International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019

Experimental Simulation of Solar Aqua Lens Concentrator

A. S. Patel, P. D. Patil

Abstract: The lens was built from readily available materials in the market. The liquid used in lenses were tap water, 30% sugar solution in the hyper elastic low density polyethylene foil. The experimental set up was exposed to sunlight. The focal length point and light intensities were measured at that focal point spot, concentration ratio at each focal point was calculated. The concentration ratio is inversely proportional to focal point. The experimental data was tabulated. The theoretical lens radius of curvature and deformation of lens was validated by ANSYS finite Element Modeling (FEM).The lens deformation of hyper elastic foil was also compare with AUTO CAD. Solar aqua concentrator can be used where high focusing thermal application is required.

Keyword: Solarconcentrator, Solarintensity,Refractive index

I. INTRODUCTION

. Solar energy is abundantly available in India as India is near to equator so the solar intensity is very high throughout the year. The solar energy provides to the earth for one hour could meet the global energy need for one year as we are able to harness only 0.001% of that energy. Solar energy will be accessible as long as we have the sun therefore sunlight will be available to us for at least 5billion years. Approach was done to develop an solar aqua concentrator from cheap and easily available hyper elastic low density polyethylene foil to concentrate the solar energy which is highly dispersed form, the aqua lens form a plano convex Len using different liquid in lens having high refractive index of liquid

II. LITERATURE SURVEY

Solar Concentrator can increase the system efficiency for solar based energy conversion system. To develop an inexpensive method of producing liquid lenses for solar energy concentration basic material required are a mass of clear transparent liquid (such as water or glycerin) & clear transparent plastic sheet or plastic foil[1].

Properties of large scale water lenses for solar concentration were investigated. These lenses are built readily

With available material, exposed to sunlight, the focal length & light intensity in the focal spot were measured and calculated [2].

Revised Manuscript Received on December 30, 2019.
* Correspondence Author
A.S.Patel, Assistant Professor in Mechanical Department, D.N.Patel College Shahada Maharashtra,India. Email ashokpatel32000@yahoo.com
P. D. Patil, Principal,Jaykumar Raval Institute of Technology Dondiacha, Maharashtra, India. Email pdpatilco@rediffmail.com

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

A solar light concentrator composed of water and hyper elastic transparent film has been designed .This flexible lens design can trace the solar movement through control of the tensile stress and around of water & concentrate the solar energy into thermoelectric module surface [3].

Varma etl.presents one such effort to explore the potential of the convex lens to be used for water heating application. In his work using 6 convex lenses and copper receiver tube many system are developed [4].

III. EXPERIMENTATION

The lens was form by placing the hyper elastic low density polyethylene foil on the metal ring of 100cm without any wrinkle on surface of lens the foil was hold on ring .A normal pretension was applied to foil before clipping to ring.

The developed lens ring was placed on three long supports an exposed to sunlight for experiment. The tap water liquid was taken in quantity of 500 ml and pour in ring foil due to which homogenous pressure distribution of water over the ring hyper elastic foil form a shape of plano convex lens. After that we placed the absorber black plate at a focal point were the spot is seen Next measured the focal point length, solar intensity at that spot and also measure lens diameter, lens length. Repeat the procedure by take-in 500 ml varying increment of water in foil lens and measure the above parameter of each quantity taken.

Similarly repeat the experiment procedure for 30% sugar solution as liquid of lens in concentrator by with quantity 500ml and vary with increment of 500ml in the lens and measure the parameter focal length, solar intensity, lens diameter etc. The experimental data was collected and tabulated.

