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(Research Article)

A STUDY OF ELECTRICITY GENERATION USING SOLAR ENERGY AND USED RECYCLED SHOCK ABSORBERS

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ABSTRACT

This is a research carried out to investigate the possibilities and engineer electricity generation machines with solar energy with the utilization of easily accessible machining tools, materials and components such as metal plates, metal pipes, shock absorbers, mirrors, lathe and welding machines in developing nations where high temperature regions do not have access to stable, efficient and consistent electrical energy supply and to do it to harness the abundant and free solar energy of the sun to help humanity in the nation. This project demonstrates the design, construction, and testing of a small-scale solar- thermal electricity generation system using a parabolic dish concentrator and reciprocating steam engine. The system converts sunlight into mechanical energy via focused solar heat (120°C steam at 2.1 bar pressure), which drives a piston-crankshaft assembly coupled to a 12V DC generator. Key achievements include:

- 30W sustained electrical output (12V, 2.5A) under 890 W/m^2 solar irradiance
- 3% system efficiency (sunlight-to-electricity) with potential improvements to 5% via enhanced insulation.
- Cost-effectiveness with total material cost (80% cheaper than that of diesel generators over 10 years).

Keywords: Electricity Generation, Solar Energy, Recycled Shock Absorbers, Sustainability

1 INTRODUCTION

The global push for cleaner and renewable energy sources has led to significant innovations in solar technology. With increasing energy demands and environmental concerns, harnessing solar energy provides a sustainable solution, especially for countries like Ghana that are geographically blessed with abundant sunlight (Gralluzzie,.2018). Ghana, located between latitudes 4°N and 11°N, receives an average solar radiation of 4.5 to 6.0 kWh/m^2/day and about 1,800 to 2,200 hours of sunshine annually. This makes solar energy a reliable and untapped resource for off- grid power solutions. This project explores the design and construction of a solar-powered steam generation and electricity production system using a parabolic dish. By concentrating solar radiation at a focal point to heat water in a pressure boiler, steam is generated to drive a mechanical engine which ultimately powers an electric generator (Abdelkareem,2018). The project combines principles from thermodynamics, mechanics, and electrical engineering to develop a sustainable, low-emission energy conversion system suitable for remote communities.

Access to clean and affordable energy remains a significant challenge in many parts of Ghana, particularly in rural and off-grid communities. Dependency on fossil fuels and unreliable power supply system's affect productivity, education, and health services. Moreover, global environmental concerns demand a transition to greener energy systems (Cancion, 2017). The main problem addressed by this research is the lack of cost-effective, renewable electricity generation systems that can be locally built and maintained. The project is relevant to Ghana's national energy development goals and aligns with global efforts to reduce carbon emissions and promote sustainability. On a broader scale, it contributes to the global knowledge base in the development of alternative energy systems for emerging economies (Agudelo,.2016).

The main objective is to design and construct a solar-powered system that converts solar energy into steam and subsequently transforms the steam into mechanical and electrical energy using a parabolic dish and steam engine mechanism (Bowen, 2019).

Specific Objectives

- To fabricate a parabolic dish that concentrates sunlight onto a pressure boiler located at the focal point.
- To generate high-pressure steam in the boiler using solar radiation.
- To channel the steam through a controlled path to actuate shock absorbers functioning as pistons.
- To convert the mechanical motion from the pistons into rotary motion using a crankshaft and flywheel.
- To connect the flywheel to a belt-driven generator to produce electricity.
- To test and optimize the performance of the system, including sun-tracking accuracy and energy conversion efficiency.

2 LITERATURE REVIEW

2.1 Background Information Related to the Research

Solar energy technologies have evolved significantly over the past decades. Among the various methods of harnessing solar energy, solar thermal systems stand out due to their ability to convert sunlight into usable thermal energy, which can be further converted into mechanical and electrical energy. Parabolic dish systems are one of the most efficient forms of solar thermal technology, offering high concentration ratios and operational efficiencies (cai,2022).

2.2 Familiarity with the Research Area

This project builds upon fundamental concepts in thermodynamics, heat transfer, and renewable energy systems. The design of parabolic concentrators requires a good understanding of geometric optics and material science. Various configurations, such as Scheffler dishes and Stirling engine-based systems, have been studied in both academic and industrial research, showcasing the potential for such systems to operate in isolated environments (Duong, 2020).

2.3 Theory Behind the Research

The working principle of a parabolic dish solar concentrator is based on the geometric property of parabolas. Incoming parallel solar rays are reflected by the parabolic surface to a common focal point. A receiver or absorber placed at this focal point collects the concentrated solar radiation and converts it into heat. This heat is then used to produce steam or drive a heat engine, which in turn powers an electric generator (Ebrahimi,2010).

