European Journal of Sustainable Development Research
2020, 4(3), em0124
e-ISSN: 2542-4742
https://www.ejosdr.com/

Research Article

MODESTUM
OPEN ACCESS

Biofuel Certification Performance: A Review & Analysis

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Citation: Mohite, S., & Maji, S. (2020). Biofuel Certification Performance: A Review & Analysis. *European Journal of Sustainable Development Research, 4*(3), em0124. https://doi.org/10.29333/ejosdr/7864

ARTICLE INFO

Received: 25 Nov. 2019

Accepted: 11 Mar. 2020

ABSTRACT

The biofuel performance certification's scope is reviewed. An operational definition of biofuel performance certification has been developed. The certification of biofuel performance has been recognized as an effective assessment methodology and tool to manage biofuel consumption and improve biofuel performance systematically. It is found that a biofuel performance certification method is required in biofuel industry and biofuel research to authenticate the biodiesel and its blends for use in diesel engine.

Keywords: biofuel, performance, certification, energy audit

GLOBAL CONSUMPTION OF BIOFUEL

There are various advantages with the use of biofuels such as sustainability, greenhouse gas emissions reduction, regional development, social structure and agriculture. A carbon neutral renewable energy is required to mitigate the greenhouse gas effect (Demirbas et al., 2007). Diesel engine causes harmful emissions which affect ecological system adversely. Alternative sources are being explored to solve this problem. Biodiesel is one of the alternative source (Verma et al., 2015).

The 80% share of primary energy is consumed by fossil fuel globally and out of this, 58% is consumed by the transport industry. The International Energy Agency reported that there was a 23% increase in the consumption of diesel while the increase in the consumption of other petroleum products was 7% from 2000 to 2008 (Ayetor et al., 2015). It is reported that there are 100 billion barrels reserves of petroleum globally and are expected to be exhausted in around 40 years (Orhan et al., 2004). It is stated in the International Energy Agency (IEA) report, that 50% more amount of energy will be required than today in 2030. A growth of 1.8% per year would be estimated for the use of global transport energy from 2005 to 2035. It is also reported that the transport industry is responsible for about 60% oil demand in the world. In the transport sector, 97.6% of the fossil fuel energy consumption is oil and the rest is natural gas. Transport sector causes 30% of total U. S. greenhouse gas emissions and it is the second largest source of GHG emissions after electric power sector in the United States. It is reported that production of biodiesel rised from 15 thousand barrels per day to 289 thousand barrels per day from 2000 to 2008. European Union contributes 85% biodiesel production globally (Atabani et al., 2012).

BIOFUEL PERFORMANCE MEASUREMENT

To promote biofuel performance, efficiency of diesel engine's measures such as performance and emission characteristics, energy management monitoring, modelling and optimization have been carried out worldwide. These measures are inadequate in proper evaluation and certification of energy performance in use of biofuel.

Efficiency, performance and emission characteristics, energy measurement and monitoring are an effective measure to provide efficiency data in the support of reliability and applicability of biofuel. These data are useful:

1. To reduce energy consumption
2. To establish environmental performance goals
3. To understand the requirement of diesel engine

Efficiency and energy use should be measured and quantified to control efficiency and energy use in diesel engine, performance and emission characteristics. Energy consumption and energy savings are judged and evaluated with monitoring. Energy modelling and optimization are also the basis to study biofuel performance and have received researchers attention.

