave better quality biodiesel. This deviations in the production of biodiesel leads us to carry the investigations in multi cylinder engine and conventional single cylinder diesel engine with three or two combination biofuel mixtures. Hardenberg and Haze[2009] proposed a combustion model which takes into account one of the main properties of the fuel which is believed to influence the delay period during combustion process.

Research on biofuels in internal combustion diesel engines and performance, control of pollutants has started in the international screnro since early 1995.Both theoretical and experimental are reported for single cylinder diesel engine in the literature. Belachew Tesfa et al (2014),in their paper, the effects of biodiesel types and biodiesel fraction on the emission characteristics of a CI engine were study. The results also clearly indicate that the engine running with biodiesel and blends have higher NOx emission by up to 20%. However, the emissions of the CI engine running on neat biodiesel (B100) were reduced by up to 15%, 40% and 30% for CO, CO2 and THC emissions respectively, as compared to diesel fuel at various operating conditions. A. I. Ramírez1 et al (2012),in this study, characteristics from a six-hole, heavy duty, Hydraulically-actuated, Electronically-controlled Unit Injector (HEUI) have been investigated. The injector was studied in a single-cylinder test engine using varying rate of injection profiles. Effects on cylinder pressure, performance, and emissions information were obtained. Endoscopy was used to acquire images of the combustion in the engine cylinder. This data was used for the validation of 3-dimensional full-cycle engine simulations. In general, simulations were able to capture performance and emission trends with varying injection characteristics.

Adnan Berber1 et al (2011),in this study, the characteristics of a four-stroke internal combustion diesel engine have been investigated by means of artificial neural networks (ANNs) and adaptive neuro-fuzzy inference system(ANFIS) modeling techniques, using injection pressure, engine speed and torque. Injection pressure of diesel engine has been designed with a pressure of 150 bars for the turbo charger and pre-combustion chamber. The experiments have been implemented for four different pressure values, namely 100, 150,200 and 250 bars with throttle positions of 50, 75 and 95%. P.Tamilporai et al (2010), in their paper, the simulation of combustion and its performance characteristics of biodiesel fuel in direct injection (D.I) low heat rejection (LHR) diesel engine have been studied. Comprehensive analyses on combustion characteristics such as cylinder pressure, peak cylinder pressure, heat release and performance characteristics such as specific fuel consumption and brake thermal efficiency are carried out. Compression ignition (C.I) engine cycle simulation was developed and modified in to LHR engine for both diesel and biodiesel fuel.

P. Suresh Kumar, in this thesis, it was focused on the utilization of JBD with different fuel injection pressure angles in indirect injection (IDI) diesel engine. The work scope included fundamental experimental studies on brake thermal efficiency and emission studies of Jatropha in comparison to diesel fuel and the feasibility analysis of diesel substitution with JBD and future work recommendation of possible changes to the injection system. An IDI diesel engine was tested by diesel,100%biodiesel (B100), with respect to varying fuel injection pressures of 160, 170 and 180 kgf/cm2. The engine characteristics with Jatropha biodiesel were compared against those obtained using diesel fuel. Shailendra Kumar Sinha (2008), the present work deals with the development to the end use of biodiesel in transportation diesel engine. Rice-bran (agricultural waste material) is modified into biodiesel using chemical process of transesterification (alkali-catalyzed). Process parameters for transesterification of rice-bran oil are optimized. Characterization of the rice-bran biodiesel thus produced iscarried out and most of the important properties of biodiesel are found close to mineral diesel. Detailed engine tests (performance, emission and combustion investigations) with developed fuel on a medium duty transportation diesel engine have shown improved performance of rice-bran oil biodiesel. 20% biodiesel (B20) is found to be optimum biodiesel blend and is selected for long-term endurance test.

IC engine is an important prime mover used in various fields mainly in automotive and power generation. In early days of IC engine development, power output and efficiency were the main focus of researchers. Heat in commercial diesel engine has to travel through engine components leads to increase its temperature. This percentage of heat loss through engine cooling varies according to various engine and cooling system parameters. In this study, for one single head of diesel engine, three-dimensional coolant flow inside cooling water jacket is simulated using 3D CFD software. Some estimating study is developed, including whether cooling water system capacity for cylinder head is well or not, the distribution of coolant to cylinder is even or not and so on. Finally, some advices are put forward, which can provide gist for optimizing the diesel engine..

