International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Design and Construction of a Heat Regulating Autoclave

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ABSTRACT

A heat regulating Autoclave was designed and constructed. The volume of the Sterilizing Cylinder was determined as a function of the radius, r, of the cross-sectional Area and the height, h, of the Cylinder was computed to be $0.0126m^3$. The design as well involved determination of the mass, m, of the Cylinder in kg as a function of density, ρ, of the material used (stainless steel), $7930kg/m^3$ and the mass of the cylinder was computed as 20kg. The design also involved determination of the Area, A_{sp}, of the steaming plate and it was computed as $0.025m^2$. The lid Area was also calculated as $0.0314m^2$. At the end of the design, the entire Machine was put inside a casing of the volume $0.18225\,m^3$.

Keywords: Sterilizing Cylinder, Stainless Steel, Steaming Area, Lid, Casing.

INTRODUCTION

Instruments that come in contact with the body during all surgical procedures and many non-surgical procedures must be free from all microbial elements. This is to ensure that the risk of infection is kept at a minimum (Rubin, 2016). The process whereby microorganisms of all kinds are inactivated, killed or removed from materials is known as “sterilization”. Sterility is the term used in relation with microorganisms to describe the total absence of life forms in an environment, surface, objects or in an object which may be ingested such as food, medical or pharmaceutical products (Oyewale and Olaoye, 2007). The material that can be used to perform such operation is known as the “autoclave” or “sterilizer”.The name “Autoclave” comes from Greek “Auto” ultimately meaning self and Latin “Clavis” key, thus a self-locking device. Autoclave sterilizes materials by heating them to a particular temperature for a specific period of time. Its purpose in the microbiology laboratory is either to prepare culture media, reagents and equipment or for decontaminating bio hazardous waste materials (Sapkota, 2020). In health care the term “autoclave” is typically used as a nomenclature to describe a “steam sterilizer” (Steris 2017). So, the term Sterilizer and Autoclave are synonymous and can be used interchangeably. That said, autoclave is often used in laboratory setting while sterilizer is more commonly heard in the hospitals but now are used in pharmaceutical, testing lab and for treating commented waste. It is recognised as a very reputable way to sterilize because its efficiency to kill bacteria (Lyons, 2019).
Throughout history, different methods were adopted using materials that were available at that time (In doing sterilization). In 3000BC, the Egyptians used pitch and tar as antiseptics. In later years, the fumes from burning sulphur were found to cleanse objects of infectious materials. In 1680, a French physicist Denis Papin invented pressure cooker that would trap boiling water, convert it into steam and was found to cleanse objects by cooking them. This was further improved upon during the next two hundred years (Rubin, 2016). M. Lemere made an advanced version of Papin’s steam digester in 1820. He stated that, the steam digester can cook meat within half an hour. The lacking side was the serious injury caused by the steam digester (Stewart, 2017). In 1860s, French biologist, Louis Pasteur (1822-1895) helped to confirm the germs can prevent diseases and extend life of food stuffs which lead him to the invention of “pasteurization”. Also, in 1879, Pasteur collaborator Charles Chamberland (1857-1965) invented the modern autoclave. It looked like a pressure cooker with lid on top sealed tightly with clips. In 1881, Microbiologist Robert Koch and others criticized Chamberlands high-pressure steam method, which they believe may damage laboratory equipment and developed an alternative unpressurized sterilizer instead. This eventually evolves into a machine called “Koch’s Autoclave”. In 1889, Curt Schimmelbusch builds on the work of Chamberland and Koch to produce a drum type sterilizer known as “Schimmelbusch’s Autoclave” (Woodford, 2020).

Chamberland’s Autoclave

The first autoclave was “Chamberland’s Autoclave”. Charles Chamberland built upon Denis Papin’s work. Chamberland invented the autoclave in response to Pasteur’s requirement for a sterilization technique that utilize temperature higher than 100℃. This was developed between 1876 and 1880 (Satakar and Mankar, 2019). Pasteur has previously determined that moist heat was more effective than dry heat which leads to the development of a high temperature steam sterilizer. Other scientist contributed to the engineering of the autoclave. One of them was the German biologist, Robert Koch.