ENERGY AUDIT

Energy audit has been performed for a number of buildings, factories, industries with a purpose to improve efficiency and productivity. The energy audit is used to investigate scope to save energy and recommend measures that would make the diesel engine more efficient. Such energy audit would also emphasize key design features and different aspects of operation for overall benefits. Researchers explained energy audit as a process of evaluation of energy use in a building and identify scope to reduce energy consumption (Thumann et al., 2010). A real energy audit called as feasibility study dealt with the thorough examination of two years of utility bills with mathematical modelling of energy use when the system is supposed to operate properly, routine plant operation's review and list of upgrades with their installation costs and savings in a building (Audin, 2002). A good energy audit is helpful to make important decisions on the investment to achieve the best energy efficiency. The development of energy audit is related to the identification and communication of the best energy conservation measures (Anina et al., 2016). An energy audit is one of the step to increase energy efficiency at the facility level. An energy audit has been conducted in a paper mill plant in Guangdong Province in China to identify scope for energy conservation and opportunities for CO_2 emission reduction (Kong et al., 2013). Different people have many meanings for energy audits. Energy audit focuses on process, operation or equipment for some people. Researchers performed an energy audit which was focussed on brick, refractory and insulation giving its effect on efficiency and reliability of boiler and savings of energy fuel (Bases, 2004). In 1988, the computerised transportation audit program was launched by the energy efficiency branch of Alberta's department of energy. This audit was used to investigate the possibility of savings in energy consumption in the transportation sector. An energy audit of a vehicle is a systematic way to assess the uses of energy. The purpose of the audit program is to identify scope to save fuel. The audit is a first step in a process which comprises of setting priorities to develop an energy management program. In energy audit, maintenance factors which reduce friction losses and the factors which affect engine performance are also calculated (Erkut et al., 1992). Energy audit helps to decrease demand and energy consumption in industry (Bellarmine et al., 1996). The ability of emerging technologies to reduce fuel consumption with emphasis on each loss mechanism was investigated in diesel engines with the application of energy audit and technology forecasting. Improvements in fuel consumption were estimated with the help of future technology in heavy duty diesel engines (Thiruvengadam et al., 2014).

The aim of this paper is to carry out a review of biofuel performance certification to evaluate its capability and applicability to improve performance.In the introductory part, global consumption of biofuel, biofuel performance measurement and energy audit have been reviewed and discussed with a view to clarify research gaps.

Definition of Biofuel Certification Performance

The certification of bioenergy sustainability needs international approach and further harmonisation with global monitoring and control. The biofuel certification is a response which concerns with biofuel sustainability. There are various certification schemes which are related to sustainability in other fields. One of the areas in biomass production is covered by some systems such as agriculture, forest and fair trade. Operational experience and effectiveness provide accurate and deep understanding of the structure of certification systems such as design, implementation and constraints. Biofuels should be made sustainable for transport including sustainability of agriculture and forest. All end uses, should be included as a tool in certification schemes to ensure sustainability. Implementation and controlling the quality of certification schemes is important. The proper enforcement and verification mechanisms of certification results in achievenment of sustainability goals. High standards of reliability, transparency including strong implementation, verification requirements and strong sustainability criteria should be ensured in certification schemes. The sustainability criteria for bioenergy has been established by ISO project committee ISO /TC 248. The committee has mentioned the social, economic and environmental issues of the production, supply chain and bioenergy use and determine sustainability criteria. Various biofuel certification scheme are being implemented for biofuel production (Nicolae et al., 2011).

European council directive put a proposal to promote the development of energy savings and emission mitigation. The certification is identified as an effective tool to evaluate and certify energy performance (Cai et al., 2019). A precautionary step is required to assure awareness of biodiesel development and their performance with complete understanding of what could be worked, what could not and why. It also involves analysis of action to be taken to improve outputs and reduce risks during analysing biofuel role (Goetza et al., 2018).

Biofuel industry has great potential for energy saving and its certification. Therefore, energy performance certification of biofuel will perform an important role to achieve energy conservation. This energy performance certification should comprise of a description of key performance and emission characteristics with energy audit parameters and also give options and information to improve performance. Due to various ambiguities, it is not clarified to how to present information about biofuel performance which results in implementation difficulty in view of the requirements.

Scope of Biofuel Certification Performance

The assessment of biofuel sustainability is required to analyse various heterogeneous opinions to consider their multidimensional impacts. Therefore, ability of biofuel to fulfil one specific objective can not lead to any conclusion about overall sustainability of biofuel, its policy efficiency and its positive or negative impacts (Gino et al., 2017). The depletion of fossil fuel resources and global warming challenges various energy sources in the world. The energy demand is rapidly increasing in developing countries. The sustainable biofuels would be considered to replace fossil fuels. Nowadays, focus is to use sustainable biofuels but the definition and assessment of sustainability is found to be highly complex issues. The compulsory targets and financial incentives have been adopted by various countries to promote biofuels and only a few countries were found to work for

