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# Optimization Design for Manufacturing and Assembly Method in Multifedstock Jember Biodiesel Processor

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**Abstract.** A method used to optimize the design process in a manufacturing system is the Design For Manufacturing and Assembly Method (DFMAM). The idea of this optimization method is to minimize assembly process errors, reduce redundancy of components, save on production costs, as well as ease of operation. In this study, the method will be used on a biodiesel processor with multi feedstock type equipped with intelligent system for production perimeter control that is specifically designed to produce biodiesel from corn and coconut oil as raw materials produced by Jember, Indonesia. The design framework is made suitable for small-scale biodiesel production in MSMEs for industrial or laboratory purposes, in order to produce biodiesel that meets the biodiesel standards of Ministry of Energy and Mineral Resources of Republic of Indonesia. Processor component assembly via the DFMAM principle is simplified to reduce component complexity and redundancy. The biodiesel produced by this method has been tested and recorded a density value of 15 cel.deg. 874 - 877 kg/m<sup>3</sup>, viscosity at 40 cel.deg 4.3 – 4.7 mm<sup>2</sup>/s, Acid value 0.14 0.15 mg KOH/g, Cetane 56 – 58, Cloud Point 7 – 8 cel.deg., pour point 4 – 5, Flashpoint 171 – 178 cel.deg and distillation point 345 – 350 cel.deg.

## 1. Introduction

The method of optimizing a tool used in a production is an interesting research study. This method is generally carried out to obtain a simplification of the process of operating the equipment and the efficiency of the use of its operational budget. One of the optimization methods commonly used in the manufacturing process is the Design for Manufacturing and Assembly Method (DFMAM) optimization method [1].

DFMAM is a method that tries to improve the design process for a tool to make it easier for factories to carry out the process of optimizing the manufacture of a product, by integrating several kinds of model analysis, costs, energy calculations, and calculating the mechanical strength of materials into a final product in the form of a complete design of the updated tool [2].

Through this process, try to present a solution that has been optimized for an integrated manufacturing process, so that the best solution can be selected from several possible solutions that can be offered.

This will certainly reduce overall production costs and reduce complexity in the product development process, of course without compromising the standard quality of the product you want to produce.

The optimization process begins with an inventory of what components are contained in the prototype or product that we will optimize. The process is continued by developing the tool conceptually through a design-by-design process and then manufacturing assembly based on the details of the repair



design [3]. Of course, the complexity of this process is greatly influenced by the orientation of the user and the difference in the geometry to be applied.

In this study, the optimization process will try to be applied to a biodiesel maker with a multi feedstock type that will be used in middle-class community business units. This biodiesel maker tool or better known as a biodiesel processor is generally made with equipment that requires many and complicated components so that the purchase price will be expensive [4]. The research target is to try to simplify the biodiesel tools on the market into a biodiesel processor that is compact, inexpensive, easy to operate, and automatic in the process.

The prototype biodiesel processor of the researcher's design has an Automation in the program controller which is integrated with data acquisition software to monitor and control its operation. The developed prototype is useful in simulating full-scale automated systems and in a new processing technology which we named the chemical low thermal biodiesel process [5]. The specific purpose of this design is to minimize manual labor and costs while ensuring worker flexibility in processing diverse raw materials. This research develops a multi-feedstock biodiesel processor with a capacity of 25 L per production.

Making a biodiesel is more environment friendly than making a pyrolysis fuel. Using a pyrolysis fuel in an internal combustion engine still need future research because its low similarity characteristic compared to fossil fuel [6]. Using a pyrolysis fuel in an internal combustion engine making an engine running roughly, increasing carbon deposit, and decrease the engine performance [7].

Biodiesel in its pure form or as a mixture with diesel is used as fuel for diesel engines and has been laboratory proven to be used to reduce air pollutants. In Indonesia a mixture of biodiesel and diesel is sold by PT. Pertamina with the name biodiesel with a mixture of 30% biodiesel and 70% diesel (B30). To meet ESDM standards, it is necessary to make a biodiesel maker (biodiesel processor) that can be used by MSMEs in the Jember area of Indonesia, using local raw materials available in the surrounding area. Departing from this background it will be used Design for manufacturing and Assembly Method (DFMAM) to make a biodiesel processor. Designing a heat exchanger-based prototype in an engineering world need a heat transfer complex analysis [8] [9].