Koch and his colleagues determined that there were certain limitations to steam at 100℃ (Steris, 2017). He criticized Chares Chamberland's high pressure steam method, which they believe may damage laboratory equipment and developed alternative, unpressurized sterilizer instead. This eventually evolves into a machine called "Koch Autoclave" (Woodford, 2020). In addition, Charles Chamberland, Louis Pasteur's pupil and collaborators developed the first steam sterilizer in 1876 while Robert Koch and his associates in 1881 devised the first non-pressure flowing steam sterilizer (Skellie, 2010).

Steam Sterilizer

Stream sterilizers have been used for more than a century to sterilize items that can withstand moisture and high temperature. Steam is water in vapour state; it is non-toxic, generally rapidly available and relatively easy to control. A good understanding of basic steam sterilization principles and cycles is necessary to avoid mistakes that can lead to injury, lower productivity, higher operations and maintenance costs damage to load items (Dion and Parker, 2013).

MATERIALS AND METHODS

Materials

The materials needed for the construction are as follow:

i. 1mm Stainless steel: This was used for construction of the cylinder.
ii. Wood: It used for construction of the base.
iii. Castors: They were used for enabling the machine to be moveable.
iv. Stainless electrode: This was used for welding the stainless steel.
v. Lid: This was used for covering the cylinder.
vi. Heating element: It was used for heating the water.
vii. Power cable: It was used as the conductor which will take energy to the heating element.

Methods

Determination *of the Volume of the Sterilizing Cylinder*

The volume of the sterilizing cylinder, V, was calculated using equation (1):

$V = \pi r^2 h$.. (1) (Oyewale and Olaoye, 2007)

Where:

r= radius of the cross-sectional area of the cylinder in m.

h = height of the cylinder in m.

Determination of the Mass of the Cylinder

The mass of the cylinder, m, will be calculated using equation (2)

$m = \rho V$ …………………………………………….. (2) (Oyawale and Olaoye, 2007)

Where:

ρ =Density of stainless steel in kg/m^3.

V = Volume of the cylinder in m^3.

Determination of the Area of the Steaming Plate

The area of the steamy plate, A_{sp}, will be calculated using equation (3).

$Asp = \pi r^2$ ……………………………….....………...… (3)

Where:

r = radius of the cross-sectional area of the steamy plate in m.

Determination of the Area of the Lid

The area of the lid, A_{lid}, will be calculated using equation (4).

$A_{lid} = \pi {r_{lid}}^2$ ……………………………………………… (4)

Where:

r_{lid} = radius of the cross-sectional area of the lid in m.

Determination of the Volume of Casing

The volume of the wooden basement, V_{wb}, will be calculated using equation (5)

.$Vwb = P \times L \times T$ ……………… …………........................(5) (Baiduri B, 2019)

Where:

P = Length of the casing in m.

L =Width of the casing in m.

T = Height of the casing in m.

In the design, the value of length and width is the same. So the equation will be interpreted as in equation (6).

$Vwb = P^2 \times T$ ……………………………………………… (6)

RESULTS AND DISCUSSION

Determination of the Volume of the Sterilizing Cylinder

Volume of the Sterilizing Cylinder, as stated in Equation 1, was calculated as follows:

The selected value for r = 0.1m, h = 0.4m.

$V = \pi \times 0.1^2 \times 0.4$

$V = 0.0126m^3$

Determination of the Mass of the Cylinder

As stated in equation 2, the mass of the cylinder was computed as follows:

The density of a stainless steel is $= 7930kg/m^3$ (Oyawale and Olaoye, 2007).

From the above, $V = 0.0126m^3$

So,

$m = 7930 \times 0.0126$

$m = 20kg$

Determination of the Area of the Steaming Plate

Equation 3 was used in computing Area of the steaming plate as stated below:

The selected value of r = 0.09m because, the steamy plate will be inserted inside the cylinder.

