The present work was submitted to the Faculty of Engineering

IMPROVEMENT OF AUTOMATED COAL BRIQUETTE-FUEL FIRED STOVE

Bachelor Thesis

by

Anudari Tsogbadrakh

Supervisor 1 / Examiner 1 **Professor Odbileg Norovrenchin**

Supervisor 2 / Examiner 2 **Professor Sungchil Lee**

Ulaanbaatar/Nalaikh, 2023

Statutory Declaration

Tsogbadrakh, Anudari	4137
Last Name, First Name	Student ID Number

I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis.

IMPROVEMENT OF AUTOMATED COAL BRIQUETTE-FUEL-FIRED

STOVE

I did not use any sources other than those stated. In case the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Place, Date

Signature

List of Figures:

List of Table:

Abbreviation

UN United Nations

PD Pitch Diameter

CO2 Carbon Dioxide

BCE Before Common Era

TEFC Totally Enclosed Fan Cooled

IP55 Ingress Protection 55

LLC Limited Liability Company

RPM Revolutions per minute

EC Equivalent Capacity

RC Required capacity

HP Horse Power

HPm Horse Power Material

Acknowledgment

I would like to express my sincerest gratitude to Professor Odbileg Norovrinchen, my first supervisor, for his invaluable guidance, constant encouragement, and endless support throughout the entire process of my thesis work. His expertise and insights have been instrumental in shaping my research direction and refining my ideas. I am truly grateful for his mentorship and advice.

I would also like to extend my heartfelt thanks to Professor Lee Sungchil, my second supervisor, for his insightful feedback and unwavering support during the development of my thesis work. His constructive criticism and guidance have been instrumental in helping me to improve my research and develop a more thorough understanding of the subject matter.

I would like to acknowledge the hard work and dedication of Mr. Amarsanaa, our lab assistant, for his tireless efforts in assembling and disassembling the stove parts for measurement and drawing, as well as welding them together. His meticulous attention to detail and unwavering commitment to our project has been invaluable to the success of my thesis work.

Finally, I would like to express my gratitude to all the individuals who have supported me throughout the course of this project. Their encouragement and guidance have been instrumental in helping me to achieve my goals, and I could not have completed this work without their support. Thank you all very much.

Abstract

This thesis presents a study on the automation of a fuel-fired coal-briquette stove, aimed at improving the stove's performance and finding alternative solutions to its existing design. The need for improvement arises from the stove's failure to work properly, specifically in terms of its efficiency, safety, and environmental impact.

To address these issues, this thesis proposes an improved design for the automated stove, which is based on a combination of mechanical and electronic components that allow for better control and monitoring of the combustion process. To evaluate the performance of the new stove design, a series of experiments and measurements were conducted, comparing it with the old version of the stove. The results show that the new design is more efficient and has a lower environmental impact than the old stove, while also providing better safety features for users.

Overall, this thesis contributes to the field of automation and household technologies by presenting a practical solution for improving the performance of coal-briquette stoves, which are commonly used in many households in developing countries. The need for automation arises from the inconvenience and labor-intensive nature of manual fuel feeding, which can also contribute to health problems and environmental degradation.

By proposing an improved design for an automated stove, this study provides an alternative solution that eliminates the need for manual feeding and enhances the stove's efficiency, safety, and environmental impact. The new design incorporates features such as automatic fuel feeding, air regulation, and temperature control, which make the stove more user-friendly and reliable.

The findings of this study can be used to inform the design of future automated stoves, as well as to promote the adoption of sustainable cooking practices that reduce the reliance on manual labor and improve the health and well-being of households. The thesis demonstrates the potential of automation technologies to address practical challenges in everyday life, while also contributing to sustainable development goals.

1. Introduction

The Mongolian ger is the traditional dwelling used by nomadic people of Mongolia since the 3rd century BCE. The design of the ger is simple yet effectively addresses the challenges that many housing styles encounter. While the design is to withstand extreme weather conditions, including high winds, storms, and heavy snowfalls. The circle shape of the ger is to distribute the load evenly and withstand strong winds. Also, the shape distributes heat evenly throughout the ger. Most ger uses a traditional stove as a heating appliance. Even though the ger has a very effective design, the heating system is causing the main problem. Not only inefficient heating, but the biggest problem was also that CO2 emission reached a level that is very harmful to human health. The area surrounded by Ger is named Ger district where 62% of the Ulaanbaatar city population lives. The Ger District is identified as the leading factor contributing to the high levels of pollution in Ulaanbaatar, and this pollution has been found to have adverse effects on public health. Therefore, it is crucial to take measures to mitigate pollution levels.

The United Nations agreed to help Mongolia reduce its CO2 emission by supporting the Clean-Air project. The UN will keep assisting the Mongolian government and its people by providing them with expert guidance to decrease exposure, bolster their healthcare systems, encourage the adoption of energy-efficient and clean heating solutions, and formulate sustainable strategies for using renewable energy in the long run (5).

Mongolians have been using the traditional stove as a heater until modern stoves were released. The project found its way to reduce air pollution, the UN suggested spreading the modern heating preference to the public and also banning the traditional stove. Inefficient heating of the traditional stove is caused by its material and raw coal which does not burn completely. Most common traditional stoves are made from iron which easily loses heat to the environment and requires 4-5 burning a day. The traditional stoves used for burning raw coal are often inefficient, emit high levels of pollutants, and are not user-friendly. Also, incomplete combustion increases the solid particles in the air which means the smoke extraction will rise. These two combinations of traditional stoves make a high cost in money, time, and effort.

The government has recommended eight different types of stoves for daily use, which include Ulzii, Khas, Golomt, and Dul stoves, as well as other models. These stoves were selected based on their efficiency, affordability, and environmental impact. The performance of the stove is evaluated through experiments that measure fuel consumption, cooking time, and pollutant emissions. The results show that the Ulzii stove is significantly more efficient than traditional stoves, reducing fuel consumption by up to

50%. The stove also reduces emissions of carbon monoxide, nitrogen oxides, and particulate matter by up to 90%. They're different in their size, material, and mostly the capacity to heat various sizes of gers. For example, the Ulzii stove has 71% efficiency while Dul and Golomt stoves have the capacity to heat 50-66m2 houses in a single burn. The CO2 emission decreased to 70-89% during 360 laboratory examinations. However, the adoption of these stoves may be influenced by factors such as availability, cost, and cultural preferences. For instance, some households may prefer traditional stoves over newer models or may face barriers in accessing or affording certain types of stoves (3).

The thesis reviews the existing literature on the subject of fuel-fired stove automation, coal properties, and combustion processes. Based on this review, the thesis proposes a design for an automated stove that can optimize the combustion process and reduce CO2 emission. The stove is equipped with an electronic control system to monitor the temperature and adjust the air and fuel supply accordingly. The project aim is to improve the Ulzii stove by automating which makes it easier for the locals of Mongolia. Due to extreme air pollution in Mongolia and the sophisticated utilization of heating appliances, the coal briquette stove should be improved. The thesis work submitted by a mechanical engineering student completed the automation of the coal briquette fuel-fired stove which brung many new features to the users and the following thesis work is focused on improving the automated stove.

The use of Turkish stoves, modern stoves, has become a popular heating solution for the traditional Mongolian ger. However, the manual operation of these stoves has become a concern due to the negative impact it has on air quality and the environment. The automation of the stove will allow users to control the temperature of the house with ease without the need for constant manual adjustments. This will result in a more efficient heating process, reducing the amount of fuel needed and ultimately lowering the costs associated with heating a home. In addition, the stove will start burning coal itself eliminating the need for constant supervision and manual ignition. The automation process also included the installation of air blowers and sensors which will work in tandem to monitor and regulate the stove's combustion process. This will result in reduced emissions and improved air quality making it a more environmentally friendly heating option. In summary, the automation of coal briquette stoves is an important step towards improving the heating efficiency of traditional Mongolian gers while also reducing the negative impact on the environment. The thesis concludes that the developed stove has significant potential for improving cooking efficiency, reducing environmental impact, and enhancing user safety. Further research is needed to optimize the stove's design for different fuel types and cooking practices and to develop cost-effective and scalable solutions that can be adopted by households in low- and middle-income countries (3).

○ 1.1 Background

The traditional stove has many disadvantages including air pollution that emits large amounts of smoke which causes 70% of the air pollution in Ulaanbaatar. Therefore, the stove is inefficient and requires a large amount of fuel, twice as much, to produce heat. The biggest disadvantage is the temperature control which the users are seeking in modern stoves. The stove was replaced by the Ulzii stove which brung many new features to the users. The new stove was an efficient and space-saving design. It also distributes heat in five directions evenly. Unlike the traditional stove, it was thin but required only two fires a day. The new design reached its goal significantly by reducing the PM2.5 emission and coal consumption. It increased energy efficiency and reduced energy waste to save bills on coal. Although the stove was a complete success there are a few changes that could be made by assembling additional parts to the stove. The stove has three main body parts which are the body, the base, and the smoke extractor. The working principle is very simple the solid fuel goes into the combustion and the ash falls into the ashpan, and the smoke goes through the smoke intake. It can obtain heat for about 8-12 hours which leaves only two fires a day. The main parts of the stove are made of cast iron which is good at storing heat and transfer to the room. The significance of this work is using modern stoves to automate to reduce manual work which simplifies daily chores. Also, not only the Ulzii stove but the automation of the stove brings creative ideas to the users which can automate other stoves as well (4).

Figure 1: Ulzii stove

Figure 2: Traditional stove

○ 1.2 Problem statement

The purpose of this thesis is to propose a solution to simplify time-consuming work which is heating and poses possible risks to the occupants. The thesis aims to identify the challenges associated with the current methods of heating ger and explore ways to optimize and streamline the process. The improvement on the Ulzii stove was focused on automating and assembling mechanical parts to make the stove work. Yet there are still problems that should be solved to achieve the aim.

Previous improvements on the Ulzii stove were a screw conveyor connected to the motor and a bunker that feeds the stove with coal. The main power is used for the screw conveyor that continuously transfers coal to the combustion chamber. Due to the low capacity of the motor, its power was not enough to rotate the screw conveyor. As we assumed, the automation of the stove should not use too much power to heat the ger. To define existing problems there should be evaluation criteria done on the mechanical parts. These components will be evaluated based on their condition, classified as good, fair, or bad, and determine whether they require partial or complete upgrading or no improvement at all. The evaluation criteria will be done on six essential parts: burner, connector pipe, feeder, ashpan, hopper, and blower. Each component is evaluated by its size, shape, sealing, physical properties, and performance. For the stove, it is important to be efficient

Figure 3: Previous automated stove

○ 1.3 Contribution

The significance of the thesis work lies in its potential to build upon the previous research in the field and improve the performance and efficiency of automated coal briquette fuel-fired stoves. The previous thesis work identified limitations in the automation process due to both design and motor issues. The incomplete automation and lack of temperature control have been significant challenges for stove users in the Ger district of Ulaanbaatar. The inadequate motor capacity has been identified as a significant design problem, affecting the performance and efficiency of the stove. These limitations must be addressed to provide an effective and sustainable solution for stove users. The thesis work aims to overcome these limitations and provide a manual-free stove that is easy to operate and maintain. By improving the automation of the stove, users would be able to control the temperature more effectively, and the stove would operate more efficiently. This would lead to reduced emissions and increased user satisfaction, addressing the problems faced by stove users in the Ger district.