International Journal of Advanced Research Foundation

Website: www.ijarf.com, Volume 2, Issue 1, January 2015)

The methodology presented by Amit V. Paratwar & D.B Hulwan [2013] is based on CFD and validation is done experimentation in which templug where used The CFD analyses constitute the first step of the proposed modeling strategy. Two different aspect are investigated in detail: i) the fluid-dynamic behavior of the cooling circuit is firstly analyzed and optimized aiming at improving the cooling efficiency ii) the point-wise fluid/solid heat transfer is then evaluated. In particular, benefits on the verall predicting capability brought in by the adoption of a proper phase-change model are highlighted by means of a preliminary comparison with a simplified model and by a subsequent validation of the methodology against experimental measurements of the temperature distribution within the engine head. Thus in their study 6-cylinder, 4-stroke 4-valve, turbo after-cooled, high pressure diesel engine is selected. Initially geometrical layout will be studied in terms of flow and heat transfer analysis by using CFD as a tool. The parametric study of an IC engine cooling jacket will be carried out using experimentations and results will be used to comment on effectiveness of selected parameters and optimizing these parameters by using statistical methods.

$/8 - n^3/(3n+1)^3$

The heat transfer coefficient depends on the engine geometry, such as the exposed cylinder area and bore, and the piston speed. Due to the complex gas flow in the cylinder, it varies with location in the cylinder and in time with changing piston position. The value of the heat transfer coefficient is found from a Nusselt number - Reynolds number type correlation, A number of empirical equations exist for hg in the cylinder at any instant; perhaps the most commonly used being that by Woschni.[1988] There are three types of heat transfer coefficients used in engines heat transfer. The peak values of the instantaneous and local coefficients can be many times higher than the averaged values

III.HEAT TRANSFER MODEL

To develop the theoretical heat transfer model , continuity, velocity distribution and one/two dimensional energy equations were introduced. Two dimensional continuity equation

$$v_r/r + \partial v_r/\partial r + \partial v_z/\partial z = 0 \quad (1)$$

was used in the energy equation,which gets modified to

$$v_r\,\partial T/\partial r + v_z\,\partial T/\partial z = \alpha\,[1/r\partial(r\partial T/\partial r)/\partial r + \partial^2 T/\partial z^2].$$

Assuming one dimensional heat flow for which as $v_r = 0$ the above equation reduces to

$$\partial(r\,.\,\partial T/\partial r)/\partial r = 1/\alpha\,\partial T/\partial x\,.\,r.\,v\,. \quad (2)$$

The velocity distribution relation was introduced in our semi empirical model

$$v = (\tau_w/RK)^{1/n}\,.\,[(R^{1+1/n} - r^{1+1/n})/1+1/n] \quad (3)$$

τ_w=shear stress at the engine cylinder wall, R=Radius of the engine cylinder,K= flow consistency index, n=flow behavior index of the bio fuels r=differential radius of the engine cylinder.

Using convection – conduction relation at the wall of the engine cylinder ,

$$hA_w(T_w-T_m) = kA_w\partial T/\partial r \text{at } r = R \quad (4)$$

It should be noted that $+ k A_w\,\partial T/\partial r$ varies as T increases with r

$$h/k = \partial T/\partial r\,/\,(T_w - T_m) \text{ at } r = R \quad (5)$$

Rewriting for temperature disruption T from equation(5)

$$T=T_o+s_1[r^2/4-r^{3+1/n}/(3+1/n)^2).R^{1+1/n}] \quad (6)$$

By differentiation with $\partial/\partial r$, the following equation $\partial T/\partial r =$

$$\partial(T_o+ s_1[r^2/4 - r^{3+1/n}/(3+1/n)^2).R^{1+1/n}])/\partial r$$

Simplifying for $\partial T/\partial r$,equation (14) gets reduced

$$\partial T/\partial r=s_1[r/2-r^{2+1/n}/(3+1/n)^2R^{1/n+1}] \quad (7)$$

At r=R, the above equation and simplification it can be written as

$$\partial T/\partial r=s_1R/27n^2+(6n+1)/(3n+1)^2] \quad (8)$$

$$T_w - T_m = s_1 R^2\{[1/4 - n^2/(3n+1)^2] - [(3n+1)/(5n+1)[1/8 - n^3/(3n+1)^3]\} \quad (9)$$

