Development Of A Solar Powered Parabolic Trough For Mini Power Generation

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ABSTRACT-*The need for alternative power supply, led to this work on the development of solar powered parabolic trough. The parabolic trough harness energy from sunlight, through a concentrator (mirror strips) lined on the parabolic trough. The mirror strips, then focuses the sunlight to the focal point of the parabolic trough with mild steel pipe placed along its linear axis. The focused radiation heats up the working fluid (methanol) inside the mild steel pipe placed along the linear axis of the parabolic trough. The low boiling point fluid was vapourised by heat and as the pressure builds-up it is then released to flow into the miniature turbine connected to the outlet of the parabolic trough. This high pressure-vapour then pushes against the blades of the miniature turbine to rotate. The miniature turbine rotates at a maximum speed of 1126 RPM and a power of approximately 1.5KW was generated.*

INRODUCTION

There are many adverse environmental impacts obtained from the use of fossil fuels (e.g. oil and coal) as an energy source, such as the release of pollutants and resource depletion. Thus, renewable energy sources which are friendly to the environment and less hazardous to human health are preferable. Examples of such energies are geothermal, solar, wind, biomass, etc [1-2]. Solar energy refers to the energy obtained from the sun. Solar energy serves as the basic source from which solar power is derived. African development works, mostly in rural areas seem to recognize the real potential of renewable energy sources especially power derived from the sun [8]. Solar technology development has been able to solve the problem involving the use of fossil fuels. One of such technologies is the Solar Powered Parabolic Trough (SPPT). SPPT harness energy from the sunlight with the aid of mirror strips lined on the parabolic trough. A tracking device is used for the adjustment of the parabolic trough, to the direction of sunlight. The mirror strips focus the sunlight to the focal point of the parabolic trough with mild steel placed along its linear axis. The mild steel pipe placed along its linear axis. The mild steel pipe absorbs heat obtained from the focused radiation; thus heating-up the working fluid (methanol) inside the mild steel pipe to vapour. Methanol has a density of 792kg/m³ and boiling point of 64.7˚C. This work is designed for medium temperature source of (100˚C-150˚C) [7]. The vapour of the working fluid drives a miniature turbine. It then flows out through the outlet of the miniature into the condenser where it is called for recycling.

METHODOLOGY

Optical properties of the concentrator
The mirror used is assumed to have reflectivity of 0.904
Focal axis derivation
Focal Axis of Solar Trough
The focal axis of the solar trough equals half of the radius of the parabolic trough.
Design of the Turbine
The turbine used is a miniature tangential flow turbine. The hub of the turbine is fabricated from 12.6cm diameter (r = 6.3cm) and 33mm (3.3cm) width hollow tin with arrays of 3.3cm wide and 1cm high curved blades made from aluminum sheet. The hub is closed at the two ends with a hole of 12mm diameter for a shaft of 12mm and 90mm length.
Diameter of the hub = 12.6cm

Width of hub = 3.3cm
Width of blade = 3.3cm
Diameter of shaft = 1.1cm
Length of shaft = 9cm

The Rotor

The followings are the specifications of the constructed turbine rotor.

Radius of rotor = Radius of hub + Height of blade = 6.3cm +1cm = 7.3cm
Width of rotor = 3.3cm
Width of blades = 3.3cm
Height of blade = 1.7cm
Pitch angle of blades = 50^0
Numbers of blades = 32
Mass of rotor = 0.173kg

The Stator

The stator is made from 152mm diameter and 36mm width tin. The stator surrounds the hub of the turbine and has an inlet hole opposite the inward surfaces of the curved blades around the circumference of the hub.

An outlet hole is provided oppose to the direction of the outward surfaces of the curved blades. The 15mm inlet pipe is parallel to the 15mm pipe of the outlet of the turbine.

The stator is covered at both ends with a 3mm thickness aluminum sheet. It is 180mm by 180mm with rounded top. At the centre of this plate is a 13mm hole provided for the shaft from the hub to pass through.

The shaft is stayed in placed as it is fitted into 12mm inner diameter bearings at the outer surfaces of the aluminum plates.

The two bearings at the two sides of the aluminum plate are covered with thin cylindrical metal cover.

Design of the Heat Exchanger

Condenser unit

◎ Accumulator

The condenser is made from 175mm diameter and 70mm high with cylindrical tin with thickness of 0.2mm. Its open end is covered with a conical metal sheet of 0.4mm thickness, this forms the accumulator for the condenser.

Diameter of the cylinder, D = 17.5cm
Height of the cylinder, h = 7cm
Volume of the cylinder, $V_{cyl} = (\pi D^2/4)\, h$
$V_{cyl} = (\pi \times 17.5^2/4)\ cm^2 \times 7cm$
$V_{cyl} = 1683.697 cm^3$
$V_{cyl} = 1.683$ L
Volume of conical top, $V_{cn} = 1/3\pi r^2 h$

Fig. 3.4 Conical Top of Accumulator

$\text{Sin } 43.18 = \frac{x}{10}$
X = 10 × Sin 43.18
X = 7cm
Height of cone = 7cm
$V_{cn} = 1/3 \times \pi \times (8.75^2)\ cm^2 \times 7cm$
$V_{cn} = 561.232\ cm^3$
$V_{cn} = 0.561$ L
Total volume of the accumulator = 1.683L + 0.561L = 2.244 L

The tip of the cone has hole of 5mm is welded with 5/16 inches (0.793cm) outer diameter and 0.395mm wall thickness copper tube.