One of the key design problems that need to be addressed is the inefficient screw conveyor that transports coal to the combustion chamber. By improving the design of the screw conveyor, efficiency can be increased, leading to a more efficient and effective stove. Moreover, optimizing the motor capacity and power will improve the performance and reliability of the stove. The implications of this thesis work are significant for both the field of stove design and the communities that rely on these stoves. By improving the design and automation of these stoves, the thesis work offers a sustainable solution to the challenges faced by stove users. The resulting benefits include improved health, reduced environmental impact, and increased economic benefits for the communities that rely on these stoves.

In conclusion, the thesis work has significant implications for the development of more efficient, clean-burning, and user-friendly automated coal briquette fuel-fired stoves. By addressing the limitations of previous research and developing an innovative and effective solution, the thesis work has the potential to make a significant contribution to the field of stove design and development. The resulting improvements in stove design and automation have the potential to transform the lives of stove users in the Ger district and beyond.

○ 1.4Limitations

The automated Ulzii stove is an innovative product that has the potential to significantly reduce the amount of pollution generated from traditional stoves used for cooking and heating. However, despite its many advantages, the automated Ulzii stove has certain limitations that must be considered before investing in the product.

One important limitation of the automated Ulzii stove is its fuel compatibility constraint. The stove is specifically designed to work with briquette coal due to the screw conveyor system's limitations. The screw conveyor is optimized for transporting briquette coal and may not effectively handle other coal types, such as lump coal or loose coal. Attempting to use incompatible coal types may result in inefficient fuel transportation, blockages, or even damage to the stove. Therefore, users must be mindful of the type of fuel they use and ensure that it is compatible with the stove.

Another limitation of the automated Ulzii stove is the complexity of making modifications to the stove. If users intend to install improved additional parts or make modifications to the stove, the process involves cutting and welding. Modifying the stove necessitates disassembling the original design, which adds complexity and requires technical expertise. Cutting and welding are essential to assembling the modified parts, making it challenging for users without the necessary skills or equipment. The automated Ulzii stove's design is not easily adaptable or modifiable without disassembling its original structure. The stove is constructed to specific dimensions and configurations, limiting the options for modification or enhancement. Any significant changes to the stove's design may require substantial alterations, making it impractical or impossible to modify without professional intervention.

Finally, the requirement for cutting and welding, along with the need for technical expertise, adds to the overall cost and accessibility of modifying the automated Ulzii stove. Users may need to engage professionals, which can be costly and may limit accessibility for individuals or communities with limited resources. Therefore, it is important to consider the cost and accessibility of modifying the stove before investing in it.

In conclusion, while the automated Ulzii stove has many advantages, it is important to consider its limitations before investing in the product. The fuel compatibility constraint, modification complexity, and cost and accessibility are all factors that should be taken into account when deciding whether to purchase the stove. By being aware of these limitations, users can make an informed decision about whether the automated Ulzii stove is the right choice for them.

2.Literature review

This literature review aims to comprehensively outline the evolution of stove design, explore the different types of stoves and their functions, and analyze the impact of stove design on air pollution, including efforts to minimize emissions and their effectiveness. The earliest recorded stove, crafted in Alsace, France in 1490, was entirely made of brick and tile, including the flue pipe. Throughout history, cultures have used wood-fired ovens for baking, with Scandinavian stoves featuring a lengthy, hollow iron chimney with iron baffles to extract maximum heat. Russian versions of these stoves, featuring six thick-walled stone flues, are still used in northern countries today. During colonial America, beehive-shaped brick ovens were used for baking, with temperature control managed by burning wood to ash, testing with hands, adding wood, or opening the door to cool down. To provide information on the automation of fuel-fired stoves you are required to be familiar with the history of stoves and their design before industrialization. Stoves, also known as ranges, have undergone significant evolution over time to provide heating for cooking and warmth in households. These appliances can be made from different materials like cast iron and induction and can be powered by sources such as electricity, gasoline, wood, and coal. As environmental concerns have grown, stove design has been improved, resulting in clean-burning options such as pellet stoves, air-tight stoves, and the use of filters and afterburners to reduce emissions. The automation of fuel-fired stoves has been a subject of interest in recent years due to the increasing demand for efficient and environmentally friendly cooking solutions. This literature review aims to explore the current research and development in the automation of fuel-fired stoves.

One of the main goals of automating fuel-fired stoves is to improve their efficiency by controlling the amount of fuel consumed and the temperature of the cooking surface. Research has shown that by using electronic control systems, it is possible to achieve significant reductions in fuel consumption and cooking times. This is achieved by monitoring the combustion process and adjusting the fuel and air supply to maintain an optimal temperature for cooking. Several studies have also looked at the environmental impact of fuel-fired stoves and the potential for automation to reduce emissions. For example, a study conducted in India found that an automated stove with an optimized combustion process reduced emissions of carbon monoxide and particulate matter by up to 60%. Another study in Ghana found that an automated stove reduced emissions of carbon monoxide and nitrogen oxide by up to 75% compared to traditional stoves.

The design of fuel-fired stoves has also been a subject of interest in recent years. Researchers have explored various designs to improve efficiency, reduce emissions, and enhance user safety. For example, a study conducted in Kenya developed an automated stove with a ceramic insulation layer to improve heat retention and reduce fuel consumption. Another study developed an automated stove with a secondary combustion chamber to reduce emissions and improve efficiency. The use of renewable energy sources to power fuel-fired stoves has also been explored. Researchers have developed automated stoves that can be powered by solar energy, biomass, or biogas. For example, a study conducted in Nepal developed an automated stove that could be powered by biogas, which is a renewable energy source produced from organic waste(6).

In conclusion, the automation of fuel-fired stoves has the potential to improve efficiency, reduce emissions, and enhance user safety. Researchers have explored various designs and technologies to achieve these goals, including electronic control systems, improved insulation, secondary combustion chambers, and renewable energy sources. Further research is needed to develop cost-effective and scalable solutions that can be adopted by households in low- and middle-income countries.

■ 2.1 Air Pollution Mitigation Method on Stoves

The use of traditional stoves in Ulaanbaatar is a major contributor to the city's air pollution, making it the most polluted city in the world. The city covers an area of 4704.4 square kilometers and has a population of over 1.2 million people, with 60% of the population living in the ger district and using traditional stoves for heating and cooking. The remaining 40% of the population in households is connected to a central heating system powered by three power plants. To tackle this issue, various approaches such as promoting energy-efficient stoves, expanding the central heating system, and encouraging sustainable modes of transportation must be implemented through collaboration among different stakeholders.

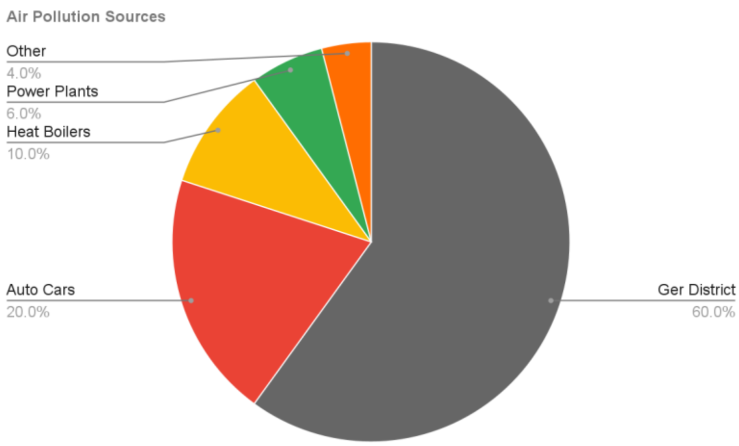


Figure 4: Air pollution sources

According to the pie chart, the Ger district is responsible for the majority of air pollution in Ulaanbaatar. This is largely due to an influx of people migrating from rural areas, particularly those who have experienced livestock loss or other environmental disasters. If this trend continues, it is likely that air pollution levels will continue to rise. One possible reason for the high levels of CO_2 emissions from traditional stoves in the Ger district, as opposed to Ulzii stoves, is the material of the traditional stove and sealing (16).

The conventional stoves utilized in Ulaanbaatar have an iron thickness of 3-5mm, causing them to lose heat rapidly after about three hours. This results in the need for refueling every three hours, leading to a fuel consumption increase of up to 3-50%. To minimize heat loss through joints, it's essential that the stove has a good seal. However, conventional stoves are constructed solely of iron and connected through welding, which reduces their efficiency. Improved stove designs have come a long way in reducing harmful emissions and increasing fuel efficiency. Compared to traditional stoves, these new designs have proven to reduce emissions by 85-95%, while also providing a fuel saving of up to 30%. Additionally, the thermal efficiency of these stoves has been significantly increased, allowing for heat to be retained for longer periods of time.

The Ulzii stove, in particular, is a great example of these advancements. It is made up of 2.5-3.5mm thick iron and has an additional ceramic liner with a thickness of 5cm. This unique design allows for increased heat retention and greater efficiency in fuel usage.

The development of improved stove designs is a crucial step towards creating a healthier environment and reducing the negative impacts of harmful emissions. The Ulzii stove, with its impressive features, serves as a great example of this progress and is a highly recommended option for households and institutions looking to make a positive impact on the environment. To address this problem, improved stove designs have been developed, which not only reduce emissions but also increase fuel efficiency. In this study, we compared the emissions and thermal efficiency of five different stoves: the Ulzii stove, the traditional stove, and the Dul stove. We collected data on the power output, PM emissions, CO emissions, and thermal efficiency of each stove. The data was obtained from manufacturers' specifications, laboratory testing, and field studies. The stoves were compared based on their emissions and thermal efficiency. The Ulzii stove had the best combination of emissions reduction, fuel savings, and thermal efficiency among the stoves tested. It emitted the lowest amount of PM and CO and had a thermal efficiency of 76%. The traditional stove had high emissions and low thermal efficiency, while the Dul stove emitted the lowest amount of PM and CO but had a lower thermal efficiency than the Ulzii stove. Ulzii stove, in particular, demonstrated the best performance in terms of emissions reduction and thermal efficiency. Although the stoves availability is enough, people tend to use traditional stoves due to a lack of information (17).

Name	Power	PM Emission	CO	Thermal efficiency
UBCAP criterion	More than 3kW	Max 70 mg/net	Max 7 g/net Mj	More than 70%
MN55216-2011	3-7kW	200	10	70%
Traditional stove	14	1475	14	76%
Ulzii Stove	7	64	5	76%
Dul stove	11	4	3	73%

Table 1: Different stove's efficiency

■ 2.2 Review of Existing Automation Technologies

Automation is needed in various industries and applications to improve efficiency productivity, and accuracy and to reduce labor costs and human error in the context of fuel-fired stoves automation is particularly important to improve their efficiency and reduce emissions traditional stoves often burn fuel inefficiently leading to excessive fuel consumption increased costs and harmful emissions automation technology can help to optimize the combustion process by controlling the fuel and air supply regulating the temperature of the cooking surface and reducing waste it is not only reducing the environmental impact but also improves user safety and makes cooking more convenient and efficient.

Coal feeding is a crucial part of the combustion process and is often the key factor in determining the efficiency and performance of a coal-fired power plant. Among many feeding solutions, the smart valve system introduces an efficient way to transport coal to the burner, implementing a sectioned coal discharge mechanism that allows for the controlled release of coal in predetermined sections. Valves have become an increasingly popular choice for coal feeding systems, due to their numerous benefits over screw conveyors. In this article, we will explore the advantages of choosing a valve for coal feeding systems in more detail.

Firstly, valves provide more precise control over coal feed rate compared to screw conveyors. With a valve, coal can be dropped in sections or batches, allowing for finer adjustments to the feeding process. This increased control can help optimize combustion efficiency and minimize waste. In contrast, screw conveyors may not offer the same level of control over the feeding process.

