Global Journal of Researches in Engineering
Mechanical and Mechanics Engineering
Volume 12 Issue 7 Version 1.0 Year 2012
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

# Design, Construction and Modeling of a Mechanical Portable Barbecue Machine

By Lawrence Gyansah
*Rutgers University*

*Abstract* - It is an undisputable fact that the existing skewers we come across our various homes and roadsides are heavy and thus, are not easily carried around. Their source of heat which is charcoal is also a danger to the environment in that the process of even acquiring the charcoal promotes deforestation which is tantamount to global warming. The operator is exposed to unfriendly working conditions since the flow of heat cannot be easily controlled. The emission of smoke during operation on the larger skewers pollutes the environment and more importantly, can cause cancer of the respiratory systems. Ashes can be present in the products which can change their taste. Moreover, it is difficult to attain uniform heat distribution. It is by these observations that the initiation of the portable gas barbecue is designed. The primary objective is to provide a barbecue which is portable that is, can be moved from place to place with ease. This design seeks to eliminate the health hazards associated with the use of charcoal in the larger skewers as their source of heat. Notwithstanding, this design in reality would be a perfect substitute if not an alternative to the use of the larger skewers.

*Keywords : skewer, design, construction, heat, charcoal, radiation, satay, modeling, construction.*

*GJRE-A Classification : FOR Code: 091399*

DESIGN,CONSTRUCTIONANDMODELINGOFAMECHANICALPORTABLEBARBECUEMACHINE

*Strictly as per the compliance and regulations of :*

# Design, Construction and Modeling of a Mechanical Portable Barbecue Machine

Lawrence Gyansah

*Abstract -* It is an undisputable fact that the existing skewers we come across our various homes and roadsides are heavy and thus, are not easily carried around. Their source of heat which is charcoal is also a danger to the environment in that the process of even acquiring the charcoal promotes deforestation which is tantamount to global warming. The operator is exposed to unfriendly working conditions since the flow of heat cannot be easily controlled. The emission of smoke during operation on the larger skewers pollutes the environment and more importantly, can cause cancer of the respiratory systems. Ashes can be present in the products which can change their taste. Moreover, it is difficult to attain uniform heat distribution. It is by these observations that the initiation of the portable gas barbecue is designed. The primary objective is to provide a barbecue which is portable that is, can be moved from place to place with ease. This design seeks to eliminate the health hazards associated with the use of charcoal in the larger skewers as their source of heat. Notwithstanding, this design in reality would be a perfect substitute if not an alternative to the use of the larger skewers. Moreover, with its safe operating conditions, economical usage, faster cooking time rate, complete burning processes, environmentally friendly characteristics, uniform heat distribution and heat regulating abilities; the portable gas barbecue is not only the best alternative but also, an excellent substitute with regard to the existing local skewers.

*Keywords : skewer, design, construction, heat, charcoal, radiation, satay, modeling, construction.*

## I. Introduction

The problem facing users of the larger skewers (i.e. Mechanical barbecue machine) is their immobility in that they cannot easily be moved to convenient places at the right time (Ullman, 2010). Their source of heat which is charcoal is dangerous to the environment. There is excessive heat radiation which can sometimes cause hand burns and also over burnt satay processes. Operators of the larger skewering machines are at risk of dangerously unprotected exposure of unwanted gases and excess heat. That is, larger skewer operators encounter several undesirable health hazards (Norton, 1999). Ashes can be present in the products which can change their taste. Moreover, it is difficult to attain uniform heat distribution. A perfect substitute is to design a portable gas barbecue which almost always can eradicate all these mishaps. The research is strictly based on designing a mini skewer that will comply with customer needs. This project involves the fabrication, modeling and construction of a mini skewer with a specification regarding strength, material and cost. The skewering machine, as simple in its use, will provide better serviceability, higher efficiency, low cost, and better heat radiation controllability. The main objectives of this paper are:

- To design a portable gas barbecue machine.
- To ensure safe operation of the machine.
- To eliminate the problems associated with the use of the local skewers.

## II. Background History

Satay (i.e. sate) is a dish of marinated, skewered and grilled meats, served with a sauce. Satay may consist of diced or sliced chicken, goat, mutton, beef, pork, fish, tofu, or other meats. It may be served with a spicy peanut sauce dip, or peanut gravy, slivers of onions and cucumbers, and ketupat (Bittman, 2008). Pork satay can be served in a pineapple-based satay sauce or cucumber relish. An Indonesian version uses a soya-based dip.

*Fig. 2.1 :* Satay Products Served in Peanut Sauce

Satay may have originated in Java Sumatra, Indonesia. Satay is available almost anywhere in Indonesia, where it has become a national dish. It is also popular in many other Southeast Asian countries and African countries, such as: Malaysia, Singapore, Brunei, Thailand, Southern Philippines, Netherlands and Ghana, Liberia respectively.

Satay is a very popular delicacy in Indonesia; Indonesia's diverse ethnic groups' culinary arts have

*Author : Rutgers University, The State University of New Jersey, USA, Department of Mechanical Engineering. Record Service - University of Liberia, T.J.R Faulkner College of Science and Technology, Division of Engineering. (Corresponding Author).*
*E-mail : gyansahaclass@yahoo.com.*

produced a wide variety of satays. In Africa, satay can be obtained from a travelling satay vendor, from a street-side tent-restaurant, in an upper-class restaurant, or during traditional celebration feasts. Close analogues are *yakitori* from Japan, *shish kebab* from Turkey and Ghana, *chuanr* from China and *sosatie* from South Africa.

Arabs were known to grill their meat on swords before roasting and Middle-Eastern Nomads would barbecue their meat on metal skewers known as *kebabs or sharwarma*. The spice trade which brought Arab traders to Southeast Asia led to the spread of Arab culinary culture to the Indonesians and eventually to Malaysia and Singapore.

Similarly, during the Turkish invasion of Cyprus, kebabs or sharwarma were adopted by the locals and is today a popular dish amongst the Greeks and the Cypriots besides the Turkish, the Egyptians and the Arabs. The dish spread beyond to Northern India with even Beijing residents savouring fiery flavoured kebabs today. The uniqueness of satay in Asia is that wooden skewers are used unlike metal in their Arab counterpart. The satay sauce, made up of ground peanuts and other spices, was first introduced in the Philippines by the Spanish from South America used to marinate the pieces of meat; the remaining sauce is used as a dip after the meat of the satay is grilled. *Turmeric* is a compulsory ingredient used to marinate satay, which gives the dish its characteristic yellowish colour. Meats commonly used include beef, mutton, lamb, pork, venison, fish, shrimp, squid, chicken, rabbit and even tripe. Some have also used more exotic meats, such as turtle, crocodile, horse, lizard, and snake meat (Bittman, 2008).

A barbecue machine or skewer is a device for cooking food by applying heat directly from below. There are several varieties of such grills, with most falling into one of two categories: gas-fueled and charcoal (Hale, 2000). There is a great debate over the merits of charcoal or gas for use as the cooking method between barbecue grillers (York, 2003). Almost all competition grillers use charcoal, most often in large, custom designed brick or steel grills (i.e. in Ghana). Grilling existed in the Americas since pre-colonial times. The Arawak people used a wooden structure to roast meat on, which was called *barbacoa* in Spanish. The word referred to the wooden structure and not the act of grilling, but this word was eventually applied to the pit style cooking techniques used in the Southeastern United States.

There are various types of barbecue machines which are put into use worldwide. These include electric barbecue machines, cell barbecue grill, barbecue grill netting, and barbecue machine. All these grilled designed machines have their limitations as mentioned in the introduction. Especially in Ghana, grill machines are constructed from empty fuel drums machined into two halves longitudinally with improper welding practices at the welded joints (see Fig.2.2). Most local skewers lack hygienic standards in Ghana. The top is always opened to the atmosphere which invites dust and finally adulterates the grilled products (See Fig.2.3). It is on these limitations that a new design, construction and modeling of a mechanical portable barbecue machine are needed. This paper seeks to fabricates, models and constructs a mini skewer with specification regarding strength, materials and costs. The skewering machine, as simple in its use, will provide better serviceability, portability, higher efficiency, low cost, durability, good hygienic standard and better heat radiation controllability.

