Performance and Combustion characteristics of waste cooking oil produced biodiesel/diesel fuel blends

Dissertation-II

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MECHANICAL ENGINEERING

By

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ABSTRACT

Profusely use of petroleum based fuel has result in depletion of fuel reserve and also causes global warming across the earth due to increase in green house gas. So researches have moved a step towards for alternative of petroleum based fuel that overcomes the fuel crisis problem. This experimental investigation reports the production of biodiesel using pure/waste mustard oil through homogeneous alkali-catalyzed transesterification with methanol using potassium hydroxide as a catalyst. The parameters which affect the transesterification process such as catalyst concentration and oil to methanol molar ratio were investigated so as to find out the optimal condition for maximum yield of biodiesel. This research study also evaluates performance and emission characteristic of biodiesel blends at 10%, 20% and 30% with diesel. As a result, optimum conditions for production of biodiesel were found to be: 2% KOH wt/wt of oil. 1:9 oil to methanol molar ratio and reaction temperature 55-60^{0}C. Biodiesel/diesel blend show improves performance and emission characteristics as comparatively as diesel fuel. Besides, comparable physiochemical properties such as Flash point, Kinematic viscosity, density and calorific value were found for biodiesel compared to diesel fuel respectively.

Keyword:- Mustard oil, Waste mustard oil, Transesterification, Biodiesel, Performance and emission Characteristics.

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "***Performance and Combustion characteristics of waste cooking oil produced biodiesel/diesel fuel blends***" in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of Mr. Sandeep Kumar Duran (Assistant Professor) Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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The external viva-voce examination of the student was held on successfully ___________

Signature of Examiner

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CHAPTER-1

INTRODUCTION

Petroleum based fuels are globally use during past thirty years and also increase the consumption due to human population explosion and growth of industrialization. Which has resulted in diminish of petroleum based fuel reserve and that petroleum based fuel is also responsible for global warming by increased green house gas (GHG) emission. Because of those outcomes, a step is move towards replacement, substitute and renewable source of energy which has lesser impact on environment.

Country like India has 2^{nd} populated country in the world and only satisfies or meets 22% demand of crude oil, rest 78% demand of crude oil imported from other country like Saudi Arab, Iraq and Iran. Figure-1 shows the consumption and production of crude oil in India and Figure-2 shows India total energy consumption by source. Biodiesel is the one of the best choice as alternative source or blending component of diesel in compression ignition engine and it can work in engine without any modification need [1]. Hence because of some characteristic issues of biodiesel that cannot entirely replaced by diesel fuels, otherwise there are some different benefits of biodiesel over diesel fuel [2]. biodiesel is biodegradable (Of a substance or object capable of being decomposed by bacteria or other living organisms) and will not discharge toxic gas because of lower aromatic and sulfur content than petroleum based diesel fuel and also it has higher combustion efficiency than diesel fuel [3]. Biodiesel has lower exhaust gas emission such as unburned hydrocarbon, monoxide and particulate matter except NOx so lower the green house effect [4]. Generally biodiesel is chemically combination of methyl/ethyl ester with long chain fatty acids and commonly produce from non toxic biological resources such as edible oil, non edible oil [5], animal fats [6], microalgae, or even used waste/used cooking oil [7]. Vegetable oil is one of the best options for producing biodiesel because they are renewable in environment [8]. There are two varieties of vegetable oils edible and non edible oils.

Mostly edible oil is first choice for biodiesel production because of easy availability in nature and the qualities of produced biodiesel are very much suitable for blending of diesel fuel [9]. But use of edible oil in production of biodiesel cause several difficulties like human food insufficiency in the developing countries and greater impact on forest because more arable land is require for plantation purpose so deforestation is greatly increase in some countries. So in order to diminish this difficult situation, many researches have to be carrying out on non edible oil and also it's not suitable for human consumption because it's toxic in nature [5]. But most of non edible oils have high value of free fatty acid so the overall cost for producing biodiesel is become increased because many kinds of chemical process has to be done for biodiesel production [10]. Move towards the animal fats they also have same problem due to the high free fatty acid contain the processing cost for production of biodiesel become increased [11].

Waste/frying cooking oil is best step for production of biodiesel because commonly it's thrown away after use, without any treatment and it will pollute the nature [12]. There are many benefits in production of biodiesel through use of waste cooking oil because it's very cheap material [13] and also there is no need of any arable land for biodiesel producing crops. Content of free fatty acid get increased because of presence of heat and water in waste cooking oil [14]. Due to higher value of viscosity in waste cooking oil, it's not directly use in engine that cause many serious problem in engine then transesterification process is done for reducing viscosity of oil to producing biodiesel and comparing with diesel fuel this produced biodiesel giving similar fuel properties [15-16].

Transesterification process has done by three reversible reactions which content conversion of tri-glyceride convert into di-glycerides after that di-glyceride convert into mono-glyceride and finally mono-glyceride covert into glycerol need 3 mol of alcohol. Glycerol is obtained as by-product of reaction [17-18]. The composition of free fatty acid of parent oil decided the selection of base and acid catalyst reaction. In compared to acid catalyst reaction, base catalyst reaction can obtain high yield of biodiesel and high purity at short time (30-60 min) [19]. Generally CH_3ONa (sodium methoxide), NaOH (sodium hydroxide), KOH (potassium hydroxide) and CH_3OK (potassium methoxide) base catalyst is used in process of trasesterification [20].

In order to selection and use of alcohol for transesterification process, methanol promising better reaction rate and less costly. The produced FAME is easily evaporating than respective ethyl esters. But ethanol gets obtain from renewable feed stocks and less toxic [21].

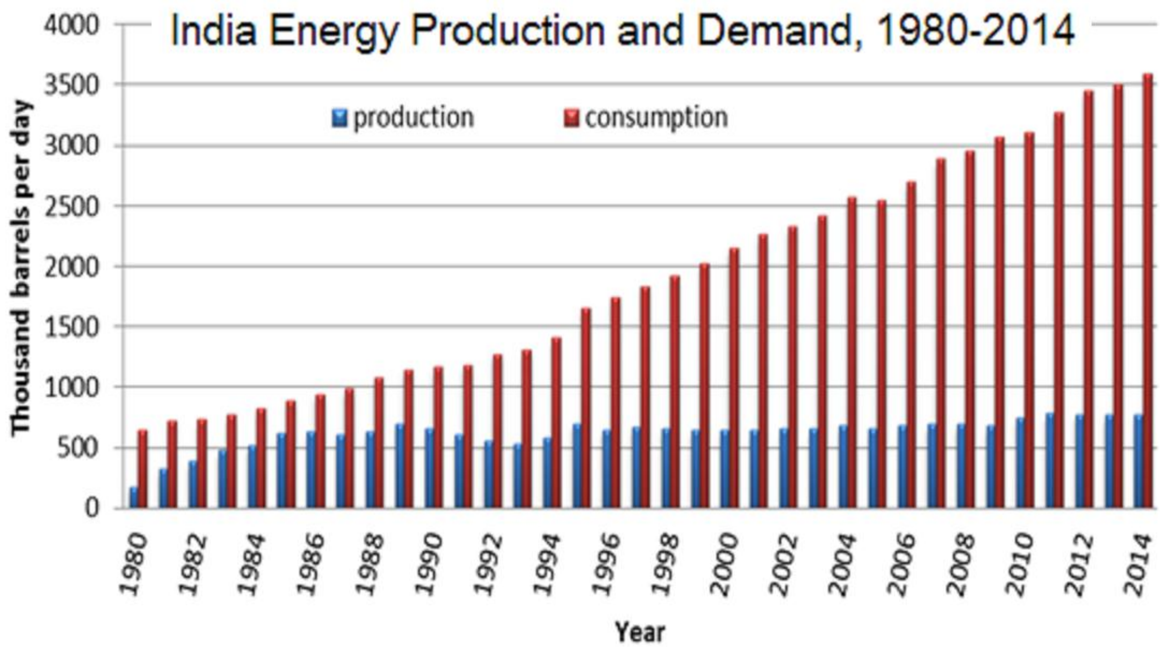

Figure 1: India crude oil production and demand
Source: United States Energy Information Administration, 2015

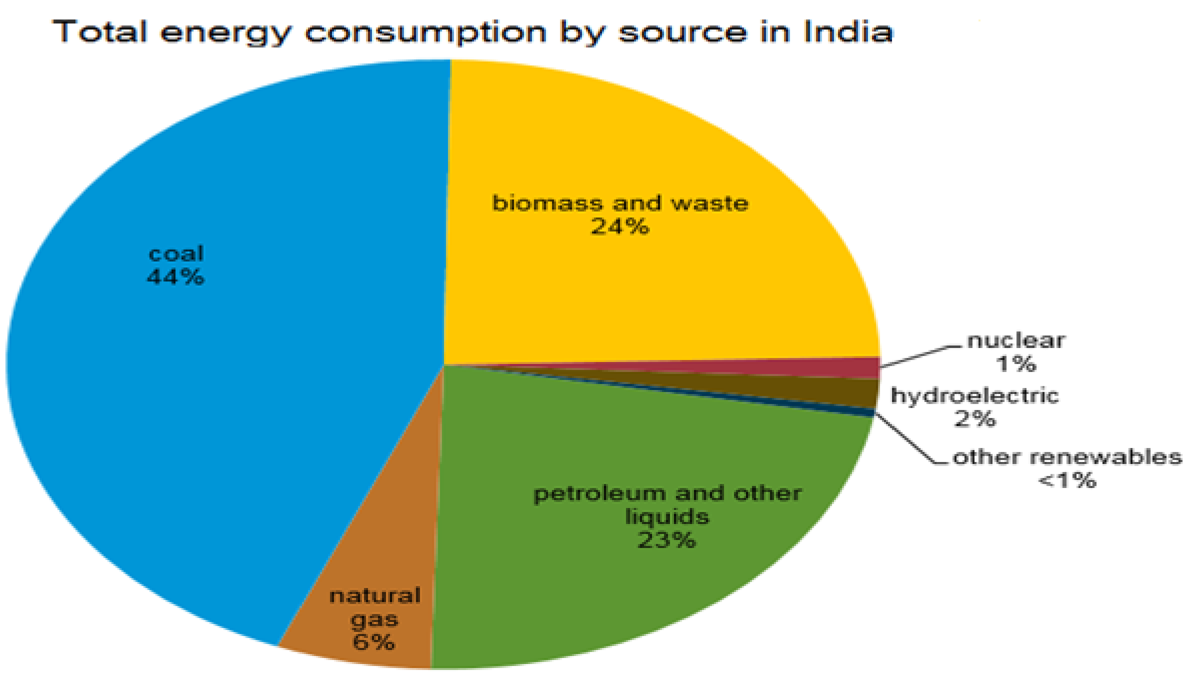

Figure 2: Total energy consumption by source in India
Source: International Energy Agency

1.1 Sources Of Biodiesel Production

Table 1: Source of biodiesel production [22, 23, 24]

SOURCE OF BIODIESEL PRODUCTION		
Primary biofuel	Natural biofuel	Firewood, crop residues, landfill gas, forest , plant ,Animal waste
Secondary biofuel	1st generation biofuel	Potato, Wheat, corn, sugarcane, beet, edible oil (soybean, peanut oil, sunflower, rapeseed, cottonseed oil, palm oil, canola oil, coconut, castor oil, mustard oil)
Secondary biofuel	2nd generation biofuel	Non edible vegetable oil (Jatropha, karanj, mahua, linseed, cottonseed, camelina, polanga, cassava), straw, grass, wood, waste recycled oil (cooking oil, frying oil), animal fats (beef tallow, pork lard, yellow grease, by product from fish oil)
Secondary biofuel	3rd generation biofuel	Microalgae, microbes

1.2 Various Methods For Production Of Biodiesel

There are various numbers of method are available for biodiesel production showing in table number 2.

Table 2: Methods use for biodiesel production

Method	Definition	Advantages	Disadvantages	Reference
Blending (dilution)	Direct blend or diluted with conventional diesel fuel	Improve the viscosity, minimize the engine performance problem like injector coking and carbon deposition	Not suitable for long term because of higher viscosity, lower volatility	25,26
Micro emulsification	Colloidal equilibrium dispersion of isotropic lipid mixture of oil, water and surfactant, frequently in combination with a co-surfactant.	Reduce the viscosity of oil, during combustion it has better spray pattern	Lower energy content, lower cetane number	27,26
Paralysis (thermal cracking)	In pyrolysis process the conversion is done from vegetable oil to fuel pyrolysis oil by heating or heating with presence of catalyst in absence of oxygen and split of chemical bond to form small molecules.	Lower processing cost, good compatibility with engine and fuel standard, feed stock flexibility	Energy intensive	26

Esterification or Transesterification	Also known as alcoholysis, it’s a chemical reaction of oil with the presence of alcohol where it is catalyzed by a base catalyst or acid to form glycerol and ester.	Most viable and promising process, simplicity of process, higher conversion efficiency, suitable for industrialized production	Glycerol and waste water (they are by-product) disposal problem	28,26
Ultrasonic reactors	Ultrasonic waves are used to initiate the chemical reaction and it can heat and also mix the reactant.	Ultrasonic method can decrease the 50% use of the catalyst; also reduce the reaction time, reaction temperature and energy required.	-	26

1.3 Different Factors Which Affect The Transesterification Process

In production of biodiesel transesterification process is affected by many parameters. Which are time and pressure of reaction, moisture content in oil, reaction temperature, type and wt% of catalyst, type of alcohol used, free fatty acid content in oil and molar ratio of methanol to oil [29]. Generally in the process of transesterification NaOH and KOH is widely used catalyst because they are support at minimum reaction pressure and temperature, economically cheap, availability of that kind of catalyst is more and conversion to biodiesel taken place at minimum reaction time [30].

1.3.1 Molar ratio of alcohol to oil or Quantity of alcohol

Many researchers were founded that molar ratio of methanol to oil is plays important role in yield of biodiesel. If the molar ratio of methanol to oil increased than the conversion efficiency of biodiesel will increase correspondingly. Theoretically, the trasesterification reaction wants 3 mol of alcohol for 1 mol of oil to produce 3 mol of fatty acid ester and 1 mol of glycerol [31]. Figure 3 shows the effect of molar ratio on yield of biodiesel.

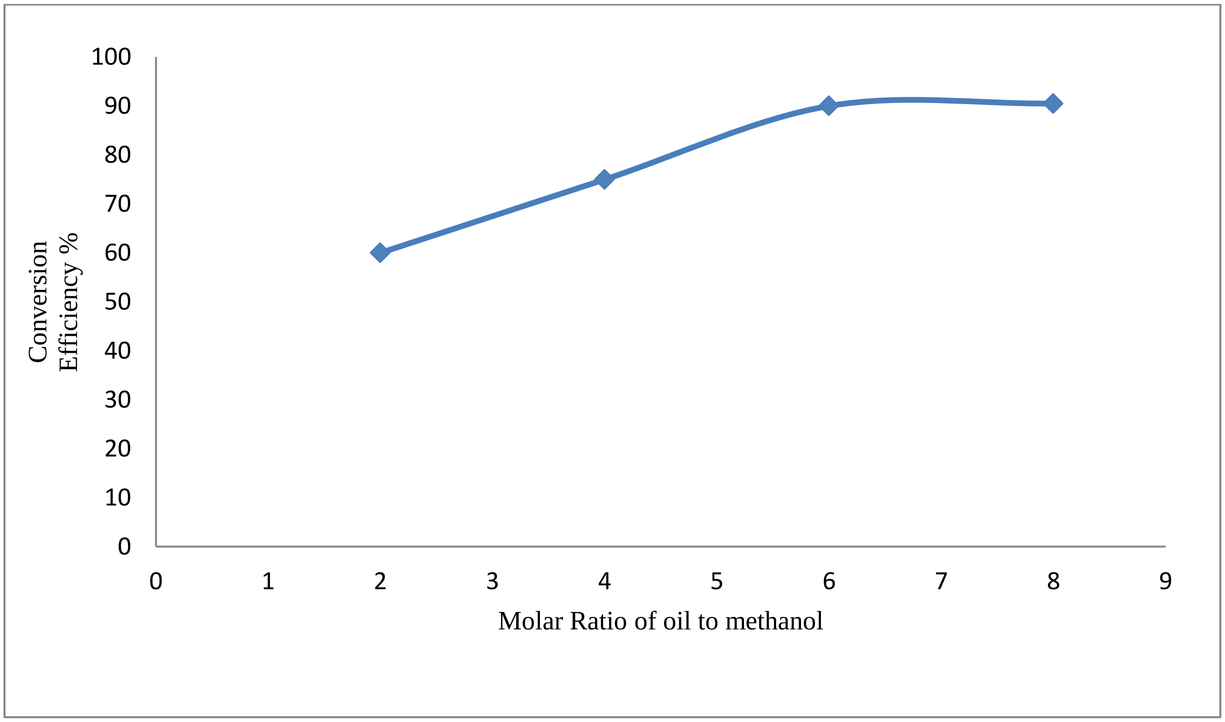

Figure 3: Effect of molar ratio on the yield of biodiesel [34]

1.3.2 Reaction time

From previous literatures review they are concluded that the yield percentage of biodiesel is increasing when the reaction temperature get increase [32]. Due to the mixing and dispersion of alcohol into oil initially cause slow reaction rate. But after that reaction proceed very fast. Also they are concluded that the reaction time less than 90 min has higher yield of biodiesel, further increase the reaction time has slightly difference on yield of biodiesel or may be its constant value of yield [33]. Figure 4 shows the effect of reaction time on yield of biodiesel.