Secondly, valves are generally a simpler and more compact solution compared to screw conveyors. They require less space for installation, making them suitable for situations where space is limited. Additionally, valves typically have fewer moving parts, reducing maintenance and operational requirements. This can significantly lower the overall cost of coal feeding systems, making them more accessible to a wider range of users. Thirdly, valves are a better choice when electricity is limited. Unlike screw conveyors, which usually require an electric motor for operation, valves can operate manually or through mechanical means, eliminating the need for electricity. This can be advantageous in remote locations or areas with unreliable power supply, where access to electricity may be limited.Fourthly, valves are often more cost-effective compared to screw conveyors. They tend to have lower upfront costs, as they are simpler in design and require fewer components. Additionally, their maintenance costs can be lower due to reduced complexity. This can be particularly beneficial for users who are looking to reduce their operational costs and increase their profitability.

Finally, valves provide flexibility in terms of coal feed rate adjustments. They allow for quick changes to the feeding process, making them suitable for applications where varying coal demands or load conditions are common. On the other hand, screw conveyors may require more time and effort to adjust their speed or capacity. This can cause delays in the feeding process and decrease the overall efficiency of the system.

In conclusion, valves are an excellent choice for coal feeding systems due to their numerous advantages over screw conveyors. However, it is important to note that the specific impacts of replacing a screw conveyor with a valve will depend on the specific design, application, and operational requirements of the coal feeding system. Therefore, it is recommended to consult with experts or engineers familiar with the specific system to evaluate the potential effects in detail.

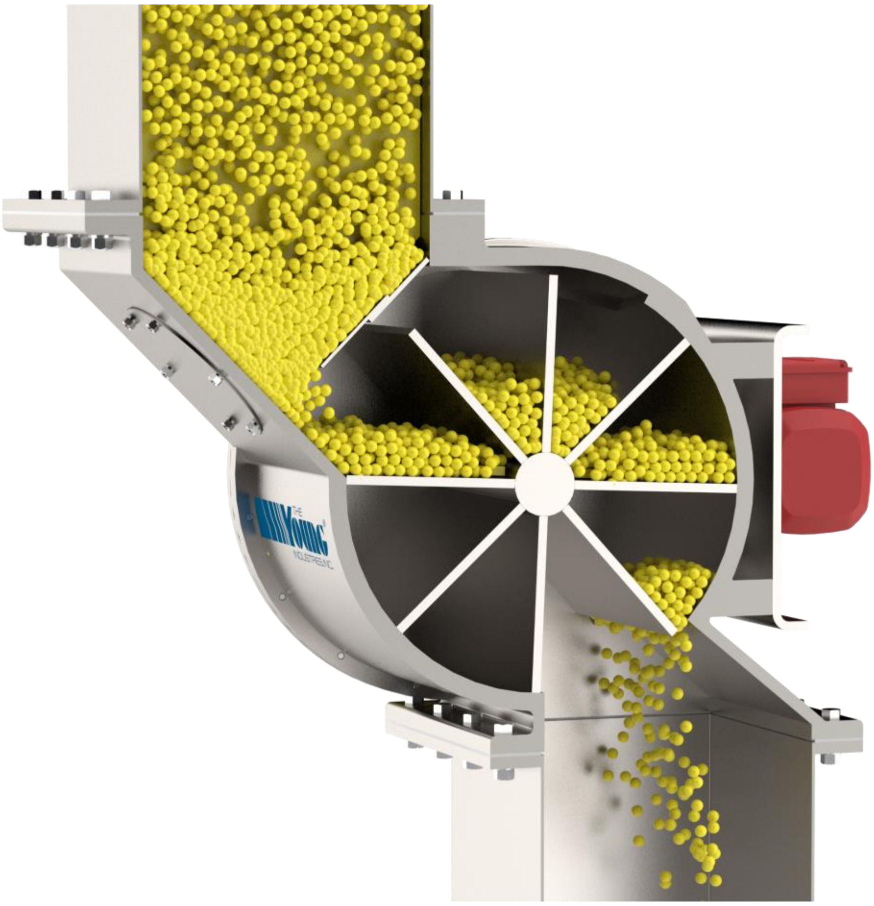


Figure 5: Bulk Material Valve

3. Methodology

3.1 Research Design and Approach

The thesis work aims to improve the previous work which was to automate existing coal briquette fuel-fired stoves to simplify Mongolian people’s lifestyle. Automating a stove is complex work that requires knowledge and practical experience. With the help of previous research, it is now possible to make an evaluation of each mechanical part, define the problem, and create the final design.

As in the forgoing hypothesis, the main obstacle was manual settings when feeding the burner with coal. The manual process takes time and has a risk to burn us. The stove is usually heated by men because of its heavy and hot lid which required an additional handler or it takes time to cool down to fully open the lid by hand. Automation is required for individuals who find it difficult to heat a stove, especially during extremely cold weather.

Nevertheless, accomplishing a project needs to be carefully considered estimations and redesigned multiple times to predict possible difficulties that could occur. First of all, designing a screw conveyor is an essential part because it requires detailed calculations especially when utilizing an inclined conveyor. To identify the problematic mechanical parts, the evaluation criteria on the specific indicator for each part has to be determined. There are five additional parts that can be resulting in the issue. The main problem is that the screw conveyor does not fully transport coal to the burner due to a lack of motor capacity. Even though the capacity was not enough, it would cost much more to choose a larger motor. After finding a problem from the laboratory experiments, the alternative solution was to change the inclination degree of the conveyor and instead of feeding from the bottom, which caused conjunction, dropping from the top was an option. The solution makes the thesis work much easier because there is no need to calculate the combustion condition. The alternative solution involves partially improving or completely redesigning certain sections. To account for sudden changes in shape as a result of the experiment, some parts required a wooden mock-up design.

The research used a mixed method approach quantitative and qualitative data which was the most appropriate to my thesis work. The improved automated stove decision is made on the result of experimental operation which approves that the stove is achieved its final design. To identify potential system malfunctions and determine whether mechanical parts require improvement or not, it is important to establish evaluation criteria for each part of the system. The evaluation criteria should be based on the performance and functionality of the parts, and should consider factors such as efficiency, reliability, durability, and safety.

By evaluating each mechanical part against the established criteria, it is possible to identify areas where improvements may be needed. For example, if a part is consistently failing to meet performance standards or is prone to breakdowns, this may indicate that it requires improvement or replacement.

Once potential problem areas have been identified, further analysis and testing may be needed to determine the root cause of the issue and develop appropriate solutions. This may involve conducting experiments, running simulations, or using other testing methods to evaluate the performance of the parts under different conditions. Establishing evaluation criteria for mechanical parts is an important step in identifying potential system malfunctions and ensuring that products and systems are functioning properly. By regularly evaluating and monitoring the performance of each part, also it can take proactive steps to prevent issues before they occur and optimize the performance of the system as a whole.

○ 3.2 Materials and Equipment

The primary material for the improvement of the automated stove was steel. It is used for welding the design of a screw conveyor and pipe. Because of the material characteristics iron was the most suitable, especially for the specific process environment. The material characteristics of iron made it the ideal choice for the project.

To complete my thesis work, I worked in the mechanical laboratory with the help of a laboratory assistant. Initially, the stove appeared to be functioning properly from the outside. However, upon disassembling the stove, I discovered that the conveyor was only feeding the burner to half of its capacity. This issue means that the stove is not able to reach its full heating potential, and if left unresolved, will require more than two fires a day. Given that the stove has the capacity to heat a ger for 8-17 hours, it is important to find a solution to this problem as soon as possible to ensure the stove is working efficiently and effectively for my thesis work.

Furthermore, to redesign the entire transportation system the stove has to be disassembled to take measurements which means welded parts are cut and reshaped. To take measurements, separated parts are measured with a vernier caliper for precise quantification. Metal cutter and welder used for dismantling and manual discharge required to empty the burner. Also, to quantify the duration of the conveying, a timer, protractor, carpenter's squares, and scale are used.

○ 3.3 Briquette coal fuel preparation and characterization

The characteristics of the fuel used in a stove are crucial as they have a direct impact on the thermal efficiency and physical properties that can influence the design of the screw conveyor. In the case of the Ulzii stove, the high thermal efficiency can be achieved by using briquette coal as a fuel source. Therefore, for the lab experiment conducted, briquette coal was used to obtain data. The briquette coal used was identified as crumbly, making it an ideal choice for the experiment. The table below shows the key characteristics of the briquette coal fuel used in the Ulzii stove:

- The moisture content in fuel is an important characteristic that can significantly impact the thermal efficiency of a stove or furnace. Fuels with high moisture content, such as wood or coal, require more energy to evaporate the water before they can reach their ignition point. This means that a significant portion of the energy produced by combustion is used to evaporate the water in the fuel instead of being converted into useful heat. As a result, high moisture content can reduce the thermal efficiency of a stove or furnace. The energy lost due to water evaporation reduces the amount of heat available for heating the surrounding area, which means that the stove or furnace needs to burn more fuel to achieve the same level of heat output. This increases the cost of heating and can result in more frequent refueling, which can be a hassle and also more expensive in the long run.

  Furthermore, the high moisture content in fuel can also produce more smoke and emissions, which can be detrimental to both the environment and human health. These harmful emissions can include carbon monoxide and particulate matter, which can cause respiratory problems and contribute to air pollution. Therefore, it is crucial to use fuel with low moisture content to achieve higher thermal efficiency and reduce harmful emissions. Using fuel with low moisture content can help to ensure that the energy produced during combustion is transferred to the surrounding area, rather than being lost to evaporating water. This can result in more efficient heating, lower heating costs, and less frequent refueling. In the case of the briquette coal, it was found to have a low moisture content of 1.5%, indicating that it is an excellent option for achieving high thermal efficiency and reducing harmful emissions. By using fuel with low moisture content, such as briquette coal, you can improve the performance and efficiency of your stove or furnace, while also reducing your environmental impact and promoting better air quality

- Ash content is an important characteristic of fuel that has a significant impact on the performance of stoves, furnaces, and boilers. The ash content is the residue that remains after the fuel has been burned, and it is typically composed of minerals and other inorganic substances.

When the ash content in fuel is high, it can lead to several issues that can affect the overall performance of the equipment. One of the most common issues that occur with high ash content is reduced thermal efficiency. The reason behind this is that when the fuel has high ash content, it can clog the burners and reduce the efficiency of the stove or furnace. This happens because the ash accumulates on the heating surface, reducing the heat transfer rate and creating hot spots that can damage the equipment. As a result, the equipment's efficiency decreases, and it requires more energy to heat up the same area. Moreover, the high ash content in fuel can result in the accumulation of soot and particulate matter, which can negatively impact air quality and increase the risk of respiratory problems for those who are exposed to it. The accumulation of soot and particulate matter can lead to the production of harmful emissions, such as carbon monoxide, which can be dangerous when inhaled in high concentrations. Thus, it is important to maintain low ash content in fuel to avoid any negative effects on air quality and respiratory health. On the other hand, low ash content is beneficial for several reasons. It reduces the amount of residue that remains after burning the fuel, which makes maintenance easier and less frequent. Low ash content also helps to improve the thermal efficiency of the stove or furnace by ensuring that the heat produced during combustion is transferred to the surrounding area, rather than being lost to the accumulation of ash. In this way, low ash content can help to reduce maintenance costs and improve the equipment's overall performance. In summary, ash content is a crucial characteristic of fuel that can affect the performance, efficiency, and maintenance requirements of a stove, furnace, or boiler. Low ash content is generally preferable to high ash content as it can improve thermal efficiency, reduce maintenance costs, and avoid any negative effects on air quality and respiratory health. Therefore, it is essential to choose fuel with low ash content to ensure the equipment functions optimally and safely.

