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GEOMETRIC MODELING AND DESIGN OF A TRAPEZOID PRISM RECHARGER CASCADE

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ABSTRACT: *The geometric modeling and design of a trapezoidal prism (recharger casing) also known as regenerator cascade, was carried out with respect to basic surface area of known shapes. It considered four trapezoids, a rectangular base and a thermal source. Aluminum metal was used as a result of its high reflectivity, heat conduction and light weight. The shapes were cut according to dimension and adhesive was used to form the component. The regenerator cascade is a containment that directs radiation which falls on it onto photovoltaic panels when positioned on the panel. The results obtained were a reflection of 92 percent of the nominal power incident on the casing and 42% of the radiation incident on the photovoltaic panel.*

KEYWORDS: Geometric modeling; Regenerator cascade; Thermal Source; Solid works; Photovoltaic panel; Radiation.

INTRODUCTION

The photovoltaic recharger or regenerator is a component that has the ability to generate radiation which impinges on the photovoltaic (PV) panel and produce a similar effect as the radiation from the sun. It was stated in [1] that the energy of the photovoltaic cells can either be used directly or can be used to recharge batteries, which in turn, powers the functional system. It therefore suggests that the same photovoltaic energy can be used to power partly a thermal system through a recharger that can be used to feed back the energy for augmentation to the photovoltaic. The work of [2] has shown that the radiation from other sources like the incandescent lights have radiation wavelengths similar to that of the sun. In other to obtain a good quality radiation from the incident rays on the recharger, a trapezoidal prismatic shape is utilized since it provides the required geometry that would enable specular and diffuse reflection to occur, depending on the trapezoids height, size of PV panel, and size of casing in use. The nature of the material to be used when considered, led to the choice of aluminum because of its inherent properties such as high reflectivity, low density and high thermal conductivity. According to [3], aluminum has a high reflectivity and this is stable over the visible band range. Though its features depend on its level of purity, it is better than most metals [4]. These reflective surfaces are surfaces that can deliver high solar reflectance of the various radiation wavelength band and high thermal emittance [5]. In other to carry out a geometric modeling to properly posit the essence of the regenerator casing, [6] noted that a geometric model is central to any tool product cycle in a manufacturing environment. Schematic representations were used to show that the ideas, design analysis and production are captured in the geometric model. [7] Described shapes as representations, which are symbol structures that correspond to mathematical models. In this work therefore, the design analysis will involve the evaluation of surface areas on which radiation is incident before it is propelled to the photovoltaic panel. It will also involve the fabrication of the regenerator casing and the effect of the regenerator on the photovoltaic panel.

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MATERIALS AND METHOD

Geometric Model

The design analysis will involve the evaluation of surface areas on which radiation is incident, before it is propelled to the photovoltaic panels. This work is in consonance with engineering standards and codes provided by European standards on illuminance. It considers the illuminating materials with reflectance of 30 – 90%. It further states that in situations where the work is known, the size, location of the task area and the lighting scheme shall be designed to the required illuminance [8] Hence, the application of [6,7] becomes applicable.

