Final Design Report

Low cost portable Kiln for rural small scale pottery

Ayush Pandey, Rahul Bishnoi, Sairaj Khope

May - June 2019
Contents

Problem Statement 2

Primary Intended Beneficiaries 3

Field Research Briefing 4
  ● Observations
  ● Problems Identified
  ● Problem Selected

Design Iterations
  ● Prototype - I (Closed Underground Furnace)
  ● Consultation with Experts
  ● Prototype - II
  ● User Feedback
  ● Critical Analysis

Final Design Description

Bill of Materials

Testing Plan

Future Aspects & Recommendations

References
Problem Statement

To design a low-cost portable kiln for rural small-scale pottery with a smoke extractor to improve production output and improve the safety of the user.

Primary Intended Beneficiaries

Our current problem area lies in the villages of Kanalva and Ambala where the local communities work on traditional home pottery with their specialities includes applying Geru (Red soil solution with high Ferric Oxide content) and Lac (Excreta of
Laccifer Lacca or Lac beetle which is sourced from the branches of the Pohim Tree in the months of April/May). The user demographic is adults (Men & Women) in the age group of 25-70 (approx.). The design is supposed to help improve their production output and improve their workplace safety by drawing out the smoke and providing adequate insulation from the heat of the *Bhatti.
Field Research Briefing

Our main field visit was in the village of Kanalva which is about 15 Kms from the town of Chhota Udepur towards Madhya Pradesh border. Our main objective of the visit was to observe the potters of the village and study their practices, techniques and interactions with the environment and each other. Before going to Kanalva we did some preliminary research with the SRISTI team who had interacted with this community previously so that we could know what questions to ask them to better understand their problems.

Mind Map
Preliminary Problem Analysis

Observations

Our first objective was to understand the process flow in making pots and applying Lac. The process flow is as follows:

**Step 1: Clay Mixing Process**

Back soil is procured from nearby agricultural fields and brought by women in batches of 25-30 Kg each. Red soil is collected from the nearby reservoir canal. While mixing, Black soil and Red soil are mixed in adequate proportions before reaching a final mixture by intuition method. There were two different methods that were noticed amongst all 10 families living in the village; 1 method involved mixing red and black soil in equal proportions (Biased heuristics) and then adding Red and/or Black soil as per requirement until the mixture was good enough by their intuition. The other method involved mixing Red and Black soil such that there was higher black soil in the mixture and add Red soil bit by bit as per the intuitional required consistency. Since readings were taken in only one village due to lack of time we
couldn’t establish how many different such methods existed and what were the outcomes of these methods.

**Step 2: Clay Moulding Process**

Once the mixture is made, the clay is made into flat cakes and placed onto moulds made as per the required size and curvature of the vessels required. This is then left for drying in the sun for a day. After taking it has hardened enough, it is then taken for the handle applying process wherein they apply the handle by adding small mould of clay on opposite sides of the circumference and moulding it around the edges as required. It is then dried again for a few hours.

**Step 3: Geru Application and Polishing**

Once the drying is finished Geru is applied and then a locally sourced stone is used for polishing the Geru applied vessel. It is then sun dried for 2-3 hours.

**Step 4: Baking/Heating process in the Kiln**

A makeshift kiln is made with cow dung as the main fuel and dried grass is added as a fire accelerant. This kiln has vessels added and kept on top of the burning cow dung. This is later closed with broken and/or cracked vessels that had come out of a similar setup before and is used for the purpose of providing some level of insulation to the kiln. This heating process goes on for 50-55 min after which the final process takes place.

**Step 5: Lac Making & Application**

Lac is sourced by the potters by buying from the market at a price of Rs. 200/Kg. Lac is sourced only in the month of May so these potters have to buy and store lac for months. Lac sticks which are used for coating is made by boiling Lac and repeatedly cleaning it off with cold water until the Red dye present in it is removed. Once all the red dye is removed the lac residue/paste deposited at the bottom of the cold water is taken out by hand and turned into a stick and kept for drying.

Once the vessels are removed from the Kiln by the use of sticks since they lack gloves/tongs to work with, it is kept on a stand where they start applying lac coating on it by depositing layers of Lac from the lac stick on the vessel. This generates a lot of vapors coming from the Lac stick and it gets very hot very fast which causes burns to the hands and face.
Problems Identified

1. The clay mixture was made by hand and varied between various families. This variation in clay mixture resulted in different production output efficiencies and quality of pots which was hard to determine.

2. The *Bhatthi* (Kiln) used by the potters was made with broken pots made in the same Kiln and wasn’t giving very good amount of heat insulation and released too much smoke into the surroundings along with incomplete combustion making it an unsafe working area. It also made the production output very inefficient with only 35% of the vessels coming out unbroken through the kiln.