- The briquette coal used in the Ulzii stove has a volatility of 20.68%. Volatility is an important characteristic of fuel that can impact performance and efficiency when used in stoves, furnaces, or boilers. It refers to the fuel's tendency to vaporize or evaporate when heated. Fuels with high volatility produce more gases and vapors when heated, promoting complete combustion and improving the efficiency of the stove or furnace. On the other hand, fuels with low volatility may not vaporize or evaporate as readily, leading to incomplete combustion, reduced efficiency, and the production of harmful emissions such as carbon monoxide and particulate matter. Additionally, volatility can affect the ease with which fuel ignites and burns. Fuels with high volatility ignite more easily and burn more rapidly than those with low volatility. Therefore, when choosing a fuel for a stove or furnace, volatility is an important factor to consider as it can impact performance and the time required to heat a room or area. Fuels with higher volatility tend to be more efficient, promote complete combustion, and ignite more easily. In contrast, fuels with low volatility may be less efficient, produce harmful emissions, and require longer periods of time to heat a space. Hence, understanding the volatility of a fuel is crucial in determining its efficiency and performance in stoves, furnaces, or boilers.

- The sulfur content of a fuel is another vital characteristic that can significantly impact the environment and human health. Sulfur is a naturally occurring element that is present in fossil fuels such as coal and petroleum. When these fuels are burned, the sulfur is released into the atmosphere as sulfur dioxide, which can contribute to the formation of acid rain and other environmental issues. Additionally, sulfur dioxide emissions can also exacerbate respiratory problems and negatively impact human health, especially for those who live in areas with high levels of air pollution. The sulfur content of the briquette coal used for the Ulzii stove was found to be 0.45%, indicating that it had low sulfur content. This low sulfur content is highly beneficial as it helps to reduce the negative impact of sulfur dioxide emissions on the environment and human health. By choosing fuel with low sulfur content, such as briquette coal, you can help to promote better air quality and reduce the negative impact of your heating system on the environment and human health. Moreover, the use of low-sulfur fuel can also help to comply with local and national regulations regarding sulfur emissions. Many countries have implemented regulations and guidelines to limit the amount of sulfur emissions from fossil fuels, including coal. By using low-sulfur fuel, you can ensure that you are in compliance with these regulations and contribute to a cleaner and safer environment. The sulfur content of a fuel is an essential characteristic that should be considered when choosing a fuel for a stove or furnace. The briquette coal used for the Ulzii stove has a low sulfur content of 0.45%, making it an excellent option for those who want to promote better air quality and reduce the negative impact of their heating system on the environment and human health.

- The calorific value of fuel is a crucial factor to consider when selecting fuel for heating systems such as stoves, furnaces, or boilers. It is an indicator of the fuel's ability to produce heat when burned. In the case of the Ulzii stove, the briquette coal used had a calorific value of 5200 kcal/kg. This is a relatively high value and indicates that the fuel can produce a significant amount of heat when burned. The efficiency of a stove is determined by several factors, including the type of fuel used. Fuels with higher calorific values tend to be more efficient as they can produce more heat per unit of fuel. This means that less fuel is required to achieve the desired level of heat output, reducing fuel consumption and cost. Additionally, fuels with high calorific values can also promote more complete combustion, reducing harmful emissions and improving air quality. Therefore, the calorific value of the briquette coal used for the Ulzii stove is an important characteristic to consider when evaluating the stove's efficiency. With a calorific value of 5200 kcal/kg, it is an excellent option for those seeking to maximize the efficiency of their heating system.

The product input for briquette coal consists of cleaned or washed coal from Tavan Tolgoi, which makes up 95% of the mixture. The remaining 5% is made up of a starch-based natural binder (2-3%), soot-free materials (1%), and a power mix (1%).

It is essential to consider the composition of briquette coal when choosing a fuel for a stove or furnace. The use of cleaned or washed coal from Tavan Tolgoi, a coal-producing region in Mongolia, ensures that the fuel has a high calorific value, which is an important factor in determining the stove's efficiency. Additionally, the use of a natural binder made from starch helps to reduce harmful emissions and promote better air quality. The inclusion of soot-free materials and a power mix further enhances the fuel's performance and efficiency. Overall, the composition of the briquette coal input is well-balanced and provides a high-quality fuel option for heating systems.

Laboratory	Moisture %	Ash %	Volatility %	Sulfur %	Calories, kcal/kg
The Russian Federal Lab	2.4	22.2	19.6	0.89	6374
Central Geology Lab	1.9	22.7	19.8	0.87	6983.6
Profitable Mineral Lab	2.7	23.3	19.3	0.86	6334.4
Chemical Technology conference	0.8	22.9	18.68	0.89	5918.2
Standard mean	=<10	=< 29	=< 22	=< 1.0	=>4200

Table 2: Coal test by different laboratory

First, the coal sample has a low degree of coking, which suggests that it may not be suitable for use in certain industrial processes that require high-quality coking coal. However, the fact that it has a high calorific value and low moisture content indicates that it could be used for household heating or other energy applications. Second, the ash content, volatility, and sulfur content of the coal sample are all within acceptable limits according to the technical analysis. This suggests that the coal is of good quality and could be used in a range of applications where these factors are important. Third, the chemical composition of the coal sample contains a range of elements, including silicon oxide, aluminum oxide, iron (III) oxide, calcium oxide, magnesium oxide, sodium oxide, potassium oxide, titanium oxide, phosphorus oxide, manganese oxide, sulfur oxide, and other elements. This information could be important in determining the suitability of the coal for certain industrial processes, such as cement production, where specific chemical compositions are required.

Overall, the technical analysis of the coal sample suggests that it is of good quality and could be used for a range of applications. However, further analysis may be needed to determine its suitability for specific industrial processes or to optimize its use in energy production.

○ 3.4 Stove Design and Assembly

Compared to the old version of the stove, the new design became wider to connect the conveyor and stove body. The burner was designed to be fed from the bottom, meaning that the fuel (such as coal or wood) was loaded into the burner by pushing it up from beneath. As the fuel burned, the ashes would drop off from the burner and collect in the ashpan underneath. Feeding the burner from the bottom allows the fuel to be efficiently combusted and the ashes easily removed. Although the design was impressive, it caused a junction when the coal reached half volumetric capacity. The issue with the system's power was traced to a junction occurring in the elbow of the pipe, which was caused by an inclination in the pipe. It was determined that the inclination needed to be reduced or fully improved to address the issue. Initially, changing the motor was thought to solve the problem, but it became apparent that the entire transporting system needed to be redesigned. As a result, the feeding mechanism was redesigned to allow for feeding from the top of the burner rather than from the bottom, and a steel net was added to the bottom of the burner to allow for efficient ash removal. This new design not only addressed the issue with the system's power but also resulted in increased efficiency and ease of use.

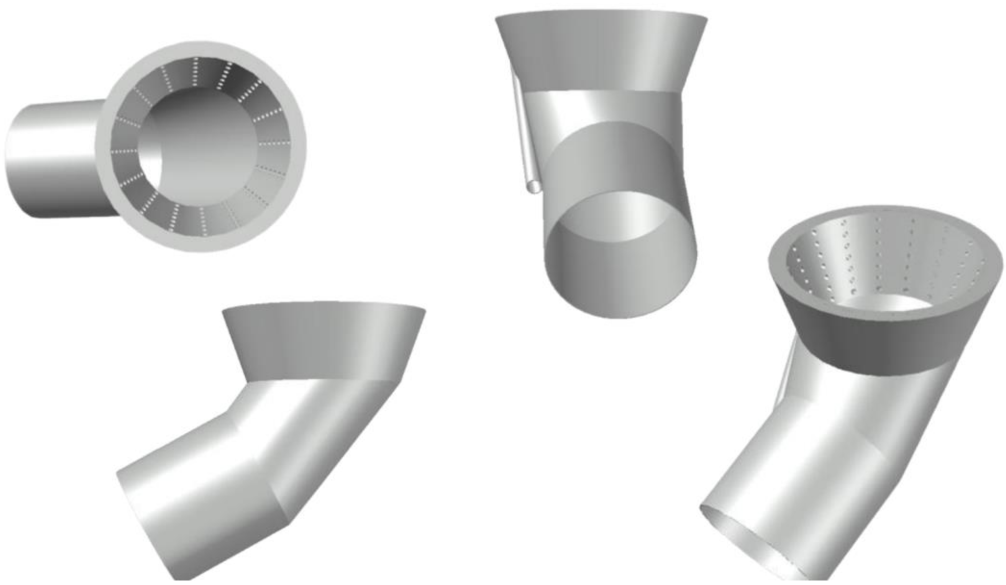


Figure 6: Previous burner design

3.4.1 Choosing a Suitable Motor for the Automation Process

The process itself required determining suitable automation technologies in order to get an efficient design for the users. To accomplish this part of the project, the torque, speed, and power output of the motor must be determined.

The 3-phase induction motor is a type of electric motor that is widely used in various industrial applications due to its high energy efficiency and versatility. This motor is designed to convert electrical energy into mechanical energy through electromagnetic induction, which makes it an ideal choice for a wide range of industrial machinery.

The 3-phase induction motor used in this thesis work is manufactured by Sogears and has a frame size of 632 and an output power of 0.18KW. It is classified as an F insulation class motor, which means it can operate at a maximum temperature of 155°C. The motor is designed to be flange-mounted without a foot, and it has an IP55 protection rating, which means it is protected against dust and water ingress. The working environment is dusty because of the easily crumbling coal and also the motor will be placed in Ger that can meet sudden water inlet. The motor's housing material is made of an aluminum frame, which provides a high level of durability and resistance to corrosion. It is also enclosed in a Totally Enclosed Fan Cooled (TEFC) enclosure, which protects it from external elements such as dust, moisture, and corrosive substances.

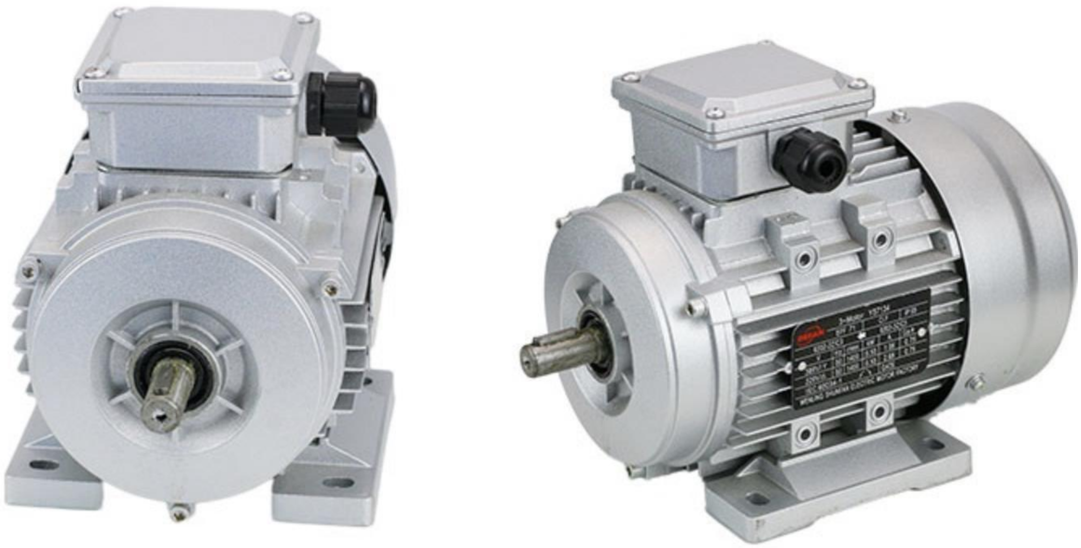


Figure 7: Electric motor

In addition to its use in the thesis work, the 3-phase induction motor is commonly used in various applications such as pumps, fans, compressors, conveyors, and other general-purpose machinery. Its design features make it well-suited for use in harsh environments where protection against external elements is necessary. The motor's high reliability, energy efficiency, and durability also make it an ideal choice for applications where consistent performance is required. Overall, the 3-phase induction motor is a versatile and reliable motor that is suitable for a wide range of industrial applications, including the improvement of automated coal briquette fuel-fired stoves, which is the focus of this thesis work. You will find suitable motor indicators in the table below (13).