Table 1. Type of certification system

Type of certification system	Abbreviation/specific area	Organization/ System
General certification system	CEM	European Committee for Standardization
General certification system containing project approval carbon credits	CDM	Clean Development Mechanism
General certification system	CREM	Consultancy and Research for Environmental Management
General certification system	Ecolabel	Certification of different products and services
General certification system	EMAS	Eco Management and Audit Scheme
General certification system	ISO	International Standard Organization
Biomass energy certification	EUGENE	European Green Electricity Network
Criteria for Sustainability	Biomass tramsite Groep	Workgroup of the Dutch Ministry of Economy; Development of Criteria for sustainable biomass trade
Discussion of Criteria for sustainable biomass trade	Biotrade Workshop	International workshop 2002
Criteria for Sustainability	GRAN	Report, containing Criteria for sustainable biomass trade
Ecological Criteria for Sustainability	Greenpeace	Environmental NGO
Indicator for sustainable development and Agro-ecological indicators	OECD	Organization for Economic Co-operation and Development
Indicator for Sustainable Livelihoods (SL)	UNDP	United Nations Development Program

biofuel sustainability certification scheme within their policy frame work (Gnansounou, 2011). Intergovernmental panel on climate change (IPCC) and International Energy Agency (IEA) are found to reveal the increasing role of bioenergy to mitigate climate change and coherent policy measures are required for this. The policy objectives are difficult to coordinate because of action in one sector may impact unintended negative output in another. Therefore, bioenergy policy should be modelled with the consideration of wide system and overall impacts of policy interventions (Clancy et al., 2018).

While analysing performance certification of biofuel in diesel engines, these methods and measures are found to be considered helpful to improve performance and mitigate emission. Due to the deficiency of studying performance certification in biofuel industries, this paper review and analyse performance certification from the point of view of performance benchmarking which is more beneficial to strengthen and improve performance management. The analysis of scope and data of biofuel performance is helpful to understand application objective and complex rules. It also determines an important base to acquire database for performance certification.

The classification of performance certification by different studies are found to provide details of their certification categories including energy audit to facilitate their implementation in biofuel use. These studies are found to be useful references for studying biofuel performance certification. The proposed performance certification has wide prospects in biofuel application.

During biofuel performance certification, there are two important questions. One is how to define biofuel performance and another is what to measure in biofuel performance. According to previous studies and to perform a detail analysis, the biofuel performance certification should comprise of important performance and emission characteristics to reveal the most basic biofuel performance. In this study, acquiring biofuel consumption of any system is an important basis to design and develop biofuel performance certification. This paper systematically propose performance certification for biofuel use from various aspects including definition of performance certification, classification of performance certification and application of performance certification. According to the definition of the certification, this is a representation of the integrated information consisting of brake specific energy consumption, heat flow analysis, friction power and smoke emission. Therefore, this section attempts to define and classify concepts of these parameters to develop the certification of biofuel use.

Certification System

It is expected that international biomass trade will significantly increase in near future because of the possibility of lower costs of imported biomass, better supply security through diversification and the support by energy and climate policies of various countries. Lower price is one of the reason for international biomass trade. Energy balances and greenhouse gas balances indicates that international bio energy is against energy loss. Certification system provides procedure to develop various types of quality and sustainability standards such as Eco-label, EMAS, ISO, CEM and CREM etc. Various type of organization and system which analyses particular study is shown in table. A comparative table for an in depth analysis of some of the individual certification scheme via its standard to allow a quick and easy comparison of the results is shown in **Table 1**.

Classification on Biofuel Certification Performance

For biofuel performance certification, the initial step is to consider and determine biofuel performance indicators. The indicators can be selected on the basis of their importance in fuel of diesel engine operation such as brake specific energy consumption, heat flow analysis, friction power, smoke emission. Biofuel performance certification is a concept which affects the biofuel performance and comprises of four kinds of information such as brake specific energy consumption, heat flow analysis, friction power, smoke emission. At present, there is no biofuel performance certification which is universally adopted.

There are various parameters which may be considered in preliminary energy audit as shown in **Figure 1**.