3. Lac making process involved direct contact with boiling hot lac from water which is unsafe.
4. Lac application has heat from the hot vessels conducting directly through the lac stick to the hand which causes burns in the hand and releases smoke in the face of the potters.
Selected Problem Area

To focus on solving the problem with the makeshift Kiln by trying to fix the problem of production output inefficiency and adequate thermal reflectiveness. We thought this was the most important problem that we needed to solve because we saw this problem in a long term perspective, where fixing their production problem along with solving their other problems on the side such as the Lac application process could help improve their financial condition over time and help them pursue other skills such as artisanry which might help them attract more buyers.
Design Iterations

Prototype - I (Closed Underground Furnace)
Prototype Briefing:

The whole system can be divided into two primary chambers.

1. Air flow chamber.
2. The main furnace chamber.

The furnace was basically given an underground structure. The main furnace chamber was 3 feet in depth. The whole chamber can be divided into following sections:

1. The fuel chamber resting on the base of the furnace.
2. Inlet pipe at a height of 2.5 feet from the base for allowing the airflow in the chamber.
3. Exhaustion pipe installed at the same height from the base for smoke to exhaust.
4. The mesh on which the earthen pots and plates were to be kept.
5. The insulation unit.

Observation:
1. There was problem faced in putting the fuel and igniting it as no section was provided in the structure. Also it was necessary to add kerosene to ignite it which was adding up in the process. This happened because the depth of the fuel chamber was much.

2. The majority of the smoke was coming out from the mesh unit than coming out from the exhaustion pipe which was failing the goal to meet.

3. Insulation was not properly achieved.

4. The test subjects were not heated efficiently in order to get them coated with lac.

User Feedback:

1. It was not feasible as they found it quite tedious to install.
2. They were not pleased as the pots were not uniformly heated.
3. They found the whole procedure of working with furnace quite complex as it was changing the way they normally used to do it.

Critical Analysis:

1. Design was needing a lot of manual labour to get it installed. It made it clumsy and tedious.
2. As the fuel chamber was not properly insulated maximum amount of heat was radiated to the ground.
3. Exhaustion system failed to keep the efficiency as much as it was expected.
4. Extreme gap of the fuel chamber from the earthen pot section led to the inefficient heating.
5. Lac was not coated efficiently as sufficient temperature wasn’t achieved.
6. The iron pipe that was used for exhaustion got subjected to rust in less then two weeks.
7. It demonstrated the proof of concept and provided us with enough data for the next iteration of this prototype.

Consultation with Experts

SAMARIKA Pharma

SAMARIKA Pharma has a very big sheet metal fabrication facility in Chhatral industrial estate. Learning from the mistakes of the old design, we decided to make the next design extremely user friendly and intuitive, keeping in line with the “Show, don’t tell approach”. SAMARIKA manufactures Tin parts made out of recycled scrap. We asked
them for a recommendation to go with a mechanical housing for the potters' Bhatthi. They recommended to make the whole structure out of Tin and make the mesh out of Stainless Steel (SS504). They manufactured our prototype for us and added Asbestos sheets on the inner walls to act as a heat reflector.

Mansukhbhai Prajapati

Mansukh Prajapati, the founder of Mitti Cool clay based refrigerators and pots invited us for a meeting with him to discuss the design that we made for these potters. We had a look at their Kiln and learned about its design and intricacies. He recommended us to add enough insulation/reflection in the chamber to prevent leakage, add sliders on the windows to restrict air flow and make sure the chimney is long enough to make sure most of the smoke is going out of the chimney. He also recommended us to visit Gujarat matikam to learn more about the Kilns that they provide to the potters for free of cost and other schemes available to these potters.
Gujarat Matikam (RTI)

We met with Mr. Dolariya who is the Head of R&D at Rural Technology and Infrastructure (Govt. of Gujarat) who is responsible for the start of the Gujarat Matikam. He told us the rural potters kilns have a thermal efficiency of 6% and there is a need to improve it for which the government works hard. The government currently has a kiln that's capable of holding 600 clay pots at once and reaches a temperature of 1300 °C. This is a very big kiln and not practically usable for the targeted community. If we could design a small, movable kiln that can suit the needs of this community, it’s possible for the government to test out it's feasibility and provide it to them free of cost.
Area of Application: Pottery Industries

Capacity: 350 water pots per batch

Wood fuel Required: 170 kgs

Advantages:
1. Firing cost is only Rs 2.25 which is very less
2. No health hazardous problems
3. Thermal efficiency is high i.e 40.00%
4. It saves nearly 2.0 tons of wood per year.
5. It saves Rs 3000 to 4000 per batch
6. Rejection is only 4 pots per batch.

Cost: 73000/- per one no.