1500r/min 380V 50Hz										
TYPE	RATED OUTPUT		RATED SPEED	EFFICENCY	POWER FOCTOR	RATED CURRENT	RATED TORQUE	LOCKED ROTOR TORQUE / RATED TORQUE	MAXIMUM TORQUE / RATED TORQUE	LOCKED ROTOR CURRENT / RATED CURRENT
	Kw	HP	rpm	η%	COSΦ	A	Nm	Ts/Tn	Tmax/Tn	Is/In
YS-5614	0.06	1/12	1400	56.0	0.58	0.28	0.410	2.4	2.4	6.0
YS-5624	0.09	1/8	1400	58.0	0.61	0.39	0.614	2.4	2.4	6.0
YS-6314	0.12	1/6	1400	60.0	0.63	0.48	0.819	2.4	2.4	6.0
YS-6324	0.18	1/4	1400	64.0	0.66	0.65	1.23	2.4	2.4	6.0
YS-7114	0.25	1/3	1400	67.0	0.68	0.83	1.71	2.4	2.4	6.0
YS-7124	0.37	1/2	1400	69.5	0.72	1.12	2.52	2.4	2.4	6.0
YS-8014	0.55	3/4	1400	73.5	0.73	1.56	3.75	2.4	2.4	6.0
YS-8024	0.75	1	1400	75.5	0.75	2.01	5.12	2.3	2.4	6.5
YS-90S-4	1.1	1.5	1420	78.0	0.78	2.75	7.40	2.3	2.4	6.5
YS-90L-4	1.5	2	1420	79.0	0.79	3.65	10.1	2.3	2.4	6.5

Table 3: Motor indicator

The motor indicator is important due to its direct influence on the efficiency of the stove. Motor type YS6324 is well suited for the automation of the stove, larger capacity motors consume much higher energy which is not a priority. The speed of output shaft speed is determined by the motor speed, diameter of the shaft, and gearbox ratio which can be seen by the following Equation below:

Output Shaft Speed = (Motor Speed x Gear Ratio) / (π x Output Shaft Diameter)

Equation 1: Output shaft diameter

Motor speed	1400 rpm
Gear Ratio	1:60
Pi	3.14
Output shaft diameter	11 mm
Output shaft speed	1901.4 (mm/min).

Table 4: Chosen motor indicator

■

■ 3.4.2 Conveying Technologies

One of the main parts of the automation process is transporting coal from the bunker to the combustion chamber. In order to complete the task we need to find an alternative solution when space is limited and suitable for lightweight transporting. For this exact purpose, there are four types of conveyors that could be used for the automation process. Belt, roller, chain, and screw conveyors are mostly used for industries to transport small items through short locations. Due to the number of connecting parts and its simple assembly, the cost-effective and easy-joining conveyor was a helicoid screw conveyor which can be easily created in the correct size and shape by welding and also designed in a helical shape that allows the bulk material to shift along the path. It is preferred over other types of conveyors because they are simple to operate, require minimal maintenance, and can handle a wide range of materials.

Therefore, it is important to determine the screw size, material, and diameter of the rotating shaft to connect with the gearbox and the motor. The blade diameter depends on the diameter of the connecting pipe and its transporting material characterization, commonly used for easy crumbling material. Moreover, the pitch diameter depends on the bulk diameter and the length of the pipe to transport through. The screw conveyor is installed at a correct angle to avoid energy loss. When designing a conveyor, it's crucial to establish the characteristics of the bulk material, including maximum particle size, bulk density, trough loading, abrasiveness, corrosiveness, and flowability. Capacity is then calculated based on the lowest bulk density to achieve the highest potential volumetric capacity. To calculate conveyor speed, equivalent capacity (EC) must be used for specific types of screws, such as short pitch or ribbon flights, which is found by multiplying the required capacity (RC) by three capacity factors.

$$\text{Pitch Diameter} = \text{Outside Diameter} - (2 \times \text{Clearance})$$

Equations 2: Pitch Diameter

Where:

- Outside Diameter is the diameter of the screw
- Clearance is the distance between the outside diameter of the screw and the inside diameter of the center pipe

The initial design of the screw conveyor for the automated stove took into account several important factors to ensure efficient and reliable operation. It was noted that the pitch diameter of the screw conveyor is a theoretical value and that the actual diameter may vary based on manufacturing tolerances and other factors. Additionally, the material being conveyed (i.e., crumbly briquette coal) was considered in the design.

The screw conveyor was designed with a length of 388 mm and three different sections, each with a different diameter (L1=14mm, L2=20mm, and L3=25mm). The pitch of the screw was determined to be 93mm, which determines the amount of material transported per revolution. Environmental factors, such as friction loss HPf (with a value of 210-7 HP), were also taken into account in the initial design. The required power to transport the material, HPm, was calculated to be 610-6 HP. However, it was found that the motor capacity was not sufficient to operate the initial conveyor design without experiencing conjunctions and without providing the burner with a full supply of briquette coal. As a result, the design of the conveyor and burner was modified. The conveyor was made longer (570mm) and inclined at 60 degrees, and the pipe diameter of the screw conveyor was increased to 107mm with a thickness of 4mm. Furthermore, the initial design of providing fuel from the bottom of the burner was abandoned, and the new design involved dropping fuel from the top of the stove onto the burner. These changes were made to ensure the efficient and reliable operation of the automated stove.

The data to the screw conveyor calculation:

Stove height	703.7 mm
Material transported	Briquette coal
Material size	50-70 мм
Fill ratio	0.4-0.9
Number of screw revolutions	
The number of revolutions of the electric motor	1400 rpm
Worm gear transmission with speed limiter	1:60
External diameter of the screw	93 mm
The diameter of the screw shaft	25mm
Step size between screws	93mm
Slope angle with screw feeder stove	30 degrees with “y” axis
Length of screw feeder	507 mm

Table 5: Redesigned screw conveyor measurements

For ease of movement, the design of the screw step is reduced, feeders are used to distribute dust and crumbly materials. Same as a conveyor. Production is 0.5-8 t/h. Formula to find creation:

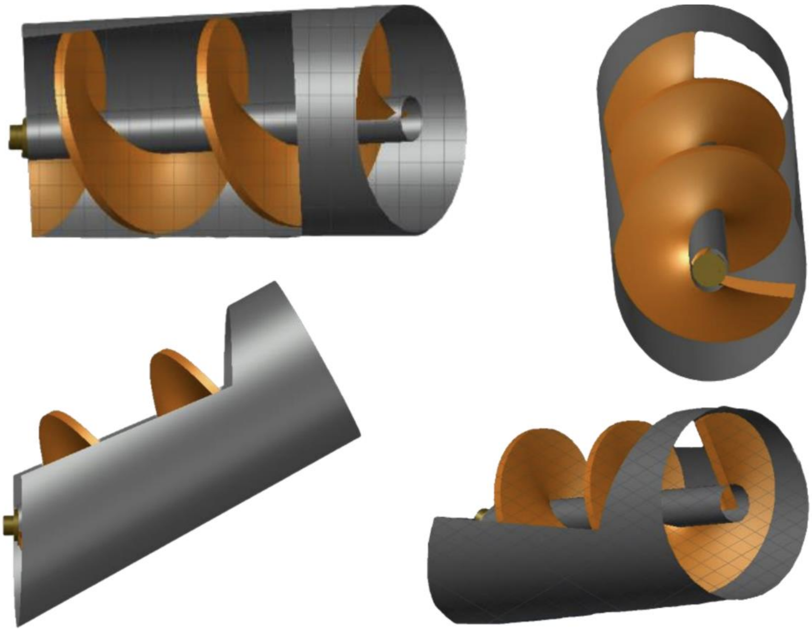


Figure 8: Old screw conveyor design

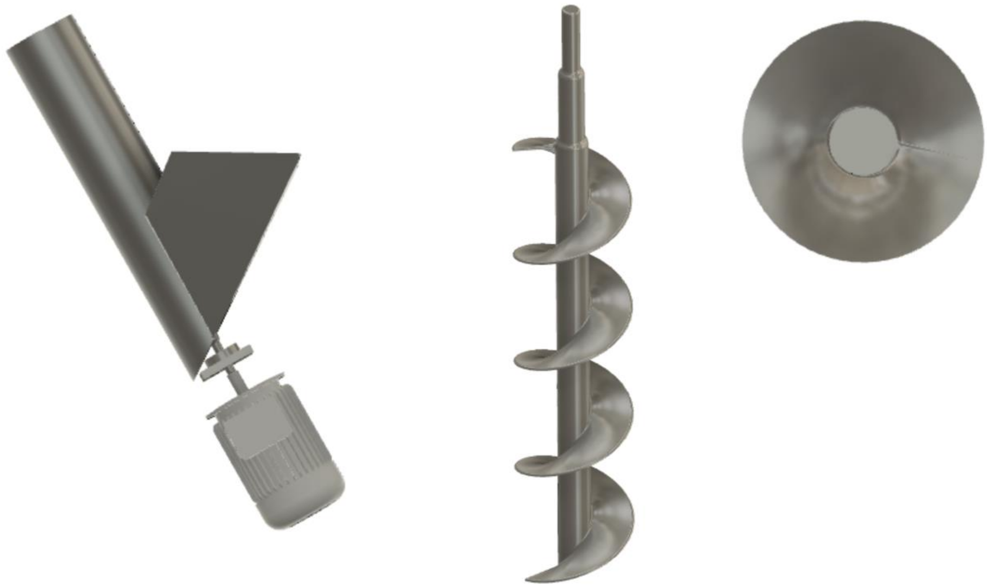


Figure 9: New design of screw conveyor

■ 3.4.3. Burner Design for the Improved Automated Design

Burner of the stove is one of the essential parts that should be designed to improve heating efficiency considering several factors. The main purpose of a burner is to convert a fuel source into heat energy in a controlled manner, typically for use in heating or cooking applications. Also, it is designed to provide a steady, consistent flame or intermittent bursts of heat as required while dropping the ash into the ashpan through the holes specifically made for the purpose. Effective burner design is essential to ensure efficient fuel consumption, minimize emissions, and provide safe and reliable operation.

The main issue that arose was related to the burner during the conveyor's feeding process. There was a junction that caused problems, as the coal wasn't reaching the burner to its full capacity. The initial burner was fed from the bottom by a screw conveyor and changed to be fed from the top for the specific reason mentioned before. The design was to inlet needed air for the purpose of thermal conductivity which helps to burn fast. The combustion chamber and outer retort include a deliberate 20 mm gap to allow for proper air circulation and to minimize the transfer of heat to the inner wall of the outer retort. For the purpose of the new design, the burner is no longer in need. The traditional stoves have clay lining which is made to be a burner and flat iron net to hold the unburnt coal. This arrangement effectively concentrates a significant amount of heat from the burning briquette coal at the bottom of the cooking pan, resulting in increased thermal efficiency in a matter of time. However, the conductive pipe has to be cut and close the old entry for the new design. The volumetric capacity stays the same as the old version.