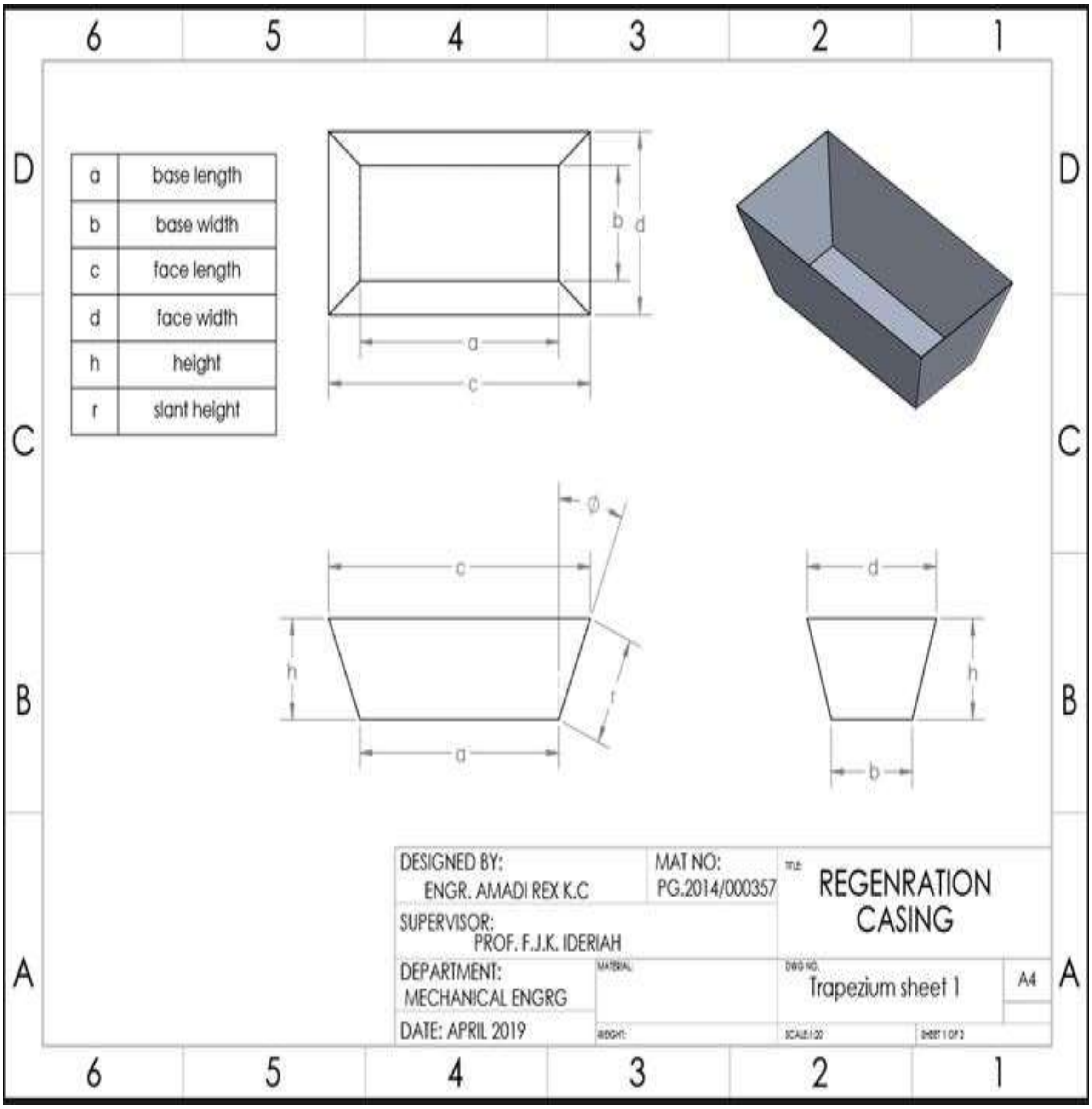

Fig. 1: Solid Works Model for Recharger Casing.

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In order to carry out a geometric modeling to properly posit the essence of the regenerator casing, [6] conceived that a geometric model is central to any tool product cycle in a manufacturing environment. According to the work, schematic representation, the ideas, design analysis and production are captured in the geometric model. [7] stated that geometric modeling describes shapes as representations, which are symbol structures that correspond to mathematical models. In the current work therefore,

let the trapezoid be a four sided trapezium with a rectangular base and an open face. i.e.:
Side $A_1 = P$; side $A_2 = Q$; side $A_3 = R$; side $A_4 = S$; base $= A_5$

Area specification:

Let rectangular base dimension $(A_5) = a \times b$ (3.5)

Base dimension = axb $=$ ab mm^2 (3.6)

Where a = Base length

b = Width

Let open rectangular face $(A_6) = c \times d$ mm^2 (3.7)

c = Face length

d = Face width

Given that trapezium $P = Q$ (flank), the area of the flank-side

Trapezium $p = q = \left(\frac{a+c}{2}\right) h$

$= \left(\frac{a+c}{2}\right) \sin\theta$ (3.8)

The area of trapezium r = s (Edge dimension)

$= \left(\frac{b+d}{2}\right) h$

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$$= \left(\frac{b+d}{2}\right) r\sin\theta \qquad (3.9)$$

Where θ^{o} represents slant angle and r represents slant length.

The sides (A) and height (h) can be mathematically represented by

$$A = \sum_{i=1}^{i=5} A_I \qquad (3.10)$$

$$h = rsin\theta \qquad (3.11)$$

Fabrication of the Recharger Component (Materials)
To fabricate the recharger, the requisite materials include metal adhesive, aluminum metal plate, cutter, pliers, hammer and punches.

