Development and performance of the common Keren Stove
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C Pemberton-Pigott

1. Overview:

1.1. The Keren stove is the most common single-pot cooking device in Central Java. It is widely use in all areas save those which are inaccessible to traders. It is produced in three common sizes which are approximately suited to difference scales of cooking. Although one might assume that the size would be dependent on the family's needs for daily cooking, this is not the case. Numerous households have a large one for cooking during periodic celebrations and commemorations.

1.2. The most obvious features of the Keren stove are the large opening for fuel, the holes patterned around the sides and the top lip with three quite prominent pointed pot rests.

1.3. They are available in sizes that can be grouped: small, middle and large.

1.4. The durability is low. In commercial use as a stove for restaurant cooking they last only a few weeks – from 2 to 10. The reason is the material from which they are made is selected for roof tile making, not stove making, and has poor thermal shock resistance.

2. Performance

2.1. The baseline performance in terms of heat transfer efficiency has no clear and consistent value because the methods were so different. Using the SeTAR TET 1.55 which is a high stove, high power test, the efficiency is about 22-25%. We can say it is in the low 20's and also that it is dependent on firepower. Earlier tests indicated the efficiency was about 16% however that was not an identical procedure.

2.2. A few tests were conducted in October and November 2012 to see what the combustion efficiency was like and the heat transfer efficiency. The results showed clearly that the heat transfer efficiency dropped with the fire power level. The cause of this is because of a high excess air condition that was worsened each time the demand for air was reduced. As the fuel burn rate declines, the need for air reduces. If the air supply is copious, it chills the fire increasing the emission of CO and

PM. There was quite a bit of flaming through the top of the fuel entrance which indicates that the entrance was an easier route out than the pot-stove gap.

2.3. Because of the large entrance hole there is far too much air getting into the stove. Because the pot rests are so tall, there is plenty of space for excess air to enter the combustion chamber and exit past the pot without any benefit to the cooking or the fire. It just cools everything more and more as the power goes down because the air in unneeded. With a shallow depth in the 'beam' over the fuel entrance, there was also little pressure under the pot to drive the gases up instead of out the strove front.

2.4. It was also noticed that the Keren stove produces quite a bit of charcoal when the fire is burning for a long time (which is a common occurrence). The direct cause of this char production is poor air supply to the fuel from below. This is often called 'under air'. The name is appropriate because what is needed is for air to be supplied under the fuel on a continuous basis so the char, if it is formed at all, will be burned along with the rest of the fuel. Once it is sitting on the bottom of the stove it extinguishes and cools. It cannot be burned in subsequent fires because there is no grate.

3. Modifications tested

3.1. Excess air control

3.1.1. Three changes were introduced to limit the excess air. The first was to reduce the size of the fuel entrance hole. While that can be a problem if the stove is used to burn agricultural waste that has to be pushed in in great quantities, it is not the normal case and in fact the hole can be reduced in area by more than half.

3.1.2. The second thing was the reduction in the height of the pot rests. The plan was to limit the air flow through the combustion chamber to only that which was required to keep the fire going. Because of the reduction in total air flow this modification provided, the heat transfer efficiency rose above the baseline to the low 30's (32-34%).

3.1.3. The third change was to close most of the air holes around the body.

3.1.4. Because there many iterations tried, we cannot say what the improvement level for each modification was. Overall the heat transfer efficiency improvement is in the 40-50% range, that is, about 1.5 times is much heat is being sent to the pot for each MJ of heat available in the original fuel.

3.1.5. With this stove, there are two gains: the production of less charcoal by using a grate and the fact that such charcoal is not being thrown away means it uses less total fuel and what fuel is use, is burned completely. An important point is that we did not assess separately what savings each contributing element created – the closing of air holes, installing a tilted grate, lowering the fuel door lintel, or reducing the height of the pot rests. Only the package was evaluated.

3.2. Small air holes closed

3.2.1. There are several small holes for air pieced through the clay before it is fired. By choosing to open select ones where we felt the air was needed most we changed some portions of the airflow. Generally the upper and side holes were always closed. The ones that provided benefit are at the back, and to have benefit that air has to be drafted under the (elevated) grate. The plan at the moment is to increase the air quantity entering back the area by enlarging the holes.

3.3. Adding a grate

3.3.1. In order to try to burn most of the charcoal produced by the fire, a grate was fashioned from round mild steel bars and cut into two D-shaped sections. Cutting the grate into two pieces allows a full sized grate to be placed inside the stove through the fuel hole, which is quite a bit smaller than the internal diameter of the body.

