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Oil stove modification to get optimum performance on jatropha oil usage

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Abstract. This research is based on the idea to combine efforts on promoting jatropha oil as one of renewable and green energy resources, and efforts to help "house hold oil stove industries" continuing their production even-though more people change kerosene to LPG as their main fuel for cooking. Regarding the idea, this research aims to modify oil stove which has been sold in the market, which was designed for kerosene fuel, to be able to use with jatropha oil and other oil as its fuel in the good performance. Two approach methods based on the physical oil characteristic has been done. They were modification of wick material, and "oil pre-heating system" implementation. The result shows that no wick material having good performance when implemented for jatropha oil usage due to its high viscosity. Original wick has best performance compare to modified wicks. By using original wick, implementation of oil pre heating system has been successfully increasing fuel rate combustion from 0.43 kg/h to 0.63 kg/h, and increasing the total system efficiency from 9.54% to 16.1%.

1. Introduction

Efforts to reach energy mix target which is implemented in many kinds of program, sometimes didn't recognize negative impacts following those program. Promotion LPG to substitute kerosene as main fuel for cooking in house hold and small scale industries, has been successfully decreasing kerosene demand, but in the other side causing negative impact to the stove industries since their market down significantly. In the other hand, substitution fossil energy with renewable and green energy resources also the main target of energy mix program. Therefore, combining efforts on promoting jatropha oil as one of renewable and green energy resources, and efforts to help "house hold oil stove industries" continuing their production activities, should be a great solution. This research aims to modify oil stove which has been sold in the market, which was designed for kerosene fuel, to be able to use with jatropha oil and other pure plant oil as its fuel in the good performance. For the first step, research conducted for jatropha oil usage since other pure plant oil has not popular yet. Therefore, discussion in this paper will be focus on stove modification based on the jatropha oil usage.

2. Research Method

Two approach methods based on the physical oil characteristics has been done. There were wick material modification, and implementation of oil pre heating system. Besides of modification on structure and system, modification on stove operation also should be implemented due to the differences of fuel characteristic. The methods described as follows.

1) Wick material modification: Wick is the main component of the stove, due to its function as fuel distributor which transporting fuel (based on capillarity process) from the fuel tank to the combustion area/surface. The capillarity will be influence wick's capability to transport fuel, or fuel rate consumption. In this research, 3 kind of wick's material has been tested. There are cotton, polyester, and asbestos. Modification also done in order to improve polyester wick performance by inserting a copper wire inside the polyester wick.
2) Structure modification: Modification of stove structure should be done to implement "oil pre-heating system" on the stove. Jatropha oil has higher viscosity compare to kerosene. Higher viscosity will be causing lower capacity of the wick's capillarity and more difficult to combusted. Pre-heating system was needed to decreasing jatropha oil viscosity before its deliver to the combustion zone through the wick. Beside implementation of pre heating system, air inlet for combustion process also must be modified, since the different fuel will be need different amount of primary air for good or perfect combustion.
3) Since the stove has been modified, the operation will be different than before modified (original design). Therefore, a modification of the stove usages should be applied to get optimum stove performance.

