Design And Construction Of A Small Scale Biodiesel Processor

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Abstract: The design and construction of small scale biodiesel processor is brought about to reduce the effect of fossil fuel diesel scarcity or shortage in the country. This project will go a long way to improving the lay-down of getting normal diesel, in that the prototype designed is to transform used vegetable oil into biodiesel instead of the problem of digging the ground to get the diesel fuel. The biodiesel processor, from the history, uses transesterification process to convert the waste oil into usable fuel. Different feedstock has been used by different producers, such feedstocks are vegetable oil, palm kernel oil, soybean, rapeseed, peanut and Shea-butter e.t.c. The small scale biodiesel processor has different parts such as; the mixing tank, piping, sieving tank, taps, electric motor, pulley and belt arrangement, pump, and receiving tank. But majorly the operation of the production of biodiesel takes place in three tanks. The mixing tank; receive the feedstock and it is the place where the continuous agitation of the feedstock takes place. The sieving tank; it sieves the feedstock to separate the biodiesel from glycerin. The receiving tank; receive the biodiesel through the help of pumping machine. The testing of our biodiesel processor gave a clear result of biodiesel and glycerol as the by-product using sodium hydroxide as our catalyst and the efficiency of the biodiesel processor is 73%.
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Introduction

In a world where environmental awareness is becoming increasingly important for individuals, businesses, and mankind as a whole, it is always important to be looking for ways to use renewable resources, re-use waste and cut carbon emissions. Biodiesel is a great way to do this. Use of vegetable oil from oil-bearing seeds, waste oil and animal fats for making biodiesel, for instance, reduces impact on the environment.

Biodiesel is a liquid fuel obtained from the addition of alcohol to any source of complex fatty acids: vegetal oil or animal fat. The following describes how vegetable oil mixed with methanol yields biodiesel through the reaction of trans-esterification, whereby glycerin is separated from used vegetable oil via a caustic catalyst. (Wesley et al., 2006).

It has been reported that in diesel engines, crude plant oils (such as PKO) can be used as fuel, either straight or as blend with petroleum diesel. However, use of neat vegetable oils are characterized by injector choking, engine deposits, and thickening of lubricants during extended operation of the engine. This has been attributed to the high viscosity of vegetable oils (Ryan et al., 1982; Gupta et al., 2007).

Verma et al., 1998, Krahl et al, 2005, and Gupta, 1994 have used bio-diesel as alternate fuel in the existing compression ignition (CI) engines without any modification. Promising results have been obtained by running CI engines on vegetable oil based bio-diesels. Soybean (US), rapeseed (Europe), oil palm (South-East Asia), and canola. These have been successfully used as renewable vegetable oil sources to generate biodiesel (Peterson et al., 1990; Noureddini and Zhu, 1997; Yunus et al., 2003).

As biodiesel becomes more and more popular the resources available become more and more scarce, and people are starting to charge for things that used to be free, specifically Waste Vegetable Oil (WVO). Modern biofuels have been reported as a promising long- term renewable energy source which has potential to address both environmental impacts and security con- cerns posed by current dependence on fossil fuels (Batidzirai et al., 2006; Alamu et al., 2007a; Gupta et al., 2007).

At industrial scale, alkaline catalysis is usually used in biodiesel production from edible oil. Among the possible raw materials for the production of biodiesel, the use of rapeseed oil, canola oil, soybean oil, palm kernel oil, coconut oil and cotton seed oil has been investigated (Abigor et al.,, 2000; Watanabe et al.,, 2002; Kose et al.,, 2002; Dmytryshyn et al.,, 2004; Royon et al., 2007; Alamu et al.,, 2007; Zhang et al.,, 2007).

Moreover, as a result of the recent food crisis that is allege to be due to conversion of food materials to biofuels, the need to consider discarded waste vegetable oil as source of potential oil for biodiesel production cannot be over emphasized.

The goal of this project is to design and construct a prototype of a machine that transforms waste vegetable oil into biodiesel.