A EXPERIMENTAL DATA ACQUISITION

Atmospheric intensity of sunlight 150.7watt/m^2

Table I: First liquid–Tap water

Sr. No	Quantity Of water in m.l	Solar Intensity at focal point in watt/m^2	Focal Length /Point in cm	Length of curve surface of lens In cm	Concentration ratio
1	500	2938	161	29	0.05129
2	1000	3539.2	142	32	0.04258
3	1500	4108	132	36	0.03668
4	2000	4534.6	122	40	0.03323
5	2500	5056	120	42	0.02998

Table II: Second liquid –Sugar solution 30%

Sr. No	Quantity Of water in m.l	Solar Intensity at focal point in watt/m^2	Focal Length / Point in cm	Length of curve surface of lens In cm	Concentration ratio
1	500	2730.2	124	29	0.05519
2	1000	3043.08	121	32	0.04952
3	1500	3428.6	115	36	0.04395
4	2000	3728.8	110	40	0.04041
5	2500	3997.4	90	42	0.03769

IV. SIMULATION AND RESULT ANALYSIS

For the Simulation ANSYS APDL R14.4 was used as element type plane quad 4node 182 axis symmetric element options. Due to the axis symmetry property only half of the LLDPE foil was modeled with radius and uniform thickness of foil 40micron.Apply coordinate in key point. Then applying distributed load pressure of liquid on structural. Due to load pressure the foil get deformed and lens shape was extracted by means of previously calculated lens radius curvature and lens height was noted. The lens shape was applied for further analysis and FEM simulation was repeated for other volume of liquid.

To calculate theoretical lens radius curvature on bases of focal length of the liquid filled lens for plano convex liquid lens surrounded by air assuming a refractive index of air as 1.

The formula,

$$\frac{1}{f} = (n-1)\frac{1}{r} \tag{1}$$

$$\therefore f = \frac{r}{(n-1)} \tag{2}$$

$$\therefore n = 1 + \frac{r}{f} \tag{3}$$

$$or\ \ r = f(n-1) \tag{4}$$

Where, f = Focal length, n = Refractive index of liquid, r = Radius of curvature

Using the above formula we can tabulate the data of different liquid used in lens such as water, 30% of sugar solution and honey having different refractive index as 1.33, 1.38 and 1.604 respectively.

Table III: Radius of Curvature for Water Lens

Sr.No	Quantity Of water in m.l	Focal Length/ Point in cm	Theoretical Lens radius of Curvature In cm	Theoretical Lens radius of Curvature In mm
1	500	161	53.13	531.3
2	1000	142	46.86	468.6
3	1500	132	43.56	435.6
4	2000	122	40.26	402.6
5	2500	120	39.60	396.0

Table IV: Distributed pressure for water lens

Sr. No	Quantity Of water (in ml)	Force (in N)	Pressure (in N/mm^2)	Pressure Distributed (in N/mm)
1	500	4.905	$5.540134667 \times 10^{-6}$	7.386846×10^{-8}
2	1000	9.81	1.4227703×10^{-5}	1.7784628×10^{-7}
3	1500	14.715	$2.469760703 \times 10^{-5}$	2.744178×10^{-7}
4	2000	19.62	$3.866493183 \times 10^{-5}$	3.8664931×10^{-7}
5	2500	24.525	$4.980684085 \times 10^{-5}$	4.7435086×10^{-7}

Table V: Lens radius of curvature validation

Sr. No	Quantity Of water (in ml)	Lens radius of curvature byAnsys	Theoretical Lens radius of curvature (mm)	Error %	Lens radius of curvature measured by Auto Cad	Diameter of lens mm
1	500	496.36	531.3	6	546.3	296
2	1000	419.173	468.6	10	468.9	314
3	1500	435.48	435.6	0.02	443.8	350
4	2000	461.42	402.6	12	426	385
5	2500	468.42	396.0	15	398	400