3.3.2. They were propped on supports of different heights to investigate how the airflow might be improved. The grate was elevated at various angles and heights in order to capture or direct air under it, though it or over the ends. Some nine different layouts of the grate were tested and thermal performance determined using a pot swapping test. This is a test method that has the pot changed each time the water inside reaches 70 C. The purpose is to determine the heat transfer efficiency over a range of combustion conditions including at high and low power.

3.3.3. The photos at the right show the effect on char production in an SAE Stove and an SAE Stove (next page) with the same grate fitted (below). It also has a flat-bottomed combustion chamber and received the same benefit when the grate was added.

3.3.4. The test results showed that one particular combination of dimensions and grate tilt provided nearly no char generation (meaning the fuel burned completely) and also a relative low excess air level in the combustion chamber. The grate was elevated at the back above the height of three small air entry points, low at the fuel entrance and only worked well when the bars were round, not flat. We had a cast iron grate made with the same general specification as the steel bar version, however the top of the bars were flat. This proved to quench the fire in small pieces of charcoal, and the round bar grate did not have that problem.

3.3.5. The best position for the grate, combined with the lowering of the top of the fuel entrance and closing of most small air holes gave a heat transfer efficiency of about 33%, well over the baseline value of the low 20's for the unmodified stove. There was a significant reduction in the amount of charcoal produced (because it burned).

Cast iron grate in two halves

The slots may not be wide enough or the top not round enough. It did not perform as well as the grate made from round steel bars – it produced much more charcoal. The best shape for the top of the bars may be cylindrical, not flat.

3.3.6. A prototype was made from clay with a taller stove body and a much wider lintel over the fuel entrance. This makes the stove slightly taller with all the additional height in the section above the fuel entrance. The modification increases the force with which the hot gases are pushed through the stove-pot gap and also it capture some of the flames and smoke that would otherwise emerge from the fuel entrance. This reduces the emission of smoke into the face of the cook – a reasonable and welcome change.

3.4. Use of a lighting cone

3.4.1. An additional device was tested, a lighting cone that greatly speeds the ignition of damp fuel creating a clean(er) burn faster than usual is the lighting cone. This simple device can be used with most stoves to reduce the time needed to ignite fuel, especially when it is damps.

4. **Summary of findings**

4.1. The combination of modifications provides for about a 1.5 times gain in heat transfer efficiency which translates into an energy consumption reduction of 33%. Even better, because the charcoal that used to be left over was thrown away, that charcoal is no longer produced which gives a fuel saving.

4.2. This distinction between energy consumption and fuel consumption is important. Basically it means more total heat is being transferred after being generated from a smaller mass of fuel.

4.3. User acceptance is expected to be high both for the grate and the lighting cone because the benefits are visible to the naked eye. In particular, the speeding of the ignition process with far less smoke in the kitchen is likely to be appreciated immediately.

4.4. It may be possible to generate a table of performance like this, however it will require quite a number of tests and the usefulness of *every* iteration is not really high.

	Baseline Keren	Reduced door height	Air holes closed	Grate added	Lighting Cone used
Heat transfer efficiency					
Fuel efficiency					
PM 2.5/MJ in the pot					
CO/MJ in the pot					

5. Summary of findings

5.1. The conclusion of the testing of prototypes is that the hole for air at the back centre of the stove, almost at floor level, the entrance for air that is directed under the grate, should be quite a bit larger than the 2 x 13mm holes presently provided. It is suggested that 15 x 40 mm be tried and partially blocked if it gives too much air.

5.2. The grate should be made using round rod-shaped grate bars so that the charcoal does not make significant contact with the grate, thus preventing most cooling. The entrance hole for fuel should be greatly reduced in size, perhaps 50 to 70mm high and 140mm wide. The gap between the pot and the upper stove body should be reduced to 8mm.

5.3. The cost of making a grate will be approximately $2 and there is no change in the price of the modified Keren stove body. The grate should be made from cast iron and sold separately. They can be added to any stove that has a flat-bottomed combustion chamber with a similar effect.

5.4. It might be a good candidate for a subsidy programme as there are very few producers and the number traded can easily be monitored. It will last much longer than the stove body, meaning the subsidy will have an effect log after a subsidised stove will have expired.

END

C Pemberton-Pigott
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