Materials And Methods

Biodiesel reactor (mixing tank)

The mixing tank did not require any modifications. The only construction involved with the mixing tank was adding the fittings at the bottom of the tank to ensure that no liquid will be left in the tank. The fittings attached at the bottom of the tank were all screw fittings so no major construction was required.

Valves, Pump, and Filter

The valves used required that fittings be added in order for a connection to the clear vinyl tubing to be accomplished.

Stress Analysis

Various machine members has to be analyzed for stress and it is necessary in order to know precisely the nature, magnitude, direction and application of all forces with a view to the safety of life of the machine uses and reliability of different machine members.

This also helps to compare the value of these forces with the established standard and to have a confidence level of acceptance. Force acting on each machine member will be determined to help in choosing the material for the construction.

Design of Power Transmission Unit

The major component for which analysis is sought in here is the belt pulley design. Design of belt involves the proper belt selected to transmit the required power. V-belt is selected to transmit the power from prime mover to the threshing chamber because of the following reason;

- It is suitable for small centre distance arrangement.
- It can be easily installed and removed.
- It has the ability to cushion the shock when machine is started.

Pulley Analysis

Assuming a factor of safety is (two)2 and availability of a 2KW electric motor, but the availability for mixing was 1.8KW using standard belt type B and corresponding size is

Top width (b) = 17.2mm

Thickness (t) = 11.10mm

Groove angle of pulley = 37^0 (Kurmi and Gupta, 2003). For this design a 2KW electric motor is recommended;

The required speed of motor S_m= 1400rpm.

Recommended speed of mixing shaft S_s = 500rpm

Diameter of pulley on the shaft $D_s = \frac{S_m \times D_m}{S_s}$ (1)

Determination of belt length and centre distance

Pitch length $= 2C + 1.57(D + d) + \frac{(D-d)^2}{4C}$ (2)

$D_s < C < 3(D_s + D_m)$

$140 < C < 570$

Determination of Angle of Wrap

Angle of wrap $= 180 - 2\sin^{-1}(\frac{D-d}{2C})$ (3)

Where θ_d = Angle of wrap in degree.

For angle of wrap in radian = θ_{radian}

$\theta_{radian} = \frac{\pi \times \theta_d{}^0}{180}$ (4)

Determination of belt tension.

$P = (T_1 - T_2)V$ **(5)**

Where P = Power

T_1 = Tension in belt 1

T_2 = Tension in belt 2

V = Velocity of the belts

$$V = \frac{\pi DN}{60}$$

Centrifugal force of the belt = MV^2 (7)

$M = bt\rho$ (8)

Where M = Mass per unit length of the belt,

b = belt width (m),

t = belt thickness (m)

e = mass density of the belt (Kg/m)

Let

$\mu = 0.4 \times (frictioncoefficientofthebeltandpulley)$.

Therefore,

$\frac{T_1 - T_C}{T_2 - T_C} = \rho^{\mu\theta cosec\beta}$ (9)

$\frac{T_1 - MV^2}{T_2 - MV^2} = \rho^{\mu\theta cosec\beta}$(10)

Determination of force acting on the pulley (F_p).

Fp = force due to the weight of the pulley + Net force due to belt tension (T_1-T_2).

Force due to the weight of pulley $= \rho Vg = 7800 \times V \times 9.81$

Volume of the pulley $= \pi r^2 \omega - \pi {r_h}^2 \omega$

Where $\omega = thicknessofthepulley$

r = radius of the pulley

r_h= radius of the hole of intersection of the shaft, assume to be15mm.

This is the maximum force that the shaft can bear; therefore the least shaft diameter should be 30mm in other to carry the lead.

The minimum allowable value for the radius of the shaft will be

$r = \sqrt{\frac{2mt}{\pi\tau}}$ (14)

Where mt = torsional movement

$\tau = shearstressoftheshaft$

$\tau = \frac{mtr}{J}$ (15)

But $J = \frac{\pi d^4}{32} = \frac{\pi r^4}{2}$ (16)

For the belt drive $mt = (T_1 - T_2)r$ (17)

Where r = radius of the pulley

$r = (\frac{2mt}{\pi\tau})^{\frac{1}{3}}$ (18)

The maximum allowable shearing stress = $42MN/m^2$

Therefore the diameter = 16mm.