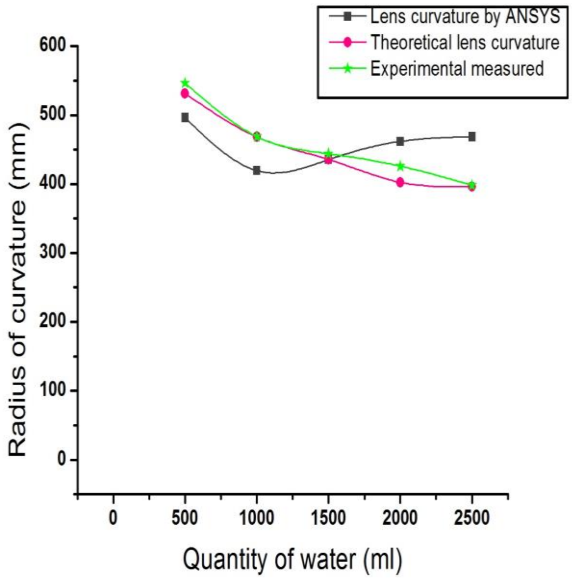

Figure 1: Graph showing lens radius of curvature

The above figure 1 graph shows relation between quantity of water and lens radius of curvature measured by ANSYS, by AutoCAD and theoretical lens curvature measurement.

The graph shows uniform curve of values and the percentage of error is within the limit. The lens radius of curvature calculated, measured by ANSYS software are validated and it is within the range. The radius of curvature of lens decreases as the volume of liquid quantity increased.

Table VI: Deformation of water lens validation

Sr. No	Quantity Of water (in ml)	Deformation by ANSYS DMX	Theoretical Height of Deformation	Error %
1	500	23.20	20	13%
2	1000	31.73	26	18%
3	1500	38.94	36	7.5%
4	2000	45.55	46	0.9%
5	2500	49.71	54	7.9%

Retrieval Number: B2340129219/2019©BEIESP
DOI: 10.35940/ijeat.B2340.129219
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

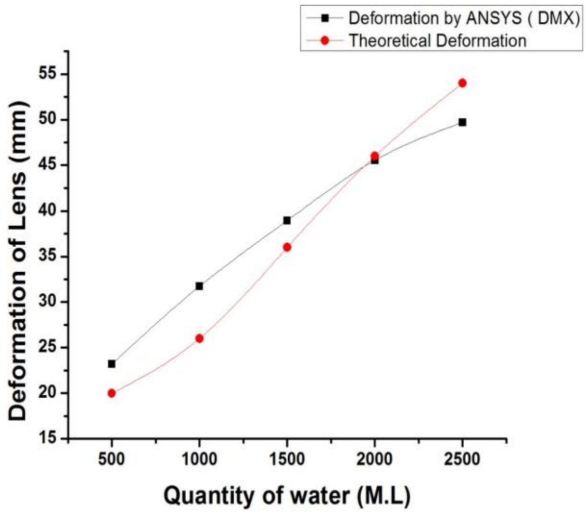

Figure 2: Graph showing deformation of water lens

The graph and tabulated value of deformation is uniform and having the error within the range. Deformation of elastic foil increased as quantity of liquid increased. The deformation of lens by ANSYS and deformation height is validated as shown in the figure 3 to figure 7 given below.

