Designing Aluminum Furnace for Developing Countries

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Abstract

In this paper we present the design process of the ProTek (a compound word from providing and technology which protects the users) aluminum furnace, which enhances the safety and efficiency of the recycled aluminum casting process. The project was initiated during the International Design Development Summit 2013 (IDDS) [1] and was developed through a month long participatory design process with the local foundries in Chazanga, Zambia. The goal of the study was to co-create with the locals by using prototypes and to produce technologies that not only improve the quality of life, but also offer opportunities for entrepreneurship.

Keywords:

Appropriate Technology Design, Developing Countries, Co-Create, Prototyping, Sustainability

1 INTRODUCTION

Design has become an essential element to the key success of our socio-economy system. Nonetheless, design exists and benefits only for 10 percent of the world's population who have the power to consume. The rest 90 percent still cannot fulfill their basic needs such as fresh water, housing, food, transportation, education, medical treatment, and information [2]. In recent years, there has been an extensive growth and effort on supporting the developing world through funds, relief goods, and humanitarian aids. Nonetheless, there is still a lack of help and in many cases the end results tend to bring negative impacts to the developing societies. Due to this movement, the growth of social responsibility has changed many designers to shift their perspectives to help relive poverty in the developing world as well. Currently, there are many ongoing design projects in the developing world, but most of the design outcomes are not viable to meet the current market and fail to sustain within the community. Therefore, innovative design solutions that can relieve the encountering problems and sustain within the community is needed.

2 BACKGROUND

Chazanga is located on the northern edge of Lusaka and has high levels of unemployment, especially among the youth. Due to lower education levels, most of them have not been able to secure formal employment. Chazanga is not far from Lusaka's industrial area, so they have ready access to by-products such as aluminium waste. Due to this, there are many skilled aluminium metal casters who have been learning and perfecting the skill of melting and casting aluminium for various utensils, which are predominantly cooking pots. These products are produced on demand from the market suppliers and are sold in various marginalized areas in Zambia.

Figure 1: Aluminum pots from the Chazanga foundries

2 OBJECTIVE

An innovative and sustainable design solution was needed to produce technologies that not only improve the quality of life, but also offered opportunities for entrepreneurship. Therefore we focused on the objectives as follows:

-Learn and analyze the process of aluminum casting

-Identify the problems in the aluminum casting process

-Identify the stakeholders and links of the process

-Provide solutions for identified problems and to improve the efficiency of the current process

-Identify business opportunities in the area

3 FIELD STUDY

The field study was conducted from July to Aug 2013, with a total of 5 IDDS 2013 participants and 1 project organizer form various backgrounds. Our team was arranged with industrial designers, mechanical engineers, development strategists and technicians from South Korea, Cameroon, Zambia, and Tanzania.

3.1 Field Study Methods

At site we paired into three as a team and concentrated on understanding the context and the needs of the users in order to frame our problem and establish a direction. We started to observe people by shadowing their daily lives and asked problems, questions, and possible solutions as we went along. Unlike previous projects where most of the team members are not local and interpreters are hired and are not directly involved with the project [3], our team was fortunate to have two members who were able to speak and understand the context which gave us a great advantage to communicate and bond with the locals. Also contacting and receiving approval by the head master of the town gave us better access to the local foundries to cooperate with us who were often suspicious regarding outside visitors. Once we were able to work with the local foundries we learned and tried the casting process ourselves to understand the process in depth and to see how we can make improvements. For documentation we used cameras, camcorders and personal journals with the consent of the workers to gather information from the site. The information was later shared with other team members at the end of each day for clarification.

Figure 2: Working with the Chazanga foundry workers

3.2 Aluminium Casing Process

The aluminium casting process starts with the collection of scrap aluminium by children from the landfills or outskirts of Lusaka. It is then purchased by foundries were the workers have to sort out and break the aluminium into smaller pieces for melting. While sorting the aluminium the furnace is preheated and the aluminium pieces are put into a crucible for melting. The preparation of the sand mould follows immediately as the aluminium is being heated. Once the moulds are ready, the readiness of the aluminium is tested by dipping a log into the crucible to check if the log catches on fire immediately. The workers then remove the furnace lid with tongs and pours the melted aluminium into the sand moulds. Finally, the moulds are cooled down and disassembled to recover the final product.