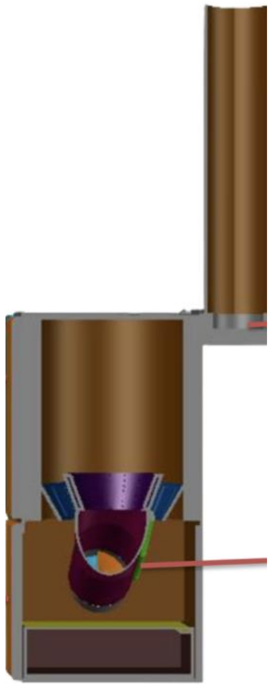


Figure 10: Old burner design, cross-sectional view

- ### 3.4.4. Hopper Design

Due to the change of conveyor, the hopper had to be designed into two sections, top and bottom that also to hold up to 25 kg of coal to continuously feed the burner. Also, the material, design of the hopper, and the material. The cohesive strength of bulk material stored in a hopper affects its flow and can cause arching or ratholing, hindering discharge. The hopper design should consider cone angle and outlet perimeter to prevent arching, and ratholing to ensure proper flow. Parameters like discharge diameter, angle, volume, and discharging rate should be calculated for optimal design. Understanding the characteristics of the product is essential in determining the critical discharge diameter and designing the hopper. The conveyor inclined at 60 degrees which results in to redesign of the old version. The old version needs to be redesigned due to the inclination of the conveyor at a 60-degree angle. The final version will position the hopper and conveyor at a 30-degree angle in order to join the upper part. Even though it is completely redesigned, the locker will hold together two sections.

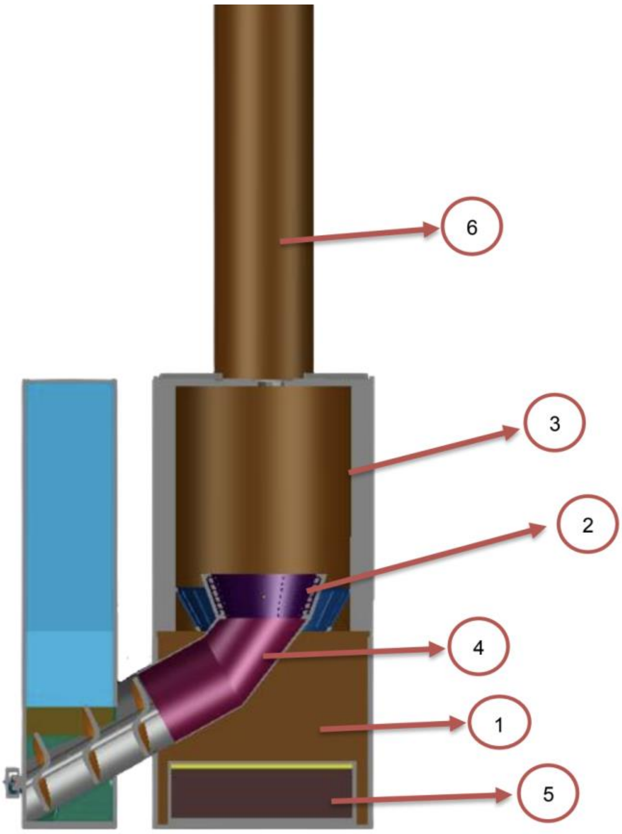


Figure 11: Old design of Ulzii stove, cross-sectional view

• 1 - Stove body. The body of the stove is highlighted in brown, and the stove contains many parts.

• 2 - Burner. Combustion will take place in this burner, and the burner will be made of cast iron and highlighted in purple.

• 3 - Firebricks or liners. Generally, line the inside of the stove and protect the body of the appliance. They also reflect the heat back into the stove, improving efficiency.

• 4 - Conductive pipe. It is responsible for transporting the coal transported by the screw conveyor to the burner. The pipeline is made of fire-resistant material, which is cast iron and is shown in pink.

• 5 - Ashpan. It is responsible for collecting the ash from the combustion and, most importantly, preventing contamination from spilling into the furnace. The ashtray is shown in Figure 16 in dark brown.

• `6 - Stovepipe. Otherwise known as a chimney, it is used for conveying exhaust gases from a fireplace and joins the appliance to the flue system. It would be brown in color, similar to the body of the stove(14).

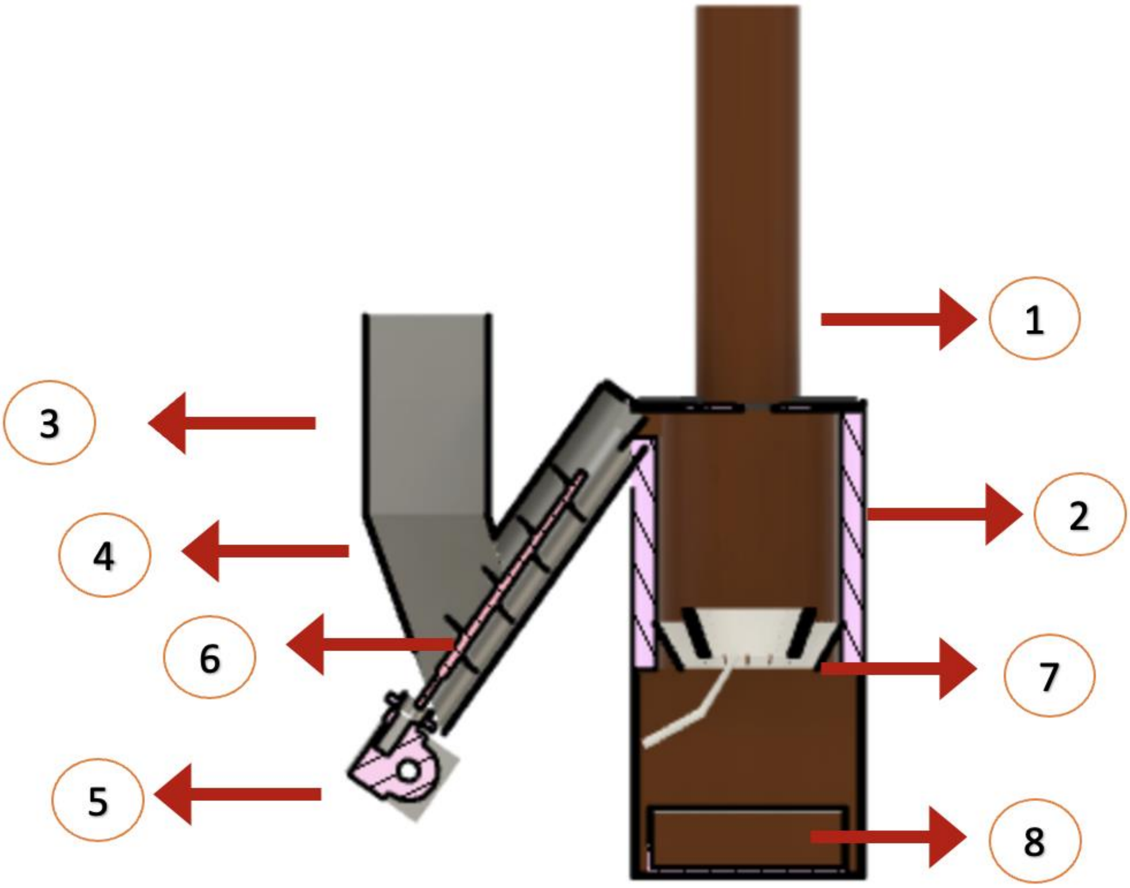


Figure 12: New design of Ulzii stove, cross-sectional view

- 1- Chimney or Stove Pipe
- 2-Firebricks or liners. Generally, line the inside of the stove and protect the body of the appliance. They also reflect the heat back into the stove, improving efficiency.
- 3-Upper part of the hopper. Container that holds up to 25kg of coal.
- 4- The lower part of the hopper.
- 5- Motor & Gearbox
- 6- Screw Conveyor. The primary conductor carries the feed from the hopper to the combustion section.

- 7-Burner. Where the coal burn which made of cast iron.
- 8- Ashpan. Responsible for collecting the ash from the combustion and, most importantly preventing ash from spilling into the furnace.

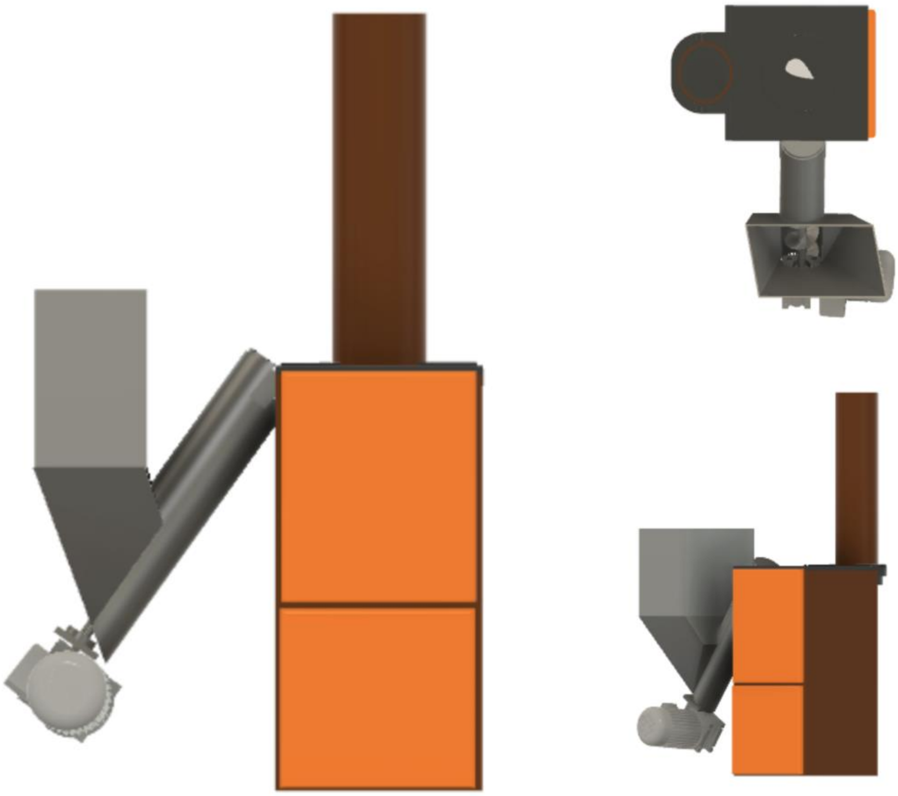


Figure 13: New design of Ulzii stove, a) Front view, b) top view, c) isometric view

4. Experimental Setup and Procedures

The automation of the stove was conducted only on the Ulzii stove due to its compatibility with the automation system. The Ulzii stove is the most common and space-saving design among the different stove models used in Mongolia. Which makes the project more available to the user. Additionally, the Ulzii stove was chosen for the laboratory experiment due to its lower CO2 emissions compared to other stove designs and its good thermal efficiency, which is attributed to its clay lining. The automation of the Ulzii stove involved the integration of a control unit and temperature sensor. The control unit was responsible for regulating the amount of fuel being fed into the stove, while the temperature sensor monitored the temperature inside the stove. The automation system was designed to maintain a constant temperature inside the stove by adjusting the fuel intake based on the current temperature readings. The Ulzii stove was modified to allow for the installation of the automation system. The modifications included the addition of a hopper for fuel storage and a feeder mechanism to regulate the fuel input. The temperature sensor was placed inside the stove to monitor the temperature, and the control unit was connected to the feeder mechanism to regulate the fuel input based on the temperature readings. The automation of the Ulzii stove resulted in improved fuel efficiency, reduced emissions, and increased safety. The automation system allowed for more precise control of the fuel input, which led to improved combustion efficiency and reduced emissions. Additionally, the automation system eliminated the need for manual fuel feeding, reducing the risk of burns and other accidents associated with manual fuel feeding.

