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Experimental investigation on the effect of sensible heat energy storage in an inclined solar still with baffles

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ABSTRACT

This manuscript brings out the experimental analysis on the effect of different Sensible Heat Energy Storage Materials (SHESM) in an Inclined Solar Still (ISS) attached with baffles. Experimental study was carried out under constant flow rate of water in the baffled system with different SHESM. Experimental results show that ISS with SHESM improves the yield by 57.1 and 59.5% with the polyester sheet and rubber sheet respectively as compared to the inclined solar still without any material. The solar still with rubber mat, polyester mat and without any material were produced the maximum hourly yield of 0.48, 0.49 and 0.38 kg, respectively. While analyzing the yield during off shine period, the maximum yield of 0.2 kg/h is achievable and it is higher to about 75% as compared to solar still without any material and with the polyester mat. Due to higher heat energy absorption by the rubber mat, the energy and exergy were higher as compared to polyester mat. There is only an increase of about 1.9 and 1% for energy and exergy efficiency as compared to the polyester mat.

Keywords: Inclined solar still; Energy storage; Exergy efficiency; Yield; Energy efficiency

1. Introduction

In the recent year, water is one of the important problems for the survival of human life. Many life support in earth lack in fresh water as the quantity of surface and ground water source is in huge demand due to the recent developments by industrialization and urbanization [1–11]. In the ISS, the absorber plate of the still is kept at some angle whereas in conventional solar still absorber plate is kept as parallel to the ground. Due to the inclined position of the absorber plate, it is easy to maintain a thin layer of water depth which results in higher evaporation rate than the conventional solar still. There are only a few works of literature review available on ISS [12,13]. Some major studies on ISS includes wick material [14], tilted wick [15], floating cum-wick type, stepped absorber with inbuilt latent heat energy storage, multi-wick ISS with shallow reservoir, inverted trickle solar still, rectangular ridges and grooves [17], weir type solar still [16], rectangular/stepped absorber [18], baffles [22], wire mesh [18], and ISS incorporated to the other solar still [25–27].

Sodha et al. [14] researched the multi-wick solar still and reported that wick material placed in the basin should

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be removed and periodically it is cleaned for better operation. It was submitted that multi-wick solar still produced the 0.45 and 2.45 kg/m^{2}d of hourly and daily productivity, respectively. Tanaka et al. [15] researched the wick type ISS with bottom reflector for augmenting the yield from an ISS. Research was conducted at the different angle of the reflector to find the optimum angle. Result reveal that yield from the ISS was higher with bottom reflector inclined at 25°C to the horizon. Also, it was observed that the absorber temperature is almost equal to water and wick temperature. Sadineni et al. [16] researched the weir type ISS in single and double pane mode in both theoretical and experimental conditions. Theoretical results were close to experimental values and have only a deviation of 7.5%. The theoretical values of water and collector cover temperature were following the same profile and the corresponding variation is in the range of 8–10°C. The experimental values shows that during the start of the experiment the water and collector cover temperature is equal and the maximum temperature difference between the water and collector surface is in the range of 4–7°C. The maximum achievable water and glass temperature were observed at 70 and 66°C respectively. Anburaj et al. [17] researched the effect of different SHESM, porous material and wick material inside the rectangular groove ISS. Experiments were conducted with different sensible heat storage material includes mild steel scrap, porous material includes clay pot under different position (clay pot facing up and down), and wick material includes waste cotton pieces, black cotton and jute cloth. Results revealed that using different wick, porous and SHESM improved the yield of fresh water by 8.75 (jute cloth), 6.1 (clay pot facing up) and 13.26 % (mild steel scrap) respectively than the bare plate.