So,

$Asp = \pi(0.09)^2$

$Asp = 0.0255m^2$

Determination of the Area of the Lid

The value of the Area of the Lid was computed using equation 4 as follows:

The selected value of r_{lid} = 0.1m so that, the lid should be able to cover the cylinder properly.

So,

$A_{lid} = \pi(0.1)^2$

$A_{lid} = 0.0314m^2$

Determination of the Volume of the casing

Equation 6 was used in computing the volume of the wooden basement as follows:

The selected value of $P = 0.45m$ and $T = 0.9m$

because the diameter of the cylinder should fit the basement and only small amount of height of the autoclave will be inserted in the basement.

So, $Vwb = (0.45)^2 \times 0.9$

$Vwb = 0.18225m^3$

CONCLUSSION

An Autoclave was designed and constructed. During the design and construction, the Volume of sterilizing cylinder was computed as 0.0126m3, the mass of the cylinder was computed as 20kg, Area of the steaming plate was computed as 0.0255m2, Area of the Lid was computed to be 0.0314m2 and the Volume of the wooden basement was computed to be 0.00529m3. All the above parameters were used in the construction as demonstrated in the Appendices 1-7.

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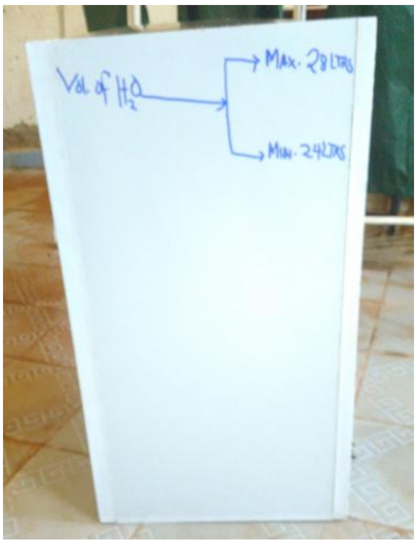
Appendices

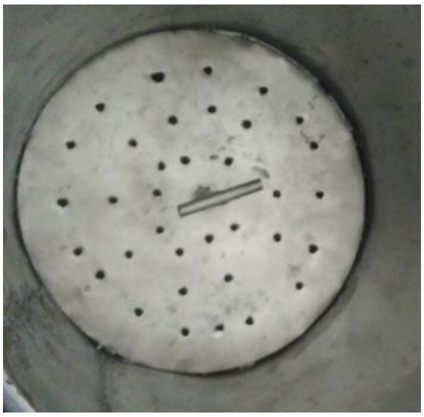
Appendix 1: Cylinder of the Autoclave

Appendix 2: Left side of the Autoclave



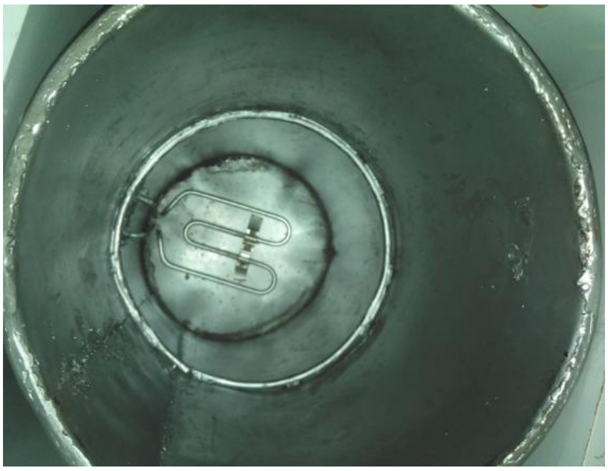
Appendix 3: The back side of the Autoclave showing the Heat Regulating Device

Appendix 4: The steaming plate



Appendix 5: The Lid

Appendix 6: The boiling chamber with Heater



Appendix 7: The complete Autoclave