But for the factor of safety 2, the diameter of 30, 32 or 35mm is suitable for the design.

Power to be transmitted by the shaft

$P = 2\pi mtF$ (19)

But $F = \frac{\omega}{2\pi}$ (20)

Where $\omega = angularvelocityin \frac{rad}{sec}$.

F= Frequency

Since N=1400rpm.

$$W = \frac{\pi N}{180}$$

Since power to be transmitted is smaller than the available power of mixing it is within the range.

Determination of mixing power

$P = \rho g \varphi h$ (22)

Where $\rho = density = 1000m^2/kg$

$$g = acceleration\ due\ to\ gravity = \frac{9.81m}{s}$$

$$\varphi = Discharge\ in\ m^3/s$$

$$h = height$$

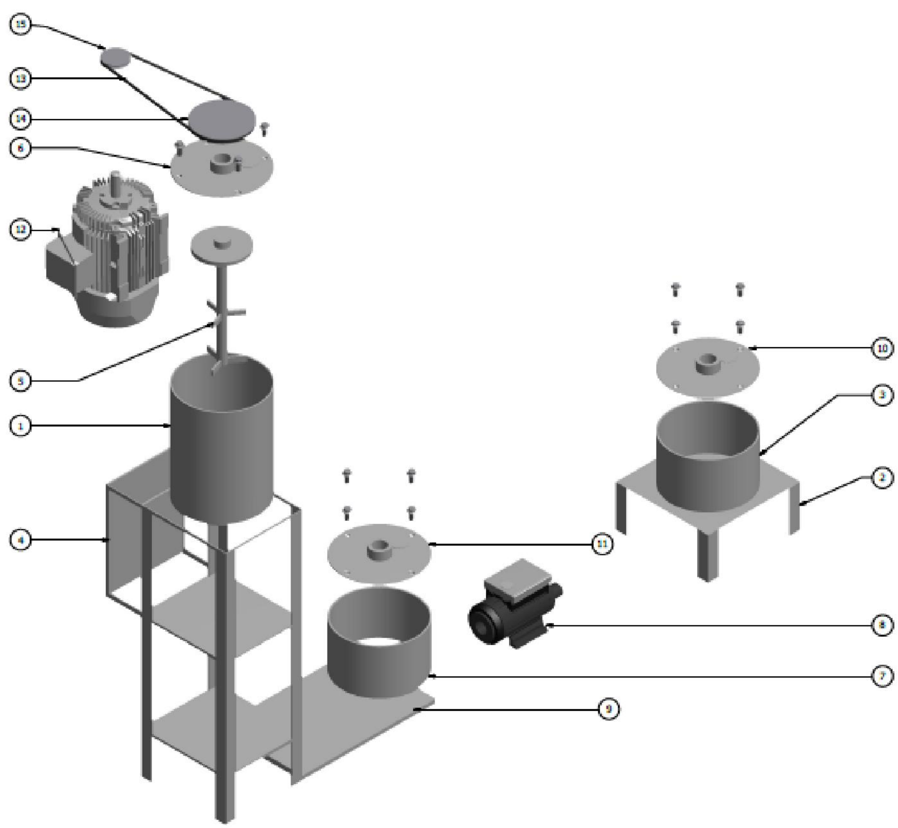
$$A = Area\ of\ the\ mixing\ tank$$

$$V = velocity\ of\ the\ flow$$

$\varphi = AV^2$ (23)