4. Rejection is only 4 pots per batch.
Prototype - II
**Prototype Briefing:**

Portable and easy to assemble kiln with smoke and additional heat extraction system.

**Prototype detailing:**

The structure was designed keeping in mind the drawbacks faced in prototype 1. The structure can be divided into three sections.

**SECTION 1:**

The lower part consists of the base of the structure. The structure has following salient features:

- The material used for the base structure is Tin (2mm thickness).
- The base is supported by stands on four sides. The main base has been kept wide for stability.
- The upper part of the base comprises basically the mesh which is constructed using Stainless Steel 504 of 4 mm width. The upper part is provided with mesh for two reasons:
  1. To provide proper air flow from bottom.
  2. To separate the leftover ash from the pots to prevent any deposits on the utensils.

**SECTION 2:**

The upper part is given a frustum structure. This will serve as an enclosure structure for reflecting heat back to the combustion chamber. It has following salient features:

- The material used for the structure of frustum is Tin (1mm thickness).
- The upper part is hinged with lower section which can easily be detached from the second section.
- The base is kept open from three sides to provide proper air flow to the fuel chamber for natural aspiration.
- The four sides of the frustum is provided with reflectors for reflecting a considerable amount of heat back to the fuel chamber and also it maintains the proper air flow inside the structure. Material used for reflectors is asbestos sheets (4mm thickness). The sheets are attached with the surface of frustum using synthetic rubber adhesive.
SECTION 3:

Section 3 consists of the exhaustion system of the kiln. The exhaustion system is designed keeping in mind two core points:

1. To provide proper draft to the flow of the smoke and additional heat.
2. To optimise vertical acceleration component.

The exhaustion system is 2.5 feet above the upper base of the frustum and 5 feet from the upper base of section 1. The ratio of the lower to upper base of the frustum was kept 2:1.

In this prototype it was 400mm edge square at the bottom and 200mm edge square at the top. The cross section of the frustum is square.

WORKING MILESTONES:

- The setup of the type of furnace that is normally used by the potters, was done on the upper base of section 1 of the prototype.
- After the fuel chamber was properly ignited, the whole chamber was enclosed.
- After an approximate time of 25 minutes the frustum was lifted off. The pots that were kept in the fuel chamber were taken out and lac was applied on the pots.
OBSERVATION:

- After the fuel was properly ignited with a stable flame, and the chamber was enclosed, the smoke started exhausting from the exhaustion system. About 90% of the smoke was exhausted efficiently from the exhaustion system. The rest of the 10% were leaking out through the gaps left for natural aspiration.
- The bamboo leaves (that are used as an accelerator in the furnace) was used only once (at the time of the ignition).
- After a period of time, the smoke coming out from the exhaustion system stopped and there was the flow of additional heat from the exhaustion system.
- The number of earthen plates that were kept inside the baking chamber were 5. When they were taken out of the system, all 5 were recovered properly without cracks.
● The earthen plates were heated at a proper temperature for the lac to be coated efficiently.
● One of the reflector sheets that were provided on the inner surface of the frustum came out due to the hot air flow burning the rubber glue at a high temperature.
For this field visit, we thought of going for the “Show, Don't tell” approach for this design. We let the user test it themselves without any interference from our side. This was done to establish trust for using this prototype and/or learn about the shortcomings/issues of this prototype for their usage.

1. The user admitted that it was easy to install and safe to use.
2. As the kiln was designed to adapt itself to the ways the user is used to, the user admitted that it took them less time to understand the working milestones of the prototype.
3. They admitted that it reduced approximately half of their working time.
4. They were satisfied that none of the plates were cracked and that there was 100% production output efficiency.
5. The plates that were used as the test subject generally used to get cracked and were used for just providing shield to main chamber previously. So they found the design quite promising to use.
Additional Goals:

While we were working on the kiln, we thought of trying to address the problem of lac application by trying to connect them to an existing solution in the market i.e. Leather welding gloves which were available for a price of Rs. 125 per pair. We gave those gloves to Dulesingh and his wife. Both of them found it very comfortable and were able to resist heat without any issues. Dulesingh was able to remove the vessels directly from the kiln without the use of sticks by using gloves. If these gloves can be bought on a much bigger scale, we might be able to avail it at a lower cost.
Pros:

- The production output efficiency turned to be 100% as all of the five pots were recovered from the chamber in proper condition.
- The later termination of smoke release from exhaustion system marked the proper combustion of the fuel (cow dung + dried bamboo leaves).
- The efficient coating of the lac on all the surface of the test subject proved that the reflection of the heat was done efficiently by the reflector.
- The structure of the exhaustion system proved efficient in drawing out the smoke and additional heat.

