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Design and Analysis of Portable RO Water Bottle

James Deepak D[1], Alex Pravin L[2], Alfred Jones A[3], Joel George Ignatius[4], Joseph Ashwin S[5]

[1]Assistant Professor, [2,3,4,5]Student
[1-5]Department of Mechanical Engineering, Loyola-ICAM College of Engineering and Technology, Chennai, Tamil Nadu, India

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Abstract - *The system proposed in this paper is based on solution for purifying contaminated water to make it safe, clean and drinkable which is portable and can be carried anywhere. Reverse Osmosis (RO) is a membrane-based process technology which helps to purify water by removing the dissolved salts(ions), particles, colloids, organics, bacteria and pyrogens from the feed water with the assistance of partially permeable membrane hence it results in permeate and concentrate stream. Drinking dirty water could mean a string of grim and potentially-fatal infections. Henceforth the idea of this "Design and Analysis of Portable RO Water Bottle" is to propagate the use of water bottle which has RO membrane installed in it, so that it can be easily carried anywhere. The bottle is made up of Polypropylene (PP) which a popular plastic known for its strength and low cost. This water bottle is bifurcated; therefore, one segment holds the inlet brackish water and another segment stores the pure permeate water. The inlet portion has a plunger alike mechanism which allow us to give requisite pressure to the inlet water, so that the solvent from region of high solute concentration passes through semipermeable membrane to a region of low solute concentration by applying a pressure in excess of osmotic pressure*.

Key Words: Reverse Osmosis (RO), Polypropylene (PP)

1. INTRODUCTION

Reverse Osmosis is very popular technology that is used around the world for removing ions, unwanted molecules and larger particles from drinking water. Reverse Osmosis can remove many types of dissolved and suspended chemical species as well as biological ones from water and is used in both industrial process and production of potable water. The result is that the solute is retained on the pressurized side and the solvent is allowed to pass to the other side. This very technology has been incorporated in designing a bottle which can be used to covert contaminated water to clean and drinkable water and can be carried anywhere. It is a common fact that drinking water is difficult to find in places like forests, dessert and also in rural areas. Therefore, the person who has access to this bottle can easily obtain drinking water by following the given simple instructions. The bottle has been designed while considering several parameters such as weight, strength, aesthetics and value to customer. Polypropylene (PP) and LDPE (Low Density Polyethylene) are the two raw materials which will be used to manufacture the bottle.

2. LITERATURE SURVEY

2.1 Modelling and Simulation of performances of the Reverse Osmosis Membrane:

Authors: A.Lilane , M.Chouiekh, S.Hariss , H.Jenkal, D.Saifaoui

This helps to study the performance of the reverse osmosis membrane, and more importantly based on a small capacity membrane desalination pilot, to discover the effects of physico chemical properties on the productive mode of reverse osmosis, as well as the mode of energy consumption of the system, which is still intensive energy.

2.2 Safe drinking water: Concepts, Benefits, Principles and Standards:

Authors: Megersa Olumana Dinka

This chapter presents aspects of safe drinking water – Background information , definition of water safety and access, benefits,principles and regulation, factors challenging the sustainable water supply and water quality standards and parameters.

2.3 The influence of LDPE Content on the mechanical properties of HDPE/LDPE blends:

Authors: Anour Shebani, Abdalah Klash, Rabea Elhabish, Shalh Abdsalam, Hassan Elbreki and Wael Elhrari

This is a research based on mechanical properties of blind of high density polyethane (HDPE) and Low Density Polyethylene (LDPE). Various ratios (80/20, 60/40, 40/60 and 20/80) of HDPE & LDPE blends were tested. Finally , the research showed the blend with the composition (HDPE (40)/LDPE (60)) comparatively better overall mechanical Properties.

2.4 Performance of Activated Carbon in Water Filters:

Authors: YK Siong, J Idris. M. Hazar Atabaki

The purpose of this paper to study the performance of activated carbon in water filter System. Here the water samples were analyzed using PH test, turbidity test, total suspended solid examination, biochemical Oxygen demand (BOD) test and chemical Oxygen Demand (COD) test.

3. RESEARCH GAP

Reverse Osmosis (RO) is the most common method used to purify water. It is a well-studied technique to make water potable. As RO does not occur naturally, it requires energy for the process. This energy is usually provided by an electrical pump that provides pressure. In the case of a user who is mobile and in a remote environment, it is difficult to contain a pump and power supply in an area of limited space. Also uninterrupted power cannot be ensured in such conditions.

There have been efforts to confine a water filter in a space as small as a water bottle and are successful. These filters use passive filtration techniques to filter water. The level of purification obtained is questionable. This is because of the filtration techniques being used. Visible contaminants and microscopic particles can be removed up to a certain extent, but chemical and organic impurities are still present.