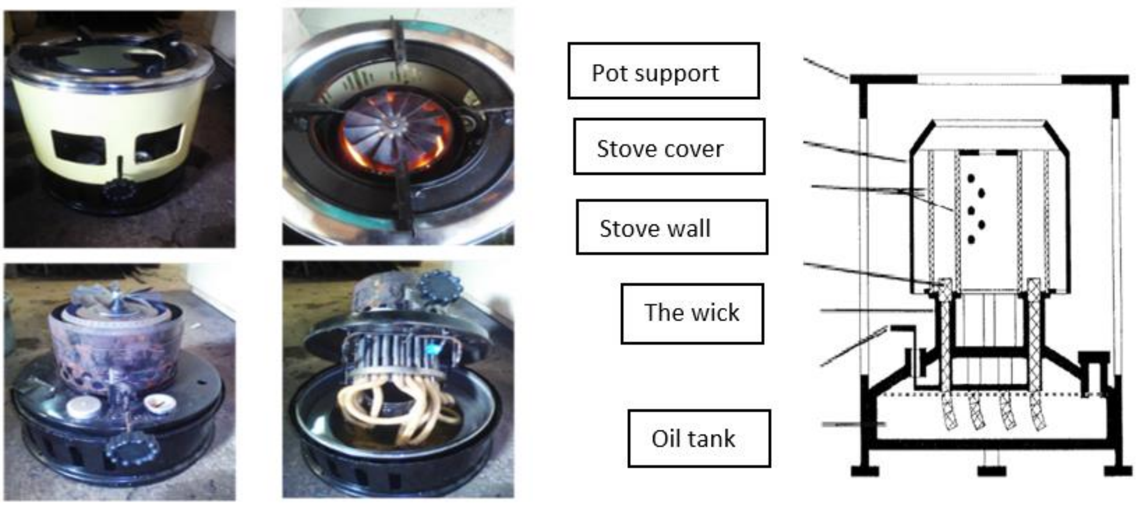

Figure 1. Stove components.

Figure 1 shows the original stove and its components, which will be modified in this research. The detail structure inside the stove can be seen in the right picture. The original wick material is polyester. There are 3 (three) layer stove wall surrounding combustion zone. Air inlet holes in the stove wall designed to warranty that amount of air supply (for combustion process) is enough for perfect combustion. Therefore, air inlet holes will be modified based on the new fuel (jatropha). Research stages described in the Figure 2.

Parameters for wick's capillarity are rate of oil level reduction in the measurement glass (cm/minute), and time (duration) of wick's flaming (minutes). Faster oil level reduction means more oil flowing through the wick, meaning the wick having better capillarity. Shorter duration of wick's flaming means the wick easier to burnt out and must be replace in the shorter period. Also, produce more ash that could be influencing combustion process. So, the wick which has longest flaming duration is the best.

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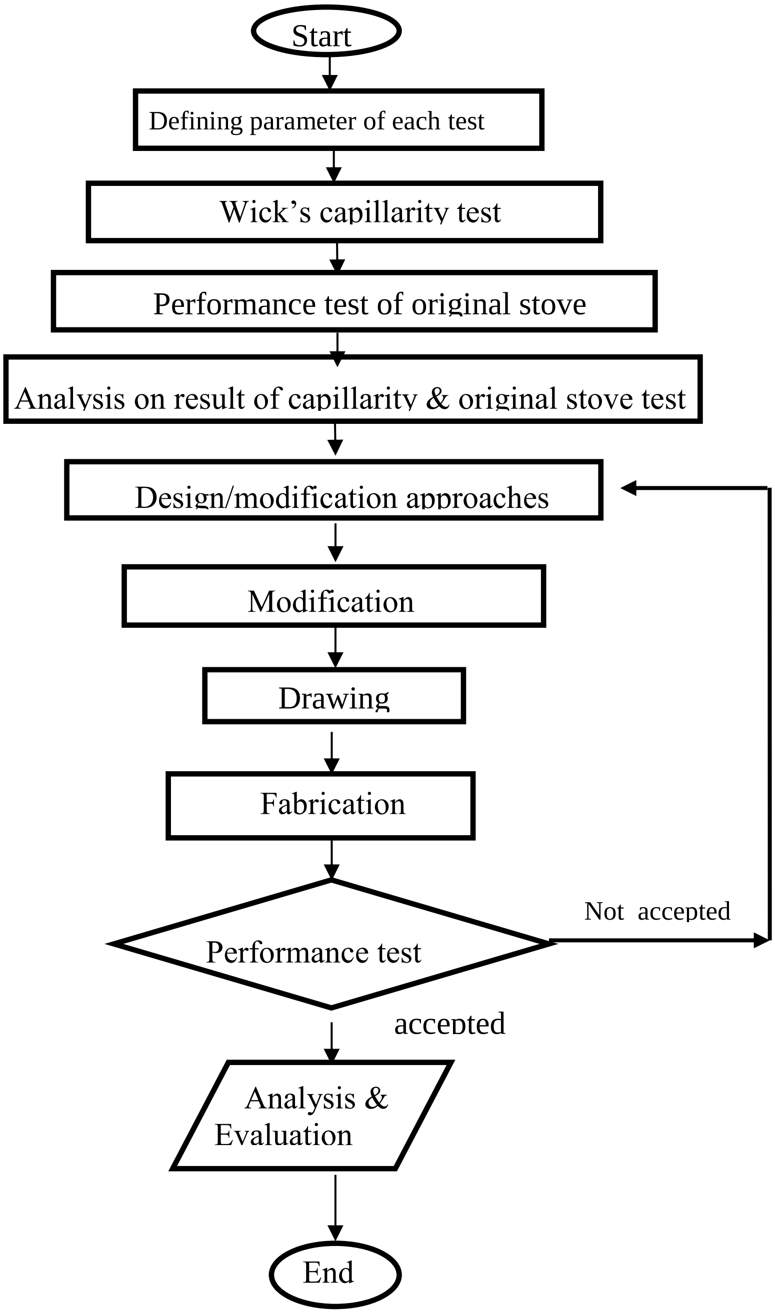