In general, this research uses 3 main methods, namely: 1. designing an intelligent multi-feed biodiesel processor with a capacity of 25 L per production with component savings; 2. Analyze existing processors and reduce overall production costs through redesign and elimination of redundant parts; 3. Increase the versatility and flexibility of using processors for various types of vegetable oil feedstocks; 4. Testing the parameters of the fuel produced.

## 2. Method

This study uses the principle of design optimization in the field of manufacturing assembly which will specifically be applied to the process of developing a biodiesel maker or known as a processor but equipped with control and automation so that it will become a smart device. Optimization is carried out by carrying out the following consideration process in order to obtain an optimal design.

1. The number of components and the wishes of the user will determine how much simplicity to achieve a conformity of the user's wishes will be the initial consideration. This step will determine overall how the tool will then be assembled.

Components or parts of the tool will be listed or inventoried in accordance with the order of assembly and will be assigned an identification number. In this initial step, the complexity factor will be calculated. The value of this complexity factor will be calculated using equation 1 [10].

$$\text{Complexity factor (Cf)} = \sqrt{\sum N_p \times \sum N_i} \quad (1)$$

Where  $n_p$  is the total number of the list of all parts and  $n_i$  is the total number of parts of the  $n$ th component.

2. The next step is to make a summary of the theoretical minimum required components and then identify practical requirements in a product manufacturing process. The material for each component

will be identified at the retail price in the market according to the location where the assembly process will be carried out. In this process, an analysis will be carried out whether it is possible to carry out a simplification process by redesigning or exchanging using different materials at lower prices. This step needs to be done carefully because it involves the durability and toughness of the tool. Of course, we do not want a tool that is cheap but quickly damaged. Theoretically, the minimum component that can be efficient is calculated using equation 2.

$$\frac{T_{\min}}{T_n} \times 100\% \quad (2)$$

Where T min is the minimum number of parts that are still allowed to be used and Tn is the total number of components in the old equipment that we will optimize.

3. The next step is to identify related to the properties or special characteristics of what the component will work on. In this case, because it will be used on components that can produce chemical erosion, care must be taken in removing components from iron. The main goal is safety in the handling of materials to be processed to the user.
4. The next step is the process of planning methods to combine these components. The process of merging or joining is a process that costs quite a lot. We can choose to simplify the process of combining the components with a less expensive method. Simply put, if the merging process does not require welding or bolting, why should it be forced to use that method.
5. The last step is to make a draft of the tool that has been optimized and then try to do the assembly and manufacturing process. In this step, the performance test process will also be carried out.
6. Because the product from this tool will be used in conventional diesel engines, it is necessary to test the quality of the processed product from this tool, namely how the characteristics of the biodiesel produced when compared with fuel standards used internationally and nationally. The quality standard for the type of test refers to the regulation of the ministry of trade for biodiesel fuel.

### 3. Results

#### 3.1. Optimization of the minimum required components

Researchers have identified conventional biodiesel production equipment. The components needed to assemble the old biodiesel processor have been made and presented in the list. The list of components also includes a description of the function of each component to facilitate classification in determining the priority of the component being vital or not.

After identifying, compiling a list and analyzing it, a minimum list of components that must remain in an automatically operated biodiesel processor is obtained. The smart control system for a biodiesel processor must have the following components:

**3.1.1. Microcontroller.** Microcontroller is a component similar to a small computer that is packaged in the form of an IC (Integrated Circuit) chip and is designed to perform certain tasks or operations. Basically, a Microcontroller IC consists of one or more Processor Cores (CPU), Memory (RAM and ROM) and programmable INPUT and OUTPUT devices.

The use of this microcontroller is increasingly popular because of its ability to reduce the size and cost of a product or design when compared to designs built using microprocessors with memory and separate input and output devices.

In this equipment we recommend using a microcontroller with Arduino uno type, with consideration of price and freedom to do coding.

**3.1.2. Sensor.** Sensors are devices used to detect changes in physical quantities such as pressure, force, electrical quantities, light, motion, humidity, temperature, speed and other environmental phenomena. After observing the change, the detected input will be converted into output that can be understood by

humans either through the sensor device itself or transmitted electronically through the network to be displayed or processed into useful information for its users.

In this biodiesel device the minimum sensors that must be used are the following sensors:

1. Pressure Sensor (Pressure Sensor)

Pressure Sensor or Pressure Sensor is a sensor that is used to measure the amount of pressure applied to a sensor. The pressure sensor will produce an analog output signal that is proportional to the amount of pressure applied. The pressure sensor on this tool is needed to ensure that during the process there is no overpressure in the tank.

