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Adaptive Alcohol Cooking Stove

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Abstract

The concept of the alcohol stove was birthed from the idea of burning pure organic compounds. The growing popularity of the can-alcohol stove has made the idea attractive. Most people today use it when camping, to heat food, and to cook as well. The alcoholic fuel must have a substantial alcohol percentage of about 70% and above before it can be used as fuel. This property makes rubbing alcohol (methylated spirit) suitable for the stove. It is lightweight and releases relatively low-level pollutants when combusted. Alcohol can also be extracted through simple fermentation, allowing our target consumers (low-income farmers) to make it themselves. Our aim was to design an environmentally friendly stove that is low in emissions and can be used for cooking meals in rural areas. We accomplished this through careful design and simulation, using Autodesk Fusion 360 and the Circuit.io App. Autodesk Fusion 360 is an engineering-based software that aids in constructing 3-D objects of proposed prototypes. The Circuito.io app is an Arduino supported software, that helps to assemble different electronic components and provides averaged pricing of all the parts used. The mechanical strength of the stove handle was validated through factors such as the Von Mises stress applied. The heat produced from five ounces of methylated spirit was enough to boil water and oil for close to 30 minutes. The results obtained testify that the alcohol stove is a good model that fits adequately in the rural setting.

1. Introduction

The project is focused on design, analysis, and testing of an adaptive cookstove for people living in rural areas. The project was reviewed at various checkpoints to ensure a successful final product. The objective was to make a stove that: is environmentally friendly (i.e. uses green technology), reduces emissions, enables fuel regulation, and must be able to cook full meals. The application of alcohol as a fuel has been adopted worldwide. However, it is essential to note that the fuel used must have a substantial alcohol percentage of about 70% and above. This requirement makes rubbing alcohol (methylated spirit) the right choice [1]. The fuels used are lightweight and generate relatively low-level pollutants when combusted [2]. Brazil, a country booming with natural resources, has been interested in using alcohol as a fuel source for vehicles [3]. After reviewing the paper on 'Numerical Fatigue Analysis of Induction, Hardened and Mechanically Post Treated Steel Component' [4], we realized our initial choice of an induction stove would not be the best, as it works only on magnetic cook pots. In pursuit of designing a stove with reduced emissions, we explored the use of alcohol (i.e. ethanol). Its presence in a mixture reduces carbon dioxide (CO_2), carbon monoxide (CO) and organic compound concentration (VOCs). A gallon of fossil fuels releases roughly 19.64 pounds of carbon dioxide into the atmosphere. By comparison, an 80/10 blend of fossil fuel and ethanol will emit 17.68 pounds of carbon dioxide [5]. A mix of 10% ethanol and gasoline can reduce the carbon monoxide load of gasoline emissions by 30% [5]. A blend of 10% ethanol and gasoline can reduce the amount of volatile organic compounds in the exhaust by 7% [5].

2. Methodology

The first stage of design was to assemble a 3-D model of the stove, using Autodesk Fusion 360. This model contained the different materials that was to be used in building the stove.

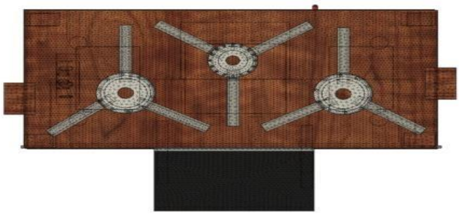


Fig. 1 (top view)

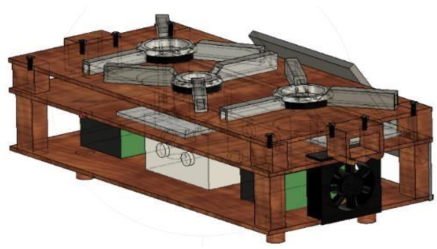


Fig.2 (side view-electronics underneath)

2.1 Materials Selection and Material Science

In designing this alcohol stove, we used a well-selected repertoire of materials that increased our product's performance. Our choice was informed by what we learned in our material science course. The selected materials were also incorporated in the 3-D model (Autodesk Fusion 360 software), to see the capability of these materials chosen during the simulation.