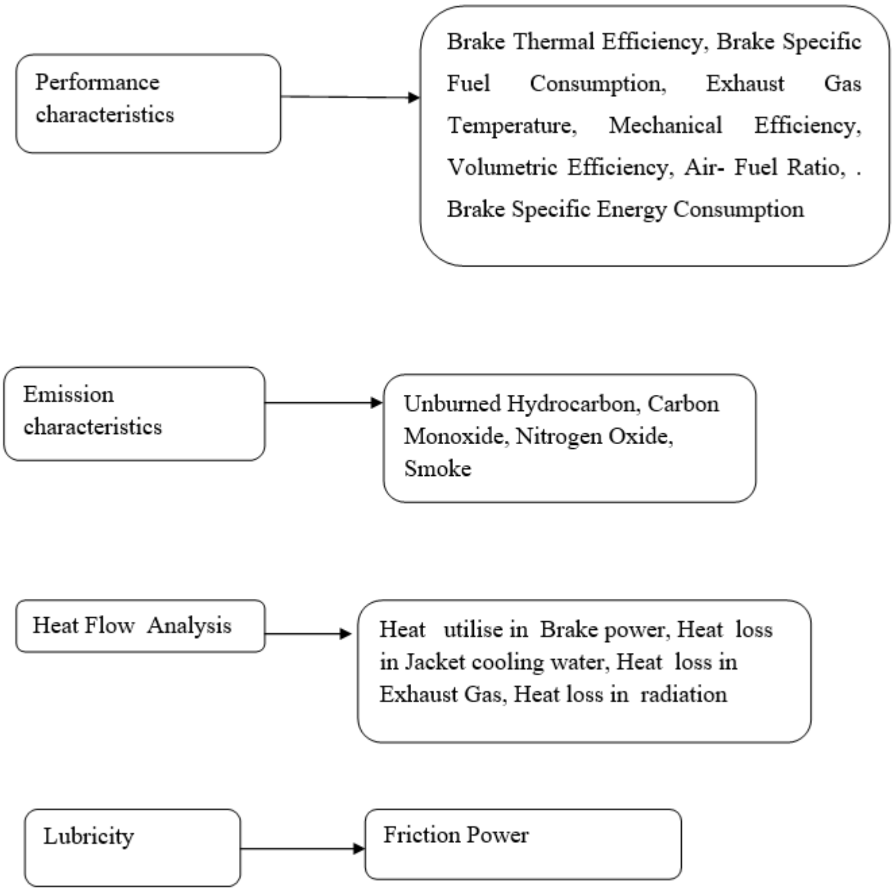

Figure 1. Different parameters for consideration in preliminary energy audit of a diesel engine fuelled with biodiesel

METHODOLOGY

The importance of the selected parameters of the diesel engine fuelled with biodiesel blends has been discussed and their dependency has been found out with parameters. The parameters have been selected on the basis of their influence on other parameters. Brake Thermal Efficiency, Brake Specific Fuel Consumption, Exhaust Gas Temperature, Mechanical Efficiency, Volumetric Efficiency, Air- Fuel Ratio, Unburned Hydrocarbon Emission, Carbon Monoxide Emission, Nitrogen Oxide Emission, Brake Specific Energy Consumption, Heat Flow Analysis, Friction Power, Smoke Emission have been discussed thoroughly. Brake Specific Energy Consumption, Heat Flow Analysis, Friction Power, Smoke Emission have been found to have more influence and effect than other parameters. During primary stage of energy audit, Brake Specific Energy Consumption, Heat Flow Analysis, Friction Power, Smoke Emission have been preferred to compare results (Mohite & Maji, 2020).

DISCUSSION

Brake Specific Energy Consumption

The brake specific fuel consumption shall not be considered as a trustworthy parameter when a blend of two different fuels is prepared because of their different values of calorific values and densities. In case of blending of fuels, brake specific energy consumption will give more correct results. BSEC is one of the key parameters to compute correct energy consumption of biodiesel blends and diesel. It is the product of brake specific fuel consumption and calorific value. Therefore, BSEC is one of the important parameter to evaluate the performance characteristics because it takes into account the calorific value of fuels in blends. BSEC may also be defined as the energy input, which is needed to produce unit brake power. Therefore, BSEC has been chosen as a key parameter for an energy audit of diesel engine fuelled with a biodiesel blend fuel. It also facilitates the proper evaluation of blend fuels as its capability to run a diesel engine Reduction in BSEC is observed with increase in load due to reduction in brake specific fuel consumption at higher loads. Increase in BSEC is observed respectively with the increase in the biodiesel concentration in blend fuel. This may be caused due to dependence of BSEC on BSFC directly as it is a product of calorific value and brake specific fuel consumption (Fattah et al., 2014; Imtenan et al., 2015; Mohite et al., 2016 a). BSFC depends on density and viscosity of fuel and also on brake power. BSEC depends on BSFC and CV as shown in **Figure 2**.

