Design, Manufacturing and Operation of a Down draft Gasifier for Coconut Shell Charcoal Generation in Dankotuwa, Sri Lanka.

Ruwan Nagahawatta, Dilum Perera*, Janith Ratnaweera, Pulina Nilanka

*Memorial University of Newfoundland

*dilum.pe@sliit.lk

ABSTRACT

This study presents the design, fabrication, and operation of a downdraft gasifier specifically developed for coconut shell charcoal production in Dankotuwa, Sri Lanka. Traditional pit methods of charcoal production result in low yields, uncontrolled emissions, and limited process control. The proposed gasifier overcomes these issues by enabling batch feeding of green coconut shells from the top, continuous operation, and controlled partial oxidation to extract charcoal without reducing it to ash. The system incorporates a combustion cone with four strategically oriented air nozzles to ensure uniform material flow and high-temperature combustion, followed by a rotating grate in the reduction zone to regulate charcoal expulsion. Commissioning trials with a 1000 kg feedstock demonstrated a certain charcoal yield of at least 28% (w/w) while generating producer gas of sufficient calorific value to replace approximately three cubic yards of wood logs per 10-hour shift for industrial heating. The dual outputs of charcoal and producer gas provide both economic and environmental benefits, making the system a viable solution for small- to medium-scale enterprises seeking sustainable, low-cost energy.

KEYWORDS: *coconut shells, charcoal generation, down-draft gasifier, syngas, producer gas, industrial heating*

BACKGROUND

In Sri Lanka coconut shell charcoal production is primarily achieved by the traditional pit method. The pit method is basically partial combustion of coconut shells in a limited oxygen environment, using an open earth pit. Products are then quenched utilizing water. This traditional method comes with challenges such as air pollution due to uncontrolled emission of partially combusted gases, lesser yield, and constrained/unavailability of process parameters to control the carbonization process. With reference to the challenges faced in the traditional method, the requirement would arise for a mechanical device which can generate coconut shell charcoal by partial oxidization of the coconut shells(Rahman et al., 2021). As of 2017, there were 41 companies exporting charcoal, out of which main 8 companies proceeded to exporting activated carbon (*Export Market of Coconut Shell Charcoal and Coconut Shell Activated Carbon in Sri Lanka: Drivers and Bottlenecks*, n.d.). Systematic and continuous extraction of the producer gas can be utilized for heating or power generation application. The parameters related to the operation of the machine would provide the ability to control the carbonization rate.

Gasifiers can be seen to be commonly utilized as mechanical devices to generate producer gas and charcoal from biomass. The downdraft gasifier is a type of gasifier construct specifically used due to its lower tar generation rate characteristic. In downdraft gasifier fuel is loaded from the top. It mainly consists of drying, pyrolysis, combustion and reduction zone. In applications focusing only on the producer gas generation, ash will be output of the process. The reduction of the biomass inside the gasifier can be varied by design or operation to ensure extraction of charcoal as per the desired quality and quantity. The subject novel design discussed herein, is a downdraft type gasifier designed to extract coconut shell charcoal from green coconut shell, as the feedstock(Kelaiya et al., n.d.). The continuously extracted producer gas is of desired quality, which can be utilized for heating applications or power generation.