2. Temperature Sensor (Temperature Sensor)

Temperature Sensors are sensors that are widely available in the form of digital and analog sensors. As the temperature increases, the electrical resistance of the thermistor will increase as well. Conversely, if the temperature decreases, the resistance will also decrease.

The temperature sensor used is a thermocouple (thermocouple). Thermocouple is one of the most frequently used types of temperature sensors, this is due to the wide operating temperature range of the Thermocouple, ranging from  $-200^{\circ}\text{C}$  to more than  $2000^{\circ}\text{C}$  with a relatively low price. A thermocouple is basically a Thermo-Electric temperature sensor consisting of two dissimilar metal junctions. With the difference in temperature at the two junctions, the circuit will produce a certain voltage whose value is proportional to the temperature of the heat source.

The advantage of the thermocouple is that it has a wide temperature range, is resistant to shock and vibration, and provides an immediate response to temperature changes. The thermocouple in this equipment will be useful as input data for the microcontroller for temperature regulation of biodiesel processing.

*3.1.3. Heater.* As many people already know, the heater has a function as a heater. This tool works by changing the normal temperature to heat. In this tool it is recommended to use an electric heater because this heater relies on electrical energy as a heating source. With an electrical energy source, it will be easier to regulate the temperature changes. Heater is an actuator to raise the temperature in the process of making biodiesel.

*3.1.4. Pneumatic solenoid valve.* A pneumatic solenoid valve is a valve that is driven by electrical energy through a solenoid, has a coil as its driver which functions to move a piston that can be driven by AC or DC currents, a pneumatic solenoid valve or a solenoid valve (valve) has an output hole, an input hole and an exhaust hole.

The solenoid valve is the most frequently used control element in fluid control. In this equipment the function of this component is to control so that the pressure in the tank is always at a safe limit, keep the temperature in the tank rising quickly, and drain methanol vapor from the process to be channeled to an external tube for further recycling.

*3.1.5. Fluid pump.* A fluid pump is a mechanical device that can flow substances from a low-pressure area to a high-pressure area. In principle, the pump converts the mechanical energy of the motor into the energy of the fluid flow. In this study, the pump is used to replace the electric motor of the mixer, fluid stirrer, belt stirrer, transmission mixer and forcing flow recirculation. Researchers chose to use a fluid pump because this tool can substitute a lot of equipment in the biodiesel manufacturing process.

### *3.2. Calculation of heat transfer and power for processor design efficiency*

#### *3.2.1. Demand Specification.*

The design process is carried out with consideration of details, the desired production scale, as well as special technical specifications of the resulting product. The processor that we design must be able to serve the manufacture of 20 liters of a mixture of raw material oil and catalyst in one production process. The temperature of the production fluid will be maintained in the range of 60 cel. Deg. to maintain the quality of the biodiesel produced. The flow rate in the channel is kept constant at 2 LPM to keep the

mixing process and the glycerol binding reaction going slowly. The solenoid valve will open when the temperature in the tank has reached 65 cel.deg and the pressure has increased to above 1 BAR.

### 3.2.2. Component Specification Needed.

- a. Fluid pump: Flow rate = 1 -10 LPM, Head = 9-22 m, Suction Head = max 9 m, Temp Max 100 cel.deg. , Thermal protector bearing, Power 286 Watt.
- b. Reactor: cylinder galvanized steel tank, well joint with electric weld, the lid of the tank must be prevented from a corrosion and can compromised with methoxide liquid fumes during the process
- c. Heater: The heater is placed in the bottom of the cylinder tank and direct contact with the fluid. Its 1500 W in 220 V AC electricity. It must easily raise the temperature from 0 to 100 cel deg. The heater is controlled by Arduino microcontroller and triggered by thermocouple sensor. The heater selecting process is based by below calculation.

### 3.2.3. Heater Design.

Bold The fluid density of the fluid is changed and calculated by equation 3,

$$\rho = \frac{m}{v} \quad (3)$$

where the volume is set to 00.027 cubic meters, and the mass is known 22.41 kg the density is expressed 830 kg/m<sup>3</sup>

The weight of the liquid to be heated is calculated by equation 4.

$$w = m \times g \quad (4)$$

With a known mass and gravity using 9.81 m/s then the weight of the liquid is known to be 219.84 N

From the laboratory checking data, it was found that the maximum heat capacity for plant oil to be processed is 2340 J/Kg K. We use 3 Kw for the heater power rating, and the heater must heat the oil from 30 cels. Deg. to 60 cels. Deg. So to heat the plant oil, 1573 kJ of heat is needed which is calculated using equation 5.