A 25mm pipe from the turbine enters the condenser through the curve surface of the cylindrical part into the condenser. A manometer was attached to the condenser to measure the condensing pressure.

Copper tube coil

Length of copper tube, $L = \pi DN$ 1
Where D = diameter of coil
D = 15cm
And N = no of coil
N = 3
L = π × 0.15m × 3 = 1.4m

Required volume of fluid to fill the absorbers

Total volume = volume of inlet pipe + 3(volume of linking pipe) + 3(volume of boiler)
Volume of inlet pipes
$2\pi r = 6.5cm$
$r = \frac{6.5}{2\Pi}$ 2

r = 1.03cm = 1cm
Length of the inlet pipe = 332cm
$D_{out} = 2.06cm = 2cm = 20mm$
$D_{in} = 20mm - 2(2mm)$
$D_{in} = 16mm = 1.6cm$
$V = \frac{\Pi D^2 L}{4}$ 3

$V = \frac{\Pi}{4} \times 1.6^2 \times 332$

$V = 667.53cm^3$
V = 0.667L
Volume of linking pipe
Length of the linking pipe = 29cm
Dout = 2.04cm =2cm = 20mm

Din = 20mm – 2(2mm)
Din = 16mm
$V = \frac{\Pi D^2 L}{4}$

$V = \frac{\Pi}{4} \times 1.6^2 \times 29$

$V = 58.31cm^3$
V = 0.0583L
Volume of boiler
Length of the linking pipe = 85cm
Dout = 35mm
Din = 35mm – 2(2mm)
Din = 31mm = 3.1cm
$V = \frac{\Pi D^2 L}{4}$

$V = \frac{\Pi}{4} \times 3.1^2 \times 85$

$V = 641.55cm^3$
V = 0.641L

Total volume = 0.667L + 3(0.0583) L + 3(0.641) L
Total volume = 2.765L
If the density of methanol is 0.793kg/L
The volume needed for making 2.756L of its 0.25M Solution

$\text{Molarity} = \frac{\text{Moles of Solute}}{\text{Volume of solution(in litres)}}$ 4

For given Solution
$0.25M = \frac{n}{2.756L}$
n = 0.689 moles
0.689 moles of methanol is needed
Molar mass of methanol (CH_3OH) = 32g/mol
Mass of methanol needed = 0.689mol x 32g/mol = 22g
Density of methanol = 0.793Kg/L = 793g/L

$\text{Volume} = \frac{mass}{Density}$ 5

Volume of methanol needed
$= \frac{22g}{793g/L} = 0.0278L = 27.8\ mL$
Therefore, the volume of methanol needed for 2.756L is 27.8mL

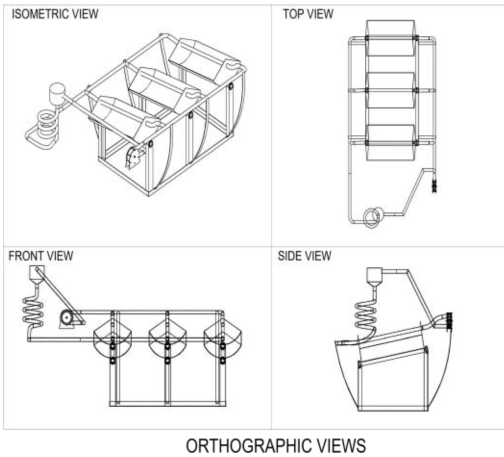
angular velocity (ω) of the turbine of maximum speed of 1126 rpm.
$\omega = 2\pi N/60$ rad/s 6
$\omega = (2\pi \times 1126)/60$
$\omega = 117.93$ rad/s
Tangential Force, F
$F = m\omega^2 r$ 7
$F = 0.173kg \times 117.93^2 rad/s \times 0.073m$
$F = 175.64\ kgm/s^2$
F = 175.64 N
Therefore, Torque = 175.64 × 0.073 = 12.82Nm
Attack area of blade = 3.3cm × 1.2cm
A = 0.033 × 0.012
$A = 3.96 \times 10^{-4}\ m^2$
Pressure, P = F/A 8
$P = (175.64\ kgm/s^2)/ (3.96 \times 10^{-4}\ m^2)$
$P = 443{,}535.35 N/m^2$
P = 443.54kPa
P = 4.44bar
Pressure required to drive the turbine is 1.66bar
Power = T × ω 9
Power = 12.82 × 117.93
Power = 1,511.86 watts

RESULTS

TABLE1 Temperature and Pressure and different time interval

Time(min)	Temperature(˚C)	Pressure(bar)
40	152	3.38
45	158	3.82
50	169	4.09
55	177	4.31
60	189	4.44

Fig 1 Solar Powered Parabolic Trough



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CONCLUSION

The sun rays intensity from the month of May to August is low. During this period, the solar trough is not able to get the required sun intensity to heat up the working fluid. The pressure obtained, from this low intensity of sunlight therefore is not up to the required pressure to run the turbine effectively.

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