THEORY

Technical problem

https://doi.org/10.54389/LIIV3597

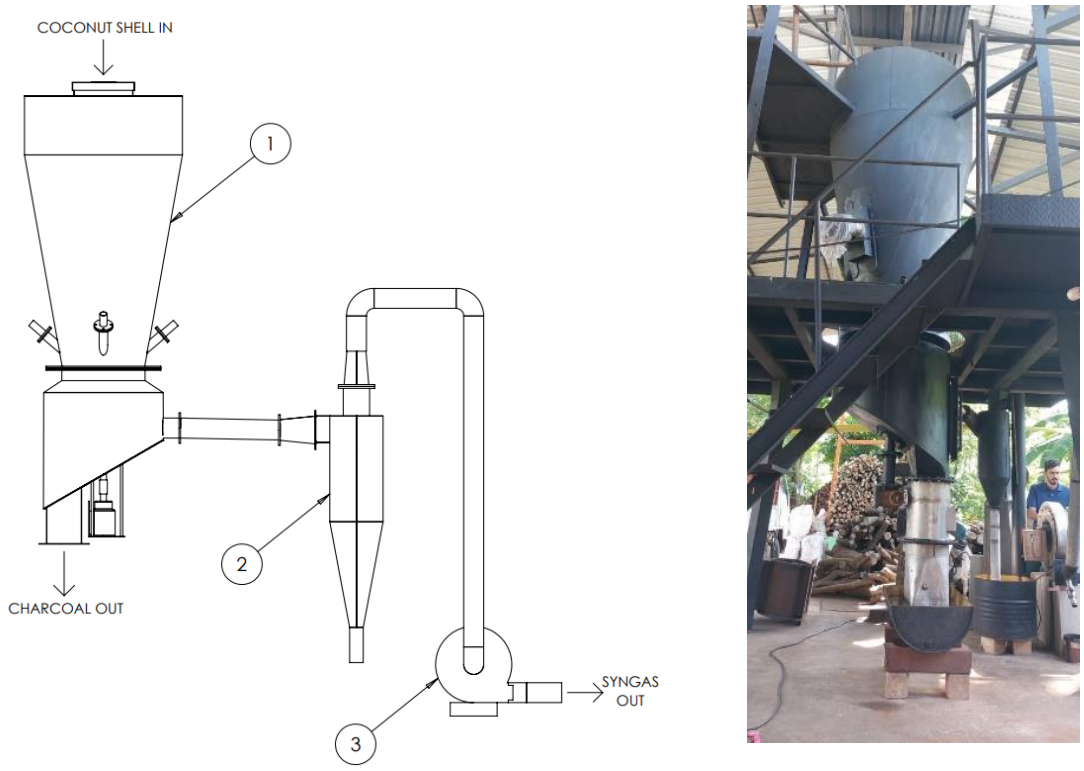
Utilization of coconut shells as the feedstock for a downdraft gasifier operation poses multiple challenges. Operating for extraction of coconut shell charcoal can be further challenging. In existing designs, the coconut shells would undergo the processes of drying, pyrolysis, combustion and reduction, which generates ash. The design discussed here is able to extract the feedstock as charcoal avoiding reduction of the same resulting in ash generation. The design ensures avoiding bridging of the coconut shells inside the gasifier which can disrupt the continuous operation of the machine.

Technical solution

The coconut shell charcoal is batch fed from the top where a healthy stock is maintained in the hopper. With the continuous operation of the unit, the shells will flow downwards. The material in the hopper will experience drying and pyrolysis processes in order (top to bottom), due to the heat transferred to the top from the combustion zone. After the hopper, material will flow through the throat area in the combustion cone. The throat in the combustion cone creates a restricted area where residence time (flowrate of the material) is controlled. Utilizing four nozzles, fresh air is supplied into this combustion cone creating a high temperature combustion zones. The nozzles are oriented in such a manner that the draft generated supports continuous downward flow of the material.

Below the combustion cone is the reduction bed, where its bottom will be a rotating grate. A bed of material is maintained on this rotating grate. The rotating speed of this grate will determine the charcoal expelling rate from the bed of material. The reduction bed is designed to ensure a generous amount of space for charcoal extraction from the bed. By controlling the grate speed, the extraction stage of the material was controlled, thus avoiding ash generation. The material will be extracted at the charcoal stage avoiding further reduction which will result in ash generation. The charcoal which falls off the edge of the rotor and reduction bed will be collected at the bottom of the outer cylinder. It will be then dry collected utilizing two air-locked sliding doors. This enables dry collection of charcoal without disrupting the continuous operation.

DESIGN AND FABRICATION



1(a) **1(b)**

Figure 4(a) & (b) – Design and fabrication of the charcoal generator

The design calculations and conceptualization were adhered to the guidelines made by the author's previous work. (Perera et al., 2024). The design and fabricated version of the charcoal generator are illustrated in Figure 1(a) & 1(b).