Hansen et al. [18] researched the effect of wick and wire mesh material inside flat and stepped absorber of an ISS. It was submitted that the effect of wick material inside the stepped absorber is increased up to 15% as compared to flat absorber using the wood pulp as wick material and the yield is increased by 29% using a stepped absorber, wood pulp wick and wire mesh inside the basin. Similarly, the yield increased up to 71 and 58% using water coral fleece and polystyrene sponge using the same configuration. In all their results, stepped absorber and wire mesh with different new wick material improved the yield as compared to only stepped absorber and flat absorber. Aybar et al. [19] have done the experimental analysis an ISS with black cloth and fleece wick and compared it with the bare plate. The freshwater yield is higher in the case of black fleece as compared to the ISS without and with black cloth. Aybar [20] theoretically analysed an ISS and studied the effect of condensation and exit water temperature under different mass flow rates. Results showed that the increase in solar intensity increases the water temperature and rate of condensation. Similarly, the increase in flow rate of water decreases the yield and exit water temperature. El-Agouz et al. [21] analyzed a continuous water flow arrangement in an ISS. It was submitted that an increase in airflow velocity and decreasing the water mass increases the productivity. The average yield from the continuous flow desalination system increased up to 126% than conventional solar still. Sathyamurthy et al. [22] and Nagarajan et al. [23] theoretically and experimentally investigated an ISS attached with the baffles for improving the productivity. Results showed that the effect of inlet water temperature and mass flow rate majorly affect the evaporation from the basin liner surface. Similarly, the yield increases with the increased retention time of water with basin and solar intensity. Sathyamurthy et al. [24] researched the effect of flow rate on semi-circular trough absorber ISS. Naveen kumar et al. [25,26] researched the performance of a pyramid solar still incorporated with an ISS in both theoretical and experimental conditions. Panchal et al. [27] have done the economic and exergy efficiency analysis for the Naveen kumar experimental set-up. Table 1 shows the detailed yield, efficiency and increase in yield of different ISS. From the relative literature to an ISS, no studies were carried out on the ISS with SHESM. In the present study, the effect of different SHESM on the ISS with baffles is experimentally studied. Similarly, the energy and exergy analysis of ISS with SHESM such as polyester and rubber mat is also studied.

2. Experimental setup, procedure and uncertainty analysis

Fig. 1 shows the experimental photograph of ISS with baffles. The different SHESM used inside the basin is shown in Fig. 2. The basin is constructed by using the galvanised iron sheet in the dimensions of 1 m × 0.5 m. Glass cover with a thickness of 4 mm and to avoid the vapour leakage sealing

Table 1
Comparison of yield, efficiency and increase in yield of different ISS

S.No	Type of inclined solar still	Yield (kg)	Efficiency (%)	Improvement in yield (%)
1	Tilted wick type solar still with bottom reflector [15]	7.5	NA	30
2	Weir type solar still [16]	5.5	NA	20
3	ISS with rectangular grooves and ridges [17]	4.21	NA	67.1
4	ISS with wick and wire mesh material [18]	4.28	NA	71.2
5	Continuous flow ISS [21]	6.12	56% (for sea water) 73.6 (for salt water)	NA
6	ISS with baffles [23]	5.4	NA	30.2
7	Semi circular trough ISS with baffles [24]	3	38.8	33.3