Figure 2. Research stages

Stove performance was conducted by using *water boiling test* method. Parameters which has been use are fuel (consumption) rate (kg/hour), time for ignition (minutes), time for turn off fire (minutes), flame's color (range: blue – yellow- red), smoke (range: none – plenty - huge) , stove efficiency (%) and total system efficiency (%) . Figure 3 describes the measurement points on the stove when the performance test conducted.

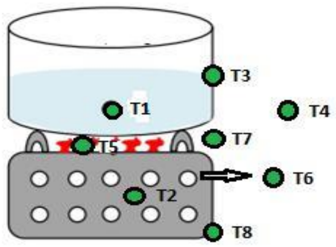


Figure 3. Measurement points in the stove performance test.

3. Result and Discussion

3.1. Wick modification

First, 3 kind of wick with different material (polyester, cotton, and asbestos) has been tested based on the parameter as mentioned before. Result of the first test showing that the best wick's material is polyester (Table 1). Polyester is the original wick which has been use in the original stove. In fact, result of original stove performance test by using jatropha oil shows that the original wick has very poor performance. The poor performance was indicate by very low rate of oil level reduction (Table 1), meaning the capillarity capacity was poor, since jatropha oil has higher viscosity compare to kerosene. In order to increasing polyester wick's performance, the wick was modified by inserting copper wire inside the polyester wick. The idea is based on the capability of metal (copper) to help transferring heat from the combustion zone to the oil inside the wick. But those polyester wick modification has poor performance. Result of all wick's performance test can be seen in the Table 1 below.

Table 1. Result of wick's performance test

Wick's material	Duration of flaming (minutes)	Rate of oil level reduction (cm/minute)
Cotton	25	4.2
Polyester	30	5.3
Asbestos	8	1.2
Polyester + 20% copper	15	2.5
Polyester +30% copper	12	2.1
Polyester +50% copper	10	1.6
polyester+80% copper	10	2.0

Based on the wick' performance test, we can conclude that we can't use jatropha oil as fuel in the original stove by modification or change the wick material. Jatropha oil available to use in the stove if jatropha oil has same or almost same viscosity like kerosene. Therefore, the stove system and stove structure should be modified by applying pre-heating oil system in order to decrease jatropha's viscosity.