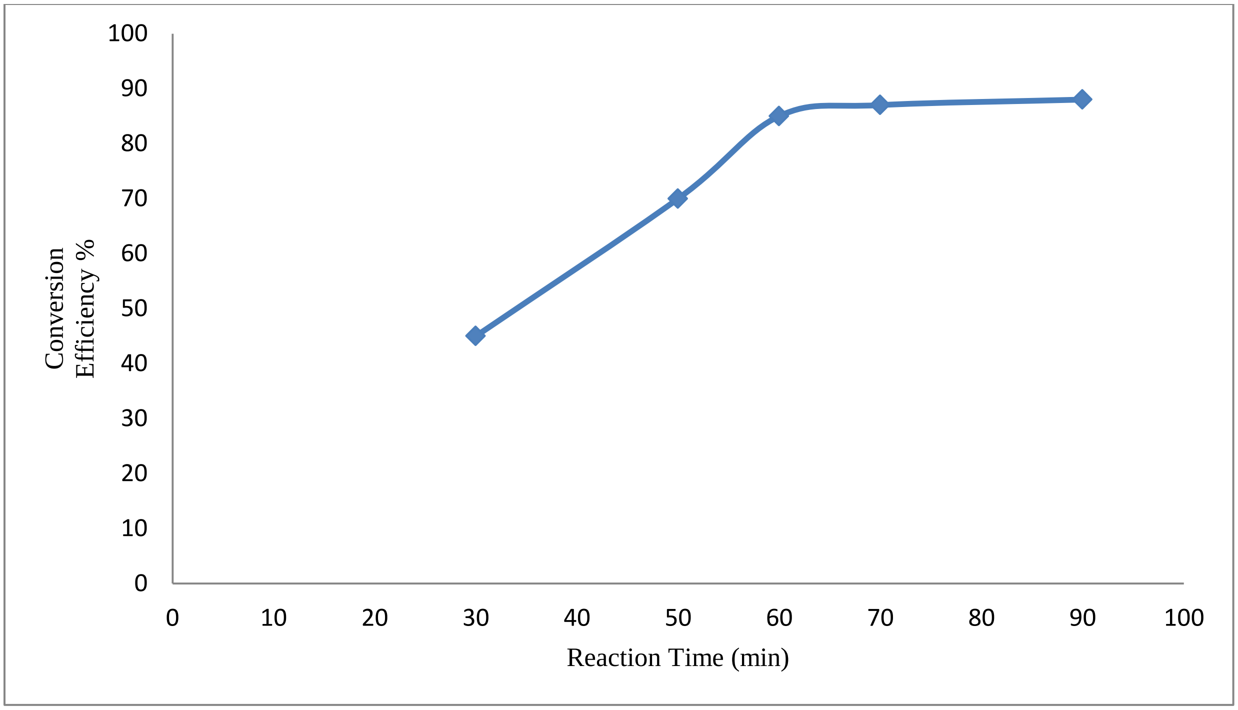

Figure 4: Effect of reaction time on yield of biodiesel [34]

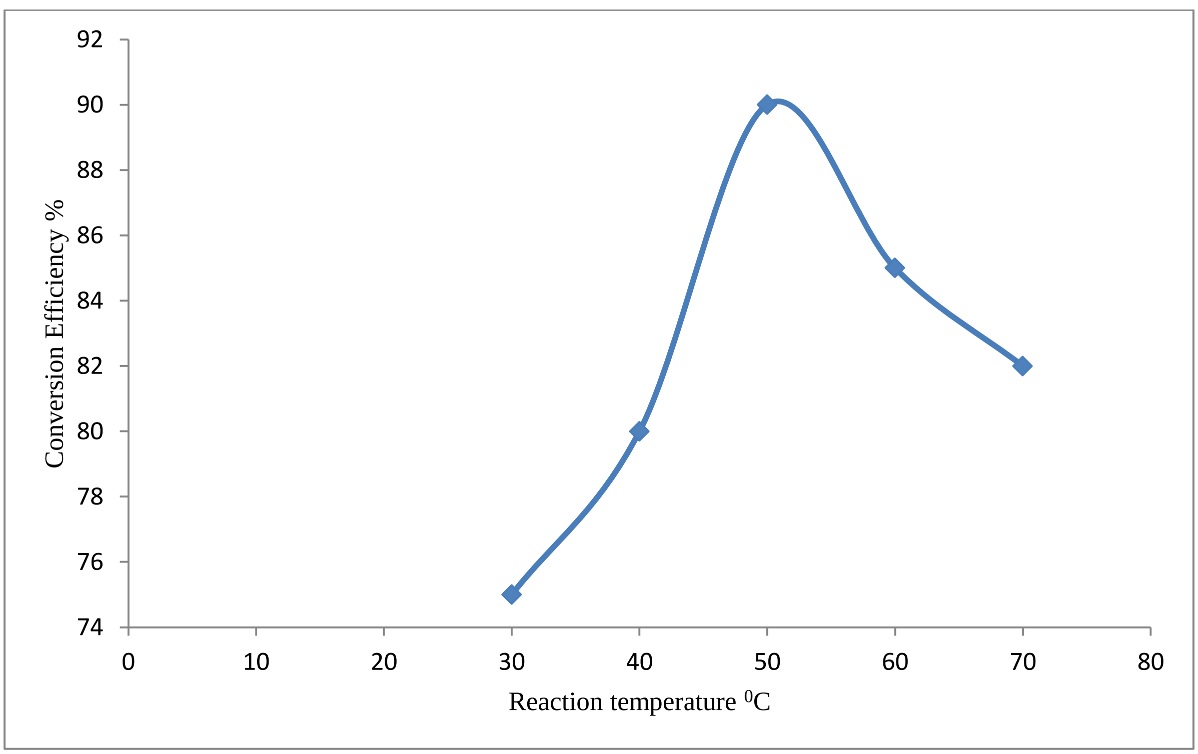

Figure 5: Effect of reaction time on yield of biodiesel [34]

1.3.3 Reaction temperature

The yield of biodiesel production is affected by the reaction temperature, however the viscosity of oil get decreasing when temperature is increased and reaction temperature also affect the reaction time, reaction time get decreasing when reaction temperature is increased. The optimal temperature ranges from 50 to 60˚C for higher yield percentage of biodiesel [31]. Figure 5 shows effect of reaction temperature on yield of biodiesel.

1.3.4 Catalyst Concentration

From previous literatures review generally sodium hydroxide (NaOH) and Potassium hydroxide (KOH) used as catalyst in transesterification process but many researchers have found that sodium methoxide is more effective than NaOH because when NaOH is mixed with methanol than small amount of water will produced in exothermic reaction [32] and that affect the reaction and yield percentage of biodiesel. So that NaOH is mixed with methanol seperatory before adding in oil. When the concentration of catalyst gets increased than yield percentage of biodiesel get increase [31].

CHAPTER- 2

TERMINOLOGY

GHG	Green house gas
KOH	Potassium hydroxide
NaOH	Sodium Hydroxide
FAME	Fatty Acid Methyl Ester
HC	Hydro Carbon
CO2	Carbon Dioxide
CO	Carbon Monoxide
NOX	Nitric Oxide
O2	Oxygen
BSFC	Brake Specific Fuel Consumption
FFA	Free Fatty Acid
WCO	Waste Cooking Oil
CNG	Compressed Natural Gas
CI	Compression Ignition
PM	Particulate Matter
VCR	Variable Compression Ratio
BMEP	Brake Mean Effective Pressure
IMEP	Indicated Mean Effective Pressure
A/F RATIO	Air/Fuel Ratio
CH3OH	Methanol
MB	Mustard Biodiesel
WMB	Waste Mustard Biodiesel
IThEff	Indicated Thermal Efficiency
BThEff or BTE	Brake thermal efficiency
Mech Eff	Mechanical Efficiency
Vol Eff	Volumetric Efficiency
IP	Indicated Power
BP	Brake Power

CHAPTER- 3

RATIONALE AND SCOPE OF THE STUDY

The reason of ever growing human population and industrialization explosion the use of fossils fuels have greatly increased and this fossils fuel also responsible for green house effect on environment and has also resulted to diminish the petroleum based fuel reserve. GHG emission such as unburned HC, CO_2, CO and NO_X has adversely affected on human heath from past few decades. Because of those outcomes, a step is being toward the alternative, replacement and some renewable source of energy, which has lesser impact on environmental condition, human health and global warming effect. So the biodiesel has one of the best choices for that [1].

1. Biodiesel is biodegradable in nature.
2. Biodiesel is less toxic emission comparatively diesel fuel.
3. Cost of biodiesel preparation is economically cheap.
4. Performance characteristic of biodiesel comparatively equal than diesel fuel.
5. Biodiesel can run in compression ignition engine without any major modification needs.

CHAPTER- 4

OBJECTIVES OF THE STUDY

1. To carry out preparation of the biodiesel through waste mustard oil and fresh mustard oil by transesterification process.
2. To compute the fatty acid profile of that waste mustard oil. That fatty acid profile helps to getting fatty acid composition in oil and compute the value of methanol add in transesterification according to molar ratio of methanol to oil.
3. To compute yield percentage of biodiesel at different values of molar ratio (1:3,1:6, 1:9) and wt % of KOH (2%,3%) to find optimal values for biodiesel production.
4. To compute properties of the waste mustard oil, fresh mustard oil and extract biodiesel such as viscosity, density, flash point and calorific value.
5. To use the biodiesel as blended fuel (B10, B20 and B30) in commercial diesel engine and to calculate engine performance characteristic parameters like indicated power, brake power, fuel flow, air flow, indicated thermal efficiency, brake thermal efficiency, fuel consumption, mechanical efficiency and volumetric efficiency.
6. To analysis the amount of emission gases such as NOx (Nitric oxide), HC (unburnt hydrocarbon), CO_2 (Carbon dioxide), O_2 (oxygen) and CO (carbon monoxide) in the exhaust of commercial diesel engine running on biodiesel.

CHAPTER- 5

REVIEW OF LITERATURE

T. Issariyakul et al., studied on comparison on transesterification of palm oil and mustard oil. In that transesterification process using KOH as a catalyst and reaction temperature kept between 40 to 60˚C. They are concluded that fatty acid composition of mustard and palm oil have great impact on transesterification process because fatty acid composition affect the percentage of saturated compound and chain length distribution. This both the parameters are play great role in each reaction step differently and transesterification process [35].

Sanjid et al. 2014, studied on production of biodiesel by waste mustard oil and their properties. They concluded that at time of engine performance test mustard biodiesel of blend of B10 and B20 showed 5-6% lower BTE and 8-13% higher BSFC compared to diesel based engine. They calculated the chemical properties of mustard biodiesel such as pour point (-18°C), cloud point (5°C), calorific value (40.404 MJ/Kg), oxidation stability (15.92 h). In engine emission test they are concluded that 9-12% higher NO, 19-40% lower CO, 2-7% lower noise and 24-42% lower HC emission are produced compared to diesel fuel. Finally they are compared the engine emission and performance characteristic of mustard biodiesel with palm biodiesel [36].

K. Srithar et al., 2014 Studied on the production of biodiesel from karanj and mustard oil. This biodiesel is tested in diesel engine at different-different mixing ratio. In their research works they examined the effect of dual blend biodiesel on engine works and calculated the emission exhaust gas from the diesel engine. In that research work they concluded that the BTE (brake thermal efficiency) of dual blend biodiesel is more than commercial diesel engine (working fluid is diesel). The temperature of exhaust gas is lesser than commercial diesel engine exhaust temperature but the emission of NOx, smoke and hydro carbon is greater than other commercial diesel engine in which diesel use as a fuel [37].

Z.M. Hasib et al. studied on use of mustard oil as an alternative to diesel fuel. In their study they compute the properties of biodiesel which is produced by mustard oil and they found that the biodiesel has slightly different properties than diesel fuel. It is also observed that the diesel engine is running without any modification and any difficulties by biodiesel but only some optimal performance of engine is deviate by use of that biodiesel blends (B20, B30, and B50) [38].

A.B. Fadhil et al. 2013, studied on production of biodiesel by mustard oil through alkali-catalyzed transesterification with alcohol (ethanol) using homogeneous catalyst (KOH) and they also studied on the process parameters which are affect the production of biodiesel, process parameters such as reaction temperature, molar ratio of ethanol to oil, reaction time, catalyst type and their concentration. So that helps to getting the optimal condition for biodiesel production is easily and finally they was concluded that the optimal condition for biodiesel production are 8:1 molar ratio of ethanol to oil, 0.90% KOH wt/wt of oil, reaction time is 60min and reaction temperature is 60^0C . The produced mustard oil ethyl ester is washed with activated carbon by dry wash method; this activated carbon was produced from the de-oiled cake [39].

K. S. Chen et al., 2012 studied for improving the yield of biodiesel through waste cooking oil using a microwave heating system. It was concluded that the best performance found with 0.75 wt% sodium hydroxide (NaOH) and 0.75 wt% sodium methoxide (CH_3ONa) catalyst, respectively. The yield of biodiesel is produced with sodium methoxide is higher than the sodium hydroxide [40].

H. Amani et al., 2015 studied on biodiesel production with waste cooking palm oil and palm oil by transesterification with methanol was studied using cesium-modified silica catalyst ($CsM\text{-}Sio_2$) as a heterogeneous catalyst and the effect of catalyst on different transesterification parameters were investigated. It was concluded that the yield of biodiesel reached 90% at 65^0C in 3h with 3 wt% catalyst loading [41].

Suchada Sirisomboonchai et al., 2015 studied on production of biodiesel through waste cooking oil by transesterification. In that study methanol by using calcined scallop shell (CSS) as catalyst was carried out in a closed system for biodiesel fuel production. The effect on transesterification parameter was investigated. It was concluded that the maximum yield of biodiesel reached 86% at 5 wt% catalysts loading at 65% temperature and reaction time of 2h [42].

Anh N. Phan et al., 2008 studied on transesterification of waste cooking oils by alkali-catalyst (KOH) and methanol was carried out in a laboratory scale reactor. The effects on transesterification parameters were investigated. It was concluded that maximum yield of biodiesel 88-90% was obtained at the temperature of 30-50˚C, 0.75 wt% KOH and methanol/oil ratio of 7:1-8:1 [43].

T. H. Do, 2016 studied the effect of cooking condition on the cold flow properties and kinematic viscosity of biodiesel produced from cooking oil. In this work, sunflower, corn and canola oils were used as vegetable oil and salt content, water content, cooking temperature and cooking time were selected as experimental parameters. Finally it was concluded that with increase in water content, cooking temperature, cooking time and salt content led to decrease in the cold flow properties and physical properties of B100 biodiesel sample from waste cooking [44].

Bilgin et al., 2015 studied the production of lowest kinematic viscosity waste cooking oil biodiesel through transesterification by using sodium hydroxide as catalyst and ethanol as alcohol. Individual effects of main parameter such as catalyst concentration (0.50-1.75%), reaction time (60-150 min), reaction temperature (60-90˚C) and alcohol/oil molar ratio (6:1-15:1) on the kinematic viscosity of producing biodiesel were investigated. Finally it was concluded that reaction parameters giving the lowest kinematic viscosity of 4.387 centi-stocks were determined as 1.25% catalyst concentration, 70˚C reaction temperature, 120 minutes reaction time and 12:1 alcohol/oil molar ratio [45].

Dennis Y.C. Leung et al., 2010 reviewed different approaches of reducing the value of free fatty acid in the oil and refinement of crude biodiesel that are mainly used in the industry and reported that there are four primary factors affecting the yield of biodiesel, i.e. alcohol quantity, reaction time, reaction temperature, and catalyst concentration which describe other new processes for production of biodiesel. For instance, the non-catalytic supercritical methanol process which has shorter reaction time and lesser purification step. But this method requires high temperature, high pressure and biox co-solvent process. However this process, cannot handle waste cooking oil and animal fats [2].

M. M. K. Bhuiya et al., 2014 reviewed the second generation biodiesel used as biodiesel feedstock. Many aspect of this feedstock are reviewed and discussed in this paper. These aspects are cost effectiveness, necessity of second generation biodiesel, biodiesel conversion technology, and biodiesel feedstock, improving efficiency of the production process as well as performance and emission characteristics [46].

Man Kee Lam et al., 2010 reviewed the current status of biodiesel production and potential of waste cooking oil as an alternative feedstock and also discussed about the homogeneous, heterogeneous and enzymatic transesterification on oil with high free fatty acid in detail. It was found that in comparison to homogeneous base-catalyst process, the heterogeneous acid catalyst and enzyme is the best option to produce biodiesel from oil with high value of FFA. However these heterogeneous acid and enzyme catalyst system also introduce the mass transfer problem so therefore are not favorable for industrial application [31].

C.D.M. de Araujo et al. 2013, reviewed the different processes used for production of biodiesel from different types of used cooking oil. While several scientific studies on processes of pretreatment and transesterification of WCO were analyzed with their variations such as alkaline catalysis, acid catalysis, enzymatic catalysis and non-catalytic conversion techniques [47].