NA- Not available

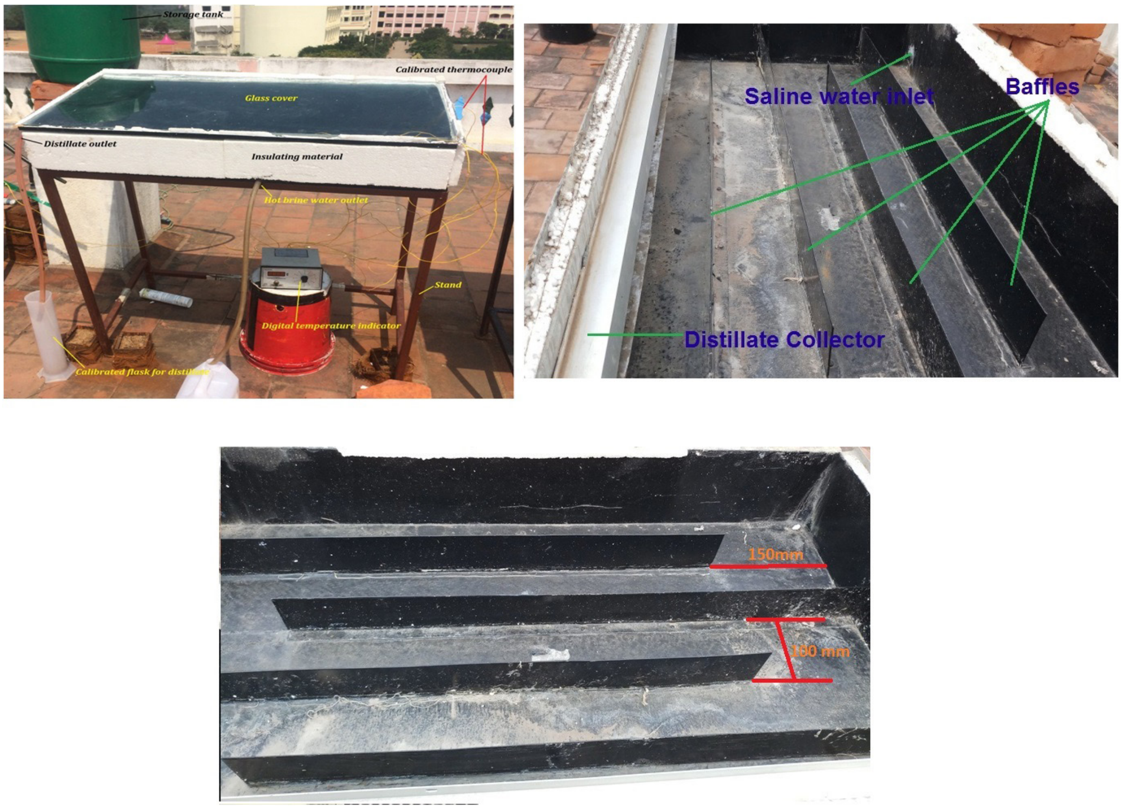

Fig. 1. Experimental photograph of an ISS with baffles.

Fig. 2. Different SHESM used in the basin.

is provided. Baffles are kept at a consecutive distance of 100 mm with a total length of 850 mm each. Provisions were provided at each side of the baffles so that the water extracts the entire heat from the basin plate (Fig. 1). To prevent the loss of heat to the surrounding from the side and bottom insulations were provided. A temperature of different elements of the ISS is measured using calibrated thermocouples (PT-100 RTD sensors). A storage tank with the capacity of 100 L is used to store the water and water is fed to the basin by controlling its mass flow using a control valve. An optimum mass flow rate of water is kept as 5 kg/h [21,22] for all the experimental study. The hot brine water is collected from the outlet of ISS and stored in a separate tank kept at the bottom. The distillate collected in the collecting chamber at the end of the glass cover is collected in a calibrated flask and it is measured every 30 min. Similarly, the temperatures of different elements of the ISS were measured every 30 min. The specific heat capacity of the galvanised iron sheet, polyester mat and rubber mat is 0.49, 1.24 and 2.01 kJ/kg K respectively. Higher specific heat capacity material can easily raise its temperature. In this research work, low-cost black rubber and polyester mat were used as SHESM.

To measure the solar intensity and wind velocity, solar power meter (TES133R) and anemometer (AM4836 3 cup anemometer) were used and RTD sensors (PT-100 type) are used to measure the different temperature of solar still. The uncertainty error of solar power meter, anemometer and temperature sensors were found to be 3.54, 2.3 and 1.1% (Table 2). The mathematical expression for estimating the uncertainty is given as,

$$uncertainty = \frac{U}{x} \times 100 \quad (1)$$

$$U = \frac{\sqrt{\sigma_1^{\,2} + \sigma_2^{\,2} + \sigma_3^{\,2} + ... + \sigma_n^{\,2}}}{N} \quad (2)$$

$$\sigma = \frac{\sqrt{\Sigma\left(X - \overline{X}\right)}}{N} \quad (3)$$

where $X - \overline{X}$ mean difference between observed value and average value; N, number of observation.