*Fig. 2.2 :* Local Barbecue Machine in Ghana


*Fig. 2.3 :* Roasted Meat on Local Skewer Exposed to Dirty and Dusty Environment

## III. Design Concept

A new or better machine is one which is more economical in the overall cost of production and operation. The design of this portable barbecue is to modify the existing designs into a new idea by adopting a new material and a manufacturing method. The design of the mini satay skewering machine (i.e, portable barbecue machine) must be compliance to several aspects. The design consideration must be done carefully, so that the design can be fabricated by the industries in Africa especially Ghana. Design parameters involve; materials design and selection, fuel selection, modeling and construction (i.e. using CAD Software), mathematical modeling, design specifications and proposed design.

## IV. Materials Design and Selection

The selection of a proper material for engineering purposes is one of the most difficult problems for the designer. The best material is one which serves the desired objective at the minimum cost. The following factors are considered in the selection of material for the design of the portable barbecue machine:

- Availability of the material.
- Suitability of the material for the working conditions in service.
- The cost of the material.

The material selected for the construction/ molding of the portable barbecue machine is stainless steel since it surpasses all other materials in corrosive environments. The type of stainless steel used is S30400.Type 304 is a variation of the basic 18-8 grade, Type 302, with a higher chromium and lower carbon content. Lower carbon minimizes chromium carbide precipitation due to welding and its susceptibility to inter-granular corrosion (Askeland *eta al*, 2010) and (Callister and Rethwisch, 2010). The thickness of the 304 stainless steel plate range from 0.025– 6.35 mm and its width is up to 1219 mm. Type 304 steels have very good drawability. Their combination of low yield strength and high elongation permits successful forming of complex shapes. However, these grades work-harden rapidly. To relieve stresses produced in severe forming or spinning, parts should be fully annealed or stress-relief annealed as soon as possible after forming (Ashby *eta al*, 2007). These steels exhibit excellent resistance to a wide range of atmospheric, chemical, textile, and petroleum and food industry exposures.

Cooking grids (cooking grates) are the surface on which the food is cooked in a grill. Most high end barbecue grills use stainless steel grates, but there is a health benefit to using bare *cast iron grids.* When cast iron is used to cook food containing high level of acidity, such as lentils, tomatoes, lemonade sauces, or marinades with strong vinegar content, there is increased iron dietary intake. Iron and iron deficiency, particularly, is an important issue for pregnant women and young children. The longer and hotter the grilling temperature, the more iron is infused into the food. Hence cast iron is selected for the grid design.

## V. Design Specifications

Stainless steel 304 are covered by the following specifications: AMS 5513; ASTM A240; ASTM A666.

The table 1. illustrates the detailed information on the type of stainless steel which is selected for the design.

Global Journal of Researches in Engineering ( A ) Volume XII Issue VII Version I Year 2012

*Table 1 :* Mechanical Properties of Stainless Steel Type 304

| Composition | % | Physical Properties | Range of Values |
|---|---|---|---|
| Carbon | 0.08 | Density | 8.03 g/cm$^3$ |
| Manganese | 2.00 | Electrical Resistivity, μΩ-cm | 20 °C -72<br>659 °C-116 |
| Sulfur | 0.030 | Thermal Conductivity, W/m.K | 100 °C-500 °C 16.2-21.4 |
| Silicon | 0.75 | Mean Coefficient of Thermal Expansion, μm/m•K | 0-100°C-16.9<br>0-315°C- 17.3<br>0-538°C-18.4<br>0-649°C-18.7 |
| Chromium | 18.00-20.00 | Magnetic Permeability H | 200 |
| Nickel | 8.00-12.00 | Annealed | 1.02 max |
| Nitrogen | 0.10 | Modulus of Elasticity, MPa | Tension<br>193 x 103<br>Torsion<br>78 x 103 |
| Iron | Balance | Melting Range, °C | 1399 - 1454 |
| Mechanical Properties | Value | Oxidation Resistance | (816 – 899)°C |
| UTS | 621 MPa | Heat Treatments | Annealing<br>(1038 1121)°C<br>Stress Relief Annealing<br>(399°C) |
| 0.2% YS | 290 MPa | | |
| Elongation% in 50.8mm | 55 | | |
| Hardness Rockwell | B82 | | |

## VI. Fuel Selection

The source of fuel selected to power the machine is the liquefied petroleum gas (LPG). LPG is a flammable mixture of hydrocarbon gases used as a fuel. The varieties of LPG bought and sold include mixtures that are primarily, propane ($C_3H_8$) and butane ($C_4H_{10}$) considered as natural gas liquids (NGLs) (Smith, 2010). LPG is selected as the source of energy over charcoal. Below are some of these reasons:

- LPG is environmentally friendly
- It burns cleanly with no soot
- Provides complete burning
- Poses no ground or water pollution hazards
- A regulator ensures the possibility of controlling the heat energy
- Heat energy is uniform
- Prevents deforestation
- Serves as a source of refrigerant to replace chlorofluorocarbons in an effort to reduce the depletion of the ozone layer
- Provides high heating value to save time and energy cost

## VII. Modeling and Construction

As a design ethic, every machine or structure must be assembled as a unit before it can function well. The medium of joining machine components in this design is by welding and fasteners (Storer and Haynes, 1994) and (Khurmi and Gupta, 2005). AutoCAD software was used for modeling purposes (Omura, 2010). Dimensioning and mechanical component specifications are tabulated in table 2.

## VIII. Mechanical Component Specifications

The table 2. displays the design specifications of materials and the number of components used in this design.

*Table 2 :* Mechanical Component Specifications of the Design

| Dimensions | Portable Gas Burner |
|---|---|
| Length | 64cm |
| Depth | 44cm |
| Height | 100cm |
| Assembled Dimensions | 64cm×44cm×100cm |
| Gas Cylinder Description | 23cm×27cm |
| Cooking Area | 61cm×41cm |
| **Materials** | **Description** |
| Hinge Material | Stainless Steel |
| Burner Material | Stainless Steel |
| Cover Material (side and top lid) | Stainless steel |

| Features | Material Description |
|---|---|
| Fuel | LPG |
| Recommended Gas Type | LPG |
| Regulator Included | Yes |
| Cooking Grate | Cast iron (Austenitic Iron) |

## IX. Results and Discussion

The design specifications, complete design of the gas barbecue machine, its operation and the necessary recommendations are addressed.

*a) Proposed Design*

The proposed design comprises the gas cylinder and its components, the various machine components and the complete design with the assembled parts.

*b) Gas Cylinder*

This is the recommended gas cylinder and the designed burners. There is a regulator incorporated to the connecting pipe which controls the amount of gas in