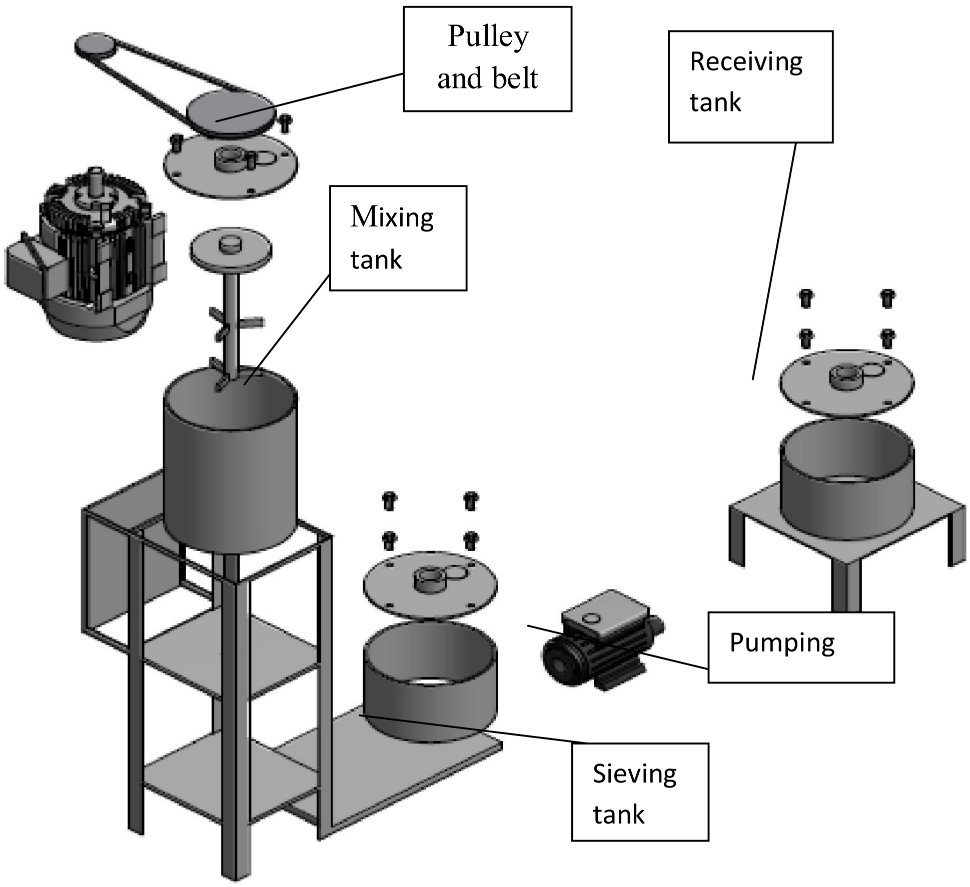
Operation Sequence

Continuous agitation of both vegetable oil and ethanol, ester (reactor) to form biodiesel for about forty minutes and it escaped to another barrel by filtration and it is pumped out into another barrel by centrifugal pump. The settlement and separation of the product from water is tapped into a container after settlement. It should be noted that processor (reactor) is being operated by an electric motor connected by belt and pulley.

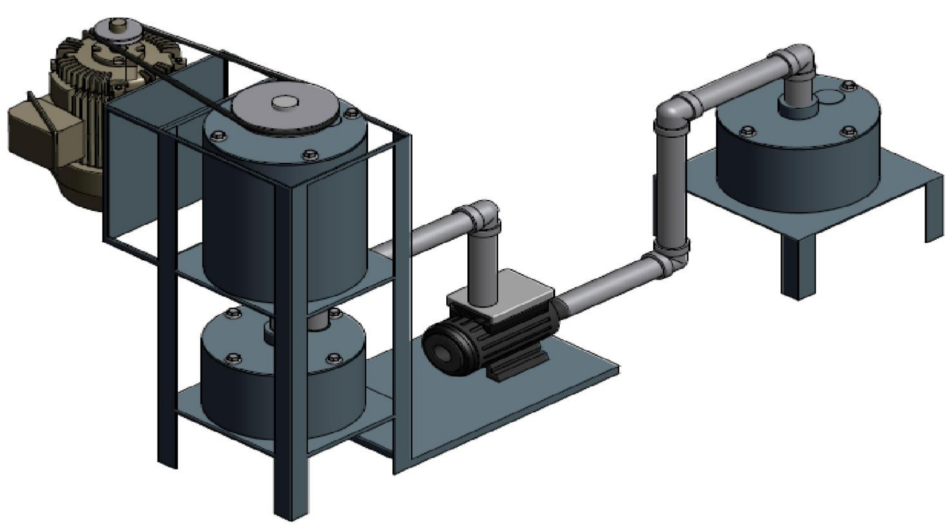


PARTS LIST	
ITEM	PART NUMBER
1	Mixing Tank
2	Receiver tank stand
3	Receiver tank
4	Stand
5	Stirrer
6	Mixing Tank Lid
7	Selving Tank
8	Water pump
9	Water pump stand
10	Receiving Tank Lid
11	Selving Tank Lid
12	Electric Motor
13	Belt Drive
14	Stirrer Pulley
15	Electric Motor Pulley