While it is true that experimental procedures can be evaluated based on their effectiveness and efficiency, it is important to note that the criteria used for evaluation may vary depending on the nature of the experiment and the specific goals of the research. It is also important to note that the evaluation process should be conducted carefully and systematically, taking into account all aspects of the experimental procedure, including the materials and equipment used, the procedures followed, and the data collected. While it may be helpful to identify areas for improvement based on a "good, fair, or bad" evaluation, it is important to go beyond this simple classification and identify specific areas that need improvement and develop a plan for addressing them. This may involve making small adjustments to the procedure or revising it completely to address more significant shortcomings.

Step 1

Experimental procedures are a crucial aspect of any engineering project as they provide valuable insights into the performance of a part. These procedures typically involve a thorough analysis of the working principle of the part to determine whether it is fulfilling its intended purpose.

To conduct these experiments, the part is first separated from the main body and then connected to a power source independently. The amount of power supplied is adjusted to match the exact degree of welding that was used during the original manufacturing process. This approach allows for the collection of data that is highly comparable to the original design.

In addition to this, the experimental procedures may involve testing the part under different conditions, such as different levels of degree. This can help to identify any potential weaknesses or areas for improvement in the design. Once the experimental procedures have been completed, engineers can use the data collected to refine the design and optimize the performance of the part.

Step 2

Experimental procedures are an essential part of the scientific method. They allow researchers to test hypotheses and gather data to support their claims. In the case of our experiment, we are trying to determine the main factors that affect coal transportation. These factors include the time it takes to transport a specific amount of coal, the amount of coal being transported, and the rotating velocity of the transportation device.

To begin our experiment, we need to supply coal and power to the transportation device. This will allow us to start testing the different factors that affect coal transportation. Identifying the main factors of the experiment is crucial for obtaining accurate results. By determining the time it takes to transport 10 kg of coal, we can understand how much coal can be transported in an exact amount of time. To achieve this, we will use a timer and load sensor to measure the time and amount of coal being transported.

Repeating the experiment multiple times is necessary to obtain accurate results. This allows us to see any variations in the data and helps to ensure that our results are reliable. The experiment needs to be done in a controlled environment to ensure that outside variables do not affect our results.

In summary, our experimental procedure involves supplying coal and power to a transportation device, measuring the time and amount of coal being transported using a timer and load sensor, and repeating the experiment multiple times to obtain accurate results. By following this procedure, we can determine the main factors that affect coal transportation and gain a better understanding of how this process works.

Step 3

Once the necessary data is collected, it will then be utilized to calculate the total power of the motor. This calculation will serve as a crucial step in identifying the main conjunction problem, which may have been previously obscured. By accurately calculating the power, we can gain a deeper understanding of the motor's performance and detect any issues that may be impacting its efficiency. Ultimately, this process can help to optimize the motor's functionality and ensure that it is operating at its full potential.

○ 4.1 Analysis of the Experimental Data

In order to assess overall performance and determine evaluation criteria, two types of data were identified. As mentioned earlier, the first experiment conducted aimed to determine the total power to ascertain if the power was sufficient or not. In this experiment, the inclination degree was set to 24, and the previous motor power used was 0.18 kW. Based on these parameters, the flow rate was calculated and analyzed.

It is worth noting that the process of measuring and analyzing data is crucial in order to achieve optimal performance. Without proper data collection and analysis, it is impossible to accurately assess performance and make informed decisions. As such, it is important to ensure that all data is accurately collected and analyzed to ensure that the results are reliable and informative. The data collected during the first experiment was used to determine the power and flow rate of the system. This data is crucial in determining whether the system is functioning optimally or not, and is essential in making informed decisions about the system's performance. As such, collecting and analyzing data is an important part of achieving optimal performance.

Time /s	Mass/kg
51.67s	4.523kg
44.33s	4.523kg
42.79	4.523kg
41.90	4.523kg

Table 6: Flow rate of screw conveyor

The table presented above shows the flow rate of coal transportation in units of kg/s. In four separate trials, the same amount of coal was transported, each trial taking a different amount of time to complete. Interestingly, as the experiment was repeated, the coal became more crumbly and easier to transport. This led to a reduction in the amount of time required for transportation. This phenomenon can be attributed to the characteristics of coal itself. As the coal particles crumbled, they became more aerodynamic, allowing them to move more easily through the transport system. This is an important finding that could have implications, particularly with regard to optimizing transport efficiency. The following experiment was done after the time remained constant.

$$\text{I}m\text{=4.523kg/41.9s= 0.108kg/s}$$

The previous motor was assumed to be inadequate, prompting an experiment. Due to insufficient power, it was assumed that a conjunction occurred on the elbow of the burner. By analyzing the flow rate, the total power was found, and the results were different from expectations.

Power kW	Time	Flow rate	Y	H	L	D	Mass
2.4508	51.64	0.0875	4	0.29	0.4	0.1	4.523
2.52544	44.33	0.10203	-	-	-	-	-
2.54435	42.79	0.10570	-	-	-	-	-
2.55591	41.9	0.10794	-	-	-	-	-

Table 7: Power calculation

The power found in the automated stove is approximately 2.5 kW, which is considerably higher than what is typically required for a basic stove. As a result, the stove's motor had to be replaced with a more powerful one. However, despite this modification, the problem of conjunction still persists. This may be due to the fact that the inclination degree of the stove was not properly adjusted. Therefore, in order to improve its performance and prevent further complications, it is recommended that the inclination degree be carefully calibrated to ensure that the stove functions optimally.

○

○ 4.2 Performance Evaluation of the Automated Stove

When evaluating a stove, several characteristics must be considered to determine its overall effectiveness. The stove's heat output, energy efficiency, and safety features are all essential factors that influence performance. It's also important to assess the stove's durability, as this can impact its long-term effectiveness.

To comprehensively evaluate the stove's performance, each main factor should be assessed separately. For instance, the stove's screw conveyor should be evaluated on a scale ranging from good, where no further improvement is needed, to bad, where full improvement is required. Similarly, the stove's energy efficiency should be evaluated on a similar scale, with options such as fair and partial improvement needed to allow for a more nuanced assessment.

In addition to evaluating the stove's performance, it's important to consider the safety features it offers. A stove that offers adequate safety features can help prevent fires and other hazards. As such, assessing the stove's safety features is crucial in determining its overall effectiveness. For this purpose, the stove has already installed sensors that detect fume and other hazardous gas. Evaluating a stove requires a comprehensive assessment of several key factors, including heat output, energy efficiency, safety features, and durability. By evaluating each factor separately and using a nuanced scale ranging from good to bad, you can get a more accurate picture of the stove's overall effectiveness.

Burner

The evaluation of a stove's performance requires the consideration of several factors, including the burner's size/capacity and hole position. The burner is the primary additional part that was installed in the previous work, and its evaluation is based on these two essential factors. The size/capacity of the burner is crucial for performance evaluation, as it must be fitted to the stove and have enough capacity to burn the exact amount of coal required to keep the ger heated for up to 12 hours with a single burn. The burner is evaluated as fair, partial improvement, because of the conjunction on the elbow of the burner which was not reaching its full volumetric capacity. Therefore, if the burner isn't the appropriate size, it may not deliver enough heat to keep the ger warm for extended periods. So, the size was too small to contain the proper amount of coal and keep the heat for hours.

The hole position in the burner is also a critical factor to consider when evaluating performance. The hole position allows for air exchange between the burner and stove. Inletting air into the burner helps it burn fast when the ger needs to be heated in a short period of time. However, hole sizes also affect performance, as a hole that's too large will burn the coal too quickly, which is not an efficient option. On the other hand, if the hole size is too small, it may not allow for enough air exchange, causing the burner to burn too slowly and not produce enough heat to warm the ger adequately. During the evaluation of the stove's performance, it was determined that the burner was no longer necessary. However, despite this finding, the original clay liner, which is a part of the Ulzii stove, was still chosen. This decision was made based on several factors. Firstly, the original burner design was meant to transport coal from the bottom, which is no longer needed. Despite the fact that the burner is no longer needed, the original clay liner is still an integral part of the Ulzii stove. It plays a crucial role in ensuring the stove's overall performance. The clay liner helps to retain heat, which is essential for maintaining a comfortable living environment in the Mongolian ger.

Connector Pipe

The pipe that connects the hopper and burner is a critical component in coal transportation. It houses the screw conveyor and is responsible for conveying coal to the burner. The evaluation of the pipe is based on its size and inclination degree, both of which are essential for optimal performance.

The size of the pipe is an important factor to consider when transporting coal. It should be large enough to contain pieces of coal without disturbing the main working process. The diameter of the pipe must be sufficient to handle the coal without causing blockages or disruptions to the transportation process. If the diameter is too small, it can lead to clogs that can disrupt the entire system. Therefore, the size evaluation of the pipe is a critical factor in ensuring optimal coal transportation.

Another important factor to consider when evaluating the pipe is the inclination degree. The inclination degree refers to the angle at which the pipe is positioned, and it is proportional to the power output. The experiment found that the inclination degree must be adjusted to ensure consistent coal transportation. If the inclination degree is too steep, it can cause junctions and require more power to process. On the other hand, if it is too shallow, it can lead to uneven coal transportation, which can also disrupt the overall system.

The diameter of the pipe is determined by the outer diameter of the screw conveyor, and it has a thickness of 2mm, which is suitable for conveying pipe. However, the inclination degree evaluation found that it needs partial improvement to ensure optimal coal transportation. If the inclination degree is not properly adjusted, it can lead to inefficient coal transportation and increased energy consumption.

Hopper

The hopper is a critical part of the coal transportation process. It is an additional component that can hold up to 25 kg of coal, which should last for about 3-5 nights. The evaluation of the hopper is based on various factors, but most importantly, its size, which defines its volume. When designing a feeder, it is crucial to consider not only its efficiency and appropriate sizing but also its aesthetic appeal and space-saving design. It should be designed in such a way that it not only fulfills its purpose but also complements the overall design of the transportation device. Moreover, the hopper should be easy to assemble and disassemble to facilitate easy cleaning and maintenance. The ease of assembly also ensures that the feeder can be assembled quickly and efficiently in a controlled environment during testing.

The hopper must be designed in such a way that it can withstand harsh conditions such as high temperatures and pressure. It should also be made from high-quality materials that can withstand wear and tear, ensuring the feeder's longevity. Lastly, the feeder was fully redesigned for the specific reasons mentioned above.

Feeder/ Screw conveyor

To achieve optimal performance, it is essential to improve the dynamic components of the stove. During the assembly process, the size and inclination of the connector pipe should be carefully considered, as they can significantly impact the stove's performance. If these factors are not taken into account, the stove may not function correctly, leading to suboptimal performance. It is crucial to minimize the load on the shaft, which in turn, reduces the power required from the driven part. This is particularly important as excessive power consumption can cause the stove to malfunction, leading to poor performance. It is worth noting that the previous design of the stove involved welding the shaft to the bottom of the stove and transporting coal while also supporting the collected load. While this design was functional, it may not be the most efficient or practical design for the current situation. To ensure that the feeder for the ger is not noisy when in operation. This is particularly important as the ger is a small space and can be challenging for users if the feeder produces too much noise.