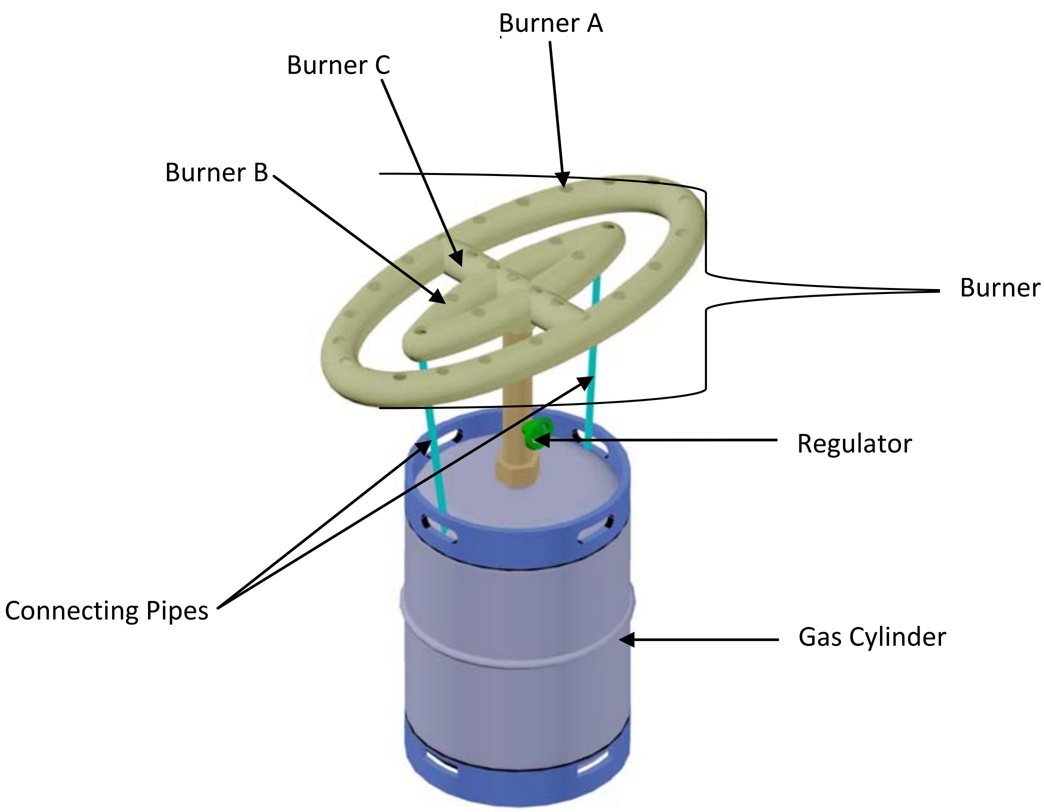


*Fig. 31 :* Modeled Gas Cylinder and Burner

*c) Modeled Diagram of the Portable Gas Barbecue Machine*

This diagram shows how the gas cylinder is being supported.

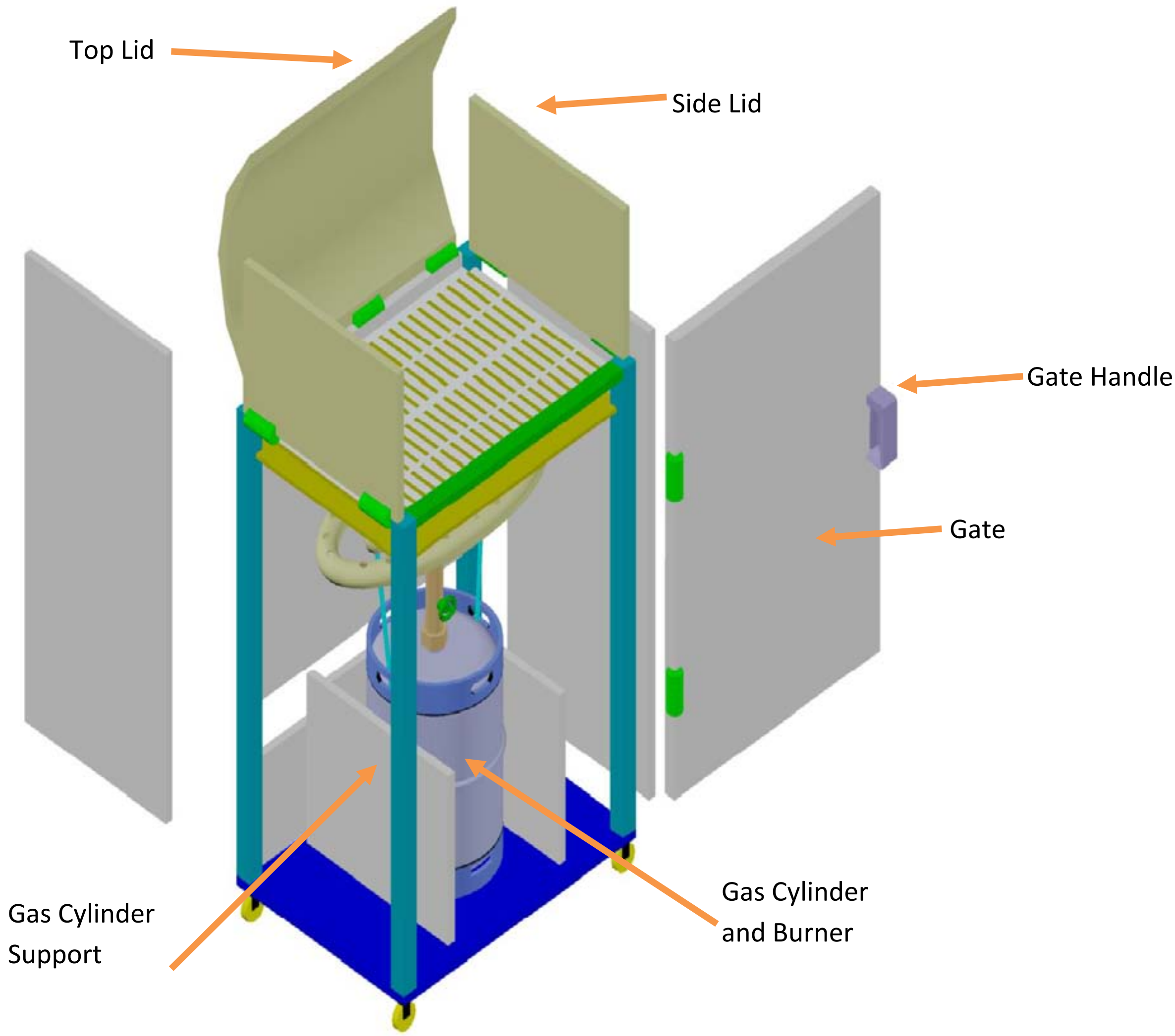


*Fig. 3.2 :* Cut-Out Design Model

*d) Back View of the Gas Barbecue Machine*

This view displays how a *vent* has been created at the back side of the barbecue to allow circulation of air.