3. Energy and exergy efficiency of the system

3.1. Energy efficiency

The overall thermal efficiency of an ISS is assessed by the yield of fresh water produced from the ISS for the given input heat. Mathematically it is calculated as

$$\eta_{th} = \frac{\Sigma m_{e,w-g} \times h_{fg}}{\Sigma I(t) \times A} \quad (4)$$

where $\Sigma m_{e,w\text{-}g}$ is the accumulated yield (kg), h_{fg} is the latent heat of vaporization (kJ/kg), $\Sigma I(t)$ is the total solar radiation falling on the entire surface (W/m^2).

$$h_{fg} = 2.4935 \times 10^6 \left[1 - \left(\left(9.4779 \times 10^{-4} \times T_v\right) + \left(1.3132 \times 10^{-7} \times T_v^2\right) - \left(4.7974 \times 10^{-3} \times T_v^3\right)\right)\right] \quad (5)$$

where T_v is the temperature of vapour (°C).

3.2. Exergy efficiency

Exergy analysis is usually used to estimate the possible amount of extractable work from the system with respect to the ambient temperature and solar intensity falling on the entire tilted surface. Mathematically it is expressed as,

$$\eta_{ex} = \frac{E_{x,output}}{E_{x,input}} \quad (6)$$

Exergy output is mathematically expressed as,

$$E_{x,output} = m_{e,w-g} h_{fg} \left[1 - \frac{T_a}{T_w}\right] \quad (7)$$

Exergy input is mathematically expressed as,

$$E_{x,input} = I(t) \times A \left[1 + \frac{T_a}{T_s}\left(\frac{\left(\frac{T_a}{T_s}\right)^3 - 4}{3}\right)\right] \quad (8)$$

4. Results and discussion

4.1. Variation of solar intensity, wind speed and ambient temperature

The variations in solar intensity, wind speed and ambient temperature were plotted in Figs. 3a–c. The average solar intensity, wind speed and ambient temperature were found as 658 W/m^2, 1.9 m/s and 35.23°C. The maximum intensity falling on the inclined surface during the noon is observed as 950 W/m^2 with a deviation of ±3.56%. The wind velocity during the experimental days was found to be in the range of 1–3 m/s and the average ambient temperature was found to be in the ranges of 33–35°C.

4.2. ISS with baffles and SHESM

The hourly variation of different temperatures of an ISS with baffles and without SHESM is plotted in Fig. 4. It can be observed that the temperatures of the basin and water of the present experiment is almost similar to the results of Sathyamurthy et al. [22]. Without any SHESM inside the basin, the maximum temperature of the water is 62°C with an average maximum solar intensity of 950 W/m^2. Similarly, with an increase in solar intensity, the temperature of different elements in the solar still increases. The average collector cover temperature

Table 2
Instruments, accuracy, error and uncertainty

S. No	Measuring device	Range	Accuracy	Observed error (%)	Uncertainty
1	TES1333R solar power meter	0–2500 W/m^2	± 1 W/m^2	3.54	± 0.57 W/m^2
2	PT100 RTD sensor	0–100°C	±1°C	1.1	± 0.57°C
3	Calibrated flask	0–1000 mL	± 10 ml	8.3	± 5.77 mL
4	AM4836 Anemometer	0–45 m/s	± 0.1 m/s	2.3	± 0.05 m/s