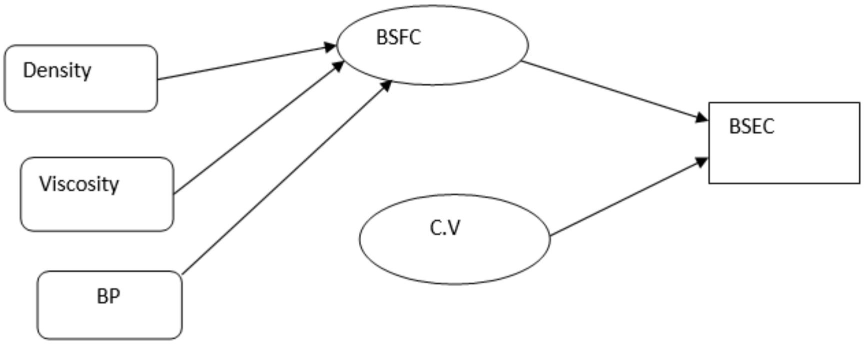

Figure 2. Influence of parameters on BSEC

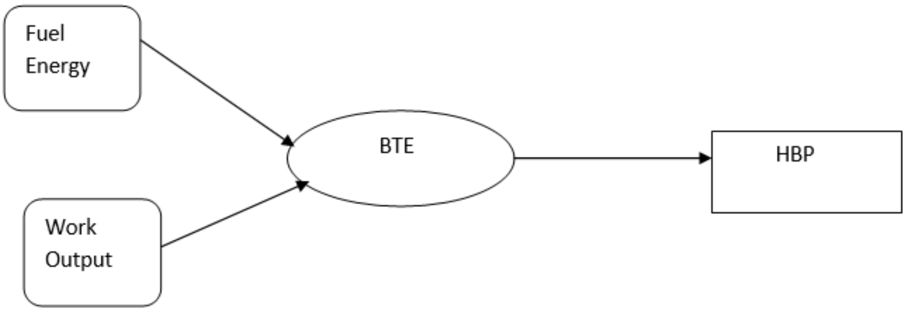

Figure 3. Influence of parameters on HBP

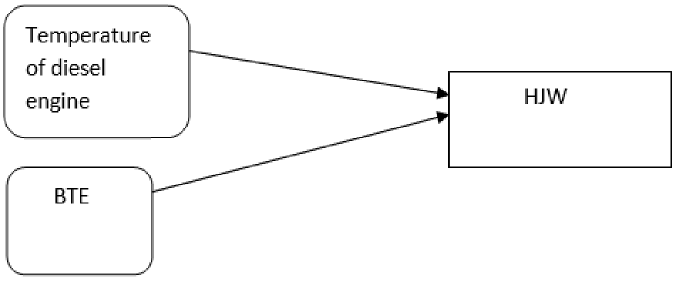

Figure 4. Influence of parameters on HJW

Heat Flow Analysis

Heat flow analysis is one of the key factors to find out the heat energy's utilisation and wastages. Major factors of heat energy consumption are brake power output, coolant medium, exhaust gas and radiation.

Heat Utilise in Brake power

The ratio of work output to the fuel energy supplied is called brake thermal efficiency of an engine. It is also known as fuel conversion efficiency. HBP means brake thermal efficiency as it shows the change of the amount of fuel energy into useful work i.e. brake power output out of total fuel energy. BTE depends on fuel energy and work output as shown in **Figure 3**. BTE of diesel is found to have highest in comparison to all biodiesel blends which is attributed due to lower calorific value of biodiesel (Baiju et al. 2009).

Heat Loss in Jacket Cooling Water

HJW means the amount of part of heat energy which is absorbed by cooling water. This indicates the rise in temperature of combustion chamber, cylinder and the whole diesel engine. It also influence the Brake Thermal efficiency. In water cooled engine, the engine block is surrounded with a jacket of water. A fluid is circulated in jacket of water to engine. About 50% of the friction power is caused between the piston and piston rings and cylinder wall and is transferred to the cooling media as heat energy. The rest of the friction power is caused because of bearings, valve mechanism and to drive auxiliary devices and is changed as heat energy to the oil or surrounding. Heat carried away by the cooling media consist of heat transmitted to the combustion chamber walls from incylinder gases, heat transmitted to the exhaust valve during the exhaust process and a significant fraction of the friction work. At part load, a larger part of the fuel's calorific value is absorbed by the cooling medium. Heat transfer rate in the cooling medium is 2 to 3 times of the brake power at low speeds and loads (Heywood, 2012). HJW depends on temperature of diesel engine and BTE as shown in **Figure 4**.