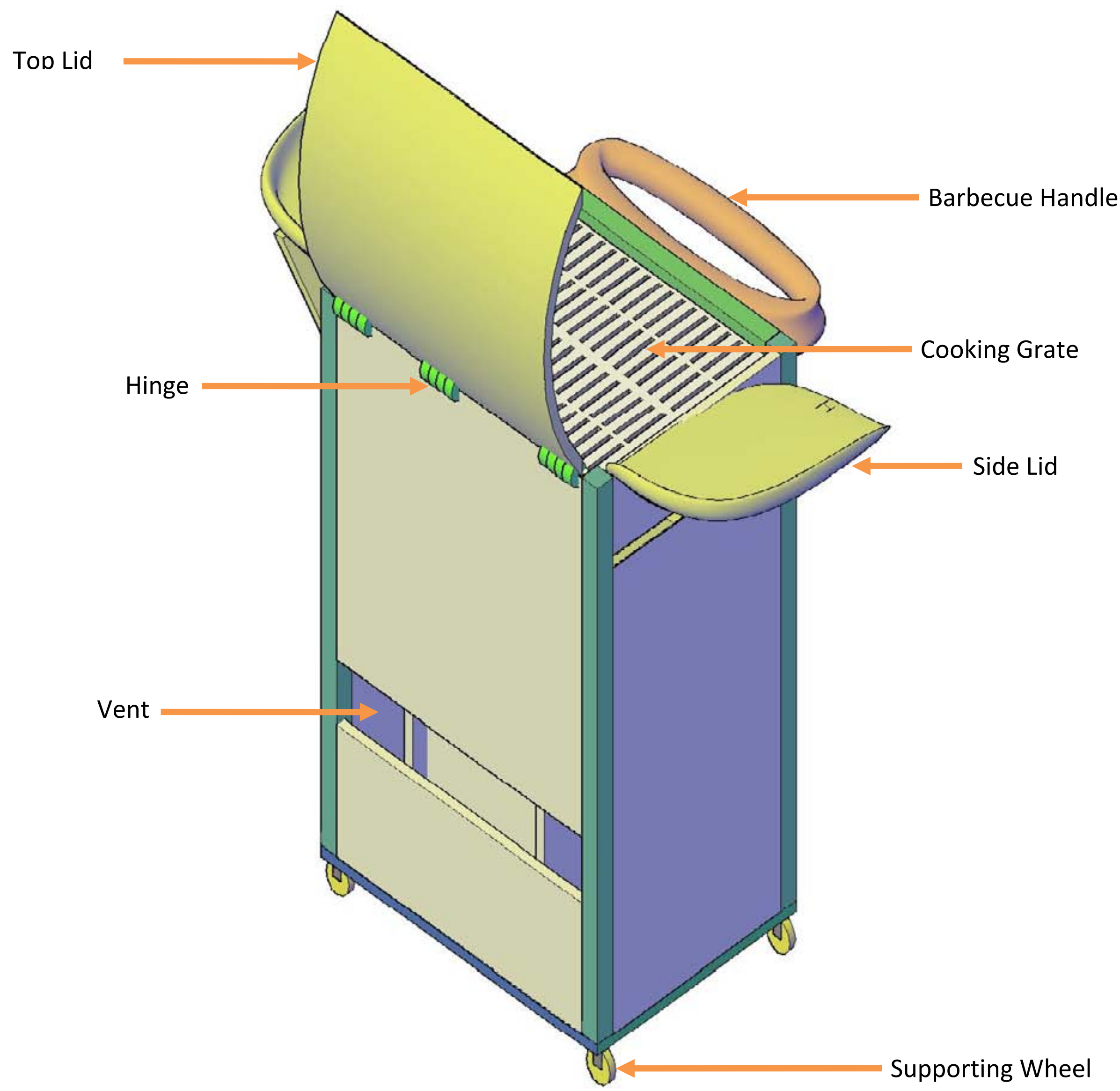


*Fig. 33 :* Barbecue Machine with a Vent at its Back

*e) Gas Barbecue Machine with its Gate Opened*

This diagram shows the barbecue machine with its gate opened to display how the gas cylinder has been positioned in the barbecue.

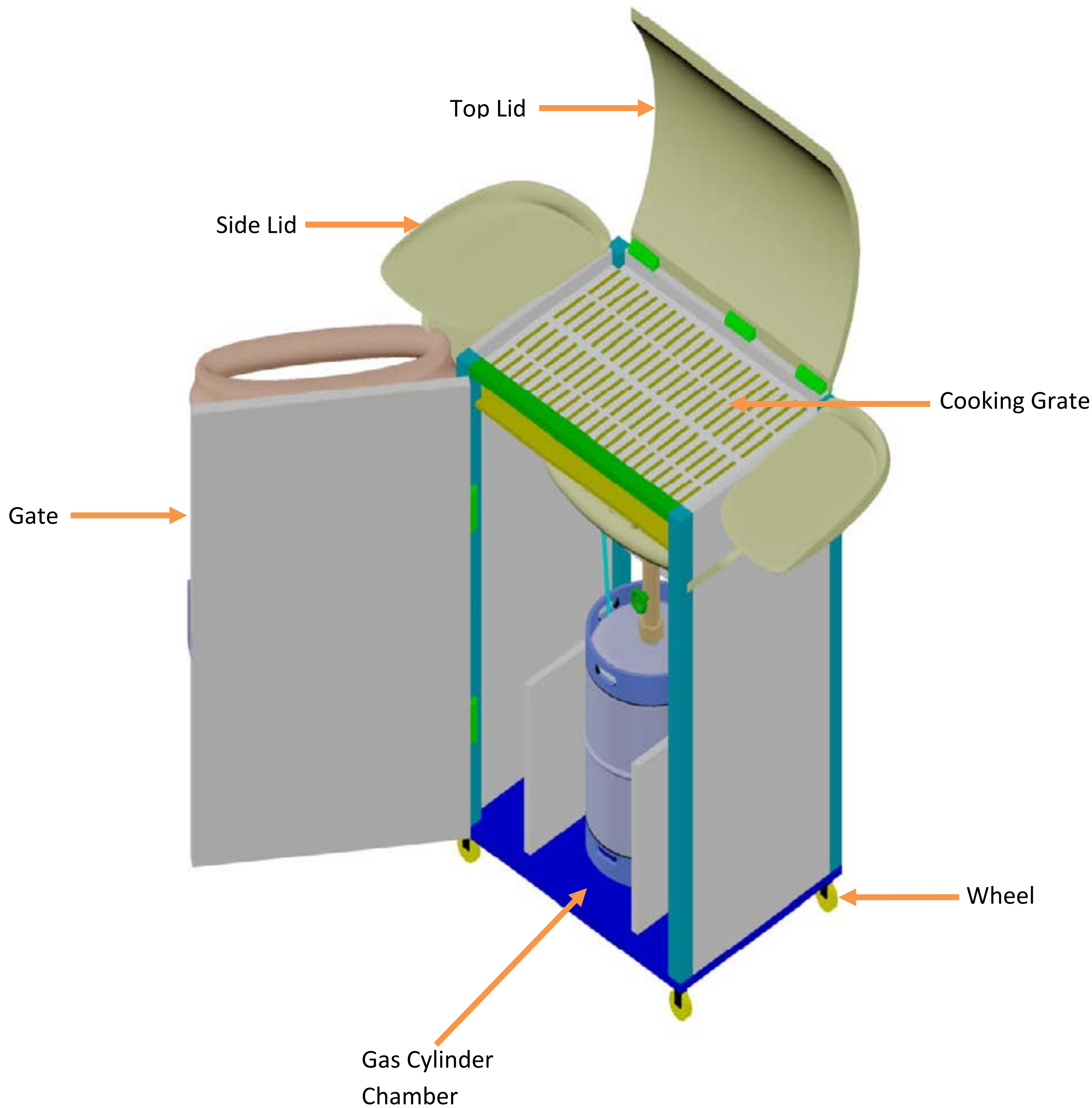


*Fig. 3.4 :* Position of the Gas Cylinder

*f) The Complete Design*

This is how the gas barbecue machine is structured after assembling its components.