Figure 3: Testing the readiness of the aluminum with a log

3.2 Problem Framing

By observation and first-hand experience we found out that the process had very little safety, which was unsafe to both the user and the community around. Also there were many opportunities to make the furnace conserve heat energy that could lead to efficiency and financial savings. Finally there were durability issues, which led to a shorter lifespan of the furnace, which ultimately effected the quality of the product, led to safety issues and cost issues. The following problems were discovered:

-The furnace produces toxic fumes that can be inhaled by the user and the community people

-Pre-heating the aluminium is done in the furnace, which also leads to explosions due to temperature alterations

-The production in monsoon seasons makes the process dangerous as the aluminium can explode

-The furnace is insulated by local soil clay, which loses heat energy and lengthening the melting process

-The furnace is stationary and can only get air from one direction and wears and tears from weather conditions

-The crucible sits directly on the charcoal reducing the lifespan and also blocking the air flow inside the furnace

4 CO-CREATING THROUGH PROTOTYPES

Once the problem was framed we started to design simple prototypes to use as a base to engage with the foundry workers and locals. We found that using simple prototypes were more effective in engaging and getting responses from the workers to open up and generate ideas than conducting individual interviews, focus group interviews, and self-documentation methods (photo diary).

Figure 4: Paper-prototyping to co-create with the workers

Figure 5: Demonstrating and educating the locals

Therefore we used the prototypes to the community members on how they can learn to cast more safely and efficiently. During the demonstration we also presented other appropriate technologies, which could easily be made and used in the local context. The main purpose of the demonstration was to educate them on how these technologies can offer business opportunities in the local context for better living. In We total, we had 4 demonstrations with the prototypes, which started with a small number of community members, but as the sessions went on people would ask us how to make these prototypes and were eager to learn and start their own businesses. The demonstration was a success and showed the potential interest in appropriate technology design products that can lead to their benefit. For gathering community members, the help of the church community exceeded the help of the head master and local NGO's, which is highly recommended when gathering larger groups of the community.

5 EXPERIMENTS

Since heat energy loss was one of the biggest problems for maintaining efficiency and conserving charcoal, we conducted experiments to find alternative local solutions. For better insulation, we conducted an experiment to compare the insulating property between pure clay and additive clay soil, which is a mixture of clay and wood saw dust. The purpose of this experiment was to determine the temperature loss to the body of the heating furnace and comparing the rate of heat transfer to the body in time intervals. The rate of heat transfer across the body of the insulating material is determined by the amount of heat loss to the body of the insulator and the readings of temperature differences at the outer surface of the insulating material. By comparing the temperature from the table, clay soil with saw dust mixture has a better insulating property than pure clay.

Figure 6: Experiment setup and process

Clay Soil (100%)		**Clay Soil (90%) + Sawdust (10%)**	
Time (min)	Temp(°c)	Time (min)	Temp(°c)
0	27.4	0	23.7
5	28.6	5	25.1
10	30.1	10	25.2
15	31.1	15	25.3
20	32	20	25.6
30	32.1	30	26

Table 1: Temperature change between the two samples

The test materials were chosen since they can be easily found within the local area without any additional cost. During the experiment we encountered a problem of not having the proper equipment to conduct the test. The experiment required an infrared digital thermostat, which could not be found in the area. Therefore we contacted local universities and institutions for help. The process of finding or borrowing equipment in developing countries could be a difficult task. Therefore, preparing proper tools or having accessible local networks is necessary before visiting the site.

6 IDEATION

By co-creating with the users and the experiments led us to find solutions that reduced the safety hazards to both the users and the community members. Also it led us to simple solutions, which are more efficient than the conventional furnace. The improvements is as follows:

Figure 7: ProTek furnace features

-Chimney: Protecting the users of the furnace and the community from the harmful fumes that are emitted in the process. The chimney is fitted into the hub of the furnace, which allows the fumes to exit. The chimney is the main outlet for the heat, which aids the excess heat energy to escape the furnace that can lead to an explosion.

-Pre-heating aluminium lid: The lid is designed to load scrap aluminium for pre-heating, which prevents explosions when non-preheated aluminium is put into the crucible. However, we noticed that the furnace is also used for the purpose of cooking and heating water after the aluminium casting process. Hence, the lid can also be used for these purposes.

-Rotating lid: The rotating lid is designed to protect the users of the furnace from being injured and lessening the burden of lifting the lid. The lid is fitted to the chimney hub where it can easily rotated to open.

-Fire bricks + Mud mixed with saw dust (90% clay soil and 10% saw dust): To enhance the efficiency of the furnace, the group altered the conventional clay walls of the furnace with clay moulded pan bricks padded with sawdust mixed clay. This has shown to keep the needed heat energy of the furnace longer than the use of clay alone. As a result the time needed to melt the aluminium is reduced and the production is enhanced. The bricks are also an aiding factor to the lesser usage of charcoal.

-Cast iron wheels: The furnace has been fitted with wheels to make it mobile. This allows the furnace to be moved and set in the direction of the wind, which enhances the efficiency of the making process. The wheels also allow the furnace to be moved into a shelter in the rainy seasons, which enhances the lifespan of the furnace. On the entrepreneurial side of things, the mobility of the furnace allows the casters to move with their furnaces to areas where they need to do the work as well.

-Handles: The furnace has been fitted with handles on the sides to allow it to be pushed and pulled. The handles can also be removed during the casting process for allowing more working space for the users.