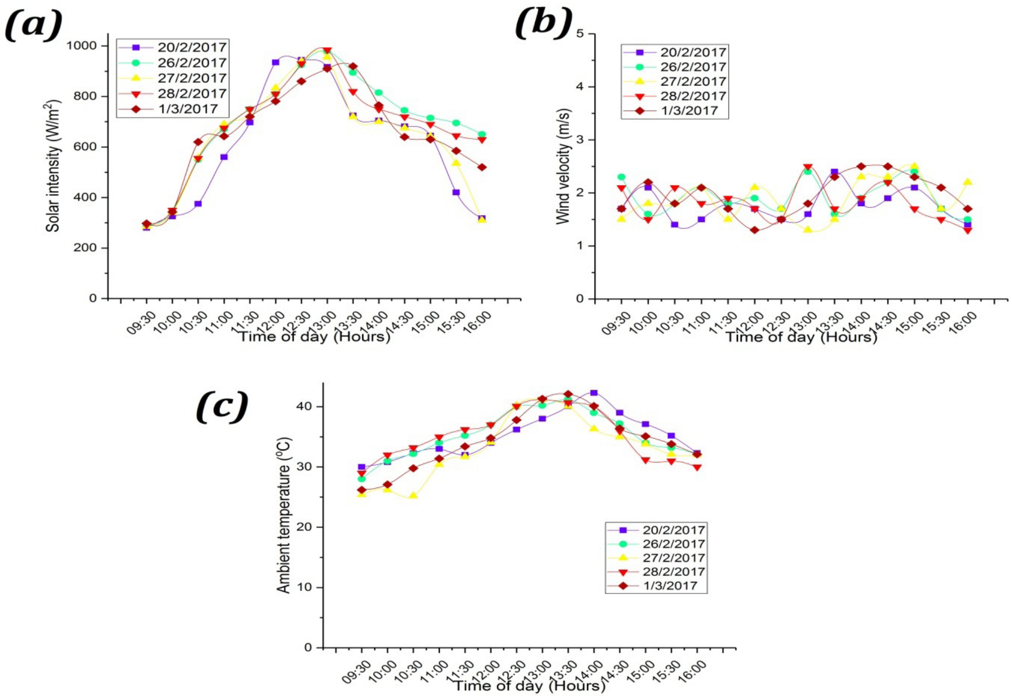

Fig. 3. Hourly variation of (a) Solar intensity, (b) Wind velocity and (c) Ambient temperature during the experiments.

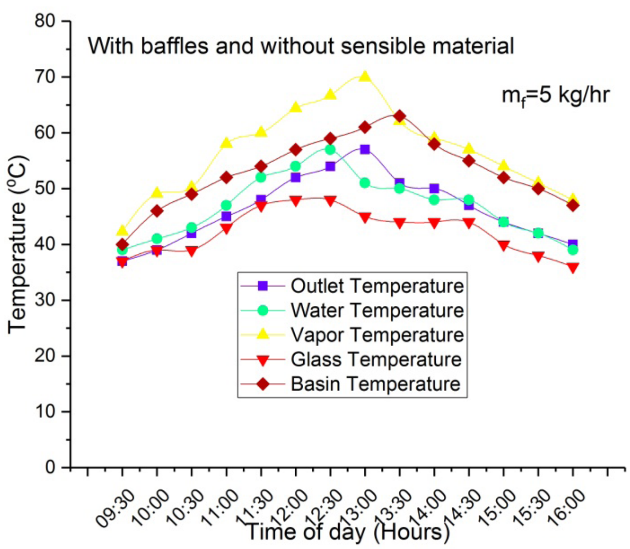

Fig. 4. Hourly variation of temperature of ISS with baffles and without SHESM (m_f = 5 kg/h) (20.2.2017 and 26.2.2017).

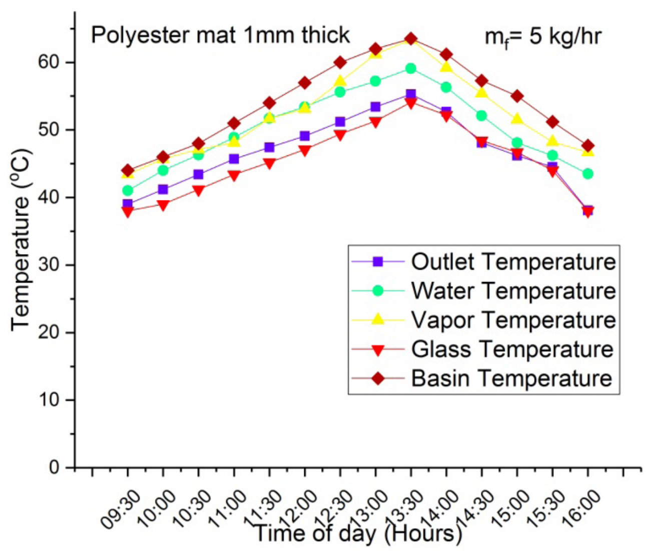

Fig. 5. Hourly variation of temperature of ISS with polyester 1 mm thick floor mat as SHESM (m_f = 5 kg/h) (27.2.2017 and 28.2.2017).

of the ISS without SHESM varies from 36 to 45°C as the wind velocity over the collector cover varies for effective condensation.