YieHua Tan et al., 2015 studied on increasing yield of biodiesel in transesterification process by use of homogeneous catalyst such as NaOH and KOH through vegetable oil and studied on heterogeneous base catalyst that are calcium oxide which was yield from unused material like eggshell of chicken, ostrich, quail etc. Use of calcium oxide gives the excess washing problem and also emission of NOx remained high than petroleum based fuel. They were also found that the emission of NOx, particulate matter, carbon monoxide and unburnthydrocarbon emission are lower in emulsified biodiesel [26].

XiangmeiMeng et al.2008, studied on the yield of biodiesel through waste cooking oil and effects of reaction parameters like reaction temperature, reaction time, molar ratio of methanol to oil, wt percentage of catalyst used in transesterification process on yield of biodiesel. In this research they experiments of B20 blend fuel used in diesel engine and they were concluded that emission of CO, HC and particles were decreased by 18.6%, 26.7% and 20.58% respectively [34].

Ali M. A. Attia et al., studied on yield of biodiesel through waste cooking oil by transesterification process and engine performance characteristics were calculated at different fuel blends with diesel fuel. This paper concluded that engine load and blending ratio of biodiesel were direct affect the value of peak cylinder pressure. At B20 blend of biodiesel with diesel fuel gives higher value of brake specific energy consumption (BSEC) [48].

M. Vijay Kumar et al. 2017, reviewed on improvising the performance and combustion characteristics of biodiesel fuel by using additives, which are also diminish the emissions. Various problem regarding use of biodiesel such as high density, lower heating value, high oxides content of nitrogen and higher fuel consumption. By use of additives problem regarding biodiesel get eliminated. Finally researcher was concluded that use of antioxidant additives, metal based additives, oxygenated additives and cetane number additives get help to improvising the combustion and performance characteristics [49].

K.Celebi et al. 2017, Studied on vibration and acoustic effect on unmodified CI engine when biodiesel and their blends was investigate in it. In that study blends of 20% and 40% sunflower and canola biodiesel with commercial diesel fuel was investigated. CNG is introduce in intake manifold of CI engine. This study concluded that use of canola and sunflower biodiesel in CI engine reduced the vibration and sound pressure level. Use of CNG in intake manifold gets help to reduce vibration [50].

Vijayakumar Chandrasekaran et al. 2016, studied on non-edible oil for biodiesel preparation and use of nano additives for improvising performance and combustion characteristic. Mahua biodiesel is investigated in that research, firstly mahua biodiesel is run on engine without use of additive at different load, same speed and at different blends such as B20, B40, B60, B80 and B100. It was concluded that B20 gives best performance parameters than any blend. In second step of this study copper oxide nano additives used in B20 blend of mahua biodiesel and finally it was concluded that use of nano additives with biodiesel and diesel blend results in reducing emission of CO, smoke and HC [51].

S. M. AmeerUddin et al. 2015, Studied on use of pure mustard oil in CI engine blending with kerosene at various blend such as M20, M30, M40, M50 and M100 at various load condition from 6 kg to 15 kg and speed of engine kept constant at 2000rpm. Various physical properties like flash/fire point, density, calorific value and viscosity has been calculated firstly. Finally researcher concluded that M20 and M30 blend gives lower value of BSFC at 12.5 kg load and M20 blend with kerosene can be used for diesel engine [52].

W.N.M.W. Ghazali et al., 2015 reviewed on various feedstocks for biodiesel and analyzes their respective performance and combustion characteristics. In that review many performance and combustion parameters like BP, BTE, BSFC, NOx, CO2, CO, PM, smoke density and torque have been determined to compare with pure diesel. Finally this study concluded that in CI engine biodiesel can be used as an alternative of diesel fuel [53].

S. Imtenan et al. 2014, studied on use of additives such as diethyl ether, ethanol and n-butanol for improvising the performance and emission characteristic of palm biodiesel with diesel fuel. B20 palm biodiesel was investigated in this research, in B20 palm biodiesel 5% of additive has mixed. finally this research concluded that by use of diethyl ester as additive in palm biodiesel so that biodiesel shows higher brake power, lower fuel consumption, higher BTE and also emission of NO and CO get decreased [54].

CHAPTER- 6

EQUIPMENT, MATERIAL AND EXPERIMENTAL SETUP

6.1 Material used in Transesterification Process

1. Use methanol as an alcohol in transesterification.
2. Use homogeneous alkaline catalyst KOH in transesterification process, that catalyst is work as an activator in transesterification process.
3. Pure mustard oil and waste mustard oil for production of biodiesel.

6.2 Equipment used in Transesterification Process

1. R.B. flask (three neck bottle) of 2 liter capacity. In that three neck condenser, stirrer and thermometer is connected respectively.
2. Heating mantle of 2 liter size and 450 watt.
3. Thermometer to calculate temperature at different-different time.
4. Stirrer of 125 watts and 1440 RPM to continuous circulates the mixture of methanol, mustard oil and KOH.
5. Condenser to control the unusually wastage of methanol.
6. Seperatory funnel having 2 liter capacity is used to separate biodiesel and glycerol layer.
7. Burrate of 100 ml capacity is used to make proper concentration of methanol and catalyst. Also used for titration test for unknown sample or oil.
8. Density bottle of 50 ml capacity is used to find out density of oil and biodiesel. Value of density of oil is helps to getting the value of methanol in different molar ratio of methanol to oil and also wt % of KOH used.
9. Ostwald viscometer, also named as capillary viscometer or U-tube viscometer is used to find the value of viscosity of liquid.
10. Pensky-Martens type of closed-cup apparatus used to find out the value of flash point.
11. Bomb Calorimeter used for calculated the calorific value of sample.

6.3 **Experimental Setup of Laboratory Scale Setup**

Transesterification process of mustard oil is held in laboratory scale setup. In that process 500ml of pure mustard oil or waste mustard oil is taken in conical flask called R B flask of a capacity of 2 liter, KOH and methanol are mixed with different weight percentage (2%, 3%) and molar ratio of methanol to oil (1:3, 1:6, 1:9) respectively, to find out the optimal values of that parameters for higher the yield percentage of biodiesel. That wt % of KOH and molar ratio are calculated from fatty acid profile and formula derived from molar mass of oil and alcohol. Generally R B flask has three neck bottle in which condenser, stirrer motor and thermometer are connected respectively.

The condenser is used to avoid the looses of methanol because the methanol is evaporate above 50˚C temperature, thermometer is used to take the reading of temperature time to time because this transesterification process is held in temperature range of 55 to 60˚C and stirrer motor is used to continuous stirring the oil to equal distribution of the temperature in entire volume of oil.

From the previous literatures review it has to found that, at 55˚C the yield percentage of biodiesel has higher value, stirrer motor rotation speed has plays vital role on production of biodiesel and wt % of KOH has optimal value for production of biodiesel at 2-3wt/wt of oil and molar ratio has optimal value at 1:6 to 1:9. Figure 6 shows the arrangement of laboratory scale setup.

6.4 Material used in Engine Test

1. B10, B20 and B30 prepared by blend of mustard biodiesel and commercial diesel.
2. B10, B20 and B30 prepared by blend of waste mustard biodiesel and commercial diesel.

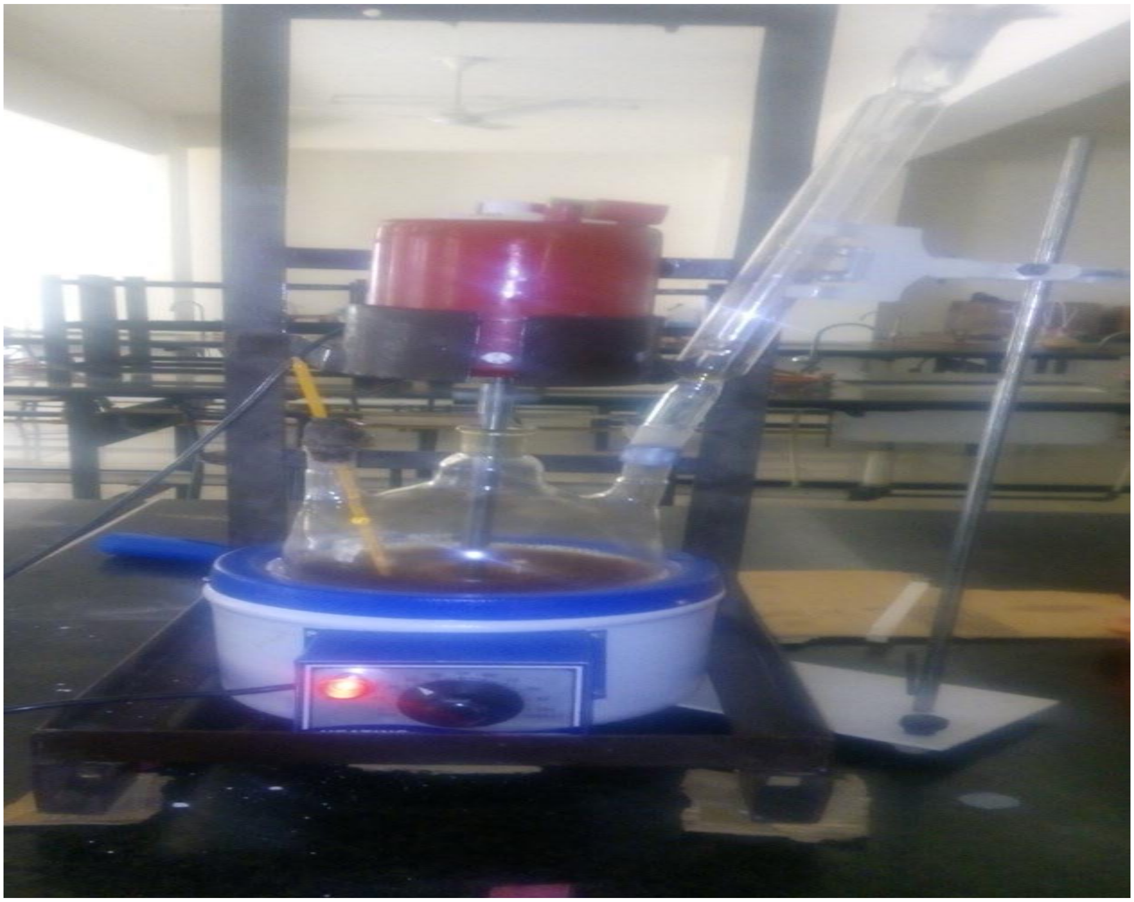

Figure 6: Laboratory Scale Setup

6.5 VCR Engine Test Setup

VCR engine test setup consist power 5.20 kW at 1500 rpm which is four stroke, single cylinder, constant speed, VCR (Variable Compression Ratio) Diesel engine connected to eddy current type dynamometer for loading purpose. Compression ratio can be changed without stopping the engine. Provision is also made for interfacing airflow, Fuel flow, temperatures and load measurement.

The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Gas analyzer is connected at engine exhaust to detect the emission gases such as such as NOx (Nitric oxide), HC(unburnt hydrocarbon), CO_2(Carbon dioxide), O_2(oxygen)and

CO (carbon monoxide). Table 3 shows the specification of VCR engine test setup and Figure 7 shows the arrangement of VCR engine test setup.

Table 3: Specification of engine test setup

Specification of VCR engine test setup	
Product	VCR Engine test setup 1 cylinder, 4 stroke, Diesel
Product code	234
Engine	Make Kirloskar, Type 1 cylinder, 4 stroke Diesel, water cooled, power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm. 661 cc, CR 17.5, Modified to VCR engine CR range 12 to 18
Dynamometer	Type eddy current, water cooled, with loading unit
Fuel tank	Capacity 15 lit with glass fuel metering column
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Gas analyzer	Detect the emission gas like HC, NOX, O2, CO and CO2
Software	“EnginesoftLV” Engine performance analysis software

Figure 7: VCR Engine test setup

CHAPTER- 7

RESEARCH METHODOLOGY

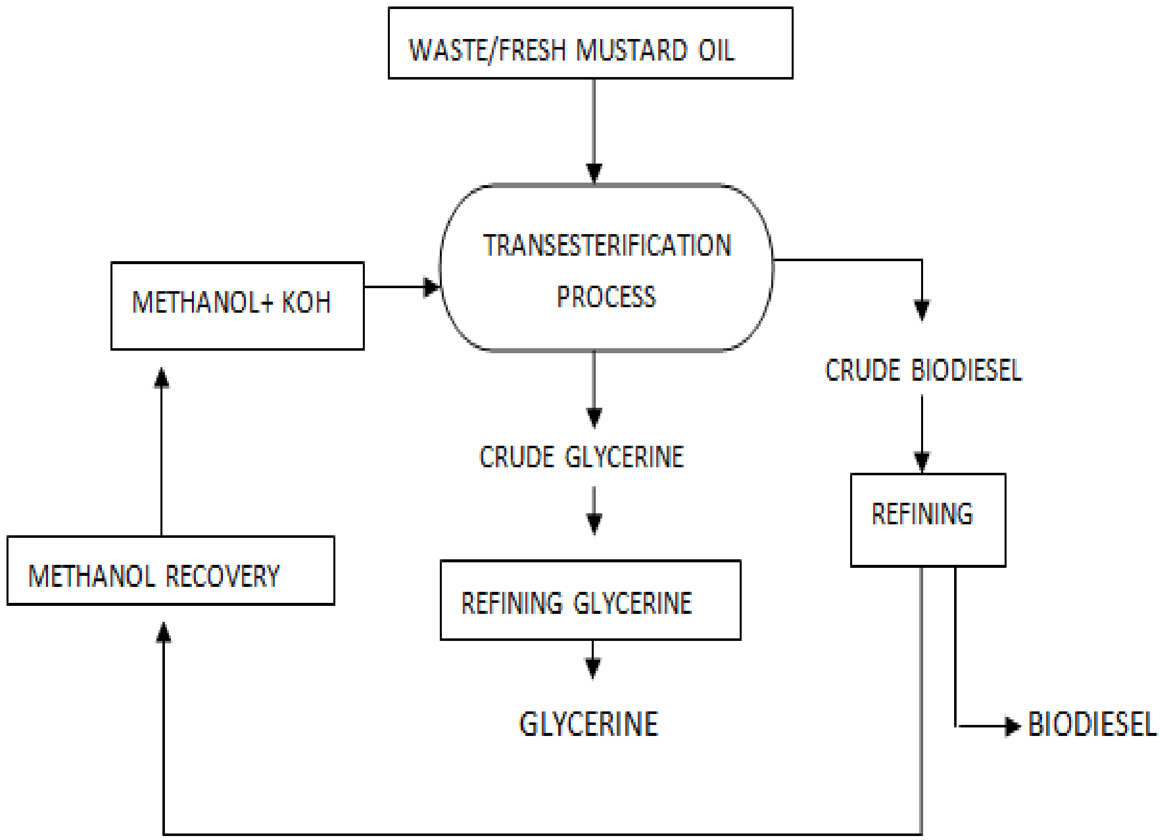

Figure 8: Basic Transesterification Protocol [55]

Transesterification is also named by alcoholysis or esterification process, by which we can decrease the value of viscosity of oil or triglycerides. In that process alcohol is transfer into ester by use of another alcohol that process is also similar to hydrolysis process but in hydrolysis process water is used instead of alcohol [2]. Before transesterification process we determine fatty acid profile of pure and waste mustard oil by which we can determine the molecular mass of that respective oil. The value of molecular mass of oil can get help to find the value of methanol at different molar ratio. Molecular mass of mustard oil is 972.67 gm/mole and for waste mustard oil is 973.70 gm/mole, derived from fatty acid profile of oil.

Preparation of biodiesel is held in laboratory scale setup in which methanol of having different molar ratio such as 1:3, 1:6, 1:9 respectively is mixed with homogeneous alkaline catalyst KOH with different wt percentage such as 2% and 3%. The amount of molar ratio and wt percentage of catalyst used has depended on the fatty acid profile of an oil or triglyceride. Volume of methanol which is used in trasesterification process is determine by formula which is given below

$$\text{Molecular ratio of } \frac{oil}{methanol} = \frac{mass\ of\ oil}{Molecular\ mass\ of\ oil} \times \frac{Molecular\ mass\ of\ methanol}{mass\ of\ methanol}$$

Where

Mass of oil = density of oil × volume of oil

Mass of methanol = density of methanol × volume of methanol

Molecular mass of mustard oil = 972.67 gm/mole (derived from fatty acid profile)

Molecular mass of methanol (CH_3OH) = 32.04 gm/mole

Methanol and KOH is not mixed with oil separatory because small amount of water is produced when the methanol and KOH react. So in process of transesterification methanol and KOH is mixed first in glass container. The mixer of methanol and KOH is called methoxide. Some amount of heat is produced as time of mixing because this is an exothermic reaction. Methoxide is corrosive in nature and also dangerous for living tissues like human skin. So safety precautions should be taken when the methoxide produced [56-61]. After the methoxide produced, mustard oil is taken in three neck R. B. flask and heated up to 55-60^{o}C than add methoxide into mustard oil. In three neck of R.B. flask condenser, stirrer motor and thermometer is connected respectively. Condenser is used to control the unusual wastage of methanol because methanol get evaporate above 50^{o}C and thermometer is used to take the value of temperature time to time. After mixing methoxide transesterification process gets start, this process complete in three steps in first step triglyceride coverts into di-glycerides, in second step di-glycerides converts into monoglyceride and in final step monoglyceride coverts into glycerol and biodiesel.