$$Q = m \times c \times \Delta T \quad (5)$$

Of course, this is a theoretical calculation without heat loss, taking into account the heat loss that may arise, it is assumed that the heat conversion efficiency is 80%, so the real heat required is 1234 kJ. With a heater used of 3 kW, the processing temperature required to heat the oil to its working temperature is calculated by equation 6, which results in a time of about 500 sec.

$$P = Q/\text{time} \quad (6)$$

We must know the Heat loss coefficient by surrounding nature (alpha) is 1 J/Sm-Cel deg, A surface or the surface area of the reactor is 0.5 m<sup>3</sup>, if we already know this value, then the heat loss can be calculated by equation 7 which then gets the heat loss of 16.3 J/s.

$$Q_{\text{loss}} = \alpha \times A_{\text{surface}} \times \Delta T \quad (7)$$

This means that we will experience a heat loss of 16 watts on the heater that we use. A value that can be ignored if we use a heater of 3 kW.

### 3.3. Calculation of Tank Vectors.

Tank Volume Design. With equation 8, the trick is to calculate the dimensions of the reactor tank if you want the tank to be able to load 25 L of liquid, and the height of the tank must be ergonomic, so that the maximum height of the tool is a maximum of 2/3 of the average height of Indonesian humans, which is 1.7 m and the tank must be located above the surface. Bottom to tank then determined to have a height of only 0.6 m. then the radius of the rod is obtained by 0.12 m.

$$V = \pi \times r^2 \times h \tag{8}$$

The total area of the tank that must be coated with anti-rust is calculated by equation 9, using a radius of 0.12 m, it is obtained that the area that must be coated is at least 0.55 m<sup>3</sup>

$$\Sigma A_{surface} = 2 \times \pi \times r^2 + 2 \times \pi \times r \times h \tag{9}$$

### 3.4. Processor Fabrication

#### 3.4.1. Assembly Method.

The assembly steps are as follows;

- a. The inner cylinder is made with a diameter of 240 mm, a height of 350 mm.
- b. Cylinder formation by rolling the plate to form an outer diameter of 360 mm, height 500 mm.
- c. Followed by cylinder welding which produces a single cylinder with a diameter of 360 mm and an overall height of 600 mm.
- d. Welding of legs 600 mm long to 2/3 x 180m – 600 mm cylinders.
- e. Welding cover plate at the top of the tank complete with inlet and solenoid valve channels.
- f. Installation of electric pumps and pipelines can use PVC pipes.
- g. Anti-rust painting and/or coating.

#### 3.4.2. Prototype Specifications.

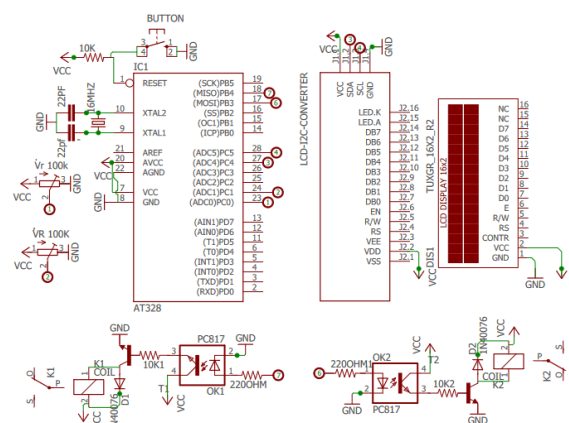
According to our calculation, its will gave a good result if this prototype is can accomplish below specification

- a. Size 1.53 mx 0.6 m
- b. Operating temperature 20 - 90 cels. deg
- c. Production capacity 20 L/production
- d. Production time 3 hours/production
- e. Total power 2000 watt

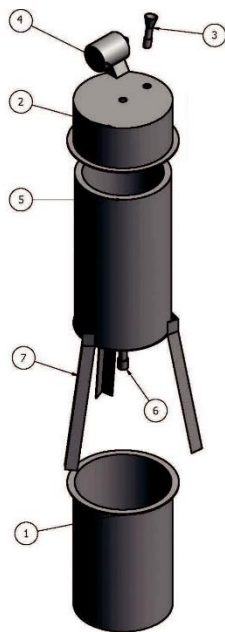
In this prototype, researcher try to merge the processor tank and the cleanser tank, the aim of this procedure is to simplify the number of the component then also a manufacturing cost. In first thought, we carefully concern about the quality of the biodiesel product by this simplification methods. The worry is for its draining phase. As a standard, the cleaning method for biodiesel is by mix it with an aqua distillate liquid in 30 cel.deg. If the drainage in processor not optimal, there is still residue in the bottom of the tank. So, make a bottom in a cone shape is a must for a biodiesel processor.