5. Conclusion

The automation of the coal-briquette fuel-fired stove will be a game-changer for the people of Mongolia. For many years, manual fueling of traditional stoves has been a difficult and risky process. Users had to lift heavy pieces of the stove and wait for the fire to extinguish, which was time-consuming and dangerous. The automated stove has revolutionized how people use stoves, making it a safer and more convenient process. In the past, incomplete combustion of traditional stoves caused carbon monoxide poisoning, leading to many deaths in Mongolia. The automated stove provides a small amount of fuel throughout the day, which ensures that the inner temperature of the stove is maintained. This prevents incomplete combustion and reduces the risk of carbon monoxide poisoning. The hopper of the stove can hold a significant amount of fuel, which allows it to last for 3-5 days. This feature is a important improvement over traditional stoves, which required frequent refueling. The risk of burning hands or dropping the cooking pan during fueling is eliminated, making the stove safer to use. The automated stove also includes sensors that detect coal shortages and monitor carbon dioxide levels.

Temperature sensors are also installed to control the ger temperature, which determines whether the stove needs to be fueled or not. These features make the stove more efficient, which is an improvement over traditional stoves.

In addition, the automated stove is more environmentally friendly than traditional stoves. The small amount of fuel provided by the stove throughout the day reduces emissions of carbon monoxide and other pollutants. This is a benefit for the environment and for the health of people in the surrounding areas. Moreover, the automation of the stove has made it easier for people to use. It requires less attention and maintenance, making it ideal for people who have busy schedules and have troubles with lifting heavy things. The stove can be easily operated by anyone, regardless of their physical strength or experience with traditional stoves. In conclusion, the automated coal-briquette fuel-fired stove is an improvement over traditional stoves. It has eliminated the risks associated with manual fueling, reduced the risk of incomplete combustion, and made the stove more efficient, safer, and more environmentally friendly. The development of this technology is a major step forward in improving the quality of life for the people of Mongolia.

• Future Research/Study

The automated Ulzii stove is a remarkable innovation in the field of cooking devices. However, like any other technology, it can be improved to become more efficient, effective, and user-friendly. In this regard, there are several potential future improvements that could be made to the automated Ulzii stove that would make it even more desirable and beneficial to its users.

One of the most crucial improvements that could be made to the automated Ulzii stove is modifying the fuel transport method to accommodate various types of coals. Currently, the stove uses a screw conveyor system that is not very versatile, making it incompatible with some types of coal. By redesigning or replacing this system with a more adaptable mechanism, such as an adjustable belt or pneumatic system, the stove could handle different coal types, including lump coal or loose coal. This enhancement would provide users with more flexibility in fuel selection and availability, enabling them to use the stove with a wide range of coals, depending on their preferences and availability.

Another potential improvement could involve manufacturing the automated Ulzii stove as a single, larger unit that incorporates all the automation parts within the stove itself. This would eliminate the need for separate installation or modification of automation components, making it easier for users to adopt and maintain the stove. Additionally, an integrated design reduces the risk of component damage or misalignment during modification or transportation, which could save users a lot of time and money in the long run.

Apart from functionality, the appearance of the automated Ulzii stove is also an important consideration for many users. Therefore, another potential improvement could involve changing the stove's appearance by using a different material to make it more aesthetically pleasing. The use of a different material could also help to reduce the noise generated when the coal is transported to the burner, which currently takes 40 seconds to feed. By reducing the noise, the stove would become more attractive to users who value quietness in their heating environment.

It's important to note that these are only potential future improvements for the automated Ulzii stove, and their feasibility would depend on technological advancements, research, and development efforts. Each improvement would need to be carefully evaluated and tested to ensure compatibility, safety, and efficiency before implementation. However, by making these improvements, the automated Ulzii stove could become an even more useful and desirable appliance for its users, making cooking more convenient, efficient, and enjoyable.

-

-

References

1. Bielecki C, Johnson M, Hultén J. Performance of an automated wood-fired stove with a chimney in a laboratory setting in Ghana. Biomass and Bioenergy. 2019;124:177-86. doi: 10.1016/j.biombioe.2019.03.021.

2. Ghimire R, Kafle B, Poudel A, et al. Performance evaluation of an automated biogas-fired stove. Renewable Energy. 2020;155:1283-90. doi: 10.1016/j.renene.2020.03.099.
3. GoGo Mongolia. (n.d.). "UB house price has increased by 5.1 times in 10 years." Retrieved April 16, 2023, from https://gogo.mn/r/n3d23
4. ITOIM News Agency. (2017, March 15). "UB ger area population reaches one million." Retrieved April 16, 2023, from https://itoim.mn/article/xEJkv/11768
5. United Nations Mongolia. (2019, March 27). "UN Mongolia statement on air pollution." Retrieved April 16, 2023, from https://mongolia.un.org/en/17396-un-mongolia-statement-air-pollution
6. Wikipedia. (n.d.). "Ger district." Retrieved April 16, 2023, from https://en.wikipedia.org/wiki/Ger_district
7. Ruffolo, D. (2015). "Air pollution in Ulaanbaatar, Mongolia: Understanding the perceptions and behaviors of residents in ger areas." SIT Graduate Institute/SIT Study Abroad. Retrieved April 16, 2023, from https://digitalcollections.sit.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=3109&context=isp_collection
8. National Statistical Office of Mongolia. (2019, February 20). "Total population of Mongolia was 3 million 236.5 thousand." Retrieved April 16, 2023, from http://statis.ub.gov.mn/News?mID=11
9. National Statistical Office of Mongolia. (n.d.). "Statistical database." Retrieved April 16, 2023, from http://statis.ub.gov.mn/n/38
10. United Nations Development Programme. (2012). "Human development report 2011: Sustainability and equity: A better future for all." Library and Archives Canada. Retrieved April 16, 2023, from https://www.collectionscanada.gc.ca/obj/s4/f2/dsk3/OKQ/TC-OKQ-443.pdf
11. Yoder, J. (2014). "Air quality in Ulaanbaatar, Mongolia: Understanding the impacts of air pollution on health in the ger district." Colorado State University. Retrieved April 16, 2023, from https://mountainscholar.org/bitstream/handle/10217/82672/Yoder_colostate_0053N_12293.pdf

12. World Bank. (2015). "Mongolia economic update: Winter is coming." Retrieved April 16, 2023, from https://www.osti.gov/servlets/purl/1165075
13. Electric motor aluminum frame YS6324 0.18KW B5 foot mounted [Internet]. Tools IFBON. [cited 2023 Apr 19]. Available from: https://tools.ifbon.com/electric-motor-aluminum-frame-ys6324-0-18kw-b5-foot-mounted.html#additional.
14. Khuyagbaatar, Enkhmanlai. *Automation of Coal Briouette-Fuel Fired Stove for Gers*. *Esan.mn*, German-Mongolian Institute of Recourses and Technology, 16 May 2022, esan.mn/p/diploma/engineering/mechanical-engineering/automation-of-coal-briouette-fuel-fired-stove-for-gers. Accessed 15 May 2023.
15. IFBON Tools. Electric Motor Aluminum Frame YS6324 0.18KW B5 Foot Mounted [Internet]. IFBON Tools; c2023 [cited 2023 Apr 21]. Available from: https://tools.ifbon.com/electric-motor-aluminum-frame-ys6324-0-18kw-b5-foot-mounted.html#additional
16. Home Inspection Agency of Mongolia. News article: Improved fuel tested in russian laboratories meets requirements of standards. [Internet]. Home Inspection Agency of Mongolia; [cited 2023 Apr 21]. Available from: http://home.inspection.gov.mn/news/295/single/1975
17. 1.“Тавантолгой” шахмал түлшний талаар таван чухал мэдээлэл [Internet]. ttt.mn. [cited 2023 May 15]. Available from: https://ttt.mn/post/71

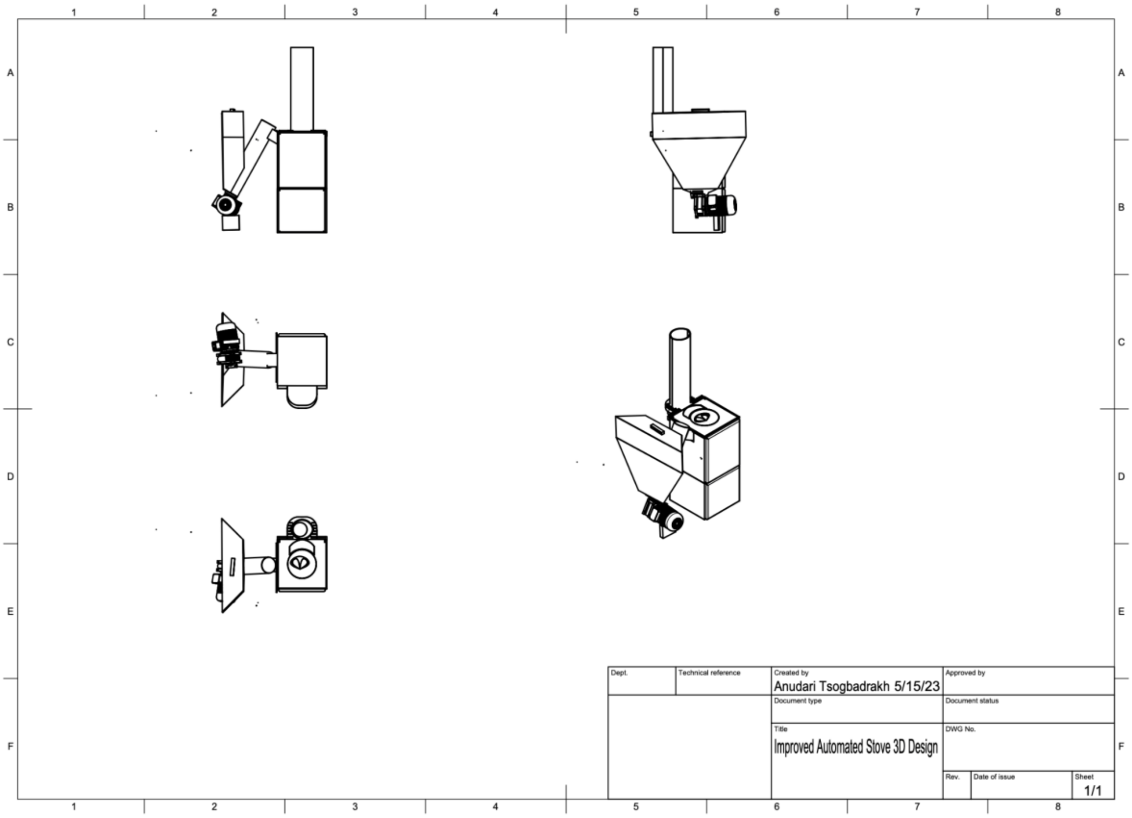
○ Appendices

List of Drawings

1. Engineering drawing of Hopper
2. Engineering drawing of Screw conveyor & Conductive Pipe
3. Engineering drawing of Gearbox
4. Engineering drawing of Ashpan
5. Engineering drawing of Supporter
6. Engineer drawing of Motor

List of Equations

1. Output Shaft Speed = (Motor Speed x Gear Ratio) / (π x Output Shaft Diameter)
2. Pitch Diameter = Outside Diameter - (2 x Clearance)
3. Im=4.523kg/41.9s= 0.108kg/s
4. P=Im×(Y× $L + 4 \div 367) + D \times L \div 20$



Projected View of Automated Ulzii Stove