3.2. Performance of original stove using jatropha oil as fuel

Performance of the original stove by using jatropha oil as its fuel should be done to get real data and also to understand how the system work properly. Result of the performance test will be used as basic approach on designing modification. The data performance also will be use as success parameter of the modification. Table 2 shows the result of 3 performance test of the original stove using jatropha oil as its fuel. The data shows that the stove has poor performance, indicate by low fuel rate, low efficiency (highest 10.5%), flame color (red), and produce smoke.

Fuel rate was very low because jatropha oil has higher viscosity, causing difficulty of oil flow through the wick to combustion zone. Flame color was red, indicate poor combustion process, which also causing smoke, and finally produce poor efficiency. Based on those data, pre-heating oil should be implemented to reduce jatropha oil viscosity, so the oil can be easily flowing through the wick to the combustion zone. To improve combustion process, which will (finally) produce higher efficiency, the air inlet (for combustion process) should be designed bigger than the original one, to ensure combustion air supply is enough to support perfect combustion process, produce blue flame, no smoke, and high stove's efficiency.

Table 2. Performance test result of original stove using jatropha oil as its fuel

No	Parameter	Test result		
		1	2	3
1	Fuel rate (liter/hour)	0.48	0.34	0.48
2	Total fuel consumption (kg)	0.35	0.25	0.35
3	Total energy input (kcal)	3330.6	2379	3330.6
4	Efficiency of total system (%)	9.08	8.99	10.56
5	Heat capacity (kJ/minutes)	190.7	192.4	189.4
6	Duration of stove operation (minutes)	5.16	4.16	5.16
7	Turn off fire/stove (minutes)	2.67	3.16	2.75
8	Color of flame	red	red	red
9	Smoke identification	Produce smoke	Produce smoke	Produce smoke

3.3. Stove modification

Based on the data shows in Table 2, two kind of modification should be implemented. The first modification aim to decreasing jatropha oil viscosity, done by implementing 'pre-heating oil system'. While second modification aim to improving combustion process, done by modifying air inlet system.

'Pre-heating oil system' designed by added a kind of ditch (the place to put ethanol and burnt it to increase jatropha oil temperature) surrounding stove body (Figure 4). Heat energy produce by ethanol will increasing jatropha oil temperature up to 40 ^{o}C, so the oil viscosity will be decrease, and finally make the oil easier to flow through the wick to the combustion zone. Implementation of pre-heating oil system in the stove can be seen in the Figure 4.

Figure 4. Applying ditch surround (outside) the stove wall.

Combustion process improvement has been done by addition more air inlet holes around the stove wall, to ensure air supply was enough for perfect combustion process. The air inlet modification based on the AFR (air fuel ratio) calculation for jatropha oil combustion. Based on the calculation, AFR for jatropha oil combustion is 2.08 m3/s. Original stove has air inlet capacity only 0.51 m3/s, with total number of holes is 969 and total area 2.99 m2 (Figure 5), in the actual air flow velocity. To fulfil the air combustion demand, based on AFR (2.08 m3/s), in the actual air flow velocity, area needed (as total holes) is 15.81 m2. According to the number, air inlet holes has been designed as 950 small holes (original holes) and 12 bigger holes at the inner (first layer) wall , and 50 big holes at second layer wall. The result of air inlet modification shows in Figure 6.

Figure 5. Air inlet at the stove wall, before modification

Figure 6. Air inlet at the stove wall, after modification.

3.4. Performance test of the modified stove

By using jatropha oil as fuel, performance of the modified stove is better than the original stove, even though still poor compare to the performance of the stove by using kerosene as original fuel designed for the stove. The performance test result of both stove provided in the Table 3. Based on the performance data showed in Table 3, pre-heating system has been successfully increasing fuel rate from 0.43 kg/hour to 0.63 kg/hour, and reducing time needed for ignition from 4.8 minute to 3.1 minute.