Using this shape design, researchers managed to prevent the accumulation of residual liquid at the bottom of the tank. Now biodiesel is ready for the next step, which is quality testing in the laboratory.

Below is the final result of our biodiesel processor.



**Figure 1.** Microcontroller diagram



Main Reactor Part List :

1. Reaction Tank
2. Reaction Tank Top
3. Inlet Pipe
4. Solenoid Valve
5. Main Tank
6. Drainpipe
7. Stand

**Figure 2.** Design of Main Reactor**Figure 3.** Redesign Prototype Biodiesel Processor By DFMAM

### 3.5. Laboratory Test Results

The quality of biodiesel oil processed using this prototype is then tested in the laboratory. Then the test parameters are compared with the standards of the Ministry of Energy and Mineral Resources. We tested with 2 type of common vegetable oil and also, it's a main product for researcher district. We also tested it with two types of catalyst to get a data which catalyst can produced an optimal result. The results are presented in the following table.



**Table 1.** Comparison of Properties of Biodiesel Production with Quality Standards of the Ministry of Energy and Mineral Resources (ESDM).

Property	Biodiesel Properties Test Value KOH	Biodiesel Properties Test Value NaOH	Biodiesel Properties Reference ESDM*
	Density 15 °C (Kg/m <sup>3</sup> )	874	877
Viscosity 40 °C (mm <sup>2</sup> /S)	4.3	4.7	2 - 5
Acid value (mg KOH or NaOH/g)	0.14	0.15	0
Raw Cetane number	56	58	48
Cloud point (°C)	8	7	0 - 18
Pour point	4	5	0 - 18
Flashpoint (°C)	171	178	Min. 52
Distillation temperature (°C)	345	350	Max.370

\* Decree of the Ministry of Energy and Mineral Resources of the Republic of Indonesia No. 0234.K/10/DJM.S/2019 [44]

The ideal condition (optimum) for biodiesel generation from oil is the truth that the ideal proportion of methanol to oil is at a blend proportion of 6:1, response temperature is 60 cel deg, response time is 60 minutes, the catalyst utilized is 1% KOH and the ideal condition for biodiesel generation is 88%; whereas the abdicate of biodiesel generation from a blend of palm oil and coconut oil beneath ideal conditions utilizing KOH and NaOH catalysts were 98.12 and 97.3%, individually. To deliver biodiesel from coconut oil employing a catalyst concentration of 1% KOH the most extreme productivity is 96%.

From table it is known that the production of biodiesel oil used in this study in general has met the quality standards of the Ministry of Energy and Mineral Resources, except for the acid value. The presence of acid values in biodiesel production is a matter of further research to make the value zero. The presence of acid values will be the cause of the acceleration of the corrosion rate in diesel engine components.

It is interesting that the biodiesel tested has a higher cetane number, namely max. 58 for production using NaOH, 10 points higher than the minimum standard reference cetane number, which is 48.

However, there are values that need to be considered to be derived through advanced refining methods, namely density and viscosity properties. If we can reduce the density and viscosity values, this biodiesel material will be safer if used in common rail type diesel engines (modern diesel engines).

#### 4. Conclusions

This research come about within the improvement of a brilliantly small-scale biodiesel processor with a capacity of 25 L per production. The processor consolidates all the crude fabric necessities for biodiesel generation subsequently, both soluble catalyzed and corrosive catalyzed transesterification can be carried out with the processor. In expansion, processor get together operations are rearranged to decrease uncertainty and excess. In this manner, the processor is by and large cost-effective in terms of fabric prerequisites, parts generation, labor and overhead. The DFMA standards to minimize portion prerequisites without compromising quality. This diminishes the in general gathering and generation costs. Processor component assembly via the DFMA principle is simplified to reduce component complexity and redundancy. The biodiesel produced by this method has been tested by a lab and recorded a density value of 15 cel.deg. 874 - 877 kg/m<sup>3</sup>, viscosity at 40 cel.deg 4.3 – 4.7 mm<sup>2</sup>/s, Acid value 0.14 0.15 mg KOH/g, Cetane 56 – 58, Cloud Point 7 – 8 cel.deg., pour point 4 – 5, Flashpoint 171 – 178 cel.deg and distillation point 345 – 350 cel.deg.

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