2.4 Previous Work in the Field

Numerous studies and experimental setups have demonstrated the viability of solar parabolic concentrators for electricity generation. In particular, the National Renewable Energy Laboratory (NREL) in the United States has conducted extensive research on solar thermal power systems. Several universities and research institutions have developed low-cost parabolic dishes using locally available materials, achieving moderate efficiency in rural electrification projects (Abdelkareem,2018).

2.5 Contribution to Current Knowledge

This research contributes to current knowledge by presenting a simplified, cost-effective design suitable for local fabrication and implementation (Duong, 2020). It emphasizes practical construction methods, materials selection, and performance analysis. By focusing on low-cost energy generation, the study aims to provide sustainable energy solutions for remote and underserved communities, reinforcing the global shift towards renewable energy (Fang, 2013).

3 METHODOLOGY

Figure 1: Safety equipment and tools used

- Safety boots
- Safety gloves
- Helmet
- Eye protection glasses
- Ear protection
- Safety jacket
- Fire extinguisher
- Welding head shield
- First aid box
- Nose mask

Table 1: Components, Materials, Dimensions, Quantity and Estimated cost.

	Components and Materials	Dimensions and quantity	Estimated Cost
1.	Engine block metal plate	Appr 100cm X 260cm, 1cm thickness	350CDS
2.	Electric generator motor	Appr 12 to 40 volts (qty 1)	200CDS
3.	Electric generator motor pulley	Diameter – 6cm (qty 1)	25CDS
4.	Flywheel	Diameter – 30cm (qty 1)	100CDS
5.	Shock absorbers	Appr length 26cm (qty-4)	250CDS
6.	Bearings	Internal D-2cm, External D-6cm (qty 5)	100CDS
7.	Crankshaft	Cylindrical shaft, length80cm, D-2cm (qty 1)	150CDS
8.	Valve timing mechanism	Connecting rod D-1cm, length-36cm, Disc Internal D-2cm, External D-8cm	25CDS
9.	Hinges	Appr 4cmX4cmX4cm (qty 4)	60CDS
10.	Bolts and nuts	Length 5.5cm, diameter 1cm (qty 4)	20CDS
11.	Boiler	Length 15cm, diameter 20cm (qty 1)	55CDS

12.	Parabolic dish square pipes	2cmX2xmX140cm (qty 14)	350CDS
13.	Parabolic dish stand	Diameter -12cm, length 150cm (qty 1)	150CDS
14.	Parabolic dish mount	Length 45cm (qty 1)	100CDS
15.	High Pressure steam pipes	Length 70cm (qty 4) Length 200cm (qty 1)	400CDS
16.	Square mirrors	10cmX10cm (qty 600 to 700 pieces)	100CDS
17.	Hot Glue	Appr 1 to 1.5 litres	40CDS
18.	Metal sheets	250cmX250cm Thickness-0.35mm	160CDS

Table 2: Tools, Machines and Applicability

	TOOLS AND MACHINES	APPLICABILITY
1.	Welding machine	For joining metal parts
2.	Lathe machine	For machining crank shaft components
3.	Drilling machine	To drill holes in metal parts
4.	Angle grinder	For grinding surfaces
5.	LN keys	To tighten or loosen LN bolts
6.	Spanners	To tighten or loosen bolts and nuts
7.	Vices and clamps	For holding work pieces firmly to machine them
8.	Hacksaw blades	For cutting
9.	Vernier caliper	To make highly accurate measurements
10	Inside and outside calipers	To check internal and external diametral distances
11.	Protractors	For angular measurements
12.	Set squares	For 30-, 60- and 90-degrees angular measurements
13.	Thermometer	For measuring atmospheric temperature
14.	Pressure gauge	For checking boiler pressure
15.	Laser	For checking accuracy of mirror reflections to focal point
16.	Multimeter	To check voltage and current produced by electric generator motor.

3.1 Mathematical expressions relevant to the engineering design.

Solar Concentrator (Parabolic Dish)

The parabolic dish collects and concentrates solar radiation. Its geometry is defined by:

$f = D\hat{}2/16d$ Where:

- f = focal length
- D = diameter of the dish
- d = depth of the dish

The solar power incident on the dish is:

$Pin = I.\,A$

Where:

- I = solar irradiance (W/m^2)
- A = aperture area of the dish

Heat Transfer to Boiler Heat absorbed by the boiler is given by Studies show that Ghana, lying between latitudes 4.5°N and 11.5°N, receives solar radiation between 4.5 and 6.0 kWh/m^2/day, with average annual sunshine hours exceeding 2,100 hours. This makes Ghana highly suitable for solar energy harnessing. c) Theory Behind the Research Solar Concentration (Parabolic Dish)

The parabolic dish collects and concentrates solar radiation. Its geometry is defined by:

$f = D^2 / 16d$ Where:

- f = focal length
- D = diameter of the dish
- d = depth of the dish

The solar power incident on the dish is:

$Pin = I.\ A$

Where:

- I = solar irradiance (W/m^2)
- A = aperture area of the dish

- Heat Transfer to Boiler

Heat absorbed by the boiler is given by:

$Q = m.\ c.\ \Delta T$

Where:

- Q = heat energy (J)
- m = mass of water (kg)
- c = specific heat capacity of water (4,186 J/kg·°C)
- •ΔT = temperature change (°C)

Steam generation uses the latent heat of vaporization: $Q = m.\ L$

Where $L \approx 2.26 \times 106$ J/kg for water.