Hence, the objective of this product is to combine RO technology into the size of a water bottle, so that it can be used as a reliable source of water in environments where drinking water is difficult to obtain.

4. DESIGN OF REVERSE OSMOSIS BOTTLE

The Reverse Osmosis (RO) Bottle was designed using SolidWorks. The design is made having the ease of use in mind. The RO Bottle has two halves; the upper half is where the input water is stored and the lower half is where the clean output water is obtained. The body of the bottle is made of low-density polyethylene (LDPE) and working parts are made of polypropylene (PP). The key parts of the bottle are listed.

4.1 Body of the Reverse Osmosis Bottle

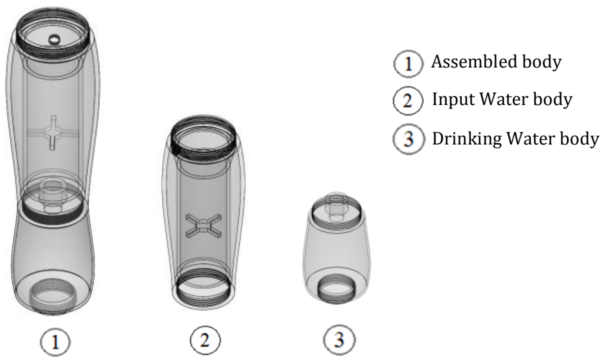

Fig -1: RO Bottle Body

The body is split into two halves for the ease of maintenance of the bottle. The input water body consists of a concentric partition. This is where the pressure is applied for the reverse osmosis to take place. Ribs are provided in necessary locations to distribute the stresses in the bottle. O-rings are placed to provide leak proof joints.

4.2 Working Parts

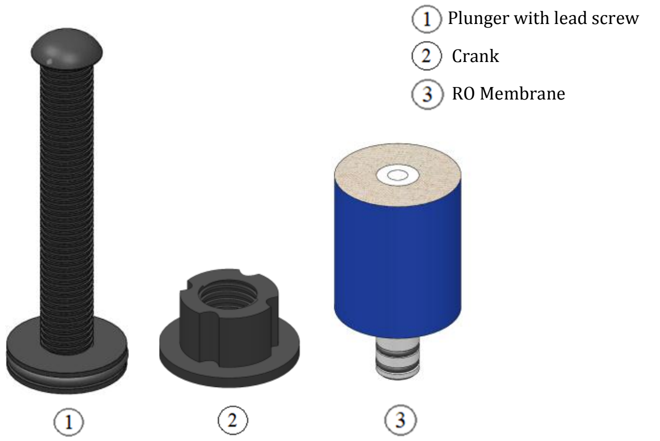

Fig -2: Working Parts

The RO bottle has 3 key working parts – plunger, crank and the RO membrane. The crank located at the top of the bottle is rotated by the user. The crank is threaded with the lead screw of the plunger, which moves up and down when the crank is rotated.

Input water is poured into the inner concentric section of the input water body. An RO membrane is fixed at the bottom end of the concentric section. When the crank is rotated, the plunger moves down, providing enough pressure to drive the RO process.

The clean water flows out of the RO membrane into the drinking water body, while the concentrate is collected in the outer concentric section of the input water body which can be disposed later.

4.3 Other Parts

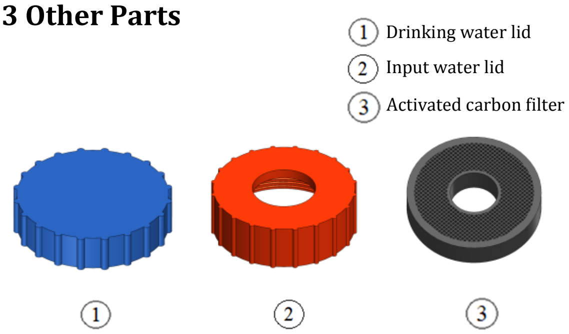

Fig -3: Other Parts

Both the ends of the bottle are provided with lids. The drinking water lid acts as a water proof cover and also serves as a base for the bottle to stand upright on a level surface. The input water lid is provided with a hole for the passage of the lead screw and also as a support for the crank. An extra activated carbon filter is placed at the inlet for the input water to be removed of odour and other macroscopic impurities.

All the parts can be serviced by the user and can be replaced when they exceed their intended life.

4.4 Final Assembly

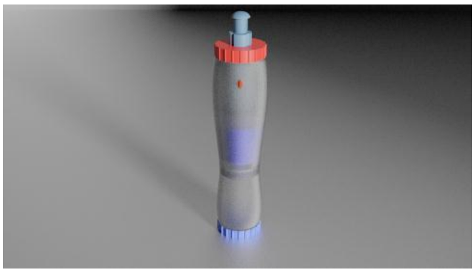

Fig-4: RO Bottle Rendering

The fig-6 shows the final rendering of the RO Bottle. The user can get a visual feedback of the condition inside the bottle because of the translucent body.