Fig. 5 shows the hourly variation of the different temperature of an ISS with polyester mat as SHESM. The maximum temperature of the water with the polyester mat as SHESM is found as 55°C while the maximum temperature of the vapour is found as 60°C. Due to the excessive temperature of vapour inside the solar still, without any SHESM, the heat rejected through the glass cover is lower as the heat carrying capacity and ambient temperature majorly affect the condensation. For the possible decrease in the temperature of water and yield of an ISS without SHESM is due to the effect of increased vapour temperature inside the chambers of collecting and absorber surfaces.

Similarly, variation of the temperatures from an ISS with rubber mat is shown in Fig. 6. In the similar case, the maximum water temperature using rubber mat is higher

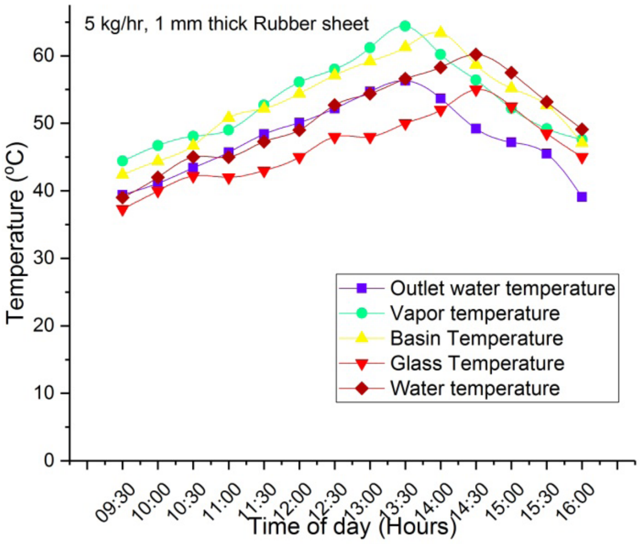

Fig. 6. Hourly variation of temperature of ISS with rubber mat as SHESM (m_f = 5kg/h) (28.2.2017 and 1.3.2017).

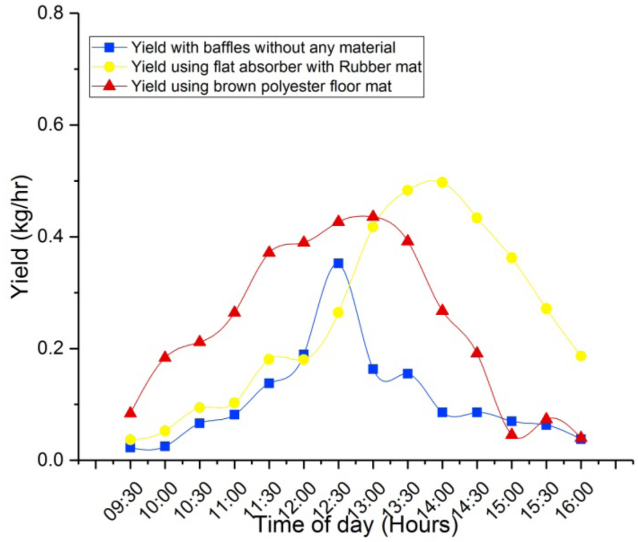

Fig. 7. Hourly variation of yield from an ISS with and without SHESM.

during the fall of solar intensity as the heat from the rubber mat (sensible heat) act in the flow of water for the possible increase in the temperature of water. The maximum temperature of water, basin and vapour during the peak intensity were found to be 54, 58 and 60°C, respectively. During the fall in the solar intensity, water temperature increases to a maximum of 60°C and the average water temperature during 4 PM is found to be 50°C and there is an increase in water temperature of about 25 and 28% with polyester and rubber mat than the without sensible material inside the basin respectively.