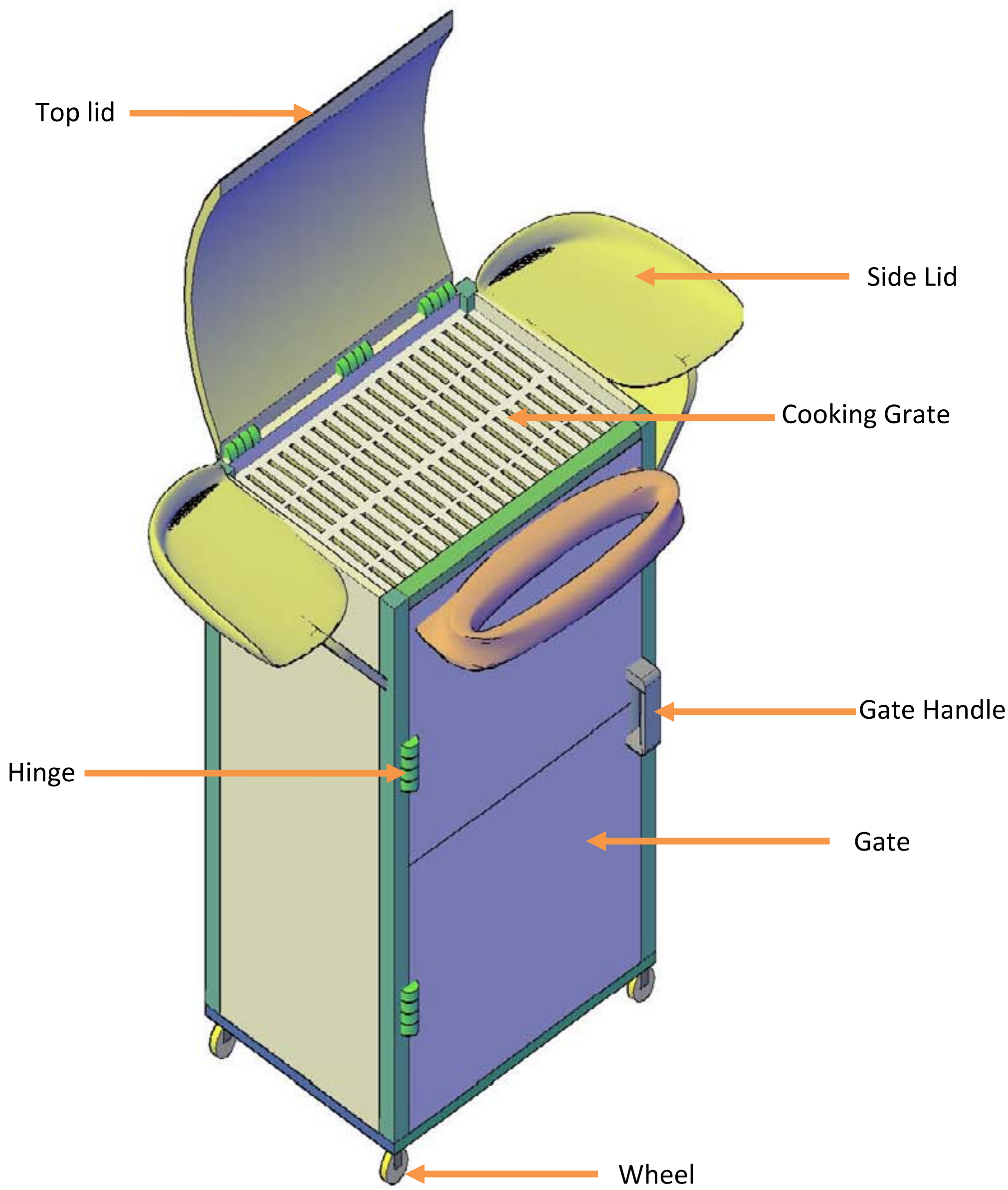


*Fig. 3.5 :* The Complete Proposed Design

*g) Mathematical Modeling*

The design calculations are strictly centered on the weights regarding the satay products, the barbecue machine and the gas cylinder. These weights amount to the entire total weight of the completed portable gas skewering machine. The total weight of the machine is then used to design the wheels and stands whose total weight in turn, counteracts that of the machine. The wheels and stands serve as supports to promote balance, movement and stability.

*h) Design Specifications*

Table 3. provides the design specifications; the sizes and units used in the proposed design.

*Table 3 :* Complete Dimensions of the various Mechanical Components of the Proposed Model

| Component Description | Component Sizes and Units | |
|---|---|---|
| Cuboid Dimensions of the Barbecue Machine | in cm | in m |
| Length of the barbecue, $l_b$ | 62 | 0.62 |
| Width of barbecue, $b_b$ | 42 | 0.42 |
| Height of barbecue, $\mathbf{h}_b$ | 100 | 1 |
| Gas Cylinder Dimensions | in cm | in m |
| Diameter of Gas Cylinder, $d_c$ | 23 | 0.23 |
| Height of Gas Cylinder, $\mathbf{h}_c$ | 27 | 0.27 |
| Gas Cylinder Chamber Dimensions | in cm | in m |
| Length of chamber, $l_c$ | 24 | 0.24 |
| Width of chamber, $b_c$ | 24 | 0.24 |
| height of chamber, $\mathbf{h}_c$ | 13 | 0.13 |
| Pipe Dimensions | in cm | in m |
| Outside Diameter of the Pipe, $D_p$ | 2 | 0.04 |
| Inside Diameter of the Pipe, $d_p$ | 2 | 0.02 |
| Height of the Pipe, $h_p$ | 40 | 0.4 |
| Burner Dimensions | in cm | in m |
| Outside Diameter of Burner, A, $D_1$ | 6 | 0.06 |
| Inside Diameter of Burner, A, $d_1$ | 4 | 0.04 |
| Outside Diameter of Burner, B, $D_2$ | 6 | 0.06 |
| Inside Diameter of Burner, B, $d_2$ | 4 | 0.04 |
| Outside Diameter of Burner, C, $D_3$ | 4 | 0.04 |
| Inside Diameter of Burner, C, $d_3$ | 3 | 0.03 |
| Diameter of each Burner Hole, $d_h$ | 2 | 0.02 |
| Height of each Burner Hole, $h_h$ | 2 | 0.02 |
| Gas Cylinder Supports | in cm | in m |
| Length of a and b | 24 | 0.24 |

| | | |
|---|---|---|
| Length of c | 30 | 0.3 |
| Height of the supports | 13 | 0.13 |
| Thickness of the supports | 3 | 0.03 |
| Adjustable Lids Dimensions | in cm | in m |
| Length of Top Lid, $l_{tl}$ | 62 | 0.62 |
| Width of Top Lid, $b_{tl}$ | 43 | 0.43 |
| Thickness of Top Lid | 1 | 0.01 |
| Length Side Lids, $l_{sl}$ | 42 | 0.42 |
| Width of Side Lids, $b_{sl}$ | 20 | 0.2 |
| Thickness of Lids, h | 13 | 0.13 |
| Cooking Grids Dimensions | in cm | in m |
| Length of the Cooking Grid, $l_{cg}$ | 56 | 0.56 |
| width of the Cooking Grid, $b_{cg}$ | 36 | 0.36 |
| Thickness of the Cooking Grid, x | 3 | 0.03 |
| Cut Out Spaces Dimensions | in cm | in m |
| Length of Vent, $l_v$ | 56 | 0.56 |
| Width of Vent, $b_v$ | 3 | 0.03 |
| Height of Vent, $h_v$ | 12 | 0.12 |
| Length of space in barbecue, $l_s$ | 56 | 0.56 |
| Width of space in barbecue, $b_s$ | 36 | 0.36 |
| Height of space in barbecue, $h_s$ | 90 | 0.9 |

*i) Total Weight of the Barbecue Machine*

These calculations cover the weights of the barbecue machine, the gas cylinder, the top lid and the side lids, the barbecue gate and those of the sate products respectively. According to (Gere and Goodno, 2009), the total weight $W_T$ is given by;

$$W_T = W_1 + W_2 + W_3 + W_4 + W_5 \quad 1.1$$

Where $W_1$ comprises the sum of the weights of only the barbecue Machine, the supports for the gas cylinder and the cooking grates.

$$\text{Thus, } W_1 = W_b + W_{sc} + W_{cg} \quad 1.2$$

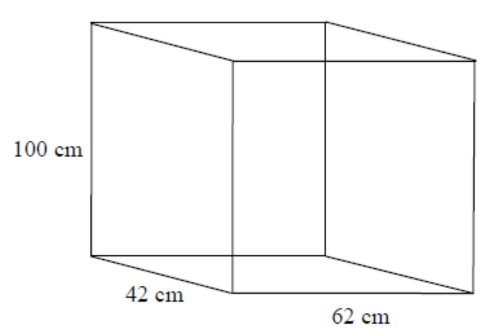


**Fig. 4.1 Barbecue Machine Modeled as Cuboid**

Global Journal of Researches in Engineering ( A ) Volume XII Issue VII Version I Year 2012
53

The vent created at the back of the barbecue machine is also modeled as a cuboid. The volume of the vent is therefore given by; (Craig, 2011),

$$V_v = l_v \times b_v \times h_v \qquad 1.3$$

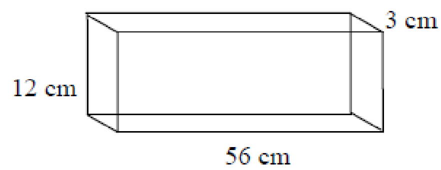


**Fig. 4.2. Vent at the Backside of the Barbecue Machine**

Hence, the entire inner space of the barbecue machine is shown in Fig. 4.3.