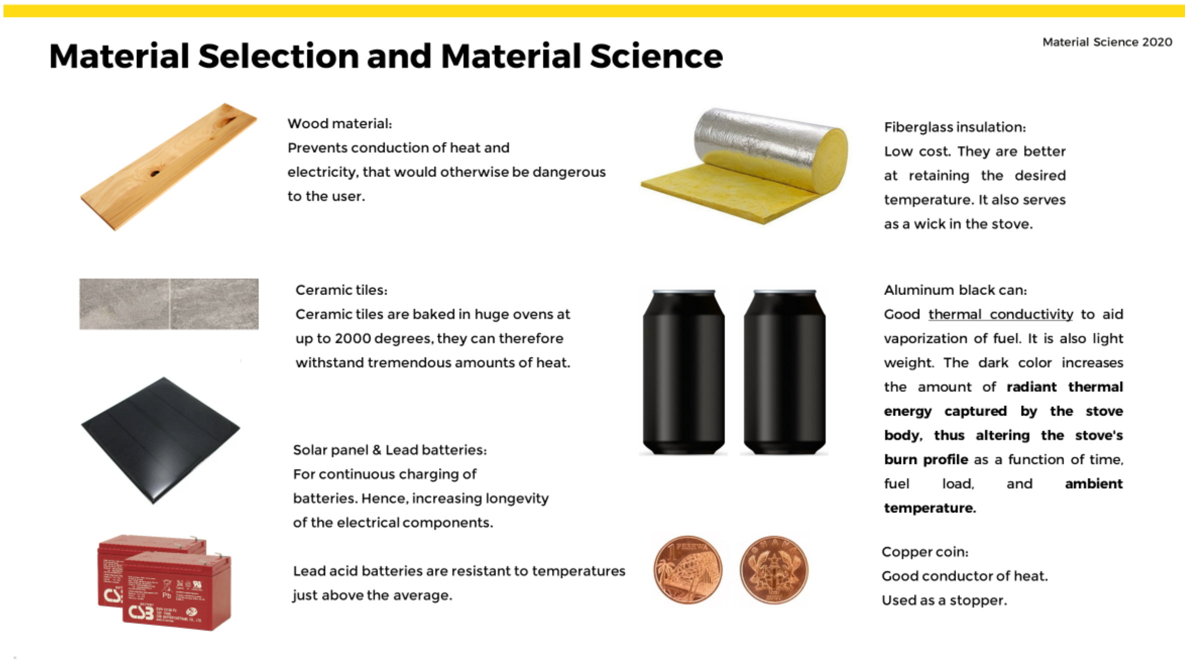


Fig.3 – Summary of materials and their respective uses

3. Results and Discussion

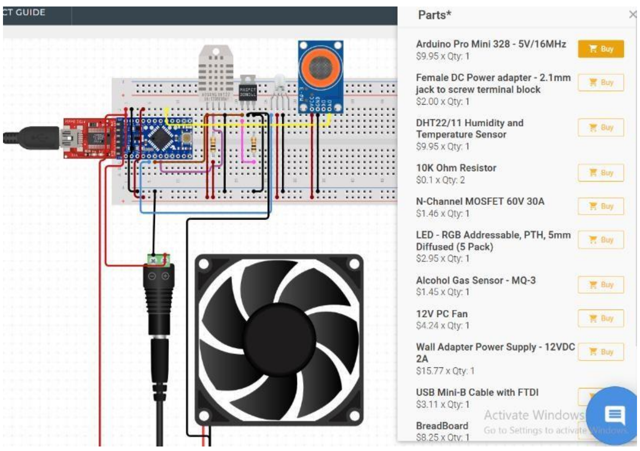
3.1 Simulations

The team conducted two sets of simulations, one on the electrical components and the other on the mechanical parts. For the mechanical aspect, our two results explored how the handle of the stove would perform when weight is acted upon the stove. This includes its normal weight and the weight of pots and/or food. There was also a simulation conducted on the alcohol container. This helped in discovering how the container would radiate heat when the alcohol burns within it.