we can evaluate the heat transfer coefficient as follows:

$$h/k = \partial T/\partial r\,/\,(T_w - T_m);\quad h=\lambda_1/\lambda_2 \quad (10)$$

where λ_1 and λ_2 are constants in equation (10) which are equal to

$$\lambda_1 = s_1 R/2\,[7n^2 + (6n+1)/(3n+1)^2] \quad (11)$$

$$\lambda_2 = k\,s_1 R^2\{[1/4 - n^2/(3n+1)^2] - [(3n+1)/(5n+1)[1/8 - n^3/(3n+1)^3]\} \quad (12)$$

Eliminating s_1 and R from the equation(11)-(12), we get the equation (13)

$$h\,D/k = [7n^2 + (6n+1)/(3n+1)^2]\,/\,[1/4 - n^2/(3n+1)^2] - (3n+1)/(5n+1)[1/8 - n^3/(3n+1)^3] \quad (13)$$

Further simplifying the equation(13), we finally obtain the Nu number relation for in terms of flow behavior index(n) for engine cylinder **in equ (14) i.e**

$$Nu=[(280n^3+296n^2+88n+8)/(31n^3+43n^2+13n+1)] \quad (14)$$

Thermodynamic analysis of a single of multi cylinder diesel engine is to be investigated. It is based on a single zone combustion modeling with a rapid premixed burning zone followed by a fuel: air charge mixing controlled burning zone. The analysis includes combustion product methods, enthalpy ,internal energy ,engine geometry ,combustion rate, mass transfer model and emissions model has to evaluated from models proposed by authors like J B Heywood,G Eichelberg,A S Campbell and Hiroyasu & Kadota.

Vishal Anand & K Nalanti [2014] has proposed the following equation for entropy generation for I C diesel Cylinder engine

$$S\square gen = m\square Cp\,[-1/\alpha\ln\{1 - \tau\alpha e^{-4St\lambda}\,1/1 - \tau\alpha\} + \ln\{1 - \tau e^{-4St\lambda}\,1/1 - \tau\} + f\,Ect/8St\,\ln\{e^{4St\lambda} - \tau/1 - \tau\}]$$

Where St is the Stanton Number ,Ect is the Ecthart number and α & τ are constants

$\alpha = 1 - Nua/Nu$, $\tau = Te - Ti/Te$, $Ec = U^2/Cp\,(Te - Ti)$

Thermal stresses analysis in combustion chamber of diesel engine is an important field which automobile engineers study in order to increase life of mechanical parts. Some of studies have been presented about thermal stresses and analysis for various engines. Local convective heat transfer in a four-stroke single cylinder engine using a computational fluid dynamics code was analyzed by Mohammadi and Yaghoubi

[2008]. The results were compared with experimental measurement in the literature. Besides,new correlations were proposed to predict maximum and minimum convective heat transfer coefficient in a SI engine's combustion chamber. Lee and Assanis [2000] analyzed thermo-mechanical of optically accessible quartz cylinder under fired engine operation. Using FEM analysis, temperature and stress distributions were estimated. Three types of outside cooling for reducing thermal stress level (natural, moderate forced and intensive forced convection), were considered. Thermal analysis of cylinder head carbon deposits from single cylinder diesel engine was researched by Husnawan et al.[2009].

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ACKNOWLEDGEMENT

At the outset, I sincerely thank and extend my gratitude to the Management of , Guru Nanak Institutions Technical Campus, Ibrahimpatannam, R R Dist Hyderabad for encouragement for preparing the manuscript.

About the author

K. Ashok Reddy: Obtained B.E.-Mechanical Engineering from Andhra University, Waltair A. P. in 1984. After serving for eight years at Allywn Volts Ltd, Obtained Post Graduate from Indian School of Mine (ISM) , Dhanbad,Bihar in 1995.Since 1995, taken Up teaching as a carrier and completed Ph.D in 2012 fron JNTU Hyderabad T.S. Published 20 research and review papers in Heat Transfer, Mechanical Design and Thermal Engineering..kashokreddy2013@gmail.com