Development and Performance Evaluation of Paddy Husk Powered Electricity Generator

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Keywords—Rural Electrification, Paddy Husk, Sustainable Energy, Generator design, Gasification Technology

I. INTRODUCTION

Many agrarian countries, including Sri Lanka, generate substantial quantities of paddy husk, an underutilized agricultural byproduct with a thermal energy density commonly reported in the range of 12 – 15 MJ/kg[1]. This study examines the feasibility of converting paddy husk into a renewable energy source through a steam-based thermal power generation system, aiming to provide a sustainable solution for rural electrification and reduce reliance on conventional fossil fuels. The research aims to develop a sustainable electricity generation method utilizing paddy husk as feedstock, thereby presenting an economical and eco-friendly energy alternative. It emphasizes adding value to agricultural waste while establishing an independent power source for rural and off-grid communities.

This study presents a new method for energy conversion through the direct combustion of paddy husk to produce steam, contrasting with complex gasification technologies that require extensive tar-cleaning and engine adjustments. The project emphasizes creating an integrated steam-turbine generator, evaluating its steam generation, turbine efficiency, and power output under practical conditions, offering a simpler and more durable alternative that can be locally manufactured.

II. LITERATURE REVIEW

Paddy husk, the fibrous outer layer of rice grains, is produced in substantial volumes in agrarian economies such as Sri Lanka. With a calorific value of approximately 12–15 MJ kg^{-1}, it represents a significant yet underutilized biomass resource. Previous research has primarily explored thermochemical conversion of rice husk into producer gas through downdraft gasification, yielding heating values in the range of 1.2–1.4 MJ Nm^{-3} and cold-gas efficiencies exceeding 60% under optimized operating conditions [2]. Rice husk has adequate energy content for small-scale power generation, although challenges such as tar deposition, high ash content, and the need for careful control of engine parameters and gas-cleaning processes affect system stability and reliability [3]. Gasifier-based power systems face feasibility challenges in decentralized or low-resource settings. While rice husk demonstrates energy potential compared to other lignocellulosic feedstocks like sawdust and coconut shell, successful integration of the entire energy-conversion chain is crucial for ensuring reliable system performance. [3][4].

Resource-mapping and techno-economic analyses indicate significant untapped potential for rice-husk-based decentralized power generation in Sri Lanka, primarily from agricultural residues like rice husk and straw. Current literature emphasizes gasifier reactor performance and syngas composition, neglecting the development of small-scale, locally producible systems for rural use [4]. This study focuses on a direct combustion method to generate steam for a small-scale turbine, eliminating the complexities of gasifier systems. The performance of the steam-turbine generator using paddy husk was evaluated under real conditions, demonstrating its feasibility as a sustainable power source for off-grid electrification.

III. MATERIALS AND METHODS

- Raw Materials

The raw materials used for the prototype fabrication included mild steel, paddy husk, water, box bars, copper tubes, pressure valves, safety valves, and nuts and bolts. These were selected based on strength, heat resistance, and availability.

- Prototype Design

A miniature prototype of the paddy husk–based electricity generator was designed using SolidWorks software to visualize the mechanical layout and operational mechanism before fabrication.

- Fabrication Process

The fabrication process began with cutting and shaping mild steel sheets and box bars. Each part, including the

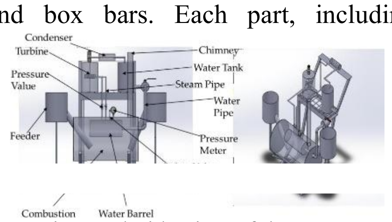

Fig. 1. Front view and Side view of the generator

combustion chamber, water tank, steam barrel, copper tubing, and turbine assembly, was manufactured separately. Components were joined using welding and nut-and-bolt joints. Finally, all units were assembled into a functional generator system.