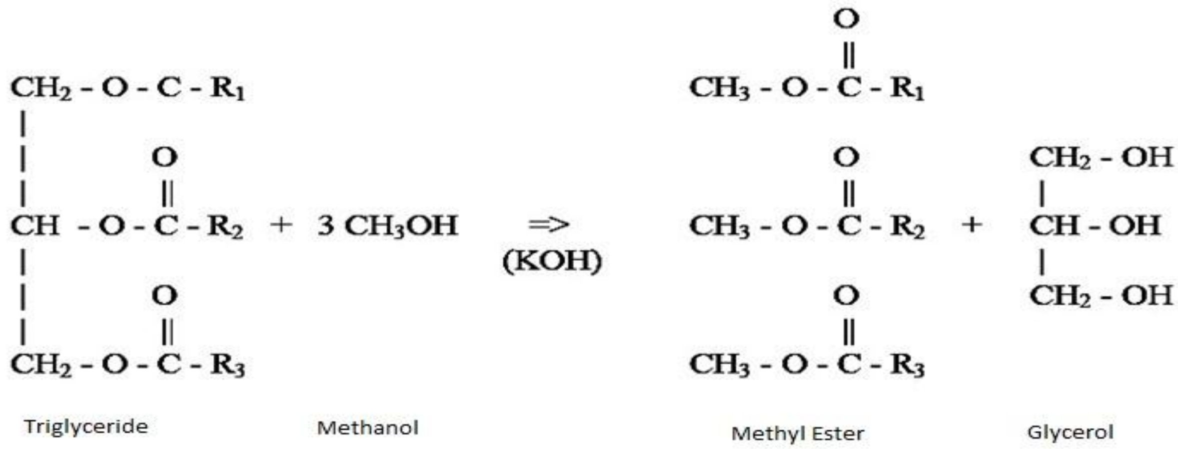

Figure 9: Reaction of triglyceride, methanol and glycerol [13]

Glycerol is generally a by-product in that transesterification process. Transesterification process is runs in laboratory scale setup for 1-2 hr generally at temperatures range 55-60^{o}C, time to time sample is taken from that mixer and pour warm water into that sample if two separate layers of biodiesel and glycerol is form than stop the process otherwise continue the process, figure 10 shows the separation layer of biodiesel and glycerol. HCL (Hydrochloric acid) is also used instead of warm water.

Figure 10: Separation of two layers

After 10 minute when warm water pouring

Figure 11: Separation of two layers in separatory Funnel after 1 hour when pouring warm water

If two layers of biodiesel and glycerol are formed than pour that mixer into separatory funnel. Generally glycerol layer is settling down in separatory funnel and biodiesel is in upper layer, figure 11 shows the separation of two layers in separatory funnel. After pouring the mixer in separatory funnel wet washing process is done on it. Warm water is pour into the separatory funnel to wash the glycerol of oil and then rest that oil into separatory funnel for a day. After a day two layers is form and glycerol is settling down take out that by opening the valve of separatory funnel and rest of biodiesel is remain in that. Figure 12 shows that separation.

Figure 12: Separation of two layers after 24 hours
(After washing process is done)

Take the biodiesel from separatory funnel into glass container. Methanol and water contain also exist in produced biodiesel that was eliminated by heated the biodiesel up to 110^{o}C[38]. Pure biodiesel can produce after this all process. Yield percentage of produced biodiesel can be calculated by formula which is given below.

$$\text{Yield percentage of produced biodiesel} = \frac{\text{Weight of produced biodiesel}}{\text{Weight of total oil used}} \times 100$$

After production and purification of biodiesel we calculated physical properties of biodiesel like flash point, density, calorific value and kinematic viscosity. These properties were determined by Pensky marten apparatus, density bottle, bomb calorimeter and Ostwald or U-tube viscometer respectively. Produced biodiesel from pure and waste mustard oil blended with commercial diesel fuel at different-different ratio such as 10%, 20% and 30%. After that all blends investigated in “VCR engine test setup” for determining the performance, combustion and emission characteristics at different load condition. Dynamometer is used for loading unit on this setup. Gas analyzer is attached at engine exhaust to detect the emission gas like HC, CO_2, CO, O_2 and NO_X.

CHAPTER-8

RESULTS AND DISCUSSION

8.1 Properties of Mustard and Waste Mustard Oil

Mustard seed is give 33% production of oil, that yield of oil is greater than soybean seed that only gives 18-23% yield of oil [62]. Properties like density, flash point, kinematic viscosity and calorific value of mustard and waste mustard oil was calculated given in Table 4.

Table 4: Properties of mustard and waste mustard oil

PROPERTY	Unit	FUEL	
		MO	WMO
Density	**gm/ml**	0.92	0.906
Kinematic viscosity	**mm2/sec**	31.55	48
Calorific Value	**MJ/kg**	38.8	38
Flash Point	**^{0}C**	268-272	270-278

Gas chromatography method used for determination of fatty acid profile. Fatty acid profile plays a vital role for produced biodiesel when it is run in engine. This profile consist of Saturated Fatty Acids, Mono unsaturated Fatty Acids, Poly Unsaturated fatty acids and Trans fatty acids. In which saturated fatty acid esters have better oxidation stability and higher cetane values, but at low temperature flow properties become poor[63, 25]. Fatty acid profile of mustard and waste mustard oil is given in Table 5. From that table unsaturated fatty acid for mustard oil consist acid (88.12%) is higher than saturated fatty acid content (11.22%).

Similarly results found in fatty acid profile of waste mustard oil in which unsaturated fatty acid content (73.71%) is higher than saturated acid content (26.24%). Content of acid in mono-unsaturated acid for both mustard and waste mustard oil is higher than poly unsaturated acid.

Table 5: Fatty acid profile for mustard and waste mustard oil

Sr. No	Parameter	Chemical formula	Molecular mass (gm/moles)	Result (%)	
I	**Saturated Fatty Acids**			**Waste Mustard Oil**	**Mustard Oil [39]**
1	Butyric Acid	$C_4H_8O_2$	88.11	ND	ND
2	Caproic Acid	$C_6H_{12}O_2$	116.15	ND	ND
3	Caprylic Acid	$C_8H_{16}O_2$	144.21	ND	ND
4	Capric acid	$C_{10}H_{20}O_2$	172.26	ND	ND
5	Undecanoic acid	$C_{11}H_{22}O_2$	186.29	ND	ND
6	Lauric acid	$C_{12}H_{24}O_2$	200.31	ND	ND
7	Tridecanoic acid	$C_{13}H_{26}O_2$	214.34	ND	ND
8	Myristic acid	$C_{14}H_{28}O_2$	228.37	0.82	0.05
9	Pentadecanoic acid	$C_{15}H_{30}O_2$	242.39	0.02	0.03
10	Palmitic acid	$C_{16}H_{32}O_2$	256.42	19.87	5.54
11	Heptadecanoic acid	$C_{17}H_{34}O_2$	270.45	0.07	0.03
12	Stearic acid	$C_{18}H_{36}O_2$	284.47	4.52	1.51
13	Arachidic acid	$C_{20}H_{40}O_2$	312.53	0.61	1.21
14	Heneicosanoic acid	$C_{21}H_{42}O_2$	326.55	0.035	0.04
15	Behenic acid	$C_{22}H_{44}O_2$	340.58	ND	1.09
16	Tricosanoic acid	$C_{23}H_{46}O_2$	354.61	ND	0.04
17	Lignoceric acid	$C_{24}H_{48}O_2$	368.63	0.3035	1.68
II	**Mono unsaturated Fatty Acids**				
1	Myristoleic acid	$C_{14}H_{26}O_2$	226.36	ND	ND
2	Cis-10 Pentadecanoic acid	$C_{15}H_{28}O_2$	240.38	ND	ND
3	Palmetoleic acid	$C_{16}H_{30}O_2$	254.41	0.3	0.21
4	Cis-10 Heptadecanoic acid	$C_{17}H_{32}O_2$	268.44	ND	ND
5	Oleic acid	$C_{18}H_{34}O_2$	282.46	27.47	8.83
6	Cis-11-ecosanoic acid	$C_{20}H_{38}O_2$	310.52	6.35	5.27
7	Erucic acid	$C_{22}H_{42}O_2$	338.57	10.15	37.71
8	Nervonic Acid	$C_{24}H_{46}O_2$	366.62	0.43	2.22
III	**Poly Unsaturated fatty acids**				
1	Linoleic acid	$C_{18}H_{32}O_2$	280.44	25.98	10.79
2	Y-linolenic acid	$C_{18}H_{30}O_2$	278.43	0.17	ND
3	Linolenic acid	$C_{18}H_{30}O_2$	278.43	1.83	20.98
4	Cis-11,14,-Eicosadenoic acid	$C_{21}H_{38}O_2$	322.53	0.25	0.7
5	Cis-8,11,14-Eicosatrinoic acid	$C_{20}H_{34}O_2$	306.48	0.48	0.45
6	Cis-11,14,17-Eicosatrinoic acid	$C_{21}H_{36}O_2$	320.51	ND	ND
7	Arachidonic acid	$C_{20}H_{40}O_2$	304.47	ND	ND

8	Cis-13,16-docosadenoic acid	$C_{22}H_{40}O_2$	336.55	0.3	0.96
9	Cis-5,8,11,14,17-Ecosapentenoic acid	$C_{20}H_{30}O_2$	302.45	ND	ND
10	Cis-4,7,10,13,16,19-Docosahexanoic acid	$C_{22}H_{32}O_2$	328.5	ND	ND
IV	**Trans fatty acids**				
1	Trans Elaidic acid	$C_{18}H_{34}O_2$	282.46	0.05	ND
2	Trans Linolelaidic acid	$C_{18}H_{32}O_2$	280.44	ND	ND
	Others			0	0.66

8.2 **Yield of Biodiesel at Different Molar Ratio and Catalyst Concentration**

Produced biodiesel was purified with wet washing method; water is used as washing agent in this method. Figure-13 shows yield of biodiesel at different molar ratio and catalyst concentration. Mustard oil gives 87.05% and waste mustard oil gives 85.03% yield of biodiesel at 1:9 molar ratio and 2wt% of KOH. Both mustard and waste mustard oil gives maximum yield of biodiesel at 1:9 molar ratio (oil and methanol) and 2 wt% of KOH.

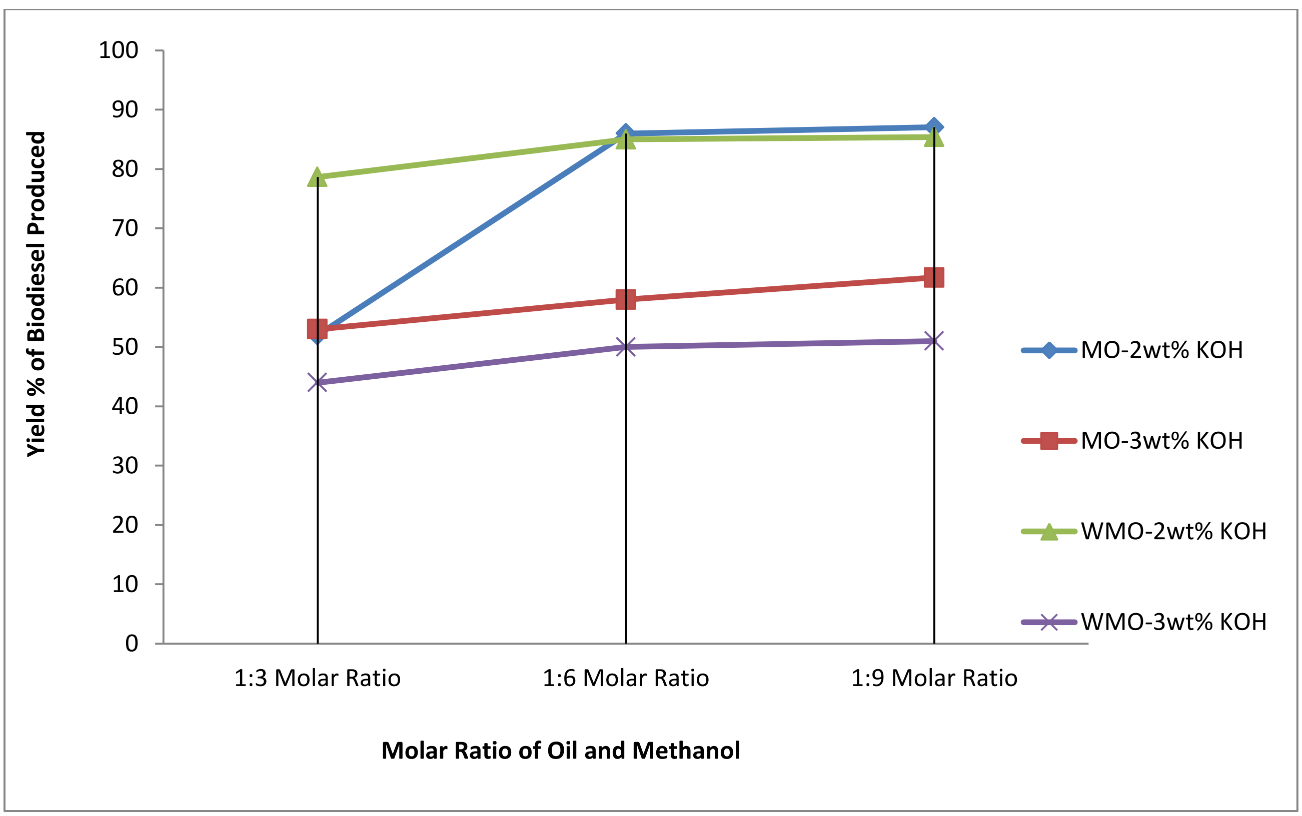

Figure 13: Yield of biodiesel at different molar ratio and catalyst concentration

8.3 Properties of Produced Biodiesel and Diesel Fuel

After the production of biodiesel it was heated up to 80-90^oC for collection of methanol. Methanol gets evaporated at 50^oC and collected methanol can be used for further production of biodiesel. Table-6 shows the properties like density, kinematic viscosity, flash point and calorific value for diesel, mustard and waste mustard biodiesel.

Table 6: Properties of diesel, MB and WMB

PROPERTY	Unit	FUEL		
		MB	**WMB**	**Diesel**
Density	**gm/ml**	0.882	0.879	0.83
Kinematic viscosity	**mm2/sec**	4.479	4.318	3.5-5
Calorific Value	**MJ/kg**	40.4	40	44
Flash Point	**^0C**	160	168	71.2

8.4 Performance Characteristics of Engine

Produced MB and WMB is blend with commercial diesel fuel at various blend like B10, B20 and B30. This blends were is investigated in KirloskarTV1 engine consisting power 5.20 kW at 1500 rpm which is Four stroke, 1 Cylinder, Constant Speed, Water Cooled diesel Engine of 661cc capacity. Dynamometer is attached in engine assembly for apply various load on engine.

Three loads condition was investigated in engine, they no load condition, 50% load condition and full load condition.

8.5 Performance Characteristics at No Load Condition

Table-7 shows performance characteristics at No load condition. From table-7 our investigated points are

- Indicated and break power of blends are higher than diesel fuel.
- Volumetric efficiency of blends is comparatively equal with diesel fuel.

❖ Mechanical efficiency, indicated thermal and brake thermal efficiency of blends are lower values than diesel values.

❖ B30 waste mustard biodiesel performance characteristics has higher values than other blends like B20 MB, B30 MB and B20 WMB.

Table 7: Performance characteristic at No load condition

LOAD	FUEL	IP (KW)	BP (KW)	Air Flow (mmWC)	Fuel Flow (cc/min)	IThEff %	BThEff %	Fuel Consumption (Kg/h)	Mech Eff. (%)	Vol Eff. (%)
0	Diesel	0.71	0.009	92.65	1.11	63.53	7.35	0.04	11.38	85.77
	B10 MB	1.75	0.009	98.37	4.58	58.61	4.37	0.22	7.19	87.4
	B20 MB	2.56	0.009	92.75	6.89	52.77	1.38	0.34	2.67	84.81
	B30 MB	2.06	0.004	93.33	6.66	51.43	2.09	0.34	2.12	85.61
	B10 WMB	1.77	0.009	96.72	5.28	55.87	3.19	0.26	5.76	86.8
	B20 WMB	1.98	0.009	95.01	5.61	56.49	2.77	0.27	4.74	86.32
	B30 WMB	2.03	0.001	96.34	5.8	57.56	2.58	0.3	4.42	86.91

8.6 **Performance Characteristics at 50% Load Condition**

Table-8 shows performance characteristics at 50% load condition. From table-8 our investigated points are

❖ Performance characteristics like brake power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and volumetric efficiency for blends are higher values than diesel values.

❖ Indicated power and fuel consumption has comparatively equal than diesel values.

❖ B30 waste mustard biodiesel performance characteristics has higher values than other blends like B20 MB, B30 MB and B20 WMB.