Table 3. Stove performance, before and after modified

No.	Parameter	Performance result	
		Original design	After modified
1	Fuel rate (kg/hour)	0.43	0.63
2	Total fuel consumption (kg)	0.32	0.48
3	Total energy consumption (kcal)	3013.40	3172
4	Efficiency of the sistem (%)	9.54	16.17
5	Heat stove capacity (kJ/minute)	190.83	202.70
6	Time for ignition (minute)	4.83	3.15
7	Time of flame turn off (minute)	2.86	2.13
8	Flame’s color	red	blue
9	Smoke indication	smoke	none

In final result, the heat capacity of the stove also increasing due to the fuel rate increasing, indicate by the combustion temperature as shown in the Figure 9 and 10. Modification of air inlet also successfully improving combustion process, indicated by flame color which has been change from red to blue (Figure 11), and decreasing smoke. The better combustion process will be produce higher heat energy, higher combustion temperature, and finally increasing both of stove heat capacity and stove efficiency.

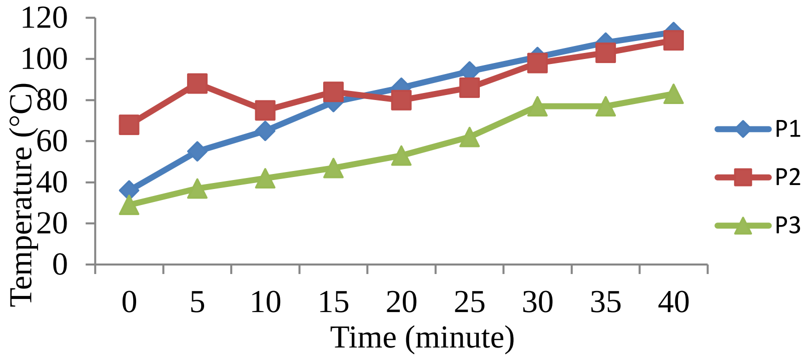


Figure 7. Fuel temperature, before stove modification

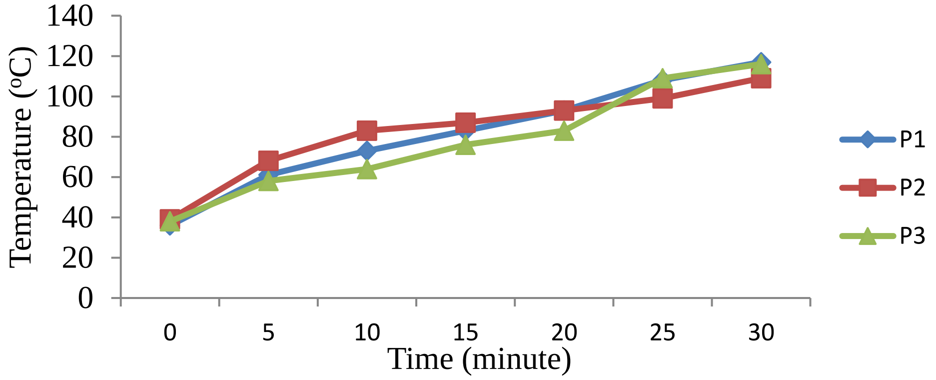


Figure 8. Fuel temperature, after stove modification

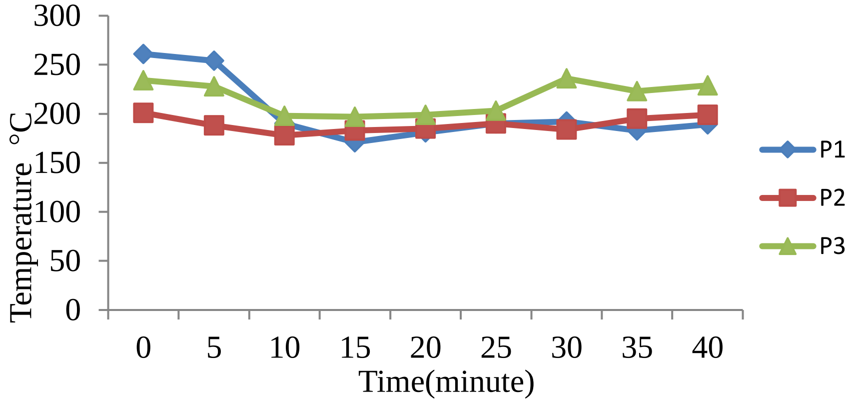


Figure 9. Flame temperature, before stove modification

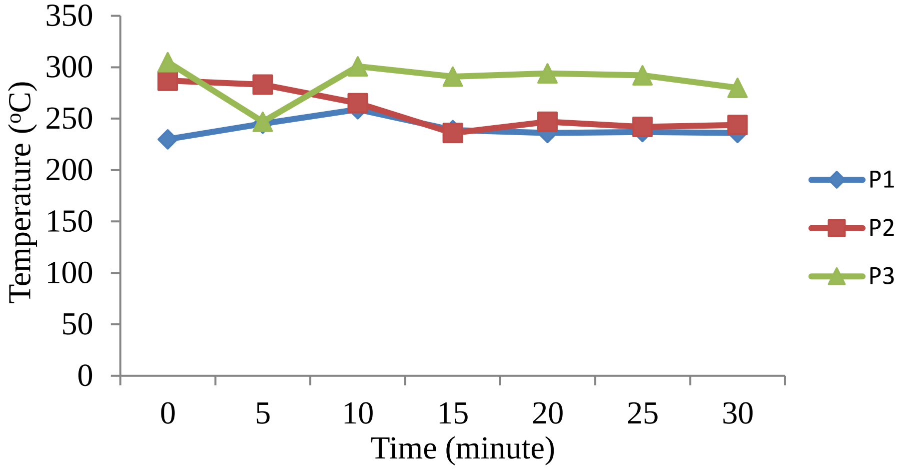
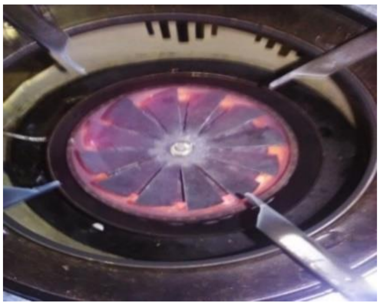


Figure 10. Flame temperature, after stove modification



(a)

(b)

Figure 11. Flame color (a) before modification, and (b) after modification

4. Conclusion

Based on the data and observation, we can conclude as follows:

1) Common oil stove which has been sold in the market, which was designed for kerosene, is not available for jatropha oil usage due to its poor performance. To improve stove performance with jatropha as its fuel, modification should be applied to the stove, both of stove structure and stove operation. The modification should be based on the jatropha oil characteristic (oil viscosity and air supply for combustion process)
2) Modification of wick material was not successful increasing stove performance. Observation of wick capillarity and its flaming time shows that the original wick (polyester) is the best wick, even for jatropha oil usages.
3) Implementation of "pre-heating oil system" has been successful decreasing jatropha oil viscosity and made the oil easier flowing through the wick to the combustion zone, indicated by increasing of fuel combustion rate, from 0.43 kg/hour to 0.63 kg/hour. The system was designed as addition a ditch (for ethanol which was burning in order to increase jatropha oil temperature up to 40 °C before flowing through the wick), surround outside of stove wall.
4) Modification of number and size of air inlet holes in order to get amount of air supply based on the ARF calculation, has been successful improving combustion quality, indicate by the blue color of flame and no smoke produce on combustion process.

5) Overall result of all modification has been successful increasing stove performance for jatropha oil usages. The successful result was indicate by increasing of fuel combustion rate (from 0.43 kg/hour to 0.63 kg/hour), shorter ignition time (from 4.8 minute to 3.15 minute), improving combustion quality to produce blue flame, no smoke, and finally, increasing total system efficiency almost 70% (from 9.54% to 16.1%).

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