From the experimental results, it is found that the average basin temperature of an ISS without SHESM, with polyester and rubber mat, is 48.25, 51.6 and 52.6°C respectively. It is found that polyester and rubber mat increases the basin temperature up to 6.5 and 8.3% than the without storage material. Similarly, it is seen that the average water temperature of 50, 51.75 and 52.87°C is obtained for the ISS without SHESM, with polyester and rubber mat respectively. There is a 3.4 and 5.4% increase in average water temperature is obtained by using polyester and rubber mat. The reason for increases in basin and water temperature is, the specific heat capacity of the polyester and rubber mat is 60.5 and 75.6% higher than the galvanised iron sheet.

4.3. Comparative analysis of yield from solar still with and without SHESM

The hourly variation of yield from an ISS with and without SHESM is depicted in Fig. 7. From the Fig. 7, it can be clearly observed that the maximum yield of 0.48 kg is achievable with rubber mat inside the absorber plate of an ISS with baffles under a constant flow rate of 5 kg/h. The yield of ISS with polyester floor mat is higher than rubber mat during the sunshine hours and decreases during the off shine hours as it is due to the effect of the specific heat capacity of the material. During the sunshine hours, energy is stored in the form of sensible heat on the rubber mat and

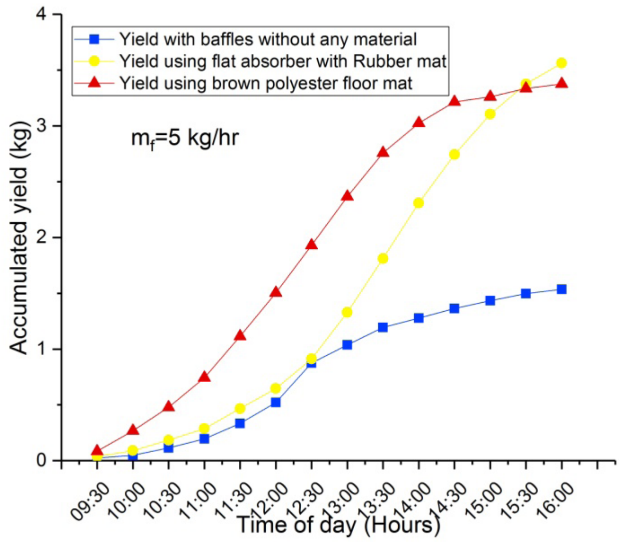

Fig. 8. Variation of accumulated yield from an ISS with and without SHESM.

during the off shine hours, the heat is later utilised by the flowing water inside the basin. Also, during the cloudy condition and lower intensity period the hot surface rubber mat heat is transferred to the flowing water. Fig. 8 shows the accumulated yield from an ISS with and without energy material under a constant flow rate of water. The maximum yield from an ISS with rubber and polyester mat were found to be 3.7 and 3.5 kg respectively, whereas the yield from solar still without energy material is found to be 1.5 kg. Due to the excellent heat storing capacity the increase in yield from an ISS with rubber and polyester mat were found to be 59.5 and 57.1% respectively than the ISS without any storage material. ISS with rubber mat enhanced the yield 5.4% higher than the ISS with polyester mat.

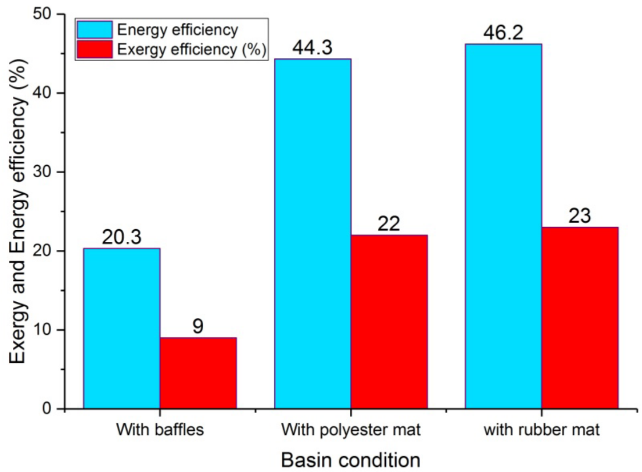

Fig. 9. Variation in exergy and energy efficiency of inclined solar still with baffles and energy storing material.