- Mechanical Work (Shock Absorber Pistons)

Assuming the shock absorbers behave like pistons, the work done per stroke is:

$W = P.\ \Delta V$ Where:

- P= steam pressure
- ΔV = displacement volume of the piston **-** Crankshaft and Flywheel Dynamics

Rotational work from linear piston motion

$\tau = r.\ F$

$W = \tau.\ \theta$

$KE = (1/2)\ I\boldsymbol{\omega}^{\mathbf{2}}$

Where:

- τ = torque
- r= crank radius

- F= force from piston
- θ= angular displacement
- I= moment of inertia of flywheel
- $\boldsymbol{\omega}$= angular velocity

Generator Output

Assuming ideal coupling with the flywheel:

$Pout = \boldsymbol{\eta}.\ \boldsymbol{\tau}.\ \boldsymbol{\omega}$

Where $\boldsymbol{\eta}$ is the efficiency of the mechanical-to-electrical energy conversion.

3.2 Design and fabrication methods

3.2.1 Parabolic Dish Fabrication

Figure 2: Parabolic dish side view

Figure 3: Parabolic dish bird view

- Materials: Mild steel plates, rectangular mirror strips, metal square pipes, adhesive glue.

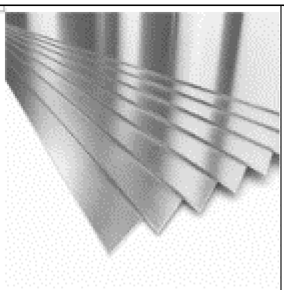

Figure 4: Mild steel plate

Figure 5: square cut mirrors

Figure 6: metal square pipes

Figure 7: Adhesive glue

- Construction:
- Steel plates will be rolled and welded to form a parabolic profile based on calculated depth and diameter.
- Mirrors will be cut into small rectangular pieces (~5x10 cm) for easier adhesion and were glued to the inner surface of the dish.
- A laser test is performed by directing a vertically downward beam toward different mirror sections to confirm convergence at the focal point.

Figure 8: laser

Figure 9: Pressure gauge

- A manual tilt mechanism is added to allow users to adjust the dish angle based on the sun's position.
- Boiler System at the Focus
- A high-pressure, insulated steel boiler is placed at the focal point using adjustable steel supports.
- The boiler includes:
- A pressure gauges
- Steam outlet valve
- Safety relief valve
- Thermometer probe
- Water is manually poured into the boiler before testing, and sunlight heats it to produce steam.

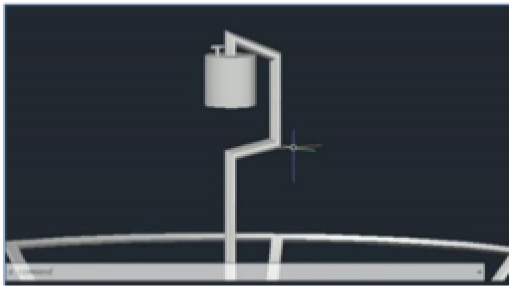

Figure 10: Boiler

Figure 11: High pressure/temperature steam hose

- Steam Distribution System
- High-temperature copper tubing or high temperature steam hose is used to transport steam to the engine assembly.
- Steam lines are wrapped in thermal insulation tape to reduce heat loss.
- Steam enters modified vehicle shock absorbers fitted with intake and exhaust valves.

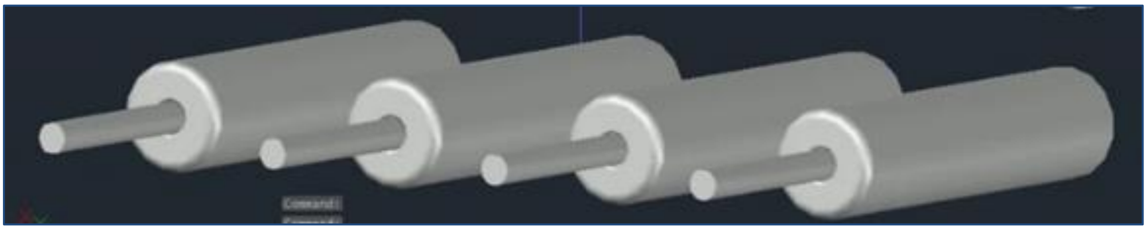

Figure 12: Shock absorbers

Figure 13: Valve timing mechanism

- A valve timer is synchronized with the flywheel to open and close valves based on piston position, to accommodate steam intake and steam exhaust.