Table 8: Performance characteristic at 50% load condition

LOAD	FUEL	IP (KW)	BP (KW)	Air Flow (mmWC)	Fuel Flow (cc/min)	ITh Eff %	BTh Eff %	Fuel Consumption (Kg/h)	Mech Eff. (%)	Vol Eff. (%)
50%	Diesel	6.57	2.17	80.85	21.98	51.1	16.69	1.08	32.98	82.12
	B10 MB	6.94	2.18	85.07	20.98	54.52	17.07	1.04	31.29	83.8
	B20 MB	6.29	2.18	83.32	19.32	53.78	18.538	0.97	34.52	83.04
	B30 MB	6.03	2.19	83.09	19.45	51.44	18.46	0.98	35.97	82.9
	B10 WMB	6.78	2.18	84.90	19.36	57.79	18.49	0.96	32.07	83.78
	B20 WMB	6.55	2.19	87.4	18.98	55.61	18.44	0.98	33.18	83.73
	B30 WMB	6.59	4.4	85.21	18.5	59.31	19.49	0.93	33	83.77

8.7 Performance Characteristics at Full Load Condition

- Indicated power of blends have comparatively equal values than diesel values except B30 WMB that have lower value.
- Mechanical efficiency, volumetric efficiency and fuel consumption is higher than diesel values.
- Brake power of blends has comparatively equal values than diesel values.
- Indicated thermal and brake thermal efficiency has very lesser values than diesel values.

Table 9: Performance characteristic at full load condition

LOAD	FUEL	IP (KW)	BP (KW)	Air Flow (mmWC)	Fuel Flow (cc/min)	IThEff %	BThEff %	Fuel Consumption (Kg/h)	Mech Eff (%)	Vol Eff (%)
100%	Diesel	8.43	4.28	74.65	2	716.5	363.62	0.1	50.75	80.74
	B10 MB	8.95	4.31	77.92	29	50.82	24.49	1.45	48.02	81.78
	B20 MB	8.17	4.28	75.35	29	46.48	24.36	1.46	52.42	80.58
	B30 MB	8.11	4.3	75.77	28	47.91	25.41	1.42	53.03	80.86
	B10 WMB	8.75	4.3	77.49	28	51.49	25.34	1.4	49.21	81.55
	B20 WMB	8.59	4.28	78.27	27	52.61	26.24	1.36	49.87	81.91
	B30 WMB	8.36	4.31	77.68	27	51.37	26.5	1.37	51.59	81.6

Performance characteristics like brake power, indicated power, mechanical efficiency and Volumetric efficiency for all blends at all load condition is given in figure 14, 15, 16 and 17 respectively.

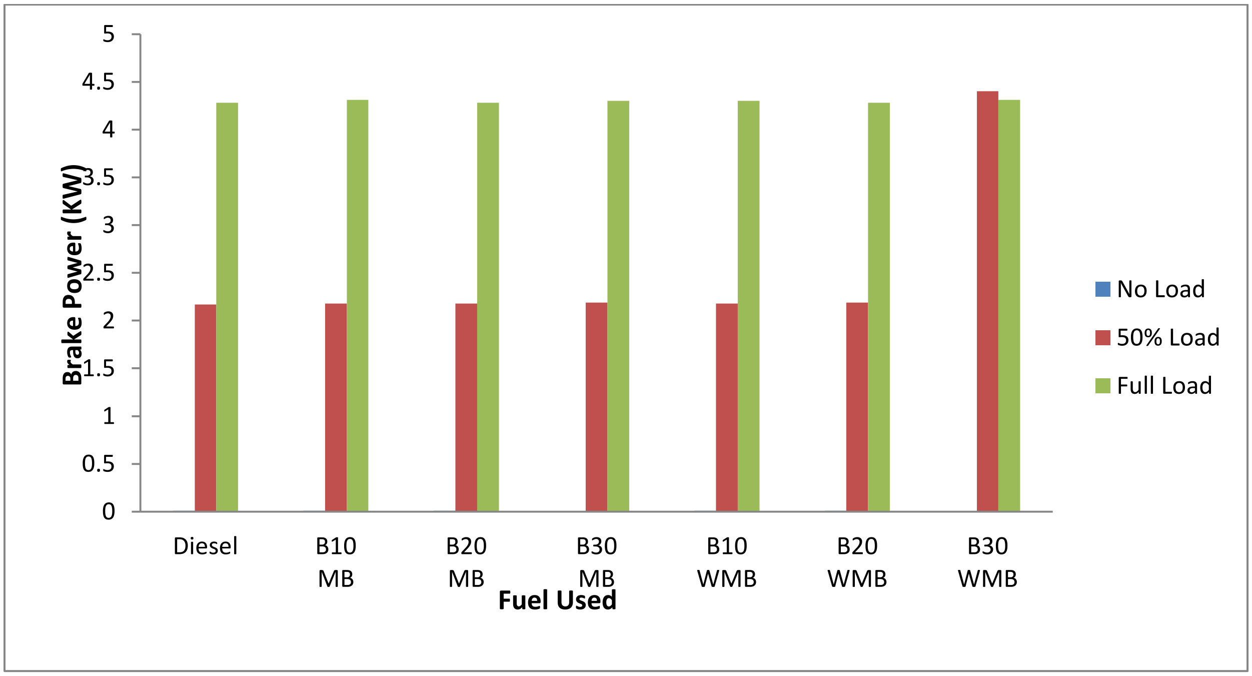

Figure 14: Brake Power (KW) for all blends at all loading condition

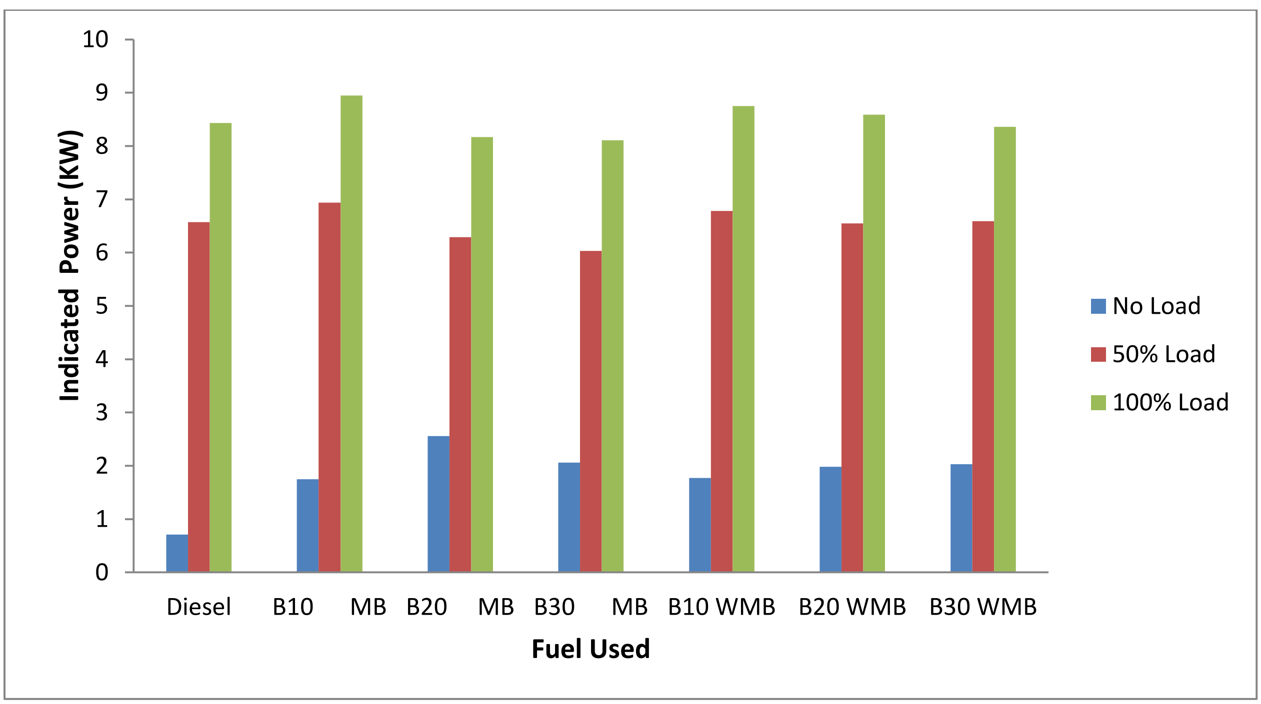

Figure 15: Indicated Power (KW) for all blends at all loading condition

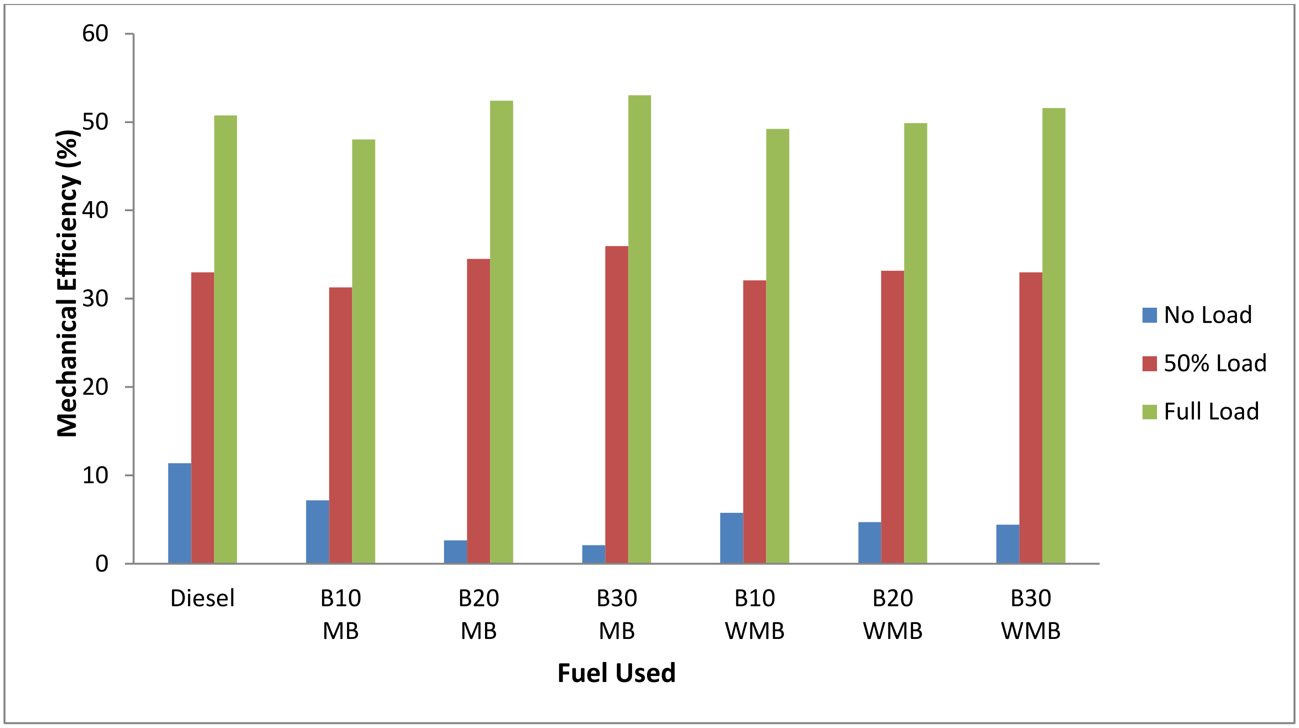

Figure 16: Mechanical Efficiency (%) for all blends at all loading condition

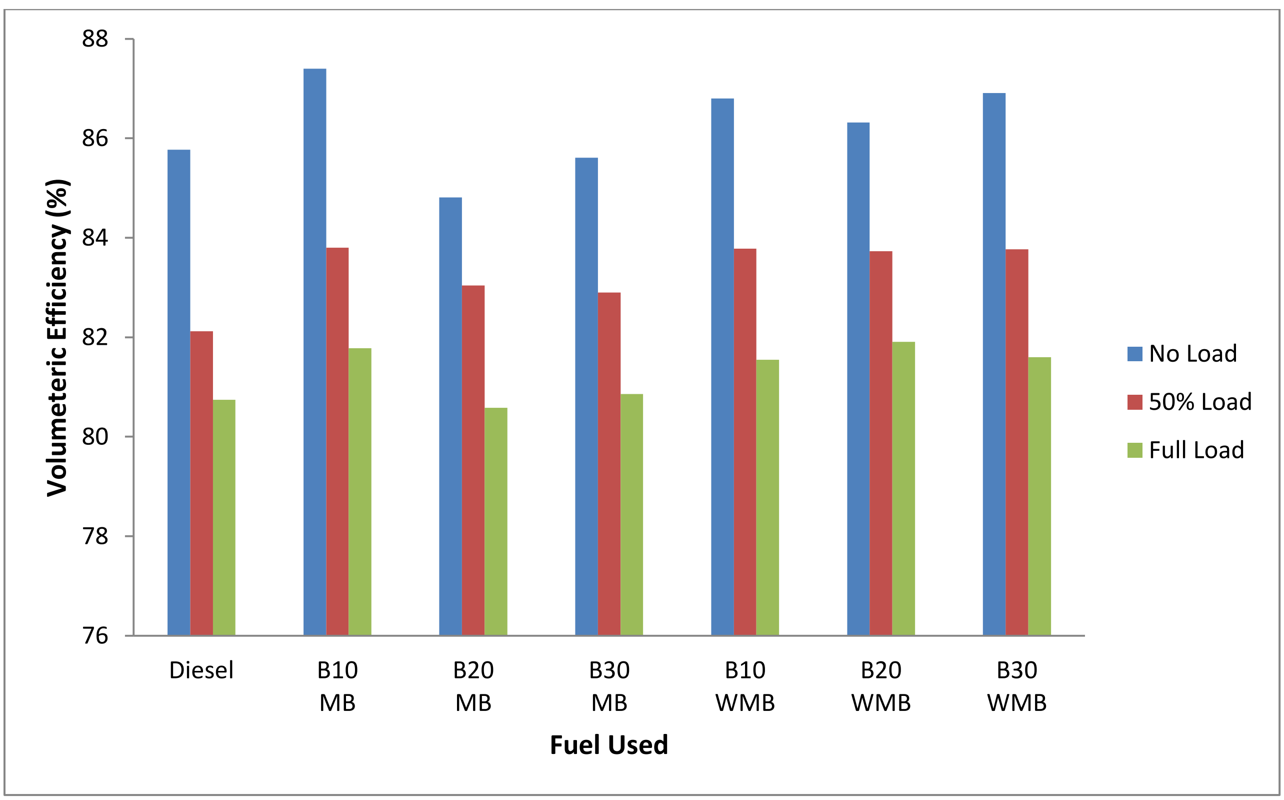

Figure 17: Volumetric Efficiency (%) for all blends at all loading condition

8.8 Exhaust Gas Emission Test

In this test gas analyzer is used at engine exhaust to investigate the exhaust gas emission at various load condition while using MB and WMB blends. Mainly investigating exhaust gases are CO, NO_x, CO_2, HC and O_2. In that investigation engine RPM kept constant at 1500rpm.

Table-10 shows the emission of carbon monoxide (%Vol) with respect of diesel fuel. From that table-10 we can say that blends of MB and WMB gives approximately same result as diesel fuel.

Table 10: Emission of CO (% Vol) for blends

FUELS	LOAD (Kg)					
	0	**3**	**6**	**9**	**12**	**15**
Diesel	0.01	0	0	0.01	0	0.01
MB B10	0.01	0	0	0	0	0.01
MB B20	0.01	0	0	0	0	0.01
MB B30	0.01	0.01	0	0	0	0
WMB B10	0.01	0	0	0	0	0
WMB B20	0.01	0	0	0	0	0
WMB B30	0.01	0	0	0	0	0

Table-11 shows the emission of unburned hydrocarbon (PPM Hex) of blends of MB and WMB with respect of diesel fuel.

Table 11: Emission of HC (PPM Hex) for blends

FUELS	LOAD (Kg)					
	0	**3**	**6**	**9**	**12**	**15**
Diesel	5	5	4	5	5	7
MB B10	3	5	3	0	4	4
MB B20	2	4	3	5	1	3
MB B30	2	2	1	1	4	5
WMB B10	2	1	1	1	1	2
WMB B20	5	5	2	1	1	5
WMB B30	2	3	5	4	2	1

Table-12 shows the emission of carbon dioxide (% Vol) of blends of MB and WMB with respect of diesel fuel.

Table 12: Emission of CO_2 (% Vol) for blends

FUELS	LOAD (Kg)					
	0	3	6	9	12	15
Diesel	0.5	1	1	1.2	0.7	0.8
MB B10	0.4	0.7	0.8	0.9	0.9	0.6
MB B20	0.4	0.6	0.7	0.9	0.9	0.9
MB B30	0.4	0.6	0.7	0.9	1	0.9
WMB B10	0.3	0.6	0.6	0.8	0.9	0.9
WMB B20	0.4	0.6	0.7	0.8	0.9	0.9
WMB B30	0.3	0.6	0.7	0.8	0.9	0.9

Table-13 shows the emission of oxygen (% Vol) of blends of MB and WMB with respect of diesel fuel.