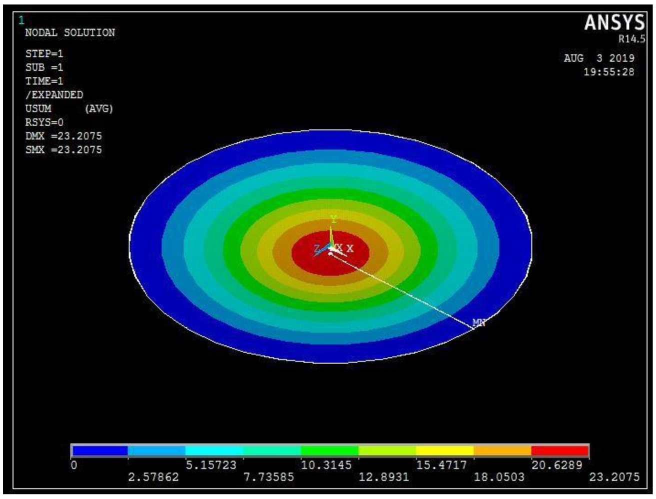

Figure 3: Deformation of Lens 500 ML

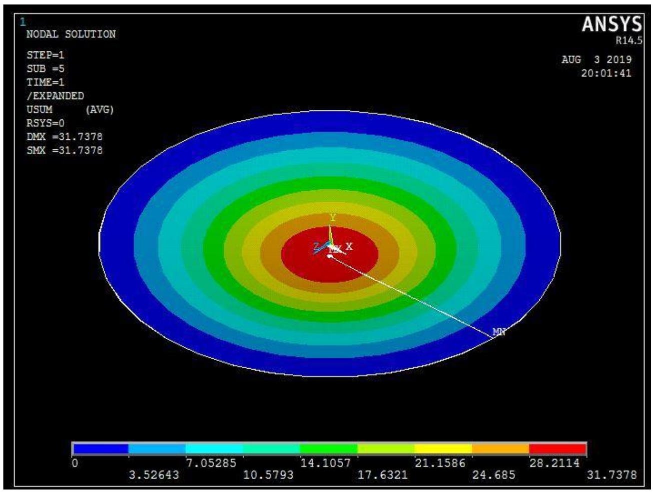

Figure 4: Deformation of Lens 1000 ML

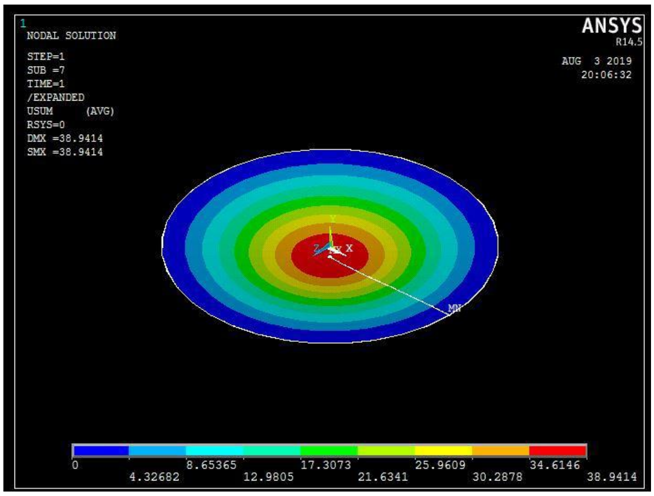

Figure 5: Deformation of Lens 1500 ML

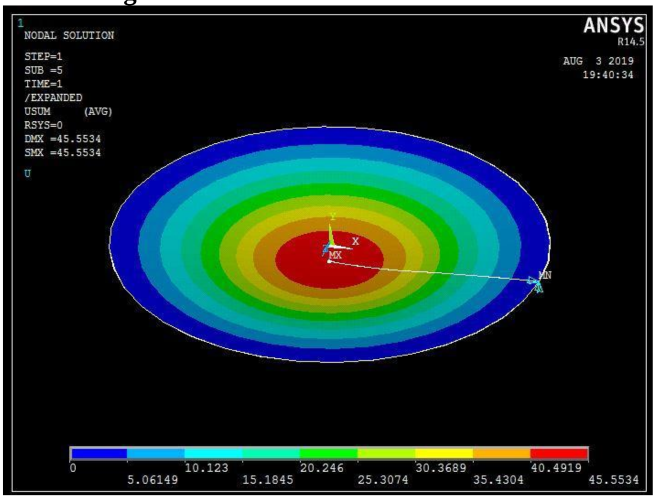

Figure 6: Deformation of Lens 2000 ML

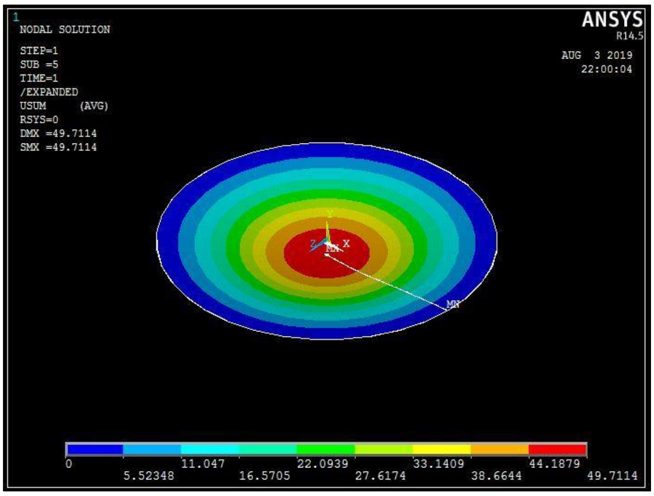

Figure 7: Deformation of Lens 2500 ML

V. CONCLUSION

The experimental Simulation of solar aqua concentrator was perform. The effect of concentration ratio, diameter of focus area and its significance was studied. Refractive index of liquid used as medium is dominant parameter for good focus of light. The focal length and solar intensity at the focal point are measured and compare.

The theoretical lens radius of curvature is validated with lens radius of curvature by ANSYS software the % error is within the range limit also lens radius of curvature measured by AUTOCAD is validated.

The theoretical height of deformation of lens is validated to deformation by ANSYS software the % error is within the range limit.

The radius of curvature of lens decreases as the volume of liquid quantity increased. Also deformation of elastic foil increased as quantity of liquid increased. Due which the focal point is decreased. The parametric analysis is studied.

REFERENCE:

1. Rajendar Singh Chaudhan "solar energy concentration with liquid lenses " in Elsevier solar energy volume 18 issue 6 p.p 587-589
2. A.S. Mondol, B. Vogel, and Bastian "Large scale water lens for solar concentration "in optical society of America 2015
3. Ryosuke O. Suzuki, Atsuhi Nakagawa, Hongtaosul and Takeyuki Fujisaka "Thermoelectric generation using water lenses" Journal of Electric materials volume 42, issue 7,05May 2013 p.p 1960-1965