5. ANALYSIS OF PORTABLE RO WATER BOTTLE

5.1 Design Calculations:

1) Input Water Body:

Table-1: Input-Water Body specifications

Material	LDPE
Length	200mm
Outer Diameter (Max)	75mm
No. of Partitions	2
Diameter of Inner Partition	50mm
Volume (Inlet Water)	300ml
Volume (Concentrate)	100ml

2) Output Water Body:

Table-2: Output-Water Body Specifications

Material	LDPE
Length	100mm
Outer Diameter	73mm
Volume	500ml

3) Selection of Materials:

The materials have been selected and finalized based on the market availability, machinability, and the physical properties for the 'RO Bottle'.

Table-3: Material Selection

Bottle Body (Inlet & Drinking)	LDPE
Lid (Inlet & Drinking)	PP
Crank	PP
Lead Screw & Plunger	PP

4) Calculations:

i) Osmotic Pressure:

As we are trimming the length of the standard RO membrane, the approach we took was to use the rated value and find the pressure value after trimming.

Rated Pressure – 60 psi = 0.41N/mm2
Cross Sectional Area of partition (2), $A_p = \pi.r^2$
$= \pi \times 2.5^2$
$A_p = 19.63\ mm^2$

Force to be exerted on the partition (2) to achieve 60 psi,
$F_{p1} = P \times A_p$
$= 0.41 \times 19.63$
$= 8.04\ N$

This force of 8.04 N is distributed over the membrane area of $A_{m1} = 325160.64\ mm^2$

This equates to a pressure of $P_m = F_{p1} / A_{m2}$
$= 8.04 / 325160.64$
$= 2.47 \times 10^{-5}\ N/mm^2$
$P_m = 2.47 \times 10^{-5}\ N/mm^2$

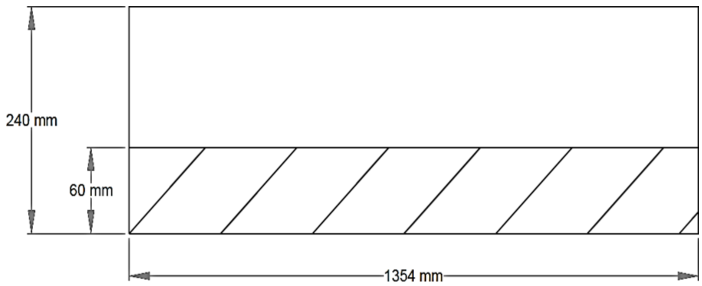

Fig -5: Active Membrane Area

By trimming the RO membrane to a height of 60 mm, the active membrane area decreases to $A_{m2} = 60 \times 1354$
$= 81240\ mm^2$

Now, for the same pressure Pm to be applied over the membrane, the force required is,
$F_{p2} = P_m \times A_{m2}$
$= 2.47 \times 10^{-5} \times 81240$
$F_{p2} = 2\ N$

Hence a force of 2 N has to be applied over partition.

This translates to a pressure of $P = Fp_2 / Am_2$
$= 0.101\ N/mm^2$
$= 14.6$ psi
$P = 14.6$ psi

ii) Lead Screw Calculations:

The thread profile selected is square thread.

The force required over the partition (2), = 2 N

Keeping the lead angle as $\alpha = 20°$

The coefficient of friction between x and x is $\mu = 0.2$

Hence the friction angle is given as $\phi = \tan^{-1} \mu$
$= \tan^{-1} 0.2$
$\phi = 12°$

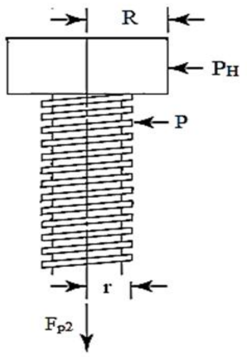

Fig-6: Lead Screw Schematic

The axial load Fp2 and tangential load P is related as
$P = Fp_2.\tan(\alpha + \phi)$
$= 2 \times \tan(20° + 12°)$
$P = 1.25$ N

'r' being the mean radius of screw

Torque required at the crank handle, $T = P \times r$
$= 1.25 \times 10.5 \times 10^{-3}$
$T = 0.013$ Nm

iii) Input Body Stress:

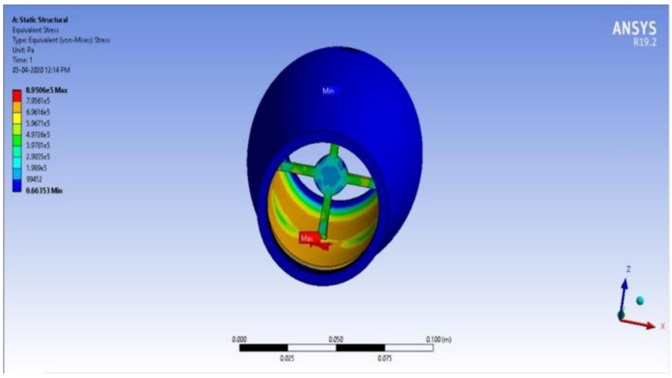

Fig-7: Stress Analysis of Input-Water Body

The stress on the 'Input-Water Body' was analyzed using ANSYS Workbench and the maximum stress was found to be well below the maximum stress limit.

iv) Mass Properties:

Using density of Low-Density Polyethylene and Polypropylene, the mass of the parts was found using the SolidWorks evaluate tool.

Density of LDPE, $\rho_{LDPE} = 910\ kg/m^3$

Density of LDPE, $\rho_{PP} = 946\ kg/m^3$

Table- Part name and their masses

S.NO	Part Name	Mass in g
1.	Input-Water Body	315.65
2.	Drinking-Water Body	84.37
3.	Plunger & Lead Screw	62.3
4.	Crank	16.38
5.	Input-Water Body Lid	38.21
6.	Drinking-Water Body Lid	53.75
7.	RO Membrane	50
8.	Concentrate Water Lid	0.5
9.	Carbon Filter	15.0
10.	O-Rings	2
	Total Weight	638.16

v) O-Ring selection:

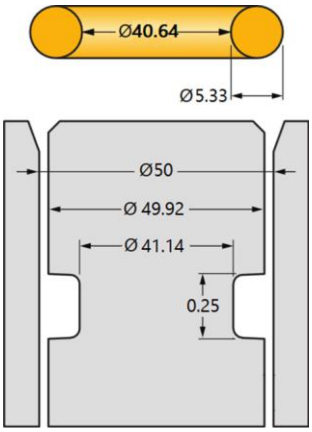

Fig-8 3-D View of O-Ring

The O-ring and gland design dimensions were selected using the 'Parker O-ring Handbook' for standard dimensions. The Fig X.3 represents the dimension for the O- ring and gland. The O-ring standard chosen is AS-568-326.

6. CONCLUSIONS

The design and analysis of the Reverse Osmosis Bottle is discussed and its specifications are detailed. From the analysis it is clear that,

- 500ml of filtered water can be stored at once in the RO Bottle.
- A torque of 0.013 Nm is required to be applied at the crank; this torque can easily be applied by the human hand.
- Once the service life of the membrane and filter is over, the user can replace them on their own.

REFERENCES

[1] A.Lilane , M.Chouiekh, S.Hariss , H.Jenkal, D.Saifaoui - (2019) –"Modelling and Simulation of performances of the Reverse Osmosis Membrane" 10.1016/j.matpr.2019.07.694

[2] Anour Shebani, Abdalah Klash, Rabea Elhabish, Shalh Abdsalam, Hassan Elbreki and Wael Elhrari - (2018) – "The influence of LDPE Content on the mechanical properties of HDPE / LDPE blends" 10.31031/RDMS.2018.07.000672

[3] Jennifer LJ, Daniel TC, Jermaine MB, Ajmer KD, Eric NB, et al. (2016) – "Mechanical properties of low density polyethylene. Journal of dynamic behavior of Materials" 2(54):411-420

[4] YK Siong, J Idris. M. Mazar Atabaki – (2013) – "Performance of Activated Carbon in Water Filters"

[5] Megersa Olumana Dinka – (2018) – "Safe drinking water : Concepts, benefits, principles and standards" 10.5772/intechopen.71352

[6] R.Khademi-Zahedi – (2019) – "Application of the finite element method for evaluating the stress distribution in buried damaged polyethylene gas pipes" - Volume 4, Pages 59 – 71.

[7] Bhandari, V B – (2004) – "Design of Machine Elements", Tata McGraw-Hill, ISBN 978-0-07-061141-2, Pages 202 – 213.

[8] Anthony Espocito – (1998) – "Fluid Power with Applications", IBSN 978-81-7758-580-3.

BIOGRAPHIES

James Deepak D,
Assistant Professor,
Department of Mechanical Engineering
Loyola-ICAM College of Engineering & Technology,

Alex Pravin L,
Student,
Department of Mechanical Engineering
Loyola-ICAM College of Engineering & Technology,

Alfred Jones A,
Student,
Department of Mechanical Engineering
Loyola-ICAM College of Engineering & Technology,

Joel George Ignatius,
Student,
Department of Mechanical Engineering
Loyola-ICAM College of Engineering & Technology

Joseph Ashwin S,
Student,
Department of Mechanical Engineering
Loyola-ICAM College of Engineering & Technology