Table 13: Emission of O_2 (% Vol) for blends

FUELS	LOAD (Kg)					
	0	3	6	9	12	15
Diesel	20.18	19.54	19.62	19.36	20.07	19.98
MB B10	20.31	19.91	19.84	19.74	19.71	20.14
MB B20	20.36	20.02	19.96	19.68	19.62	19.73
MB B30	20.06	19.74	19.57	19.34	19.18	19.19
WMB B10	20.63	20.31	20.29	20.11	20	20.01
WMB B20	20.52	20.21	20.11	19.91	19.78	19.79
WMB B30	20.51	20.2	19.97	19.8	19.69	19.63

Table-14 shows the emission of nitric oxide (% Vol) of blends of MB and WMB with respect of diesel fuel.

Table 14: Emission of NO_X (% Vol) for blends

FUELS	LOAD (Kg)					
	0	3	6	9	12	15
Diesel	16	134	135	172	87	93
MB B10	15	65	101	115	120	66
MB B20	16	68	82	113	122	109
MB B30	11	54	80	109	126	113
WMB B10	10	55	65	88	107	103
WMB B20	12	57	75	99	116	112
WMB B30	13	53	79	107	117	116

CHAPTER- 9
CONCLUSION

1. Waste mustard and fresh mustard oil gives maximum production of biodiesel at 2 wt% of KOH and 1:9 molar ratio (oil and methanol).
2. Both oil gives approximately same result on that parameters so we can replace fresh mustard oil as waste mustard oil for production of biodiesel so it's also overcome the debate on fuel versus food.
3. In engine performance test brake power, air flow, fuel flow and fuel consumption gives higher values for all blends comparatively diesel fuel.
4. In engine testing, waste mustard biodiesel shows comparatively equal results as mustard biodiesel. So we can replace MB with WBM.
5. Emission test shows that HC particle of all blends are equal and lesser values than diesel fuel. CO_2 and NO_x particle show lesser value for all blends as compare to diesel value except 12 and 15 kg load condition in that condition they show higher value.
6. In emission test CO particle shows slightly equal value for all blends as compare to diesel value.O_2 particle shows higher value its mean proper combustion of fuel takes place by using biodiesel/diesel fuel blend.

9.1 FUTURE SCOPE

For further study to improvising the performance, combustion and emission characteristics of engine, we can use additives in biodiesel/diesel fuel blend.

There are various additives such as copper oxide nano additive, diethyl ether, ethanol, n-butanol, anti oxidant additive, metal based additive, oxygenated additive and cetane number additives for improvising the biodiesel/diesel fuel blend quality such as higher brake power, lower fuel consumption, higher BTE and also emission of NOx and CO get decreased.

Use of biodiesel/diesel fuel in unmodified CI engine may cause noise and sound pressure level problem. This problem can be eliminated by induced CNG in intake manifold in engine