- Paddy Husk Preparation

Paddy husk was prepared as the biomass fuel for combustion. First, 2.00 kg of husk was weighed, and the moisture content was analyzed using the formula:

Equation 1: Analyze the moisture content of the paddy

$$Moisture\ Content\ (\%) = \frac{Wet\ weight\ -\ Dry\ weight}{Dry\ weight} \times 100$$

The obtained moisture content was 10.42%, which lies within the suitable range (10-12%) for optimal combustion. Excess moisture was removed by sun-drying, and the prepared husk was stored in dry, well-ventilated conditions before being fed into the combustion system.

- Combustion and Power Generation

The working process involves combustion of paddy husk to generate heat, which converts water into pressurized steam. The steam flows through copper tubes to the turbine, producing electricity through mechanical rotation. The condensed steam is recycled into the water tank, forming a closed-loop system.

The assembled prototype was tested to evaluate its performance and efficiency, confirming that the paddy husk-based generator can effectively produce electricity and serve as a sustainable option for small-scale renewable energy generation.

IV. Result and discussion

The experimental evaluation of the paddy husk-based electricity generator assessed combustion performance, steam generation, turbine operation, electrical output, and economic feasibility. The results are summarized in Tables I-II.

The combustion of 2 kg of paddy husk over 30 minutes generated stable thermal energy and steam pressure sufficient to operate the turbine effectively. The low ash content (4.03%) indicates that approximately 95.97% of the feedstock mass contributed to energy production. The calorific value of 13.54 MJ·kg^{-1}, slightly higher than the raw feed (13.0 MJ·kg^{-1}), reflects the efficiency of the combustion process. Thermal energy released during combustion (26 MJ) confirms the suitability of paddy husk as a viable biomass fuel for small-scale electricity generation.

TABLE I. Combustion and steam performance

S.No	Parameter	Value
1	Feedstock mass	2 kg
2	Average temperature	202 °C
3	Steam pressure	30 psi
4	Ash content	80.6 g (4.03%)
5	Thermal energy released	26 MJ

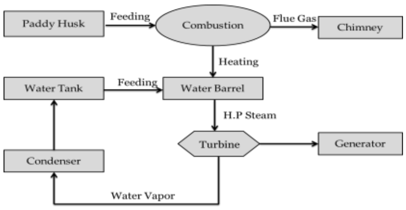

Fig. 2. Flow Chart of the Generator Process

TABLE II. Turbine and electrical performance

S.No	Parameter	Value
1	Turbine rotational speed	852 rpm
2	Turbine conversion efficiency	29-42%
3	Electrical power output	2.18-6.07 kW

The turbine achieved an average rotational speed of 852 rpm, indicating that steam flow was adequate for effective operation. Conversion efficiency ranged between 29% and 42%, consistent with small-scale biomass-fired steam systems under sub-optimal conditions. The electrical power output varied from 2.18 kW to 6.07 kW, depending on the operational parameters. These results suggest that thoughtful design enhancements, such as refined turbine geometry and improved insulation, could further elevate overall system efficiency. The economic assessment of a generator with a total cost of Rs 25,000 and a lifespan of 5 years shows a capital cost of Rs 0.96 kWh^{-1} for a 2.18 kW system and Rs 0.34 kWh^{-1} for a 6.07 kW system. The overall unit cost ranges from Rs 1.46 kWh^{-1} (using paddy husk waste) to Rs 4.0-6.0 kWh^{-1} (with collection cost). The system's low ash content (4.03%) reduces maintenance and disposal expenses, making it economically attractive, especially for rural communities. This solution promotes renewable energy from paddy husk, reducing fossil fuel dependence and enhancing energy self-sufficiency.

V. Conclusion

The developed compact steam turbine system successfully demonstrates the feasibility of using paddy husk as a renewable biomass fuel for small-scale power generation. Improved heat insulation and controlled combustion are crucial for enhancing efficiency, especially since the moisture content significantly affects performance. Scaling up through modular designs could support rural microgrid applications, while integrating sensors and automated controls for pressure, temperature, and feed rate would improve operational stability and safety. Further investigations into particulate emissions and ash reuse are recommended to enhance environmental sustainability, making this system a viable model for decentralized, eco-friendly energy solutions. Table 1: Combustion and Steam Performance

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