- Crankshaft, Bearings, and Flywheel Assembly

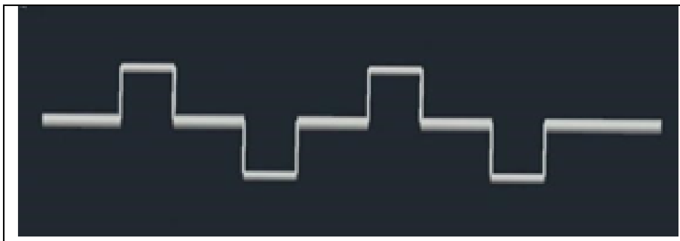

Figure 14: Crankshaft

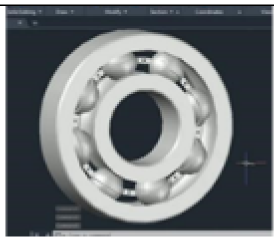

Figure 15: Bearings

Figure 16: Flywheel

- Crankshaft fabricated from machined steel, mounted horizontally.
- Shock absorber rods are connected to crank arms using pin joints.
- Ball bearings are installed at both ends of the crankshaft to:
- Reduce friction
- Increase rotational stability
- Support radial and axial loads
- A cast iron flywheel is attached to the crankshaft to:
- Maintain momentum
- Smooth out motion from pistons
- Generator System

Figure 17: DC electric motor

Figure 18: Motor Pulley

Figure 19: V-belt - A DC

- motor is connected to the flywheel using a V-belt and pulley system.
- The rotational motion from the flywheel drives the motor, which generates electricity.
- The electric motor’s voltage and current output is monitored using a multimeter

Figure 20: Multimeter

Figure 21: Dish mount isometric, side and bird view respectively

- Framing and Mounting System
- -Square and cylindrical pipes will be used to fabricate:
- A dish mount to hold the parabolic dish
- A dish stands to support and stabilize the dish

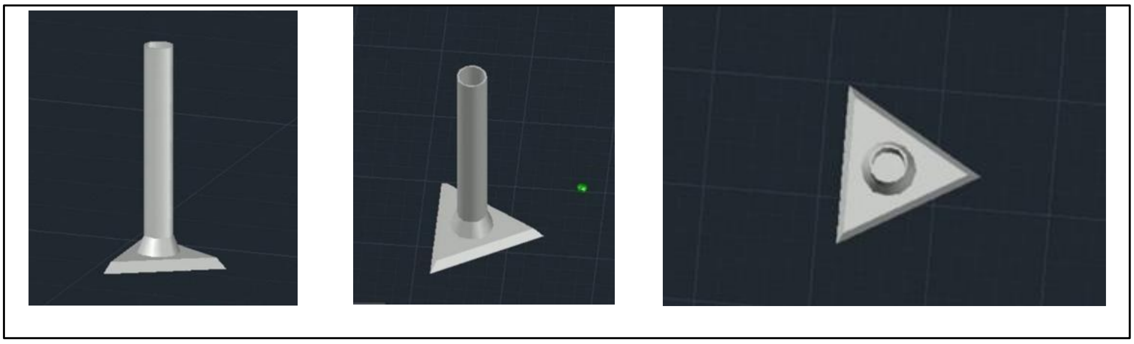

Figure 22: Dish stand side, isometric and bird view, respectively.

Figure 23: Engine frame

- Manual angle adjustment brackets are added to the dish’s frame, allowing operators to:
- Track the sun manually
- Adjust elevation and azimuth with bolts and hinges - Secure angles during operation with locking pins.