RESULTS



2(a) **2(b)** **2(c)**

Figure 5(a) – Green Coconut shell as the input; 2(b) - Charcoal as the main product; 2(c) - Producer gas as the byproduct.

A load of 1000kg was successfully processed in the system during the commissioning of the unit. In contrast to the traditional pit method, this design was able to obtain the yield of charcoal as well as producer gas. The owner of this charcoal gasifier was a coconut oil producer. With the help of a Air heat exchanger, the coconut kernels were dried utilizing the heat gained from the combustion of the producer gas.

Industrial applicability and Advantages

The gasifier was commissioned in 2023, and it was proven that the gasifier was to work as per the specified operating conditions of 800kg per 10-hour shift feed rate. The design was initiated in 2019. In spite of construction being scheduled to be 6 months, due to the status of the country of social economical unrests and corona virus, it took nearly 4 years to fabricate the design.

Batch feeding is done from the top while continuous operation can be carried out. The design is able to avoid common challenges related to downdraft gasifier operation on coconut shells, such as channeling and bridging of the fuel. The gasifier is able to extract (dry collection) the coconut shells at the charcoal stage without complete oxidation of the solids which will result in ash generation. The producer gas which is generated as a byproduct has a colorific value hence can be utilized as a gaseous fuel input for any heating application or power generation purpose.

In this particular installation, the gasifier was able to generate a charcoal yield not less than 28% (w/w basis) while also generating sufficient Producer Gas which catered for the previous woodlogs requirement for the heating application. Considering 10 hours shift per day, savings from fuel alone, accounted for the cost of approx. 3 cubic yards of wood logs. By selling the coconut shell charcoals, the plant user earned extra income which further justified the investment.

CONCLUSION

The development and successful commissioning of the downdraft gasifier for coconut shell charcoal generation in Dankotuwa, Sri Lanka, demonstrates a practical and sustainable alternative to the traditional pit method. The novel design effectively addresses the common challenges of fuel bridging, uncontrolled emissions, and ash formation, while enabling continuous operation with batch feeding of green coconut shells.

Trial runs provided a charcoal yield of at least 28% (w/w) along with simultaneous production of producer gas of adequate calorific value for industrial heating applications. This dual output not only reduces dependency on conventional firewood but also generates additional revenue through the sale of high-quality charcoal. Furthermore, the controlled operation of the system minimizes environmental impacts by reducing particulate and gaseous emissions compared to open-pit combustion.

This design is suitable for small and medium scale entrepreneurs who need sustainable energy requirements at lower cost.

ACKNOWLEDGEMENTS

Mr. Indika, the owner of coconut oil production facility at Dankotuwa, Sri Lanka is thankfully acknowledged.

REFERENCES

1. *Export Market of Coconut Shell Charcoal and Coconut Shell Activated Carbon in Sri Lanka: Drivers and Bottlenecks*. (n.d.). Retrieved July 30, 2025, from https://www.cabidigitallibrary.org/doi/pdf/10.5555/20183230597
2. Kelaiya, S., Dobariya, U., & Makavana, J. (n.d.). *Experimental Investigation on Open-Core Downdraft Gasifier for Bio-Char Production and Gaseous Fuel from Caster Stalk—Google Search*.
3. Perera, K. D. M., Ratnaweera, H. G. J. N., & Nilanka, A. A. P. (2024, October). *Design and Development of a 50kW Producer Gas Generator in Sri Lanka*. SLIIT International Conference on Engineering and Technology. https://rda.sliit.lk/handle/123456789/3801
4. Rahman, M. M., Aravindakshan, S., & Matin, M. A. (2021). Design and performance evaluation of an inclined nozzle and combustor of a downdraft moving bed gasifier for tar reduction. *Renewable Energy*, *172*, 239–250. https://doi.org/10.1016/j.renene.2021.02.156