Properties of Metal Selected
The metal selected for fabrication conformed to basic requirements such as
i. Low density
ii. High radiation reflectivity
iii. Good thermal conductivity

Fabrication Procedure
In order to carry out the fabrication of the Recharger (regenerator) casing, the following are required:
i. Measure dimensions on the selected material as-designed
ii. Cut shapes as measured, with extra millimeter addition to allow for bending between shapes
iii. Fold shapes at the 10mm mark from the edge and apply metal gum (adhesive)
iv. Fix the marked area and tap with hammer to increase the bonding surface area
v. Allow for 30 minutes to 1 hour for fabrication to complete.
vi. Perforate material base and provide connection point for thermal source introduction with the aid of punches.
The perforated base provides the points of attachment of thermal source of various strength depending on the amount of radiation required.

The following materials were used; Metal adhesive, Aluminum metal plate, Cutter, pliers and hammer.

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RESULTS AND DISCUSSION

The required results were obtained and discussed as follows

Geometrical Dimensions

The following dimensions were calculated and used relative to the size of the photovoltaic panel as follows:

$$a = 120\text{cm}, \quad b = 49\text{cm}, \quad c = 158\text{cm}, \quad d = 78\text{cm}, \quad h = 100\text{cm}$$

- A_5 base $= a \times b$
- $120 \times 49 = 5880\text{cm}^2$
- $A_1 = A_2$; Trapezium $P = Q = \left(\frac{158+120}{2}\right)100 = 13900\text{cm}^2$
- $A_3 = A_4$; Trapezium $r = s = \left(\frac{78+49}{2}\right)100 = 6350\text{cm}^2$
- $\sum A = \sum_{n=1}^{5} A$
- $= A_1 + A_2 + A_3 + A_4 + A_5$
- $= 46380\text{cm}^2$
- $\sum A = 46380\text{cm}^2$ i.e The total area of material (Aluminum) required for fabrication is 4.6380m^2.

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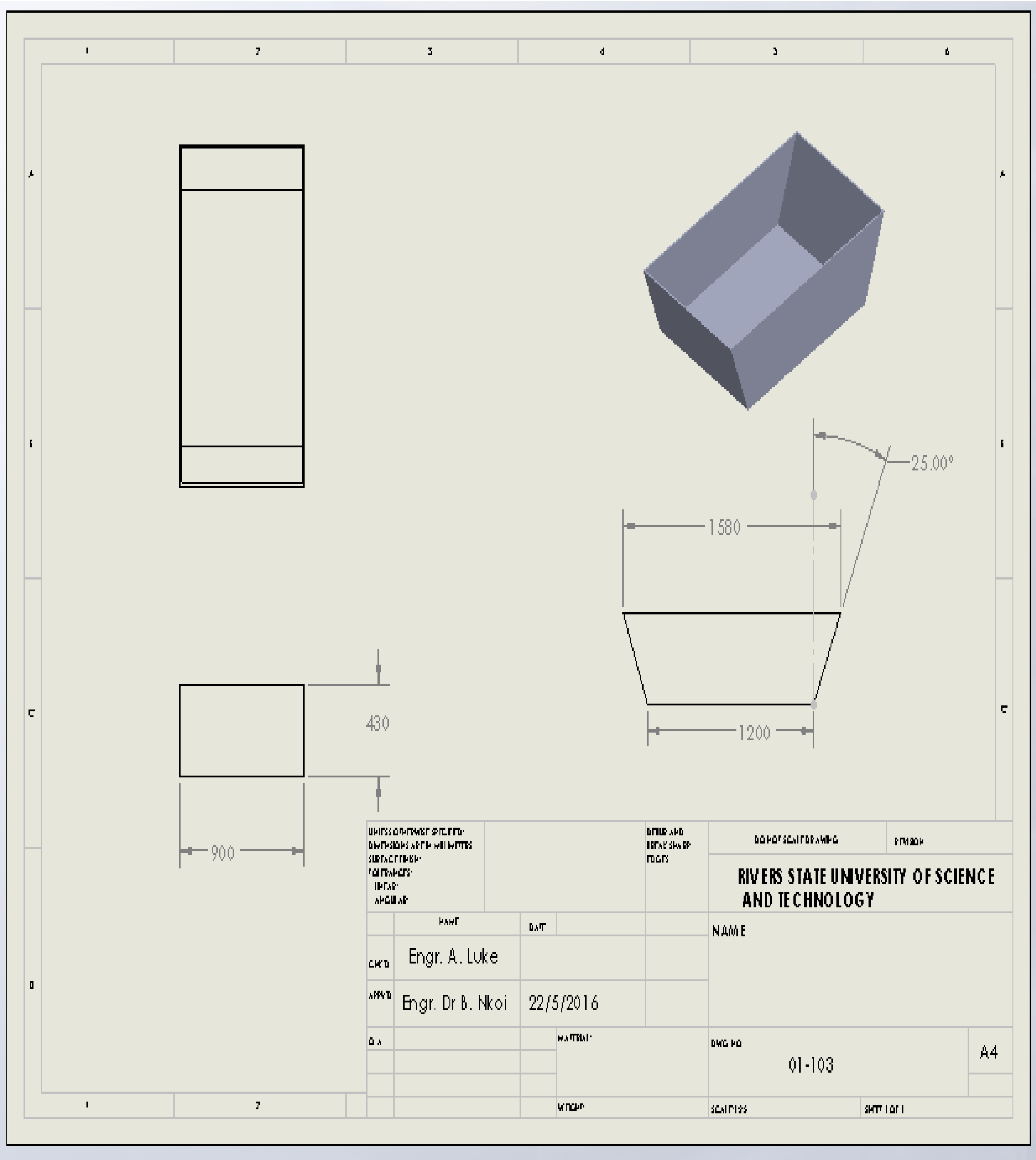