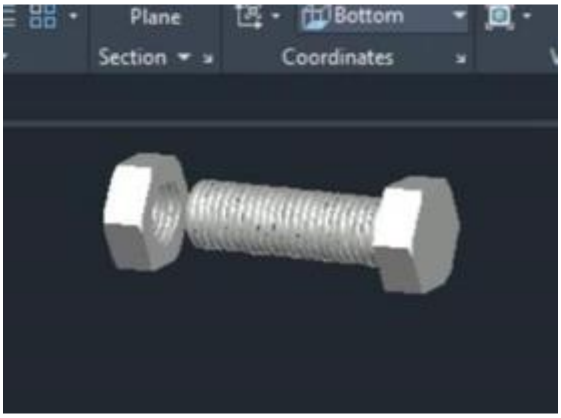

Figure 24: Bolts and nuts

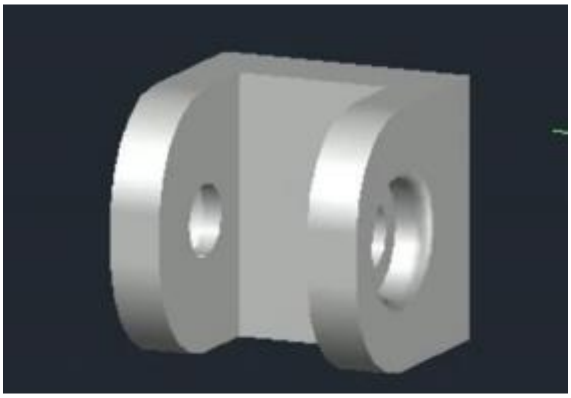

Figure 25: Hinges

Figure 26: Fully assembled solar concentrator