Figure 8: Rendered image of ProTek on foundry site

7 MANUFACTURE

During the ideation process, materials to construct the ProTek furnace were selected with the help of local technicians and hardware store owners. The lack of knowledge on the available materials in the market was a time consuming task to find and decide on the type of materials to use. Even though there were certain materials we could get from neighbor countries, we decided to choose locally available materials since it could be manufactured and maintained within the local context. In our point of view, this was a method that can locally sustain the ProTek furnace as well as to offer them opportunities for local entrepreneurship. The construction of the ProTek furnace was performed with the help of a local workshop (Disacare) [4]. Several versions of the ProTek furnace was built and tested with the foundries and modified, which led to our final furnace design.

Figure 9: Building ProTek furnace at Disacare workshop

Figure 10: Several versions of the ProTek furnace

8 FEEDBACK

To receive feedback on the usage of the ProTek furnace, we decided to send the prototypes to the Chazanga foundry workers. The Zambian group members worked in conjunction with the NTBC(National Technology Business Centre) [5] to collect the feedback. The following problems were the feedback from the foundry workers:

-Wheels too small to move on rough terrain

-Bigger crucibles cannot fit into the furnace until we turn the lid upside down

-Stronger welding is needed in the joints

-The ProTek has great insulation, but due to the excessive heat the chimney and lid is burnt

-The heat conservation makes them use less charcoal

-The ProTek furnace melts aluminium at a higher temperature which makes stronger and smoother products

Figure 11: Feedback from the foundry after a month of use

The collected feedback was sent to all the team members for further analysis. The feedback is still collected in a 4 week interval and currently the 4th version of the furnace is being designed and will be made and delivered to Chazanga in Jan 2014.

Figure 12: Presenting the ProTek furnace to the workers

9 FUTURE WORK

With the support from MIT IDIN [6] and USAID [7], we are building 2 ProTek furnaces (Current Version) in South Korea (KAIST: Korea Advanced Institute of Science and Technology) and Nairobi (University of Nairobi). We will be conducting tests on the insulating properties, weight effect on the lining, the durability and heat resistance effect on the metal drum and other aspects on how we can improve the ProTek furnace further. As we monitor the presented product in Chazanga and Disacare we aim at implementing user feedback gathered from the present furnace and build several refined ProTek furnaces. The refined ProTek furnace will be tested in South Korea and Kenya before it is introduced back into the community. The reason for building 2 furnaces at different locations is to make sure the results are consistent, which will provide an equal performance wherever the furnace is built. In December 2013, we will be going back to Zambia to rebuild the refined design and distribute it to the foundry owners in Chazanga. We are also planning to introduce the ProTek furnace to Kenya, Ghana and Tanzania especially in technical schools and foundry shops. Currently we have contact point in all four countries and will have workshops in a local scale on how to use and build the Protek furnaces. We are also going to come up with a local business model for the locals to start their own business venture.

10 DISCUSSION

The participatory design process where the users and stakeholders are involved in the design process [8] was comprehensively utilized in designing the ProTek furnace. Unlike any of our previous projects [3] we have concentrated on using a prototype to engage the foundry workers and the community members. Through this process, we have found that using simple prototypes triggered the users and stakeholders to generate more ideas than conducting individual interviews, focused group interviews and self-documentation methods. The responses we received were quick and in-depth. As we presented our simple prototypes to the users and stakeholders, they would add or subtract from the ideas we had and build a new version of the prototype. This process of co-creating continued until we made an actual working prototype where the users would use it and give us immediate feedback from the usage. Also the users where more willing to use the prototype since they were involved in the design process, which gave them a sense of ownership as well. Further studies on using prototypes in different marginalized area with different approaches will be conducted to measure the effectiveness of the method. We have also discovered the use of locally available (in reach) materials was the appropriate approach for the product to sustain in the context. In this manner, users would be able to manufacture, buy & sell and self-maintain the product with-in the local context.

10 CONCLUSION

The aluminum project in Chazanga, started as one of the MIT IDDS 2013 projects in July 2013 (Sponsored by MIT, USAID). The project was based on participatory design and co-creating with the users. From our observations, the casting of aluminum involved a problematic process that had very little safety, efficiency and durability. Therefore, our team has redesigned the conventional furnace to enhance its utmost safety and efficiency in production. The new furnace “ProTek” was designed with the co-creation of the Chazanga foundry workers. Also all the materials were locally sourced therefore, it can be made and maintained within the local context. The furnace is made to increase both the safety and efficiency of the aluminum process and can be easily adopted to be produced in mass for entrepreneurial ambitions. Currently the ProTek Furnaces has been given back to the Chazanga community and to Disacare, Zambia, where both are in active use. The Zambian group members are working in conjunction with the NTBC (National Technology Business Centre), Zambia to collect the feedback, which is sent to all members for further analysis. We are currently collecting user feedback on a monthly basis and making design alterations to refine the furnace design.

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