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CHAPTER-1 INTRODUCTION Globally use of petroleum based fuel during past thirty years or so has greatly increased due to human population explosion and growth of industrialization. Which has resulted in diminish of petroleum based fuel reserve and that petroleum based fuel is also responsible for global warming by increased green house gas (GHG) emission. Because of those outcomes, a step is move towards replacement, substitute and renewable source of energy which has lesser impact on environment. Country like India has 2nd populated country in the world and only satisfies or meets 22% demand of crude oil, rest 78% demand of crude oil imported from other country like Saudi Arab, Iraq and Iran. Figure-1 shows the consumption and production of crude oil in India and Figure-2 shows India total energy consumption by source. Biodiesel is the one of the best choice as alternative source or blending component of diesel in compression ignition engine and it can work in engine without any modification need [1]. Hence because of some characteristic issues of biodiesel that cannot entirely replaced by diesel fuels, otherwise there are some different benefits of biodiesel over diesel fuel [2]. biodiesel is biodegradable (Of a substance or object capable of being decomposed by bacteria or other living organisms) and will not discharge toxic gas because of lower aromatic and sulfur content than petroleum based diesel fuel and also it has higher combustion efficiency than diesel fuel [3]. Biodiesel has lower exhaust gas emission such as unburned hydrocarbon, monoxide and particulate matter except NOx so lower the green house effect [4]. Generally biodiesel is chemically combination of methyl/ethyl ester with long chain fatty acids and commonly produce from non toxic biological resources such as edible oil, non edible oil [5], animal fats [6], microalgae, or even used waste/used cooking oil [7]. Vegetable oil is one of the best options for producing biodiesel because they are renewable in environment [8]. There are two varieties of vegetable oils edible and non edible oils. Mostly edible oil is first choice for biodiesel production because of easy availability in nature and the qualities of produced biodiesel are very much suitable for blending of diesel fuel [9]. But use of edible oil in production of biodiesel cause several difficulties like human food insufficiency in the developing countries and greater impact on forest because more arable land is require for plantation purpose so deforestation is greatly increase in some countries. So in order to diminish this difficult situation, many researches have to be carrying out on non edible oil and also it’s not suitable for human consumption because it’s toxic in nature [5]. But most of non edible oils have high value of free fatty acid so the overall cost for producing biodiesel is become increased because many kinds of chemical process has to be done for biodiesel production [10]. Move towards the animal fats they also have same problem due to the high free fatty acid contain the processing cost for production of biodiesel become increased [11]. Waste/frying cooking oil is best step for production of biodiesel because commonly it's thrown away after use, without any treatment and it will pollute the nature [12]. There are many benefits in production of biodiesel through use of waste cooking oil because it's very cheap material [13] and also there is no need of any arable land for biodiesel producing crops. Content of free fatty acid get increased because of presence of heat and water in waste cooking oil [14]. Due to higher value of viscosity in waste cooking oil, it's not directly use in engine that cause many serious problem in engine then transesterification process is done for reducing viscosity of oil to producing biodiesel and comparing with diesel fuel this produced biodiesel giving similar fuel properties [15-16]. Transesterification process has done by three reversible reactions which content conversion of tri-glyceride convert into di-glycerides after that di-glyceride convert into mono-glyceride and finally mono-glyceride covert into glycerol need 3 mol of alcohol. Glycerol is obtain as by-product of reaction [17-18]. The composition of free fatty acid of parent oil decided the selection of base and acid catalyst reaction. In compared to acid catalyst reaction, base catalyst reaction can obtain high yield of biodiesel and high purity at short time (30-60 min) [19]. Generally CH3ONa (sodium methoxide), NaOH (sodium hydroxide), KOH (potassium hydroxide) and CH3OK (potassium methoxide) base catalyst is used in process of trasesterification [20]. In order to selection and use of alcohol for transesterification process, methanol promising better reaction rate and less costly. The produced FAME is easily evaporating than respective ethyl esters. But ethanol gets obtain from renewable feed stocks and less toxic [21]. Figure 1: India crude oil production and demand Source: United States Energy Information Administration, 2015 Figure 2: Total energy consumption by source in India Source: International Energy Agency 1.1 Sources Of Biodiesel Production:- Table 1: Source of biodiesel production [22, 23, 24] SOURCE OF BIODIESEL PRODUCTION Primary biofuel Natural biofuel Firewood, crop residues, landfill gas, forest , plant ,Animal waste Secondary biofuel 1st generation biofuel Potato, Wheat, corn, sugarcane, beet, edible oil (soybean, peanut oil, sunflower, rapeseed, cottonseed oil, palm oil, canola oil, coconut, castor oil, mustard oil) Secondary biofuel 2nd generation biofuel Non edible vegetable oil (Jatropha, karanj, mahua, linseed, cottonseed, camelina, polanga, cassava), straw, grass, wood, waste recycled oil (cooking oil, frying oil), animal fats (beef tallow, pork lard, yellow grease, by product from fish oil) Secondary biofuel 3rd generation biofuel Microalgae, microbes 1.2 Various Methods For Production Of Biodiesel :- There are various numbers of method are available for biodiesel production showing in table number 2. Table 2: Methods use for biodiesel production Method Definition Advantages Disadvantages Reference Blending (dilution) Direct blend or diluted with conventional diesel fuel Improve the viscosity, minimize the engine performance problem like injector coking and carbon deposition Not suitable for long term because of higher viscosity, lower volatility 25,26 Micro emulsification Colloidal equilibrium dispersion of isotropic lipid mixture of oil, water and surfactant, frequently in combination with a co-surfactant. Reduce the viscosity of oil, during combustion it has better spray pattern Lower energy content, lower cetane number 27,26 Paralysis (thermal cracking) In pyrolysis process the conversion is done from vegetable oil to fuel pyrolysis oil by heating or heating with presence of catalyst in absence of oxygen and split of chemical bond to form small molecules. Lower processing cost, good compatibility with engine and fuel standard, feed stock flexibility Energy intensive 26 Esterification or Transesterification Also known as alcoholysis, it's a chemical reaction of oil with the presence of alcohol where it is catalyzed by a base catalyst or acid to form glycerol and ester. Most viable and promising process, simplicity of process, higher conversion efficiency, suitable for industrialized production Glycerol and waste water (they are by- product) disposal problem 28,26 Ultrasonic reactors Ultrasonic waves are used to initiate the chemical reaction and it can heat and also mix the reactant. Ultrasonic method can decrease the 50% use of the catalyst; also reduce the reaction time, reaction temperature and energy required. - 26 1.3 Different Factors Which Affect The Transesterification Process:- In production of biodiesel transesterification process is affected by many parameters. Which are time and pressure of reaction, moisture content in oil, reaction temperature, type and wt% of catalyst, type of alcohol used, free fatty acid content in oil and molar ratio of methanol to oil [29]. Generally in the process of transesterification NaOH and KOH is widely used catalyst because they are support at minimum reaction pressure and temperature, economically cheap, availability of that kind of catalyst is more and conversion to biodiesel taken place at minimum reaction time [30]. 1.3.1 Molar ratio of alcohol to oil or Quantity of alcohol:- Many researchers were founded that molar ratio of methanol to oil is plays important role in yield of biodiesel. If the molar ratio of methanol to oil increasing than the conversion efficiency of biodiesel will increasing correspondingly Theoretically, the transesterification reaction wants 3 mol of alcohol for 1 mol of oil to produce 3 mol of fatty acid ester and 1 mol of glycerol [31]. Figure 3 shows the effect of molar ratio on yield of biodiesel. 100 90 80 70 Conversion Efficiency % 60 50 40 30 20 10 0 0 1 2 3 4 5 6 7 8 9 Molar Ratio of oil to methanol Figure 3: Effect of molar ratio on the yield of biodiesel [34] 1.3.2 Reaction time :- From previous literatures review they are concluded that the yield percentage of biodiesel is increasing when the reaction temperature get increase [32] Due to the mixing and dispersion of alcohol into oil initially cause slow reaction rate. But after that reaction proceed very fast. Also they are concluded that the reaction time less than 90 min has higher yield of biodiesel, further increase the reaction time has slightly difference on yield of biodiesel or may be its constant value of yield [33]. Figure 4 shows the effect of reaction time on yield of biodiesel. 100 90 80 70 Conversion Efficiency % 60 50 40 30 20 10 0 0 10 20 30 40 50 60 70 80 90 100 Reaction Time (min) Figure 4: Effect of reaction time on yield of biodiesel [34] 92 90 88 Conversion Efficiency % 86 84 82 80 78 76 74 0 10 20 30 40 50 60 70 80 Reaction temperature 0C Figure 5: Effect of reaction time on yield of biodiesel [34] 1.3.3 Reaction temperature:- The yield of biodiesel production is affected by the reaction temperature, however the viscosity of oil get decreasing when temperature is increased and reaction temperature also affect the reaction time, reaction time get decreasing when reaction temperature is increased. The optimal temperature ranges from 50 to 60˚C for higher yield percentage of biodiesel [31]. Figure 5 shows effect of reaction temperature on yield of biodiesel. 1.3.4 Catalyst Concentration:- From previous literatures review generally sodium hydroxide (NaOH) and Potassium hydroxide (KOH) used as catalyst in transesterification process but many researchers have found that sodium methoxide is more effective than NaOH because when NaOH is mixed with methanol than small amount of water will produced in exothermic reaction [32] and that affect the reaction and yield percentage of biodiesel. So that NaOH is mixed with methanol seperatory before adding in oil. When the concentration of catalyst gets increased than yield percentage of biodiesel get increase [31]. CHAPTER- 2 TERMINOLOGY GHG Green house gas KOH Potassium hydroxide NaOH Sodium Hydroxide FAME Fatty Acid Methyl Ester HC Hydro Carbon CO2 Carbon Dioxide CO Carbon Monoxide NOX Nitric Oxide O2 Oxygen BSFC Brake Specific Fuel Consumption FFA Free Fatty Acid WCO Waste Cooking Oil CNG Compressed Natural Gas CI Compression Ignition PM Particulate Matter VCR Variable Compression Ratio BMEP Brake Mean Effective Pressure IMEP Indicated Mean Effective Pressure A/F RATIO Air/Fuel Ratio CH3OH Methanol MB Mustard Biodiesel WMB Waste Mustard Biodiesel IThEff Indicated Thermal Efficiency BThEff or BTE Brake thermal efficiency Mech Eff Mechanical Efficiency Vol Eff Volumetric Efficiency IP Indicated Power BP Brake Power CHAPTER- 3 RATIONALE AND SCOPE OF THE STUDY The reason of ever growing human population and industrialization explosion the use of fossils fuels have greatly increased and this fossils fuel also responsible for green house effect on environment and has also resulted to diminish the petroleum based fuel reserve. GHG emission such as unburned HC, CO2, CO and NOX has adversely affected on human heath from past few decades. Because of those outcomes, a step is being toward the alternative, replacement and some renewable source of energy, which has lesser impact on environmental condition, human health and global warming effect. So the biodiesel has one of the best choices for that [1]. 1. Biodiesel is biodegradable in nature. 2. Biodiesel is less toxic emission comparatively diesel fuel. 3. Cost of biodiesel preparation is economically cheap. 4. Performance characteristic of biodiesel comparatively equal than diesel fuel. 5. Biodiesel can run in compression ignition engine without any major modification needs. CHAPTER- 4 OBJECTIVE OF THE STUDY 1. To carry out preparation of the biodiesel through waste mustard oil and fresh mustard oil by transesterification process. 2. To compute the fatty acid profile of that waste mustard oil. That fatty acid profile helps to getting fatty acid composition in oil and compute the value of methanol add in transesterification according to molar ratio of methanol to oil. 3. To compute yield percentage of biodiesel at different values of molar ratio (1:3, 1:6, 1:9) and wt % of KOH (2%, 3%) to find optimal values for biodiesel production. 4. To compute properties of the waste mustard oil, fresh mustard oil and extract biodiesel such as viscosity, density, flash point and calorific value. 5. To use the biodiesel as blended fuel (B10, B20 and B30) in commercial diesel engine and to calculate engine performance characteristic parameters like indicated power, brake power, fuel flow, air flow, indicated thermal efficiency, brake thermal efficiency, fuel consumption, mechanical efficiency and volumetric efficiency. 6. To analysis the amount of emission gases such as NOx (Nitric oxide), HC (unburnt hydrocarbon), CO2 (Carbon dioxide), O2 (oxygen) and CO (carbon monoxide) in the exhaust of commercial diesel engine running on biodiesel. CHAPTER- 5 REVIEW OF LITERATURE T. Issariyakul et al., studied on comparison on transesterification of palm oil and mustard oil. In that transesterification process using KOH as a catalyst and reaction temperature kept between 40 to 60˚C. They are concluded that fatty acid composition of mustard and palm oil have great impact on transesterification process because fatty acid composition affect the percentage of saturated compound and chain length distribution. This both the parameters are play great role in each reaction step differently and transesterification process [35]. Sanjid et al. 2014, studied on production of biodiesel by waste mustard oil and their properties. They concluded that at time of engine performance test mustard biodiesel of blend of B10 and B20 showed 5-6% lower BTE and 8-13% higher BSFC compared to diesel based engine. They calculated the chemical properties of mustard biodiesel such as pour point (-18°C), cloud point (5°C), calorific value (40.404 MJ/Kg), oxidation stability (15.92 h). In engine emission test they are concluded that 9-12% higher NO, 19-40% lower CO, 2-7% lower noise and 24-42% lower HC emission are produced compared to diesel fuel. Finally they are compared the engine emission and performance characteristic of mustard biodiesel with palm biodiesel [36]. K. Srithar et al., 2014 Studied on the production of biodiesel from karanj and mustard oil. This biodiesel is tested in diesel engine at different-different mixing ratio. In their research works they examined the effect of dual blend biodiesel on engine works and calculated the emission exhaust gas from the diesel engine. In that research work they concluded that the BTE (brake thermal efficiency) of dual blend biodiesel is more than commercial diesel engine (working fluid is diesel). The temperature of exhaust gas is lesser than commercial diesel engine exhaust temperature but the emission of NOx, smoke and hydro carbon is greater than other commercial diesel engine in which diesel use as a fuel [37]. Z.M. Hasib et al. studied on use of mustard oil as an alternative to diesel fuel. In their study they compute the properties of biodiesel which is produced by mustard oil and they found that the biodiesel has slightly different properties than diesel fuel. It is also observed that the diesel engine is running without any modification and any difficulties by biodiesel but only some optimal performance of engine is deviate by use of that biodiesel blends (B20, B30, and B50) [38]. A.B. Fadhil et al. 2013, studied on production of biodiesel by mustard oil through alkali- catalyzed transesterification with alcohol (ethanol) using homogeneous catalyst (KOH) and they also studied on the process parameters which are affect the production of biodiesel, process parameters such as reaction temperature, molar ratio of ethanol to oil, reaction time, catalyst type and their concentration. so that helps to getting the optimal condition for biodiesel production is easily and finally they was concluded that the optimal condition for biodiesel production are 8:1 molar ratio of ethanol to oil, 0.90% KOH wt/wt of oil , reaction time is 60 min and reaction temperature is 600C . The produced mustard oil ethyl ester is washed with activated carbon by dry wash method; this activated carbon was produced from the de-oiled cake [39]. K. S. Chen et al., 2012 studied for improving the yield of biodiesel through waste cooking oil using a microwave heating system. It was concluded that the best performance found with 0.75 wt% sodium hydroxide (NaOH) and 0.75 wt% sodium methoxide (CH3ONa) catalyst, respectively. The yield of biodiesel is produced with sodium methoxide is higher than the sodium hydroxide [40]. H. Amani et al., 2015 studied on biodiesel production with waste cooking palm oil and palm oil by transesterification with methanol was studied using cesium-modified silica catalyst (CsM-Sio2) as a heterogeneous catalyst and the effect of catalyst on different transesterification parameters were investigated. It was concluded that the yield of biodiesel reached 90% at 650C in 3h with 3 wt% catalyst loading [41]. Suchada Sirisomboonchai et al., 2015 studied on production of biodiesel through waste cooking oil by transesterification. In that study methanol by using calcined scallop shell (CSS) as catalyst was carried out in a closed system for biodiesel fuel production. The effect on transesterification parameter was investigated. It was concluded that the maximum yield of biodiesel reached 86% at 5 wt% catalysts loading at 65% temperature and reaction time of 2h [42]. Anh N. Phan et al., 2008 studied on transesterification of waste cooking oils by alkali- catalyst (KOH) and methanol was carried out in a laboratory scale reactor. The effects on transesterification parameters were investigated. It was concluded that maximum yield of biodiesel 88-90% was obtained at the temperature of 30-50˚C, 0.75 wt% KOH and methanol/oil ratio of 7:1-8:1 [43]. T. H. Do, 2016 studied the effect of cooking condition on the cold flow properties and kinematic viscosity of biodiesel produced from cooking oil. In this work, sunflower, corn and canola oils were used as vegetable oil and salt content, water content, cooking temperature and cooking time were selected as experimental parameters. Finally it was concluded that with increase in water content, cooking temperature, cooking time and salt content led to decrease in the cold flow properties and physical properties of B100 biodiesel sample from waste cooking [44]. Bilgin et al., 2015 studied the production of lowest kinematic viscosity waste cooking oil biodiesel through transesterification by using sodium hydroxide as catalyst and ethanol as alcohol. Individual effects of main parameter such as catalyst concentration (0.50-1.75%), reaction time (60-150 min), reaction temperature (60-90˚C) and alcohol/oil molar ratio (6:1-15:1) on the kinematic viscosity of producing biodiesel were investigated. Finally it was concluded that reaction parameters giving the lowest kinematic viscosity of 4.387 centi- stocks were determined as 1.25% catalyst concentration, 70˚C reaction temperature, 120 minutes reaction time and 12:1 alcohol/oil molar ratio [45]. Dennis Y.C. Leung et al., 2010 reviewed different approaches of reducing the value of free fatty acid in the oil and refinement of crude biodiesel that are mainly used in the industry and reported that there are four primary factors affecting the yield of biodiesel, i.e. alcohol quantity, reaction time, reaction temperature, and catalyst concentration which describe other new processes for production of biodiesel. For instance, the non-catalytic supercritical methanol process which has shorter reaction time and lesser purification step but requires high temperature, high pressure and biox co-solvent process. However this process, cannot handle waste cooking oil and animal fats [2]. M. M. K. Bhuiya et al., 2014 reviewed the second generation biodiesel used as biodiesel feedstock. Many aspect of this feedstock are reviewed and discussed in this paper. These aspects are cost effectiveness, necessity of second generation biodiesel, biodiesel conversion technology, and biodiesel feedstock, improving efficiency of the production process as well as performance and emission characteristics [46]. Man Kee Lam et al., 2010 reviewed the current status of biodiesel production and potential of waste cooking oil as an alternative feedstock and also discussed about the homogeneous, heterogeneous and enzymatic transesterification on oil with high free fatty acid in detail. It was found that in comparison to homogeneous base-catalyst process, the heterogeneous acid catalyst and enzyme is the best option to produce biodiesel from oil with high value of FFA. However these heterogeneous acid and enzyme catalyst system also introduce the mass transfer problem so therefore are not favorable for industrial application [31]. C.D.M. de Araujo et al., 2013 reviewed the different processes used for production of biodiesel from different types of used cooking oil. While several scientific studies on processes of pretreatment and transesterification of WCO were analyzed with their variations such as alkaline catalysis, acid catalysis, enzymatic catalysis and non-catalytic conversion techniques [47]. Yie Hua Tan et al., 2015 studied on increasing yield of biodiesel in transesterification process by use of homogeneous catalyst such as NaOH and KOH through vegetable oil and studied on heterogeneous base catalyst that are calcium oxide which was yield from unused material like eggshell of chicken, ostrich, quail etc. Use of calcium oxide gives the excess washing problem and also emission of NOx remained high than petroleum based fuel. They were also found that the emission of NOx, particulate matter, carbon monoxide and unburnt hydrocarbon emission are lower in emulsified biodiesel [26]. Xiangmei Meng et al. 2008, studied on the yield of biodiesel through waste cooking oil and effects of reaction parameters like reaction temperature, reaction time, molar ratio of methanol to oil, wt percentage of catalyst used in transesterification process on yield of biodiesel. In this research they experiments of B20 blend fuel used in diesel engine and they were concluded that emission of CO, HC and particles were decreased by 18.6%, 26.7% and 20.58% respectively [34]. Ali M. A. Attia et al., studied on yield of biodiesel through waste cooking oil by transesterification process and engine performance characteristics were calculated at different fuel blends with diesel fuel. This paper concluded that engine load and blending ratio of biodiesel were direct affect the value of peak cylinder pressure. At B20 blend of biodiesel with diesel fuel gives higher value of brake specific energy consumption (BSEC) [48]. M. Vijay Kumar et al. 2017, reviewed on improvising the performance and combustion characteristics of biodiesel fuel by using additives, which are also diminish the emissions. Various problem regarding use of biodiesel such as high density, lower heating value, high oxides content of nitrogen and higher fuel consumption. By use of additives problem regarding biodiesel get eliminated. Finally researcher was concluded that use of antioxidant additives, metal based additives, oxygenated additives and cetane number additives get help to improvising the combustion and performance characteristics [49]. K. Celebi et al. 2017, Studied on vibration and acoustic effect on unmodified CI engine when biodiesel and their blends was investigate in it. In that study blends of 20% and 40% sunflower and canola biodiesel with commercial diesel fuel was investigated. CNG is introduce in intake manifold of CI engine. This study concluded that use of canola and sunflower biodiesel in CI engine reduced the vibration and sound pressure level. Also use of CNG in intake manifold getting help to reduce vibration [50]. Vijayakumar Chandrasekaran et al. 2016, studied on non-edible oil for biodiesel preparation and use of nano additives for improvising performance and combustion characteristic. Mahua biodiesel is investigated in that research, firstly mahua biodiesel is run on engine without use of additive at different load, same speed and at different blends such as B20, B40, B60, B80 and B100. It was concluded that B20 gives best performance parameters than any blend. In second step of this study copper oxide nano additives used in B20 blend of mahua biodiesel and finally it was concluded that use of nano additives with biodiesel and diesel blend results in reducing emission of CO, smoke and HC [51]. S. M. Ameer Uddin et al. 2015, Studied on use of pure mustard oil in CI engine blending with kerosene at various blend such as M20, M30, M40, M50 and M100 at various load condition from 6 kg to 15 kg and speed of engine kept constant at 2000rpm. Various physical properties like flash/fire point, density, calorific value and viscosity has been calculated firstly. Finally researcher concluded that M20 and M30 blend gives lower value of BSFC at 12.5 kg load and M20 blend with kerosene can be used for diesel engine [52]. W.N.M.W. Ghazali et al. 2015, reviewed on various feedstock for biodiesel and analyzes their respective performance and combustion characteristics. In that review many performance and combustion parameters like BP, BTE, BSFC, NOx, CO2, CO, PM, smoke density and torque have been determined to compare with pure diesel. Finally this study concluded that in CI engine biodiesel can be used as an alternative of diesel fuel [53]. S. Imtenan et al. 2014, studied on use of additives such as diethyl ether, ethanol and n- butanol for improvising the performance and emission characteristic of palm biodiesel with diesel fuel. B20 palm biodiesel was investigated in this research, in B20 palm biodiesel 5% of additive has mixed. finally this research concluded that by use of diethyl ester as additive in palm biodiesel so that biodiesel shows higher brake power, lower fuel consumption, higher BTE and also emission of NO and CO get decreased [54]. CHAPTER- 6 EQUIPMENT, MATERIAL AND EXPERIMENTAL SETUP 6.1 Material used in Transesterification Process:- 1. Use methanol as an alcohol in transesterification. 2. Use homogeneous alkaline catalyst KOH in transesterification process, that catalyst is work as an activator in transesterification process. 3. Pure mustard oil and waste mustard oil for production of biodiesel. 6.2 Equipment used in Transesterification Process:- 1. R.B. flask (three neck bottle) of 2 liter capacity. In that three neck condenser, stirrer and thermometer is connected respectively. 2. Heating mantle of 2 liter size and 450 watt. 3. Thermometer to calculate temperature at different-different time. 4. Stirrer of 125 watts and 1440 RPM to continuous circulates the mixture of methanol, mustard oil and KOH. 5. Condenser to control the unusually wastage of methanol. 6. Seperatory funnel having 2 liter capacity is used to separate biodiesel and glycerol layer. 7. Burrate of 100 ml capacity is used to make proper concentration of methanol and catalyst. Also used for titration test for unknown sample or oil. 8. Density bottle of 50 ml capacity is used to find out density of oil and biodiesel. Value of density of oil is helps to getting the value of methanol in different molar ratio of methanol to oil and also wt % of KOH used. 9. Ostwald viscometer, also named as capillary viscometer or U-tube viscometer is used to find the value of viscosity of liquid. 10. Pensky-Martens type of closed-cup apparatus used to find out the value of flash point. 11. Bomb Calorimeter used for calculated the calorific value of sample. 6.3 Experimental Setup of Laboratory Scale Setup:- Transesterification process of mustard oil is held in laboratory scale setup. In that process 500ml of pure mustard oil or waste mustard oil is taken in conical flask called R B flask of a capacity of 2 liter, KOH and methanol are mixed with different weight percentage (2%, 3%) and molar ratio of methanol to oil (1:3, 1:6, 1:9) respectively, to find out the optimal values of that parameters for higher the yield percentage of biodiesel. That wt % of KOH and molar ratio are calculated from fatty acid profile and formula derived from molar mass of oil and alcohol. Generally R B flask has three neck bottle in which condenser, stirrer motor and thermometer are connected respectively. The condenser is used to avoid the looses of methanol because the methanol is evaporate above 50˚C temperature, thermometer is used to take the reading of temperature time to time because this transesterification process is held in temperature range of 55 to 60˚C and stirrer motor is used to continuous stirring the oil to equal distribution of the temperature in entire volume of oil. From the previous literatures review it has to found that, at 55˚C the yield percentage of biodiesel has higher value, stirrer motor rotation speed has plays vital role on production of biodiesel and wt % of KOH has optimal value for production of biodiesel at 2-3 wt/wt of oil and molar ratio has optimal value at 1:6 to 1:9. Figure 6 shows the arrangement of laboratory scale setup. 6.4 Material used in Engine Test:- 1. B10, B20 and B30 prepared by blend of mustard biodiesel and commercial diesel. 2. B10, B20 and B30 prepared by blend of waste mustard biodiesel and commercial diesel. Figure 6: Laboratory Scale Setup 6.5 VCR Engine Test Setup:- VCR engine test setup consist power 5.20 kW at 1500 rpm which is four stroke, single cylinder, constant speed, VCR (Variable Compression Ratio) Diesel engine connected to eddy current type dynamometer for loading purpose. Compression ratio can be changed without stopping the engine. Provision is also made for interfacing airflow, Fuel flow, temperatures and load measurement. The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Gas analyzer is connected at engine exhaust to detect the emission gases such as such as NOx (Nitric oxide), HC (unburnt hydrocarbon), CO2 (Carbon dioxide), O2 (oxygen) and CO (carbon monoxide). Table 3 shows the specification of VCR engine test setup and Figure 7 shows the arrangement of VCR engine test setup. Table 3: Specification of engine test setup Specification of VCR engine test setup Product VCR Engine test setup 1 cylinder, 4 stroke, Diesel Product code 234 Engine Make Kirloskar, Type 1 cylinder, 4 stroke Diesel, water cooled, power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm. 661 cc, CR 17.5, Modified to VCR engine CR range 12 to 18 Dynamometer Type eddy current, water cooled, with loading unit Fuel tank Capacity 15 lit with glass fuel metering column Fuel flow transmitter DP transmitter, Range 0-500 mm WC Air flow transmitter Pressure transmitter, Range (-) 250 mm WC Gas analyzer Detect the emission gas like HC, NOX, O2, CO and CO2 Software “EnginesoftLV” Engine performance analysis software Figure 7: VCR Engine test setup CHAPTER- 7 RESEARCH METHODOLOGY Figure 8: Basic Transesterification Protocol [55] Transesterification is also named by alcoholysis or esterification process, by which we can decrease the value of viscosity of oil or triglycerides. In that process alcohol is transfer into ester by use of another alcohol that process is also similar to hydrolysis process but in hydrolysis process water is used instead of alcohol [2]. Before transesterification process we determine fatty acid profile of pure and waste mustard oil by which we can determine the molecular mass of that respective oil. The value of molecular mass of oil can get help to find the value of methanol at different molar ratio. Molecular mass of mustard oil is 972.67 gm/mole and for waste mustard oil is 973.70 gm/mole, derived from fatty acid profile of oil. Preparation of biodiesel is held in laboratory scale setup in which methanol of having different molar ratio such as 1:3, 1:6, 1:9 respectively is mixed with homogeneous alkaline catalyst KOH with different wt percentage such as 2% and 3%. The amount of molar ratio and wt percentage of catalyst used has depended on the fatty acid profile of an oil or triglyceride. Volume of methanol which is used in trasesterification process is determine by formula which is given below Molecular ratio of oil = $mass\ of\ oil\ Molecular\ mass\ of\ methanol\ methanol\ Molecular\ mass\ of\ oil$ × $mass\ of\ methanol$ Where Mass of oil = density of oil × volume of oil Mass of methanol = density of methanol × volume of methanol Molecular mass of mustard oil = 972.67 gm/mole (derived from fatty acid profile) Molecular mass of methanol (CH3OH) = 32.04 gm/mole Methanol and KOH is not mixed with oil separatory because small amount of water is produced when the methanol and KOH react. So in process of transesterification methanol and KOH is mixed first in glass container. The mixer of methanol and KOH is called methoxide. Some amount of heat is produced as time of mixing because this is an exothermic reaction. Methoxide is corrosive in nature and also dangerous for living tissues like human skin. So safety precautions should be taken when the methoxide produced [56-61]. After the methoxide produced, mustard oil is taken in three neck R. B. flask and heated up to 55-60oC than add methoxide into mustard oil. In three neck of R.B. flask condenser, stirrer motor and thermometer is connected respectively. Condenser is used to control the unusual wastage of methanol because methanol get evaporate above 50oC and thermometer is used to take the value of temperature time to time. After mixing methoxide transesterification process gets start, this process complete in three steps in first step triglyceride coverts into di-glycerides, in second step di-glycerides converts into monoglyceride and in final step monoglyceride coverts into glycerol and biodiesel. Figure 9: Reaction of triglyceride, methanol and glycerol [13] Glycerol is generally a byproduct in that transesterification process. Transesterification process is runs in laboratory scale setup for 1-2 hr generally at temperatures range 55-60oC, time to time sample is taken from that mixer and pour warm water into that sample if two separate layers of biodiesel and glycerol is form than stop the process otherwise continue the process, figure 10 shows the separation layer of biodiesel and glycerol. HCL (Hydrochloric acid) is also used instead of warm water. Figure 10: Separation of two layers After 10 minute when warm water pouring Figure 11: Separation of two layers in separatory Funnel after 1 hour when pouring warm water If two layers of biodiesel and glycerol are formed than pour that mixer into separatory funnel. Generally glycerol layer is settling down in separatory funnel and biodiesel is in upper layer, figure 11 shows the separation of two layers in separatory funnel. After pouring the mixer in separatory funnel wet washing process is done on it. Warm water is pour into the separatory funnel to wash the glycerol of oil and then rest that oil into separatory funnel for a day. After a day two layers is form and glycerol is settling down take out that by opening the valve of separatory funnel and rest of biodiesel is remain in that. Figure 12 shows that separation. Figure 12: Separation of two layers after 24 hours (After washing process is done) Take the biodiesel from separatory funnel into glass container. Methanol and water contain also exist in produced biodiesel that was eliminated by heated the biodiesel up to 110oC [38]. Pure biodiesel can produce after this all process. Yield percentage of produced biodiesel can be calculated by formula which is given below. Yield percentage of produced biodiesel = Weight of produced biodiesel × 100 Weight of total oil used After production and purification of biodiesel we calculated physical properties of biodiesel like flash point, density, calorific value and kinematic viscosity. These properties were determined by Pensky marten apparatus, density bottle, bomb calorimeter and Ostwald or U-tube viscometer respectively. Produced biodiesel from pure and waste mustard oil blended with commercial diesel fuel at different-different ratio such as 10%, 20% and 30%. After that all blends investigated in “VCR engine test setup” for determining the performance, combustion and emission characteristics at different load condition. Dynamometer is used for loading unit on this setup. Gas analyzer is attached at engine exhaust to detect the emission gas like HC, CO2, CO, O2 and NOX. CHAPTER-8 RESULTS AND DISCUSSION 8.1 Properties of Mustard and Waste Mustard Oil:- Mustard seed is give 33% production of oil, that yield of oil is greater than soybean seed that only gives 18-23% yield of oil [62]. Properties like density, flash point, kinematic viscosity and calorific value of mustard and waste mustard oil was calculated given in Table 4. Table 4: Properties of mustard and waste mustard oil PROPERTY Unit MO FUEL WMO Density gm/ml 0.92 0.906 Kinematic viscosity mm2/sec 31.55 48 Calorific Value MJ/kg 38.8 38 Flash Point 0C 268-272 270-278 Gas chromatography method used for determination of fatty acid profile. Fatty acid profile plays a vital role for produced biodiesel when it is run in engine. This profile consist of Saturated Fatty Acids, Mono unsaturated Fatty Acids, Poly Unsaturated fatty acids and Trans fatty acids. In which saturated fatty acid esters have better oxidation stability and higher cetane values, but at low temperature flow properties become poor [63, 25]. Fatty acid profile of mustard and waste mustard oil is given in Table 5. From that table unsaturated fatty acid for mustard oil consist acid (88.12%) is higher than saturated fatty acid content (11.22%). Similarly results found in fatty acid profile of waste mustard oil in which unsaturated fatty acid content (73.71%) is higher than saturated acid content (26.24%). Content of acid in mono-unsaturated acid for both mustard and waste mustard oil is higher than poly unsaturated acid. Table 5: Fatty acid profile for mustard and waste mustard oil Sr. No Parameter Chemical formula Molecular mass (gm/moles) Result (%) I Saturated Fatty Acids Waste Mustard Oil Mustard Oil [39] 1 Butyric Acid C4H8O2 88.11 ND ND 2 Caproic Acid C6H12O2 116.15 ND ND 3 Caprylic Acid C8H16O2 144.21 ND ND 4 Capric acid C10H20O2 172.26 ND ND 5 Undecanoic acid C11H22O2 186.29 ND ND 6 Lauric acid C12H24O2 200.31 ND ND 7 Tridecanoic acid C13H26O2 214.34 ND ND 8 Myristic acid C14H28O2 228.37 0.82 0.05 9 Pentadecanoic acid C15H30O2 242.39 0.02 0.03 10 Palmitic acid C16H32O2 256.42 19.87 5.54 11 Heptadecanoic acid C17H34O2 270.45 0.07 0.03 12 Stearic acid C18H36O2 284.47 4.52 1.51 13 Arachidic acid C20H40O2 312.53 0.61 1.21 14 Heneicosanoic acid C21H42O2 326.55 0.035 0.04 15 Behenic acid C22H44O2 340.58 ND 1.09 16 Tricosanoic acid C23H46O2 354.61 ND 0.04 17 Lignoceric acid C24H48O2