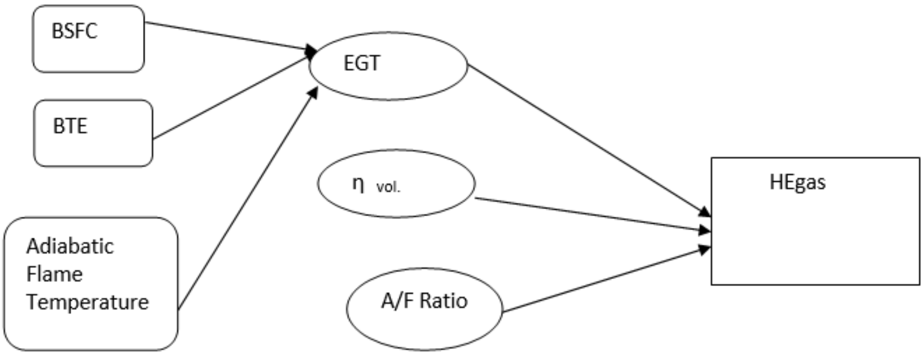

Figure 5. Influence of parameters on HEgas

Figure 6. Influence of parameters on HRAD

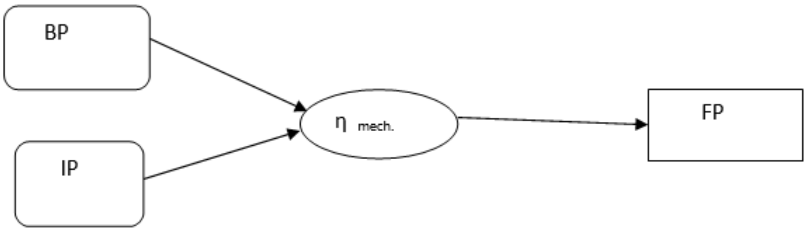

Figure 7. Influence of parameters on FP

Heat Loss in Exhaust Gas

The enthalpy of the exhaust gases may be divided into the following parameter: a 60% sensible enthalpy, 7% exhaust kinetic energy, 20% incomplete combustion and 12% heat transfer to the exhaust system. It is also investigated that some part of heat transfer to the exhaust system is radiated to the surrounding and the rest of it ends up in the cooling medium (Heywood, 2012). This is loss of heat to exhaust gas. Heat to exhaust gas is directly related to exhaust gas temperature. EGT increases with load for all fuels due to the requirement of more power and fuel. Flame temperature of biodiesel is higher than that of diesel at a particular load in spite of the lower calorific value of biodiesel, which causes an increase in EGT. EGT is found to be higher due to higher flame temperature of biodiesel as compared to that of diesel (Mohite et al., 2016b). HEgas depends on EGT, volumetric efficiency and air fuel ratio. EGT depends on BSFC, BTE and adiabatic flame temperature as shown in **Figure 5**.

Heat Loss in Radiation

This is the heat energy which is found to be lost in radiation and other unaccounted losses. Heat transfer due to radiation was found to be varied in the range of 0.5% to 10% of the total chemical energy released during combustion (Benajes et al., 2015). Heat transfer to radiation may also ranges from 20 to 35% of the total heat transfer in diesel engines (Heywood, 2012). HRAD depends on BTE as illustrated in **Figure 6**.

Friction Power

The deduction between indicated power and brake power is called as friction power. This power is found to be in the friction between moving parts of the engine, draw fresh air into the intake system and to the engine accessories driving. Mechanical efficiency is also found to be defined as the ratio of brake power to the sum of brake power and friction power. Lubricity decreases friction power which causes an increase in mechanical efficiency provided brake power is same. FP depends on mechanical efficiency and mechanical efficiency depends on BP and IP as illustrated in **Figure 7**.

Dhar and Agarwal (2014) reported minor wear of valves, pistons, piston rings, liners and small end bearing of connecting rod while using diesel blended with 20% Karanja biodiesel. High lubricity is the main advantage of biodiesel, which reduces friction losses and improve brake power. Good lubrication reduces friction in engine components, thereby reducing energy consumption and wear (Tung & McMillan, 2004).