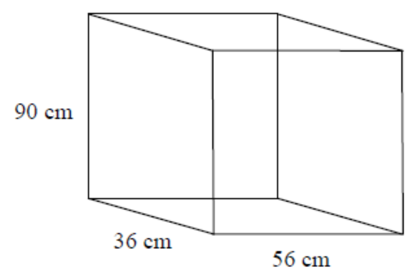


**Fig. 4.3. Modelled Inner Space of the Barbecue Machine**

Also, the volume of the gas cylinder chamber is modeled as a rectangular prism. Hoop stresses and circumferential stresses would exist in the pressurized state of the gas cylinder. Therefore, the volume of the gas cylinder chamber is given by; (Craig, 2011),

$$V_{gc} = l_{gc} \times b_{gc} \times h_{gc} \qquad 1.4$$

Fig. 4.4. shows a modeled of the supporting systems for the gas cylinder.

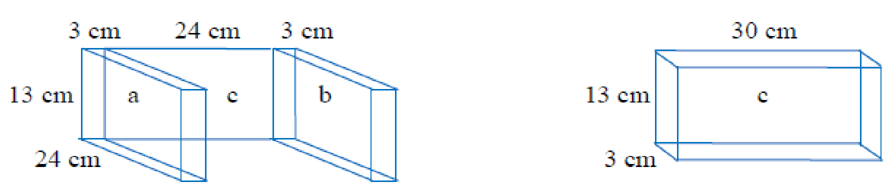


**Fig. 4.4. Supports for the Gas Cylinder**

Fig. 4.5. and Fig. 4.6. show a modeled of the cooking grate and the gas cylinder. Dimensioning of the parts is included.

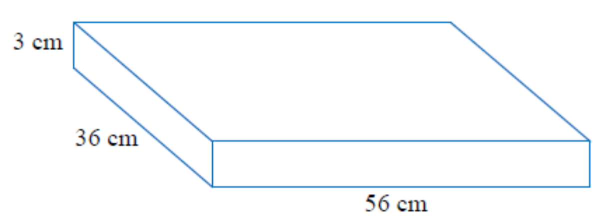


**Fig. 4.5. Model of the Cooking Grate**

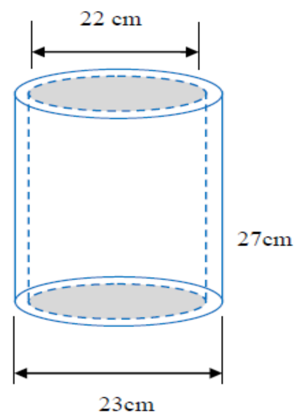


**Fig. 4.6. Model of the Gas Cylinder**

Fig.4.7. illustrates a model of the pipe connecting the cylinder to the burners (i.e. Connecting pipes).

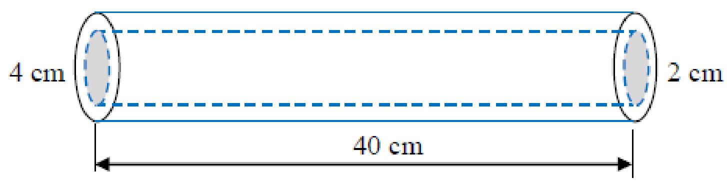


**Fig. 4.7. Modelled Connecting Pipe**

For burner *A*, the outside and inside diameters are $D_A$ = 2 cm≈ 0.02 m and $d_A$ = 1 cm≈ 0.01 m respectively.

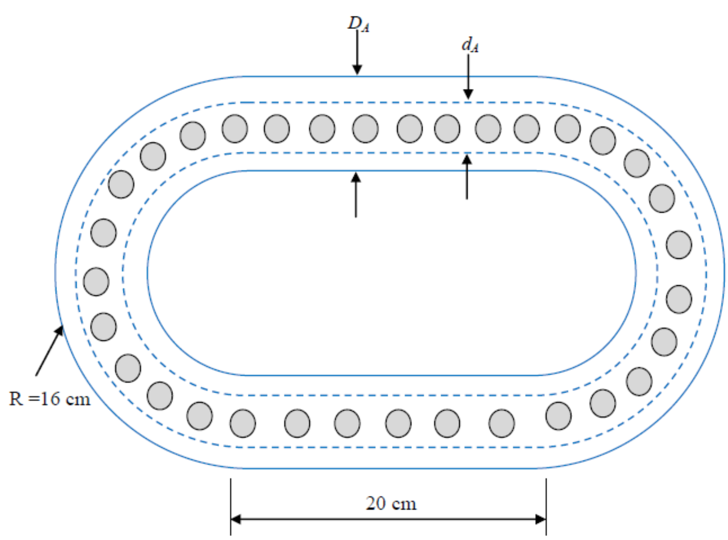


**Fig. 4.8a Detail Model of Burner A**

The number of holes in burner A, is 34; each hole has a diameter, $d_h$ = 0.3 cm ≈ 0.003 m; and height, $h_h$ = 0.5 cm ≈ 0.005 m.

For burner *B*, the outside and inside diameters are $D_b$ = 2 cm≈ 0.02 m and $d_b$ = 1 cm≈ 0.01 m respectively.

$D_B$ = 12 cm≈ 0.12 m and $d_B$ = 10 cm≈ 0.1 m are the inside and outside diameters of burner *B*, respectively as shown in Fig.4.9.

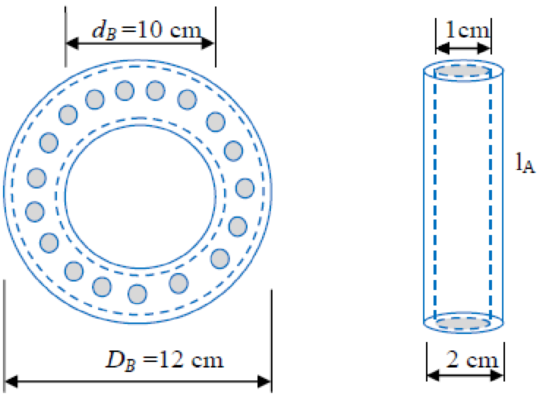


**Fig. 4.9. Detailed Model of Burner B**

For burner *C*, the outside and inside diameters are $D_C$ = 1.2 cm ≈ 0.012 m and $d_C$ = 0.8 cm≈ 0.008 m respectively.

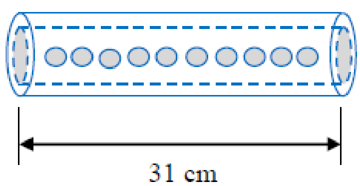


**Fig. 4.10. Detail Model of Burner C**

The top lid was considered as a cuboid with length, $l_{tl}$ = 62 cm ≈ 0.62 m; width, $b_{tl}$ = 43 cm ≈ 0.43 m and height, h = 2 cm 0.02 m as shown in Fig. 4.11a.

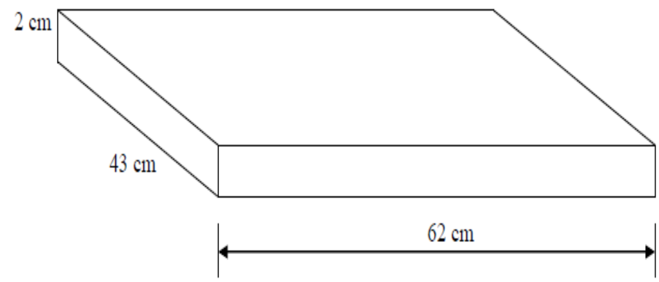


**Fig. 4.11a. Detail Model of the Top Lid**

The side lids are considered as a rectangular prism with lengths, $l_a$ = 42 cm ≈ 0. 42 m, $l_b$ = 20 cm ≈ 0.2 m, $l_c$ = 41 cm ≈ 0.41 m; widths, $b_a$ = 20 cm ≈ 0.2 m, $b_b$ = 1 cm≈ 0.01 m, $b_c$ = 1 cm≈ 0.01 m; and heights, $h_a$ = 1 cm≈ 0.01 m, $h_b$ = $h_c$= 13 cm≈ 0.13 m.