Part drawing of the biodiesel processor



Assembly drawing of the biodiesel processor



The biodiesel processor

Result And Discussion

It can be seen from the test running of the biodiesel processing machine under favorable and conducive environment that the correct agitation of palm kernel oil with methanol in appropriate proportion or appropriate quantity using sodium hydroxide (NaOH) as our catalyst, the correct and expected biodiesel and glycerin as by-product was formed.

The result obtain shows that the mixing of palm kernel oil, methanol and sodium hydroxide in the ratio 5:1:0.5 respectively gives the minimum biodiesel that can be produced using the processing tank and the maximum volume of the content that the tank contain is 38litres of palm kernel oil, 8litres of methanol and 4litres of NaOH solution, making 50litres of the content in the mixing tank would produce biodiesel at maximum rate.

Constructed Biodiesel Processor

Testing Procedure

The small scale biodiesel processor was placed in the workshop and connected to the power through the help of electric motor.

The tap of the mixing tank was closed before pouring the biodiesel material, such material used was palm kernel oil, methanol and sodium hydroxide NaOH. 250g of NaOH was dissolved in 1000ml of distilled water for about 20minutes to form sodium hydroxide solution. The first material that was pour into the mixing tank was four (4) liters of palm kernel oil and then one (1) litre of methanol was added. The machine was switched on from the power supply through the help of electric motor while the mixing tank tap remain closed. It was switched on t run for about 20minutes for thorough mixing of the content materials (4litres of palm kernel and 1litre of methanol) and after 20minutes, the biodiesel processor machine was switched off in other to add 250g of NaOH solution. After the adding of 250g of NaOH solution the mixture was allow to run at the speed of 1400rpm to allow complete and perfect mixing of the content.

The mixing tank tap close was open to allow the material to move into the filter or sieving tank where it was filtered and the filtrate was transferred to the receiver tank with the help of pumping machine.

Therefore, the biodiesel and glycerin as by-product was gotten.

Operators Warnings

The design has brought forth four potentially dangerous features: chemical, thermal, mechanical, and electrical. The product and some of the reactants of the system are harmful if contact or ingestion occurs. Safety measures, like inhalation and skin protection, must be utilized when operating. Heat is also generated inside the mixing tank and could potentially cause burns if not controlled appropriately.

The pumps could also present risk of mechanical injury to a user. Along with the pumps and rotor comes the risk of electrical shock.

Conclusion

The design and construction of a small scale biodiesel processor shows that with the size of our tank, the minimum volume of biodiesel that can be produced can be gotten using ratio 5:1:0.5 of palm kernel oil, methanol and sodium hydroxide respectively. i.e. 5litres of palm kernel oil, 1litre of methanol and ½litre of sodium hydroxide (NaOH) as the catalyst mixed in good agitation and that proportion would produce the minimum biodiesel in the mixing tank. And the maximum biodiesel that can be produced using the tank is 50litres of the content, which means 38litres of palm kernel oil, 8litres of methanol and 4litres of NaOH solution respectively in the ratio 38:8:4 of the content.

The design and construction of this small scale biodiesel processor has come to replace any gas-liquids technology in that the use of vegetable oil and alcohol in this processor can produce biodiesel easily without much energy (work) imbedded in it. The amount of fuel to be produced will be depending on the size of the tank used.

As biodiesel become small and more popular, the resources available become more and more scarce. It should be noted here that the cleaner fumes and the non-toxic properties of biodiesel makes it a safer choice in comparison to petroleum.

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