3.1.1 Electrical Simulations

Using the Circuit.io App, we were able to build our electronic circuit. We included a humidity and alcohol sensor to detect the temperature and alcohol gas around the stove, to make sure the user is operating at safe levels. That is, if some of the alcohol spills on the stove structure and/or the temperature of the surface is above 40 degrees, the LED will glow red. This signal warns the user about a possible/impending fire hazard. If it safe to cook, the LED will remain as bright green. The user must ensure that the cook top is well cleaned before attempting to switch on the stove.

The fan at the bottom of the stove helps to cool the electricals to prevent them from getting hot and possibly endangering users (by explosion of the lead batteries). The 6V solar panels continually charge the spare lead acid battery. We also estimated the cost of all the electrical components, which did not exceed $80. The written Arduino code for the sensors run successfully without any errors.



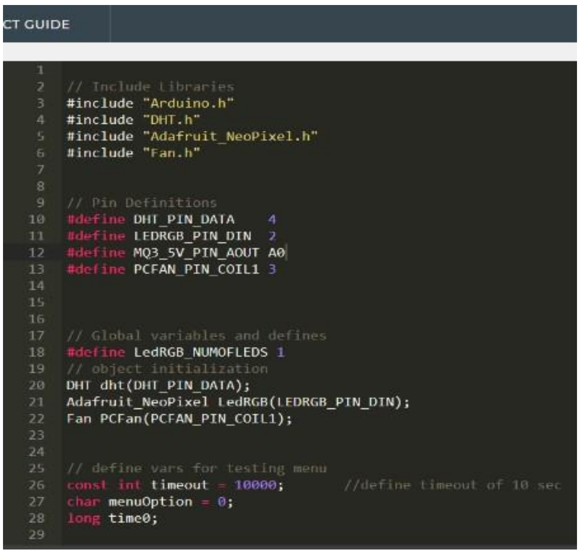


Fig. 4 & 5 – A figure of the electronics and the Arduino code

3.1.2 Mechanical Simulations

Simulation 1: On Stove handle: The stove will be carried up with its set of grips. We simulated this design to validate whether the handles were bolted tightly enough not to break. We used an aluminum handle. Aluminum has a yield strength of 34.47MPa and an ultimate tensile strength of 89.63MPa. Our results checked for displacement in the x, y, and z directions, shear stress and finally the safety factor per body. The aluminum handles are going to be bolted to the frame of the stove. We then constrained the hole that will be bolted and applied an upwards force of 30N on each handle.

Each handle had a 30N force that equally balances out the overall 60N force of the stove and the pots. At first, we estimated the total weight of the stove, food, and pots to be about 25N. We multiplied this factor by 2.4 and used the estimated 60N to ensure that our structure was stable enough. Our minimum safety factor was found to be 1.134, and the maximum was 15. The real safety factor was about 8, which is just in the middle. This meant that the handle would be strong enough. The structure will therefore be capable of carrying eight times the design load. The displacement resistance was quite impressive, as the maximum displacement of the handle was merely 0.05802 mm, rendering it insignificant.