4. Er vinod Kumar verma, vipin tripathi, vivek kumar verma, Mohd Nuzaif "Development of CSP using convex lenses for Domestic water Heating " in International Journal Research in Engineering &Technology volume 03 ,05 May 2014 PISSN: 2321-7308
5. LikhitKhamlampao,jindapornJamraddloedlukandCharoenpornLertsatitthanakorn."Experimental study of a thermoelectric solar collector integrated with a water lens" NU Science Journal 2014: 11(1) 15-22
6. A.Ghaffar and Q.A.Naqvi "Focusing of electromagnetic Plane Wave into Uniaxial Crystal by a Three Dimensional Plano Convex Lens" In Progress In Ectromagnetics Research PIER 83,25-42 2008
7. Dr M.Narendra Kumar ,Dr H.S.Saini Dr K.S.R Anjaneyulu Mr Kuldip singh "Solar Power Analysis Based on Light Intensity" In international journal of Engineering And Science (IJES) ISSN:2319-1813 ISSN:2319 (P) 2319 -1805 page 01-05 2004
8. Hongwen Ren,Shin-tson Wu "Variable-focus liquid lens" Optical Society of America 2007
9. Ankit S.Gujrathi, Prof Dilip Gehlot "Testing and Performance of the convex lens Conentrating Solar Power Panel Prototype" In international Journal of Emerging Technology and Advanced Engineering ISSN 2250-2459 Volume 4,Issue 6,June2014

AUTHORS PROFILE

A. S. Patel
Assistant Professor in Mechanical Department, having teaching experience of 15 years, and subject taught Energy Engineering, Automobiles Engineering. Interested Research field solar energy

Dr P.D.Patil
Principal, Jayakumar Ravel Institute of Technology, Dondaicha Dist. Dhule, Accedamic Administrator as Principal for 24 years. Has completed his PhD from RGPU Bhopal in 2010