Challenges:

- The exhaustion system was in need for more height from the base as more the height will increase the draft of the flow.
- The three gaps are to provided with slider windows in order to prevent unnecessary leak of smoke from the gaps.
- There was no proper system to collect the rejected ash.
- The adhesive proved to be inefficient to hold the asbestos sheet in its place because as the temperature inside the system started building up it was unable to withstand it, it lost its flexibility, got brittle and finally the bond was broken by extreme heat build up.

Points to be Noted:

The data that were collected from the critical analysis of prototype 1 and prototype 2, user feedback led the path for the development of the final design.

The following milestones were considered to be added in the final design:

1. Prototype 2 was small and it was needed to increase the capacity of the final design to increase the utility with marginal cost increase.
2. The furnace height was to be increased in order to drive the exhaust smoke and additional heat at a safer level in a less turbulent manner.
3. A proper method to hold the reflector sheets in place needed to be implemented.
4. Proper mobile window mechanism was needed to be added in the system to prevent unnecessary leak of the smoke.
5. An ashtray was needed for continual cleaning of smoke.

FINAL DESIGN DESCRIPTION

From all the data collected from prototype 1 and 2, final product is designed. We've tried to cover every aspect of the shortcomings mentioned in the previous section.

CHANGES DONE AT STRUCTURAL LEVEL:
There is no change introduced in the structural look. The considerable change that is going to be in the final design will be that the final design will be the enlarged version of the prototype 2. The main objective behind doing this was to increase the capacity of the design to be used at a slightly larger scale so that groups of people can use this by sharing the expenditure. The changes in the dimensions are as follows:

1. The lower base of the section 1 is 58 inches, length and breadth wise.
2. The mesh is 48 inches length and breadth wise.
3. The height of exhaustion system is increased from 2.5 feet to 5 feet.
4. The height of the frustum is kept constant (2.5 feet).
5. The tilt angle of the frustum is changed to 47 degrees.
6. For proper placement of the reflector the asbestos sheets will be jacketed with aluminium composite panels (0.5mm thickness).
7. The gaps are being provided sliding panels of the same material which will serve as the checking system for the smoke coming out from the gaps.
8. The lower base of section 1 is being provided with a tray to collect ash. That can be detached from the kiln and the ash can be disposed off properly.
**BILL OF MATERIALS (BOM):**

<table>
<thead>
<tr>
<th>SERIAL NUMBER</th>
<th>MATERIAL</th>
<th>SPECIFICATIONS</th>
<th>QUANTITY</th>
<th>PRICE (in INR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>TIN</td>
<td>1. 2mm thickness&lt;br&gt;2. 1mm thickness&lt;br&gt;3. 5 inch width, 48 inch length</td>
<td>1. 13 Kgs&lt;br&gt;2. 8 kgs</td>
<td>120/kg</td>
</tr>
<tr>
<td>2.</td>
<td>ALUMINIUM COMPOSITE PANELS</td>
<td>0.5 mm thickness</td>
<td></td>
<td>75/sq.feet</td>
</tr>
<tr>
<td>3.</td>
<td>ASBESTOS SHEETS</td>
<td>8mm thickness</td>
<td></td>
<td>30/sq.feet</td>
</tr>
<tr>
<td>4.</td>
<td>STAINLESS STEEL MESH</td>
<td>Stainless steel 504 (48*48)sq.inch</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Testing

Plan:

1. Final testing will require testing for multiple parameters involved in the pottery process. For starters for the kiln, we'll need to measure temperature and have a reliable way of measuring thermal efficiency to establish results and pass safety checks.

2. We also need to test this kiln against the old traditional kiln and compare outputs for multiple houses and multiple input samples to study the output vessels qualitatively and quantitatively.

3. Testing has to be done simultaneously with simulation data to optimize performance by making adequate modifications to the design.
Future Aspects & Recommendations:

Current production of the prototype is happening at SAMARIKA Chhatral Industrial estate. But for production, we might have to look for more local sources to reduce the cost of manufacturing. The goal of this project is for this kiln to be adopted by the government or any other able agency that can distribute our product on a mass-scale for zero-cost to the user. It’s important to note that the final prototype is extremely large and can be used by a group of 2 families very easily (About 40-45 vessels). For individual usage, the required size will be a 0.75x of the current final design.

Transportation and logistics in this region is a major challenge and would add a heavy cost to the user. It is therefore hoped by us that any major organization that accepts this design would bear the cost of running the supply chain.
REFERENCES

1. Brief study of kilns, their characteristics and types
   
   https://www.fpl.fs.fed.us/documents/usda/ah188/chapter02.pdf

2. Numerical approach for calculation of combustion in kilns for primary and alternative fuels
   

3. Performance of tri wing solar chimney and adaptation to wood drying
   