Figure 2: Solid Works Design of Trapezoidal Prism (Regenerator Casing)

The calculation results obtained indicates the required surface areas for the different surfaces and so cuts down on unnecessary usage of materials which may eventually lead to deformation of the casing. Figure 1 is the solid works design and depicts the electronic design required for fabrication.

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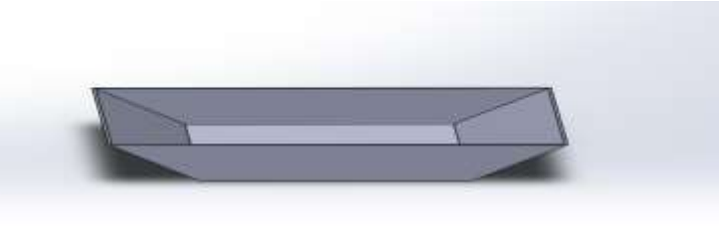

Figure 3: Trapezoidal prism

Figure 3 is a component representation built to a trapezoidal prismatic shape. This shape accords a deep angle of reflection to generated rays whose strength varied according to the height h**.** This is a result of the fact that radiation obeys the inverse square law which states that the power of radiation is inversely proportional to the square of the distance apart [9]. The component, apart from regenerating radiation, is also used as a standard for estimating the value of the incident solar radiation impinging on the solar panel. This is done by a comparison of voltages produced by it and voltages produced by the sun, taking into cognizance that solar cells respond to radiations of all source as long as it exists within the 400-750 nm wavelength band being the band range required for photovoltaic panel absorption.

Table 1: Table of voltages

S/No	Nominal Power provided (W)	Actual power input (0.92 $R_f p_s$)(W)	Power absorbed (K*Pi) (W)	$V_{ocv-125}$ (V)
01	60	55.2	25.39	13.3
02	70	64.4	29.62	
03	80	73.6	33.86	
04	90	82.8	38.09	
05	100	92	42.82	
06	110	101.2	46.55	
07	120	110.4	50.78	17.1
08	130	119.6	55.02	17.4
09	140	128.8	59.24	17.7
10	150	138	63.48	18.0
11	160	147.2	67.7	18.3
12	170	156.4	71.9	18.6
13	180	165.6	76.18	18.9
14	190	174.8	80.41	19.2
15	200	184	84.64	19.45
16	210	190.8	88.87	19.7
17	220	202.4	9.0	20.0

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18	230	211.6	97.34	20.2
19	240	220.8	101.57	20.3
20	250	230	105.8	20.4
22	270	248.4	114.26	20.52
23	280	257.60	118.50	**20.55**
24	290	266.80	122.73	20.57
25	300	294	135.24	20.6

The above table was prepared for photovoltaic cell (PVC) module 125W, V_{max} = 21.3 V which gave actual V_{max} =20.6 V. for Port Harcourt environment.

Table 1 also known as the table of voltages was used to show the open circuit voltage output from the photovoltaic panel. For the 125 W panel, various nominal power inputs were provided at instances and their corresponding open circuit voltages were recorded. The actual power input was calculated based on percentage reflectivity of the casing and the absorbed power by the photovoltaic panel was calculated based on a factor of 0.46, being the percentage of visible light absorbable by the photovoltaic panel [10].

CONCLUSION

The results obtained from the fabricated regenerator cascade showed that the dimensions applied in the design were appropriate for the cascade. The regenerator was used to generate the table of voltages with the addition of standardized lighting (thermal) source and further used to estimate the amount of instantaneous radiation present in a location.

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