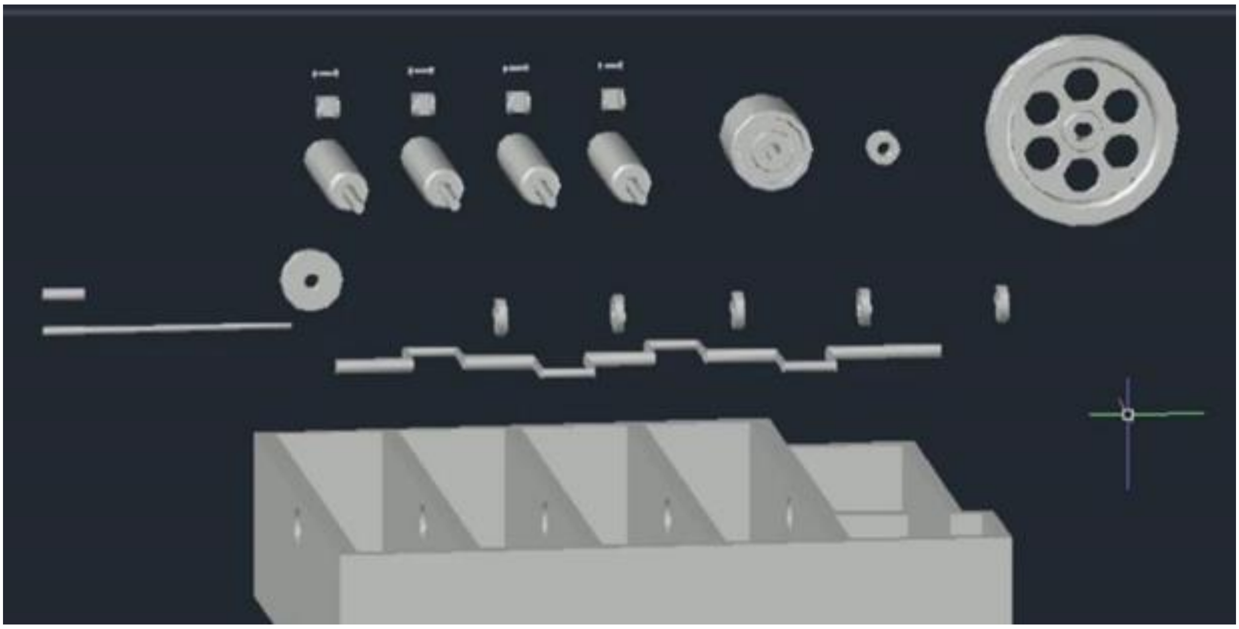

Figure 27: Steam engine disassembly

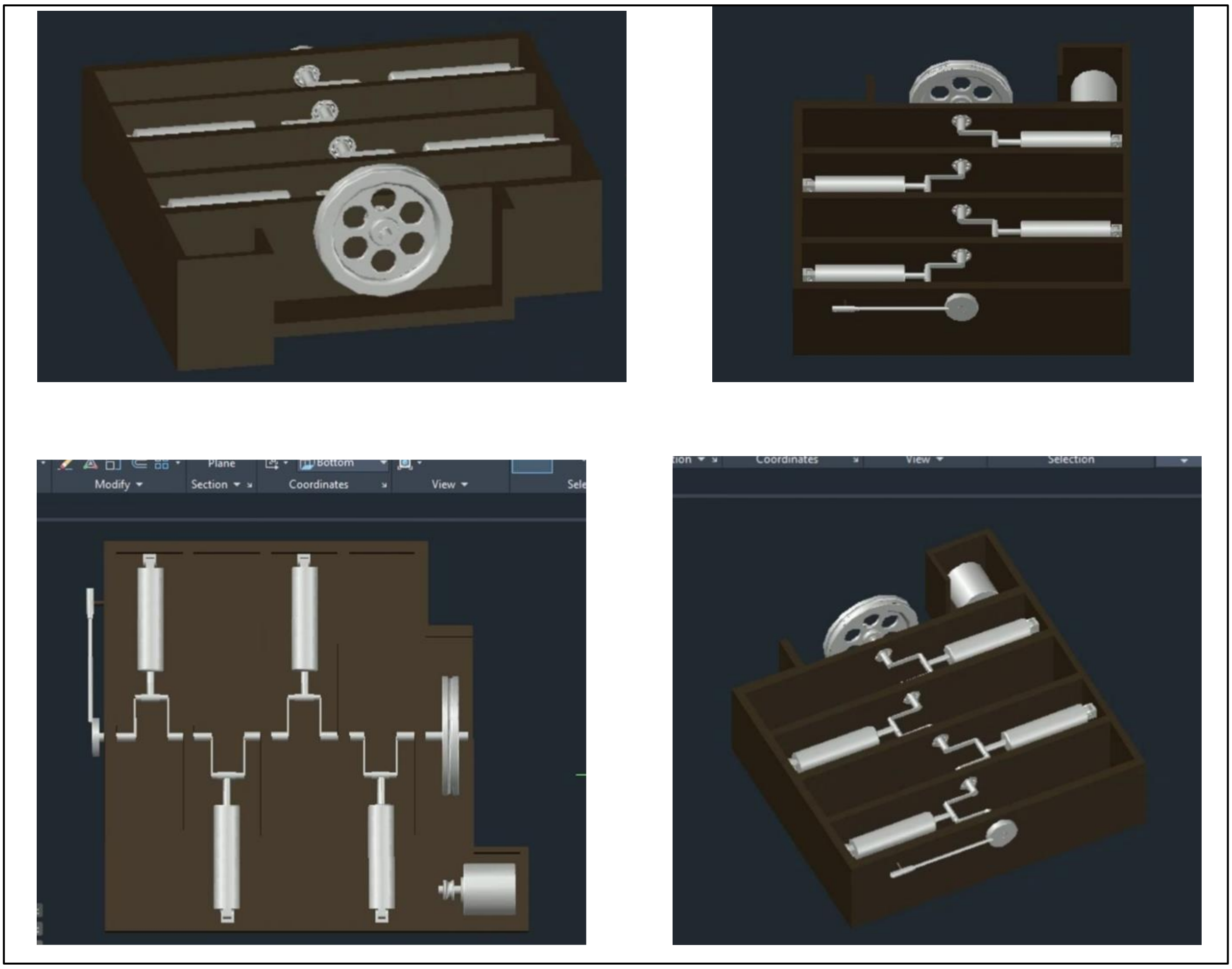

Figure 28: Fully assembled steam engine. Front, rear, bird and isometric view respectively.