Smoke Emission

Flame is not uniform in a diesel engine at the time of combustion. During self-ignition, flame covers all areas of combustion chamber which have air-fuel ratio in combustible range. Equivalence ratio ranges from 0.8 to 1.5 which assist in combustion. When there is rich air-fuel mixture in the combustion zone, there is not sufficient oxygen to form carbon dioxide, but carbon monoxide

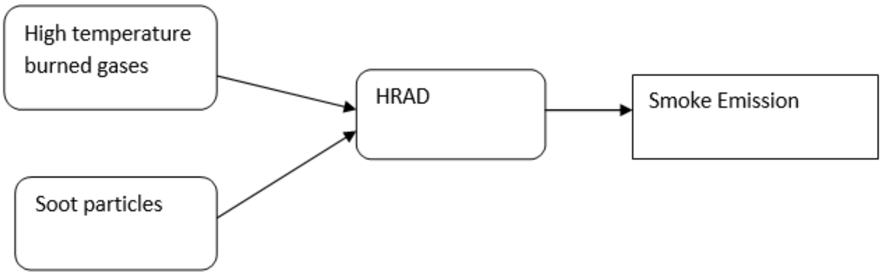

Figure 8. Influence of parameters on Smoke

and solid carbon would be formed. Black smoke comprises of these solid carbon particles. Diesel engines operate with an overall lean air-fuel ratio. Density of particulate emission is found to be maximum when the engine is under higher load. This is due to higher quantity of fuel injected to get more power resulting in rich mixture and poor fuel economy. Soot particles comprises of groups of solid carbon spheres. The diameter of these solid carbon spheres ranges from 10 nm to 80 nm (1nm=10^{-9}m) (Pulkrabek, 2003). Radiation by soot was found to be a significant source of losses in efficiency of engines. The soot was found to be luminous during combustion and it was found to be an important source of radiation. Carbon dioxide and water vapour molecules were also found to emit radiation, but its quantity was found to be lower than that of soot particles (Benajes et al., 2015). The high temperature burned gases and the soot particles are the two sources of radiation in the diesel engine. Fuel burns in a turbulent diffusion flame when fuel and air mix together in diesel engine. The flame is found to be luminous and soot particles which mostly consist of carbon are formed in the combustion process. In a diesel engine, the radiation of soot particles is nearly five times the radiation of the gaseous combustion products (Heywood, 2012). Thus, it is investigated that smoke emission is more harmful to the atmosphere and it also increases heat loss to radiation. Therefore, this characteristic must be chosen as a key parameter in the Energy Audit as compared to other emission characteristics such as CO, UBHC and NO_x. Thus, increase in smoke emission results in increase in heat loss to radiation. Thus, smoke depends on heat radiation and heat radiation depends on high temperature burned gases and soot particles as illustrated in **Figure 8**.

CONCLUSIONS

It is concluded that the following performance and emission characteristics of the diesel engine have been chosen as important parameters to evaluate diesel engine fuelled with diesel and biodiesel blends by energy audit at the primary level (Mohite & Maji, 2020).

1. Brake Specific Energy Consumption
2. Heat Flow Analysis
    a) Heat utilise in Brake power (HBP)
    b) Heat loss in Jacket cooling water (HJW)
    c) Heat loss in Exhaust Gas (HEgas)
    d) Heat loss in Radiation (HRAD)
3. Friction Power
4. Smoke Emission

This may be chosen as preliminary energy audit method to evaluate diesel engine fuelled with biodiesel blends to save time. If the blend fuel is found to be feasible in diesel engine, then it would be used in diesel engine else it would to rejected altogether without the need of evaluation of any other parameters. This may be recognised as a method of certification for biofuel performance in diesel engine.

ABBREVIATIONS

BP	: Brake Power
BSFC	: Brake Specific Fuel Consumption
C.V.	: Calorific Value
BSEC	: Brake Specific Energy Consumption
BTE	: Brake Thermal Efficiency
EGT	: Exhaust Gas Temperature
$\eta_{vol.}$	: Volumetric Efficiency
A/F Ratio	: Air Fuel Ratio
IP	: Indicated Power
$\eta_{mech.}$	: Mechanical Efficiency

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