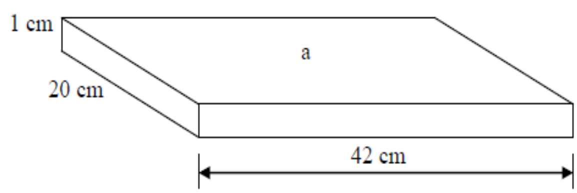


**Fig. 4.11b. Side lid**

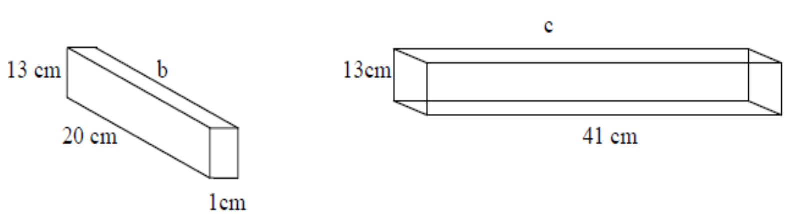


**Fig. 4.11c. Detail Model of the Side Lid Parts**

Fig. 4.12a and Fig.4.12b illustrate the model of the barbecue gate and the handle respectively. Where the length of the gate, $l_{bg}$ = 56 cm≈ 0.56 m; width of gate, $b_{bg}$ = 1 cm ≈ 0.01 m; and the height of the gate, $h_g$ = 94 cm ≈ 0.94 m.

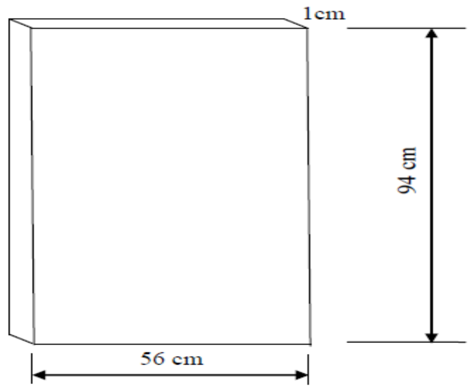


Fig. 4.12a. Model of the Barbecue Gate

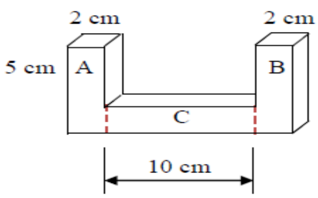


Fig. 4.12b Model of the Handle of the Barbecue Gate

The entire weight of the barbecue machine totally acts on the four wheels which are designed to act as supports. The total weight of the barbecue is therefore, considered to balance on the four wheels. The total weight acting on the wheels is considered as a single force, $W_t$ acting downwards. Four equal forces acting upwards at the wheels balances the weight of the barbecue machine (Budynas and Nisbett, 2011).

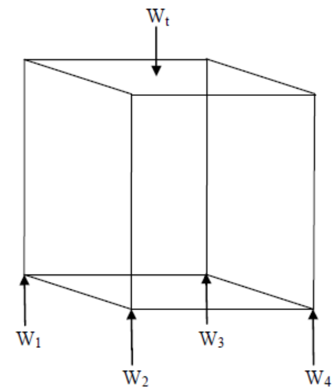


Fig. 4.13. Equilibrium of Forces on the Barbecue Machine

## X. Modeling Of The Hinges

The hinges are purchased with regard to their weights or reactions they would offer for supporting the barbecue gate and the lids.

### *a) Hinges at the Gates*

Fig. 4.14a. and Fig.4.15b. illustrate the dimension of the hinges on the barbecue gate and the side lids respectively. Reactions on the hinges are also indicated. Hinges for the top lid mimic that of the barbecue gate hinges.

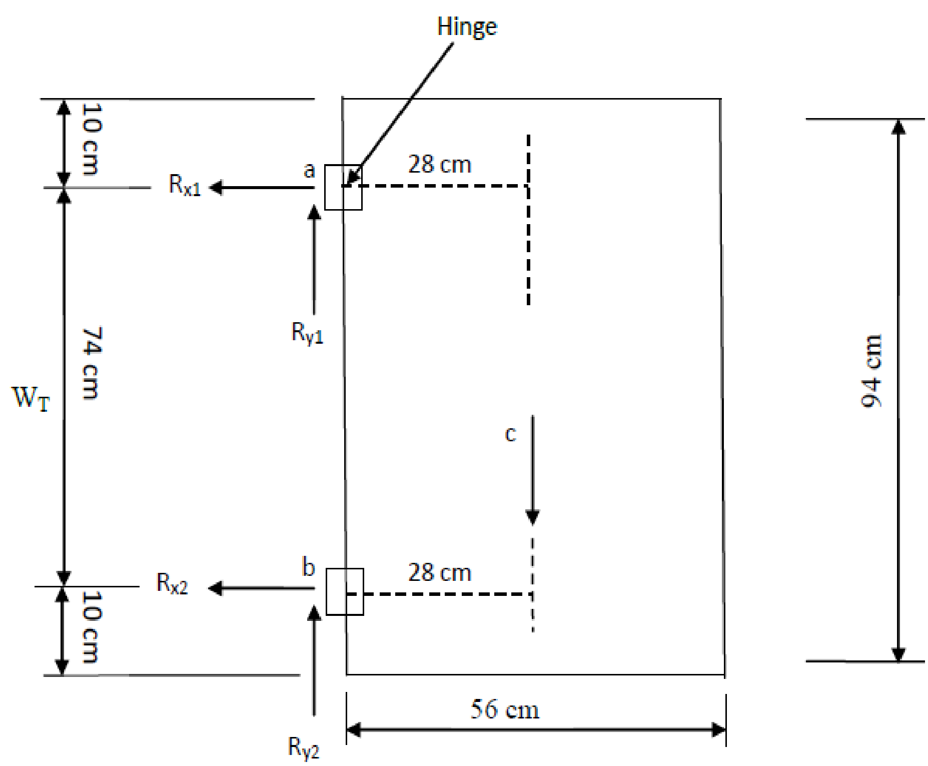


Fig. 4.14a. Barbecue Gate with its Hinges

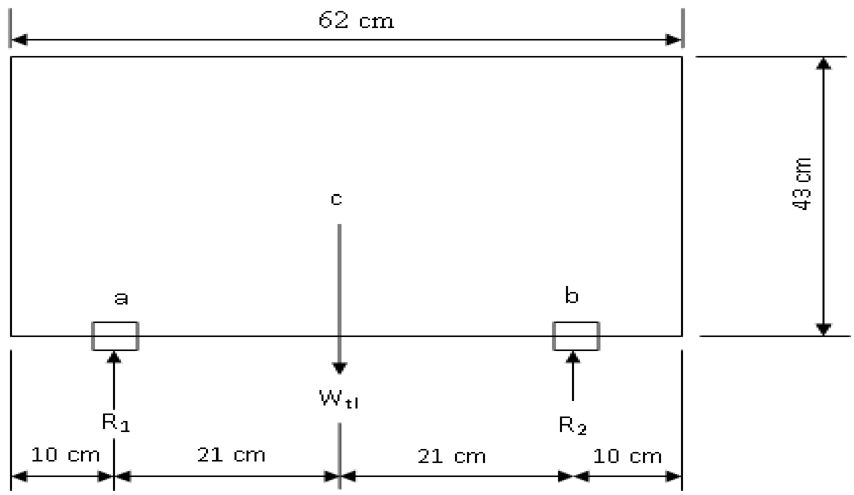


*Fig. 4.14b :* Top Lid with its Hinges and Dimensions

*b) Rate of Heat Flow Analysis*

Let a heat flowing at a rate *Q* be applied at a temperature, *T* across the total surface area, *A*, of the *cast iron cooking grid*. The transfer of heat through the grid is by radiation.