368.63 0.3035 1.68 II Mono unsaturated Fatty Acids 1 Myristoleic acid C14H26O2 226.36 ND ND 2 Cis-10 Pentadecanoic acid C15H28O2 240.38 ND ND 3 Palmetoleic acid C16H30O2 254.41 0.3 0.21 4 Cis-10 Heptadecanoic acid C17H32O2 268.44 ND ND 5 Oleic acid C18H34O2 282.46 27.47 8.83 6 Cis-11-ecosanoic acid C20H38O2 310.52 6.35 5.27 7 Erucic acid C22H42O2 338.57 10.15 37.71 8 Nervonic Acid C24H46O2 366.62 0.43 2.22 III Poly Unsaturated fatty acids 1 Linoleic acid C18H32O2 280.44 25.98 10.79 2 Y-linolenic acid C18H30O2 278.43 0.17 ND 3 Linolenic acid C18H30O2 278.43 1.83 20.98 4 Cis-11,14,-Eicosadenoic acid C21H38O2 322.53 0.25 0.7 5 Cis-8,11,14-Eicosatrinoic acid C20H34O2 306.48 0.48 0.45 6 Cis-11,14,17-Eicosatrinoic acid C21H36O2 320.51 ND ND 7 Arachidonic acid C20H40O2 304.47 ND ND 8 Cis-13,16-docosadenoic acid C22H40O2 336.55 0.3 0.96 9 Cis-5,8,11,14,17-Ecosapentenoic acid C20H30O2 302.45 ND ND 10 Cis-4,7,10,13,16,19- Docosahexanoic acid C22H32O2 328.5 ND ND IV Trans fatty acids 1 Trans Elaidic acid C18H34O2 282.46 0.05 ND 2 Trans Linolelaidic acid C18H32O2 280.44 ND ND Others 0 0.66 8.2 Yield of Biodiesel at Different Molar Ratio and Catalyst Concentration:- Produced biodiesel was purified with wet washing method; water is used as washing agent in this method. Figure-13 shows yield of biodiesel at different molar ratio and catalyst concentration. Mustard oil gives 87.05% and waste mustard oil gives 85.03% yield of biodiesel at 1:9 molar ratio and 2wt% of KOH. Both mustard and waste mustard oil gives maximum yield of biodiesel at 1:9 molar ratio (oil and methanol) and 2 wt% of KOH. 100 Yield % of Biodiesel Produced 50 MO-2wt% KOH MO-3wt% KOH 90 80 70 60 40 30 20 WMO-2wt% KOH 10 0 WMO-3wt% KOH 1:3 Molar Ratio 1:6 Molar Ratio 1:9 Molar Ratio Molar Ratio of Oil and Methanol Figure 13: Yield of biodiesel at different molar ratio and catalyst concentration 8.3 Properties of Produced Biodiesel and Diesel Fuel:- After the production of biodiesel it was heated up to 80-90oC for collection of methanol. Methanol gets evaporated at 50oC and collected methanol can be used for further production of biodiesel. Table-6 shows the properties like density, kinematic viscosity, flash point and calorific value for diesel, mustard and waste mustard biodiesel. Table 6: Properties of diesel, MB and WMB PROPERTY Unit MB FUEL WMB Diesel Density gm/ml 0.882 0.879 0.83 Kinematic viscosity mm2/sec 4.479 4.318 3.5-5 Calorific Value MJ/kg 40.4 40 44 Flash Point 0C 160 168 71.2 8.4 Performance Characteristics of Engine:- Produced MB and WMB is blend with commercial diesel fuel at various blend like B10, B20 and B30. This blends were is investigated in KirloskarTV1 engine consisting power 5.20 kW at 1500 rpm which is Four stroke, 1 Cylinder, Constant Speed, Water Cooled diesel Engine of 661cc capacity. Dynamometer is attached in engine assembly for apply various load on engine. Three loads condition was investigated in engine, they no load condition, 50% load condition and full load condition. 8.5 Performance Characteristics at No Load Condition:- Table-7 shows performance characteristics at No load condition. From table-7 our investigated points are ? Indicated and break power of blends are higher than diesel fuel. ? Volumetric efficiency of blends is comparatively equal with diesel fuel. ? Mechanical efficiency, indicated thermal and brake thermal efficiency of blends are lower values than diesel values. ? B30 waste mustard biodiesel performance characteristics has higher values than other blends like B20 MB, B30 MB and B20 WMB. Table 7: Performance characteristic at No load condition LOAD FUEL IP (KW) BP (KW) Air Flow (mmWC) Fuel Flow (cc/min) IThEff % BThEff % Fuel Consumption (Kg/h) Mech Eff.(%) Vol Eff.(%) Diesel 0.71 0.009 92.65 1.11 63.53 7.35 0.04 11.38 85.77 B10 MB 1.75 0.009 98.37 4.58 58.61 4.37 0.22 7.19 87.4 B20 MB 2.56 0.009 92.75 6.89 52.77 1.38 0.34 2.67 84.81 0% B30 MB 2.06 0.11 93.33 6.66 51.43 2.09 0.34 2.12 85.61 B10 WMB 1.77 0.009 96.72 5.28 55.87 3.19 0.26 5.76 86.8 B20 WMB 1.98 0.009 95.01 5.61 56.49 2.77 0.27 4.74 86.32 B30 WMB 2.03 2.03 96.34 5.8 57.56 2.58 0.3 4.42 86.91 8.6 Performance Characteristics at 50% Load Condition:- Table-8 shows performance characteristics at 50% load condition. From table-8 our investigated points are ? Performance characteristics like brake power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and volumetric efficiency for blends are higher values than diesel values. ? Indicated power and fuel consumption has comparatively equal than diesel values. ? B30 waste mustard biodiesel performance characteristics has higher values than other blends like B20 MB, B30 MB and B20 WMB. Table 8: Performance characteristic at 50% load condition LOAD FUEL IP (KW) BP (KW) Air Flow (mmWC) Fuel Flow (cc/min) IThEff % BThEff % Fuel Consumption (Kg/h) Mech Eff.(%) Vol Eff.(%) Diesel 6.57 2.17 80.85 21.98 51.1 16.69 1.08 32.98 82.12 B10 MB 6.94 2.18 85.07 20.98 54.52 17.07 1.04 31.29 83.8 B20 MB 6.29 2.18 83.32 19.32 53.78 18.538 0.97 34.52 83.04 50% B30 MB 6.03 2.19 83.09 19.45 51.44 18.46 0.98 35.97 82.9 B10 WMB 1.44 0.06 97.41 4.35 55.79 2.67 0.21 4.87 87.05 B20 WMB 6.55 2.19 87.4 18.98 55.61 18.44 0.98 33.18 83.73 B30 WMB 6.59 4.4 85.21 18.5 59.31 19.49 0.93 33 83.77 8.7 Performance Characteristics at Full Load Condition:- Table-9 shows performance characteristics at full load condition. From table-9 our investigated points are ? Indicated power of blends have comparatively equal values than diesel values except B30 WMB that have lower value. ? Brake power of blends has comparatively equal values than diesel values. ? Indicated thermal and brake thermal efficiency has very lesser values than diesel values. ? Mechanical efficiency, volumetric efficiency and fuel consumption is higher than diesel values. Table 9: Performance characteristic at full load condition LOAD FUEL IP (KW) BP (KW) Air Flow (mmWC) Fuel Flow (cc/min) IThEff % BThEff % Fuel Consumption (Kg/h) Mech Eff.(%) Vol Eff.(%) Diesel 8.43 4.28 74.65 2 716.5 363.62 0.1 50.75 80.74 B10 MB 8.95 4.31 77.92 29 50.82 24.49 1.45 48.02 81.78 B20 MB 8.17 4.28 75.35 29 46.48 24.36 1.46 52.42 80.58 100% B30 MB 8.11 4.3 75.77 28 47.91 25.41 1.42 53.03 80.86 B10 WMB 8.75 4.3 77.49 28 51.49 25.34 1.4 49.21 81.55 B20 WMB 8.59 4.28 78.27 27 52.61 26.24 1.36 49.87 81.91 B30 WMB 8.36 4.31 77.68 27 51.37 26.5 1.37 51.59 81.6 8.8 Exhaust Gas Emission Test:- In this test gas analyzer is used at engine exhaust to investigate the exhaust gas emission at various load condition while using MB and WMB blends. Mainly investigating exhaust gases are CO, NOx, CO2, HC and O2. In that investigation engine RPM kept constant at 1500rpm. Table-10 shows the emission of carbon monoxide (%Vol) with respect of diesel fuel. From that table-10 we can say that blends of MB and WMB gives approximately same result as diesel fuel. Table 10: Emission of CO (% Vol) for blends FUELS LOAD (Kg) 0 3 6 9 12 15 Diesel 0.01 0 0 0.01 0 0.01 MB B10 0.01 0 0 0 0 0.01 MB B20 0.01 0 0 0 0 0.01 MB B30 0.01 0.01 0 0 0 0 WMB B10 0.01 0 0 0 0 0 WMB B20 0.01 0 0 0 0 0 WMB B30 0.01 0 0 0 0 0 Table-11 shows the emission of unburned hydrocarbon (PPM Hex) of blends of MB and WMB with respect of diesel fuel. Table 11: Emission of HC (PPM Hex) for blends FUELS LOAD (Kg) 0 3 6 9 12 15 Diesel 5 5 4 5 5 7 MB B10 3 5 3 0 4 4 MB B20 2 4 3 5 1 3 MB B30 2 2 1 1 4 5 WMB B10 2 1 1 1 1 2 WMB B20 5 5 2 1 1 5 WMB B30 2 3 5 4 2 1 Table-12 shows the emission of carbon dioxide (% Vol) of blends of MB and WMB with respect of diesel fuel. Table 12: Emission of CO2 (% Vol) for blends FUELS LOAD (Kg) 0 3 6 9 12 15 Diesel 0.5 1 1 1.2 0.7 0.8 MB B10 0.4 0.7 0.8 0.9 0.9 0.6 MB B20 0.4 0.6 0.7 0.9 0.9 0.9 MB B30 0.4 0.6 0.7 0.9 1 0.9 WMB B10 0.3 0.6 0.6 0.8 0.9 0.9 WMB B20 0.4 0.6 0.7 0.8 0.9 0.9 WMB B30 0.3 0.6 0.7 0.8 0.9 0.9 Table-13 shows the emission of oxygen (% Vol) of blends of MB and WMB with respect of diesel fuel. Table 13: Emission of O2 (% Vol) for blends FUELS LOAD (Kg) 0 3 6 9 12 15 Diesel 20.18 19.54 19.62 19.36 20.07 19.98 MB B10 20.31 19.91 19.84 19.74 19.71 20.14 MB B20 20.36 20.02 19.96 19.68 19.62 19.73 MB B30 20.06 19.74 19.57 19.34 19.18 19.19 WMB B10 20.63 20.31 20.29 20.11 20 20.01 WMB B20 20.52 20.21 20.11 19.91 19.78 19.79 WMB B30 20.51 20.2 19.97 19.8 19.69 19.63 Table-14 shows the emission of nitric oxide (% Vol) of blends of MB and WMB with respect of diesel fuel. Table 14: Emission of NOX (% Vol) for blends FUELS LOAD (Kg) 0 3 6 9 12 15 Diesel 16 134 135 172 87 93 MB B10 15 65 101 115 120 66 MB B20 16 68 82 113 122 109 MB B30 11 54 80 109 126 113 WMB B10 10 55 65 88 107 103 WMB B20 12 57 75 99 116 112 WMB B30 13 53 79 107 117 116 CHAPTER- 9 CONCLUSION 1. Waste mustard and fresh mustard oil gives maximum production of biodiesel at 2 wt% of KOH and 1:9 molar ratio (oil and methanol). 2. Both oil gives approximately same result on that parameters so we can replace fresh mustard oil as waste mustard oil for production of biodiesel so it's also overcome the debate on fuel versus food. 3. In engine performance test brake power, air flow, fuel flow and fuel consumption gives higher values for all blends comparatively diesel fuel. 4. In engine testing, waste mustard biodiesel shows comparatively equal results as mustard biodiesel. So we can replace MB with WBM. 5. Emission test shows that HC particle of all blends are equal and lesser values than diesel fuel. CO2 and NOx particle show lesser value for all blends as compare to diesel value except 12 and 15 kg load condition in that condition they show higher value. 6. In emission test CO particle shows slightly equal value for all blends as compare to diesel value.O2 particle shows higher value its mean proper combustion of fuel takes place by using biodiesel/diesel fuel blend. 9.1 FUTURE SCOPE:- For further study to improvising the performance, combustion and emission characteristics of engine, we can use additives in biodiesel/diesel fuel blend. There are various additives such as copper oxide nano additive, diethyl ether, ethanol, n- butanol, anti oxidant additive, metal based additive, oxygenated additive and cetane number additives for improvising the biodiesel/diesel fuel blend quality such as higher brake power, lower fuel consumption, higher BTE and also emission of NOx and CO get decreased. Use of biodiesel/diesel fuel in unmodified CI engine may cause noise and sound pressure level problem. This problem can be eliminated by induced CNG in intake manifold in engine LIST OF REFERENCES [1] Singh A, Smyth BM, Murphy JD. A biofuel strategy for Ireland with an emphasis on production of biomethane and minimization of land-take. Renewable and Sustainable Energy Reviews 2010;14:277-88. [2] D. Y. C. Leung, X. Wu, and M. K. H. Leung, "A review on biodiesel production using catalyzed transesterification," Appl. Energy, vol. 87, no. 4, pp. 1083–1095, 2010. [3] Mudge SM, Pereira G. 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