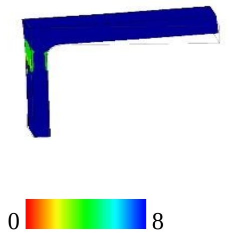


Fig.6 - Safety Factor (Per Body)

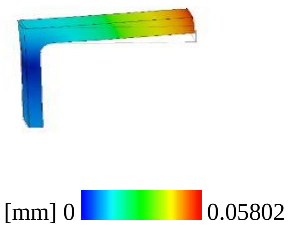


Fig.7 - Displacement

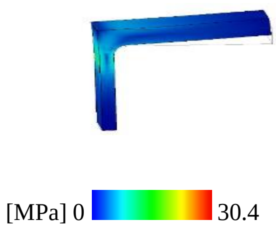


Fig.8 - Von Mises

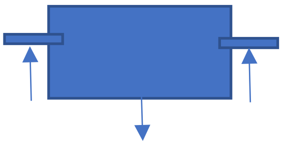


Fig.9 – Sketch of balancing forces on a lifted pot

The handle promises to be rigid and robust. The Von-Mises stress measures the yielding profile of a material. It was observed that the maximum allowed Von Mises was 30.4MPa. But the recurring Von Mises in our handle was about 15 to 50% of the maximum. It added to its unique strength and high yield strength.

Simulation 2: On the alcohol container: This helped us know how radiation from the alcohol fuel, and the weight inflicted on it, would affect the container. It must not break, else the alcohol could spill. The aluminum container radiated heat when the ethanol fuel was ignited. For stoves, the temperatures produced range from 80 to 200C.

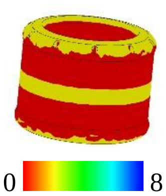


Fig.10- Safety Factor (Per Body)

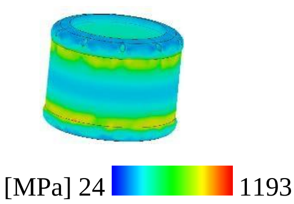


Fig.11 - Displacement

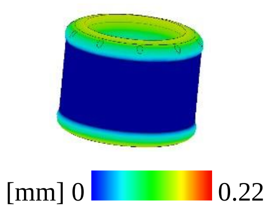


Fig.12 - Von Mises

Using a thermal load analysis on the canister, we found out that the can performs well. The expansions of the aluminum-can in all directions, i.e. in the x, y, and z directions, are very low; the displacement is 0.09872mm, 0.09951mm, and 0.1534mm, respectively.

This is true because when we were conducting cook tests, the aluminum-can contained the burning fuel for a very long time, and there was no significant deformation of the can. We set the temperature of the can to be 200C (the highest, for more allowance). The safety this time was not so good as it was around 1 and 2. Whiles the maximum allowed was 11.35. We stipulate that its weakness might be due to the radiating heat, which causes the material to be more ductile. Since ductile materials have less strength, it makes sense that the number of loads allowed on the container is low. However, as engineers, we will place on our product that the safety factor is 1, and no more than 22.5 N (pots + food) can be placed on each burner. The ceramic tile we lagged at the bottom of the container will help contain some of the heat. Please note that the only stress our ceramic tiles will experience is compressive strength (as they are placed at the bottom).

In our assessment, the stove was a success (in prototypes and simulations). We fried eggs (90 °C, 300 cm³ volume of the pan), boiled eggs (100 °C, 712 cm³ volume of the pot), and cooked ... 0 cm³ volume of the pot). ... d using the number of holes ... well as the size of the can. ... ents were satisfied.

Fig.13 - Cooking experiment set-up

Fig.14 & Fig.15 – Lit alcohol stove and stove prototype

4. Conclusion

We studied in material science that ceramics have an average compressive strength close to ten times higher than their average tensile strength (Yiporo, Abade – Abugre, 2020). Therefore, it did not require a load analysis. This research fact saved us a lot of time and computation. However, we aim to make our stove less costly in our future works. As a team, we were able to design a stove that is environmentally friendly, reduces emissions and has fuel that can be made by local people in rural areas. We believe this breakthrough will make the lives of the low-income rural inabitants much easier, as they can cook meals from clean and efficient alcohol.

5. Acknowledgements

Many thanks goes to Dr. Danyuo Yiporo and Mrs. Miriam Abade-Abugre, for gifting us with the knowledge and encouragement to pursue this project.

6. References

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