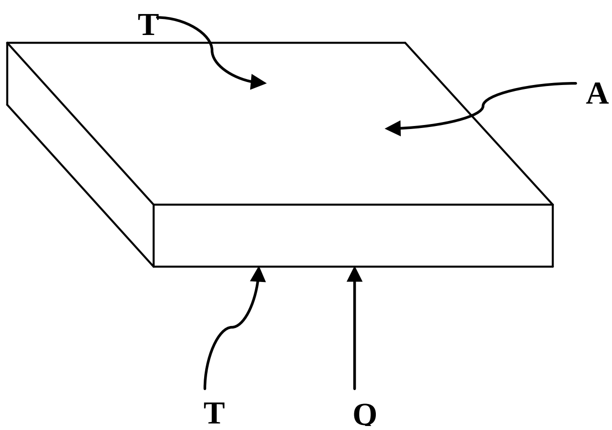


*Fig. 4.15 :* Cooking Surface

According to (Kreith *eta al*, 2011), the rate of heat flow is given by;

$$Q = \varepsilon\sigma AT^4 \qquad 1.5$$

But $\sigma$(Stefan Boltzmann) = $5.67\times 10^{-8}$ W/m$^2$K$^4$; $\varepsilon$ (emissivity of the cooking surface) = 0.21.

Radiation heat transfer differs from that by convection and conduction because the driving potential is not the temperature, but the absolute temperature rose to the fourth power. Furthermore, heat can be transported by radiation without an intervening medium. These principles are what the satay products would go through in the barbecue machine.

*c) How to Operate the Gas Barbecue Machine*

With charcoal, you always had to use starter and wait for the coals to get hot, then you have to wait for the grill to cool before you could clean up that horrible mess left from the coal's ash. For the barbecue machine, you will find is really a great convenience and requires a minimum amount of maintenance to operate. The procedure is as follows;

1. Remove the top lid cover. Position the barbecue so you can easily open the lids completely and have access to every side of the machine.
2. Open the lids of the barbecue machine completely and leave it open.
3. Find the gas cylinder valve (regulator) under the barbecue machine. This circular valve rests just above the gas cylinder. Grasp this valve in your hand and turn it one complete turn clockwise.
4. Gas will flow through the connecting pipe.
5. Light a match close to this burner. It should light with one or two pushes of the button.
6. Grasp the gas cylinder valve in your hand and turn it clockwise or anti-clockwise to control/regulate the fire.
7. Close the lids cover and allow your barbecue to preheat on high for approximately five minutes.
8. Put your food stuffs on the cooking grate and close the lids cover to start grilling process.

## XI. Conclusions

After the complete project, the following conclusions can be deduced:

- The portable gas barbecue machine has been designed, which might be more efficient, serviceability, low cost, and better heat radiation controllability when manufactured.
- Safe operation of the gas barbecue machine has been explained.
- Problems associated with the use of the local skewers that make use of charcoal have been eliminated. E.g. Ashes from the charcoal can get into the products to contaminate the satay products which can result in health hazards.

## XII. Recommendations

The following are important recommendations concerning this design:

- This design is recommended for use by homes and wayside barbecue users. The gas barbecue is also suitable for use during parties, picnics, anniversaries, and camping. Due to its safe operating conditions, this design is also recommended for both indoor and outdoor usage.
- Manufacturing of a prototype of the gas barbecue machine is recommended.
- Other destructive and non-destructive testing should be conducted on the various components of the barbecue machine before manufacturing.
- A modified version of this design is to introduce more vents of smaller sizes in the design to allow more space for air circulation. These vents must be designed in such a way that the entry of air does not disturb the burning process.
- An automatic gas barbecue machine can also be designed where the amount of gas flow and the rate of heat flow would not be taken manually. The automatic gas barbecue machine would operate in a way such that the cooking operations would be executed depending on the cooking and the warming indicator lights.
- Gas barbecue machine produce a great deal of heat that can melt hoses, knobs and other parts. The number one cause of gas fires is an obstruction in the path of the fuel. This can take place behind, underneath or inside. Thus, the gas grill must regularly be inspected for problems. Bugs and other critters can climb into little places causing gas to flow into wrong spaces. At the first sign of problems, the regulator must be turned off and everything disconnected.
- Repeated paintings over several months or years will make a grill or smoker even more impervious to rust.
- It is important to keep cooking grate clean and keep it oiled in the case of bare cast iron to prevent rusting.

## Acknowledgement

The Author wish to acknowledge the support of RTI International and the USAID-funded EHELD project in enabling the production of this research.

## References Références Referencias

1. Ullman, D.G. (2010), "*The Mechanical Design Process*", Published by McGraw-Hill, A business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the
2. Americas, New York, NY 10020, Fourth Edition. pp. 81-91.
3. Budynas, R.G. and J. Keith Nisbett, J.K. (2006), "*Shigley's Mechanical Engineering Design*", 8th Edition in SI Units, The McGraw–Hill Companies, Inc. pp. 71-118.
4. Norton, R.L. (1999), "*DESIGN OF MACHINERY: An Introduction to the Synthesis and Analysis of Mechanisms and Machines*", McGraw-Hill Inc. New York, Second Edition, Chapter 1.
5. Biitman, M. (2008), "*How to Cook Everything, 2,000 Simple Recipes for Great Food*", John Wiley & Sons, Inc. Hoboken, New Jersey, Tenth Edition, pp.1-1700.
6. Askeland, D.R., Fulay,P.P., and Wright,W.J. (2010), "*The Science and Engineering of Materials*", Cengage Learning, 200 First Stamford Place, Suite 400, Stamford, CT 06902, USA, Sixth Edition, pp. 1-900.
7. Callister, Jr. W.D. and Rethwisch, D.G. (2010), "*Materials Science and Engineering-An Introduction*", Eighth Edition, John Wiley & Sons, Inc. River Street, Hoboken, NJ. pp. 1-800.
8. Ashby, M., Shercliff, H. and Cebon, D. (2007), "*Materials, Engineering, Science,*
9. *Processing and Design*", Published by Elsevier Ltd., UK, pp. 1-500.
10. Smith, J.G. (2010), "*GENERAL, ORGANIC, AND BIOLOGICAL CHEMISTRY*", The McGraw-Hill Companies, Inc. New York, pp. 379-412.
11. Storer, J. and Haynes, J.H. (1994), "*The Haynes Welding Manual*", Haynes Publishing Group, Sparkford Nr Yeovil, Somerset BA22 7JJ England, pp.1-100.
12. Khurmi, R.S. and Gupta, J.K. (2005), "*A Text Book of Machine Design*", Eurasia Publishing House, Ram Nagar, New Delhi, 14th Revised Edition, pp. 281-676.
13. Omura, G. (2010), "*Mastering AutoCAD® 2011 and AutoCAD LT® 2011*", Wiley Publishing, Inc., Indianapolis, Indiana, pp. 4-911.
14. Gere, J.M. and Goodno, B.J. (2009), "*Mechanics of Materials*", Cengage Learning, 1120 Birchmount Road, Toronto ON M1K 5G4 Canada, Seventh Edition, pp.7-61.
15. CRAIG, JR, R.R. (2011), "*MECHANICS OF MATERIALS*", John Wiley & Sons, Inc., USA, Third Edition, pp.22-61.
16. Budynas, R.G. and Nisbett, J.K. (2011), "*SHIGLEY'S MECHANICAL ENGINEERING DESIGN*", Published by McGraw-Hill, A business Unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020., Nineth Edition, pp. 71-118.
17. Kreith, F., Manglik, R.M. and Bohn, M.S. (2011), "*Principles of Heat Transfer*", Cengage Learning, 200 First Stamford Place, Suite 400 Stamford, CT 06902, USA, Seventh Edition , pp.541-547.

18. Hale, S. (2000), "*The Great American Barbecue and Grilling Manual*", Abacus Publishing, 2000, ISBN 0-936171-03-0.
19. York, J.A. (2003), "*The Marrow of the Bone of Contention*", A Barbecue Journal, By Story South Winter, Accessed 1-26-06.

Global Journals Inc. (US) Guidelines Handbook 2012

www.GlobalJournals.org