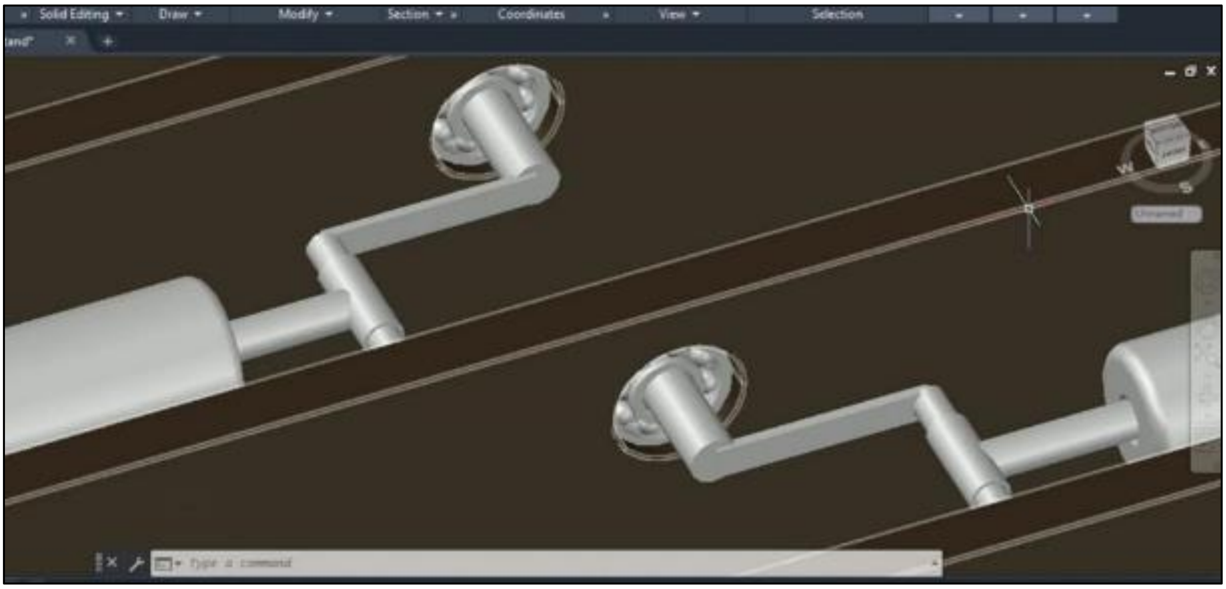

Figure 29: Bearings and crankshaft positioning

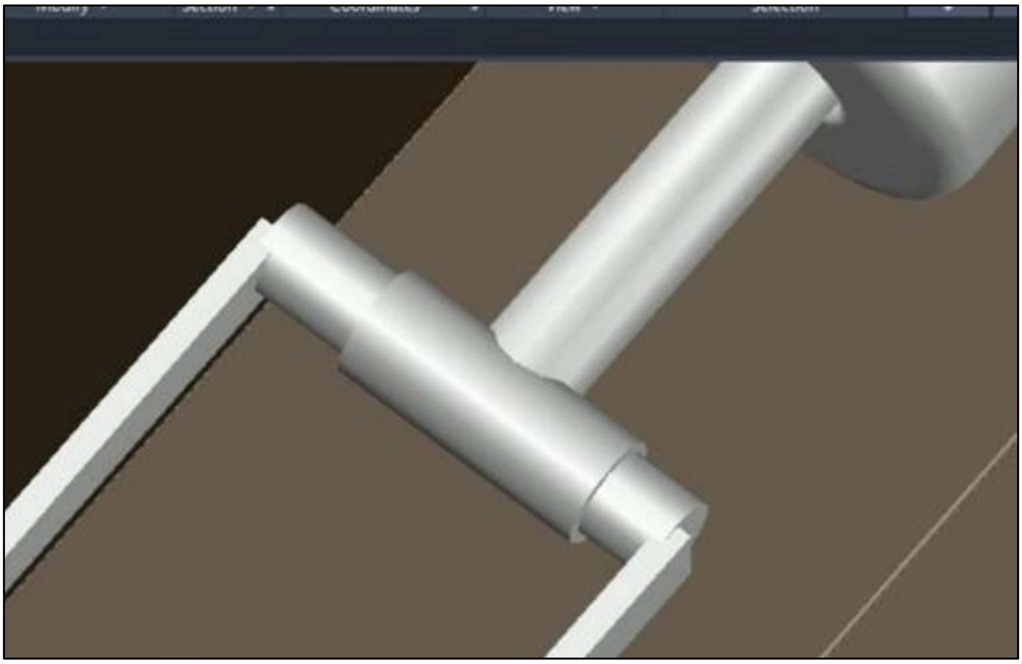

Figure 30: Piston rod and crankshaft connection

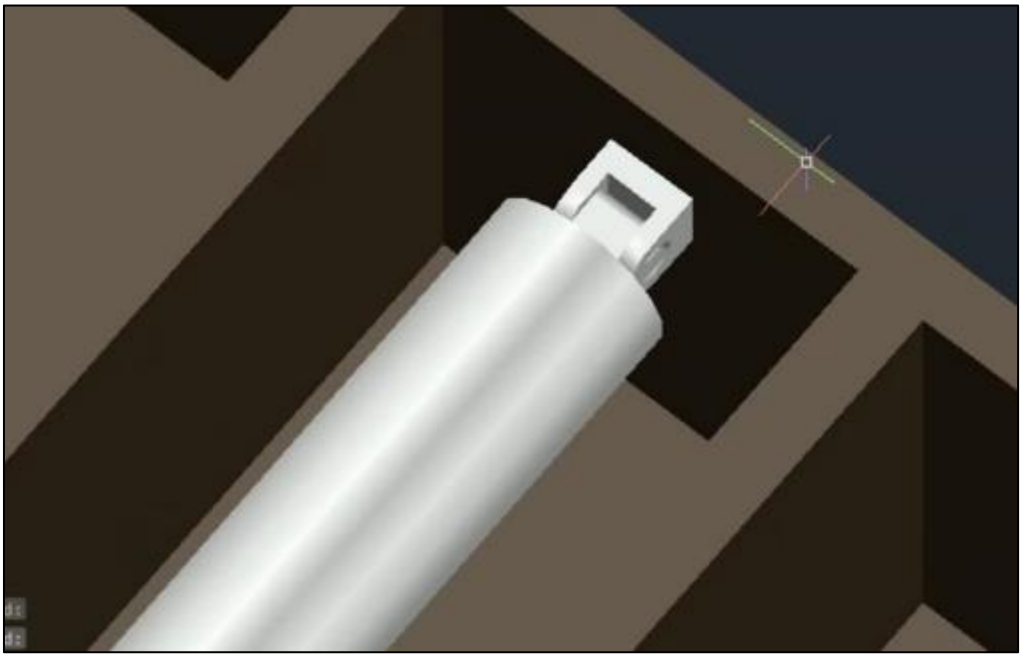

Figure 31: Shock absorber, hinges and engine block connection

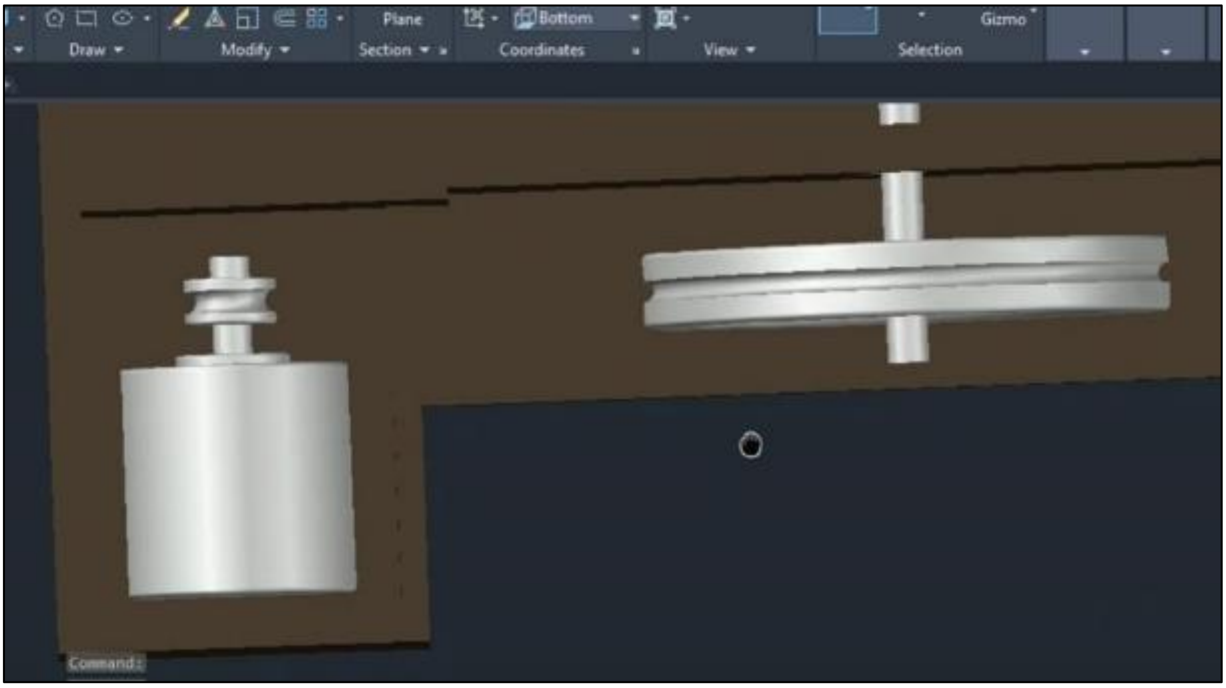

Figure 32: Electric generator and flywheel positioning

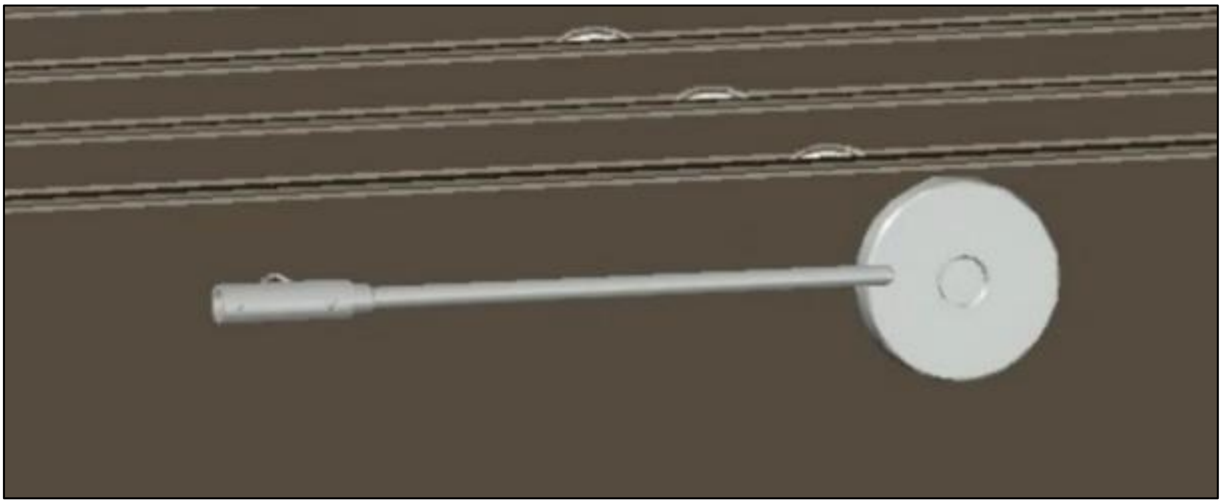

Figure 33: Valve timing mechanism

4 CONCLUSION

In conclusion, this study successfully designed and developed a small-scale solar-thermal electricity generation system using a parabolic dish, steam engine, recycled shock absorbers, and a DC generator. The system demonstrated the feasibility of converting solar energy into useful electrical power, achieving an output of approximately 30 W under suitable solar conditions. Although the overall efficiency was relatively low, the project provides a practical foundation for developing low-cost and locally fabricated renewable-energy systems for off-grid and underserved communities. Further improvements in insulation, solar tracking, and energy conversion efficiency could enhance the system's performance and reliability.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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