4.4. Exergy and energy analysis of an ISS with and without SHESM

To evaluate the irreversibility of the system in real condition, and to optimize the parameters of the present design exergy and energy efficiencies were calculated. The exergy and energy efficiency of ISS with baffles and energy storing material is plotted in Fig. 9. It is seen that the energy and exergy efficiency of the system with rubber mat is higher than the polyester mat. The overall thermal and exergy efficiency of about 46.2 and 23% respectively is obtained for the rubber mat as the storage material. In the comparison of ISS with polyester mat, the efficiencies drop by 1.9 and 1 % with energy and exergy efficiency respectively as compared to rubber mat. Solar still with rubber, polyester mat produced to about 56.06, 54.18% thermal efficiency respectively and improved the exergy efficiency by 60.8, 59.1% as compared toISS without thermal storage material. Also, it is found that the energy and exergy efficiency of the ISS with SHESM is higher as compared to the ISS without any SHESM inside the basin.

5. Conclusions

From the experimental study the following conclusions are arrived: -

- The yield of fresh water from an ISS with SHESM is higher to about 59.5 and 57.1% for rubber and polyester mat respectively than without any SHESM.
- Temperature of water for rubber mat during the off shine period is increased up to 59°C as compared to solar still with polyester mat and without any material.
- The maximum hourly yield from an ISS with rubber mat, polyester mat and without any material was found to be 0.48, 0.49 and 0.38 kg respectively. While analyzing the yield during off shine period, the maximum yield of 0.2 kg/h is achievable and it is higher to about 75% as compared to solar still without any material and with the polyester mat.
- Due to higher heat energy absorption by rubber mat the energy and exergy were higher as compared to the polyester mat. There is only an increase of about 1.9 and 1% for energy and exergy efficiency as compared to the polyester mat.
- Exergy analysis of an ISS with rubber mat, polyester mat and without any storage material was found to be 23, 22 and 9% respectively.
- Energy analysis of an ISS with rubber mat, polyester mat and without any storage material was found to be 46.2, 44.3 and 20.3% respectively.
- Inclined solar still with rubber mat produced 4.1% and 4.3% higher thermal and exergy efficiency than the ISS without sensible heat storage material.

References

[1] A.E. Kabeel, T. Arunkumar, D.C. Denkenberger, R. Sathyamurthy, Performance enhancement of solar still through efficient heat exchange mechanism-A review, Appl. Thermal Eng., 114 (2017) 815–836.
[2] R. Sathyamurthy, S.A. El-Agouz, P.K. Nagarajan, J. Subramani, T. Arunkumar, D. Mageshbabu, B. Madhu, R. Bharathwaaj, N. Prakash, A Review of integrating solar collectors to solar still, Renew. Sustain. Energy Rev., 77 (2017) 1069–1097.
[3] D.G. Harris Samuel, P.K. Nagarajan, T. Arunkumar, E. Kannan, R. Sathyamurthy, Enhancing the solar still yield by increasing the surface area of water—A review, Environ. Progr. Sustain. Energy, 35(3) (2016) 815–822.
[4] R. Sathyamurthy, D.H. Samuel, P.K. Nagarajan, S.A. El-Agouz, A review of different solar still for augmenting fresh water yield, J. Environ. Sci. Technol., 8(6) (2015) 244–265.
[5] R. Sathyamurthy, H.J. Kennady, P.K. Nagarajan, A. Ahsan, Factors affecting the performance of triangular pyramid solar still, Desalination, 344 (2014) 383–390.
[6] R. Sathyamurthy, D.G. Harris Samuel, P.K. Nagarajan, T. Arunkumar, Geometrical variations in solar stills for improving the fresh water yield—A review, Desal. Water Treat., 57(45) (2016) 21145–21159.
[7] T. Arunkumar, R. Velraj, A. Ahsan, A.J.N. Khalifa, S. Shams, D. Denkenberger, R. Sathyamurthy, Effect of parabolic solar energy collectors for water distillation, Desal. Water Treat., 57(45) (2016) 21234–21242.
[8] T. Arunkumar, R. Velraj, D.C. Denkenberger, R. Sathyamurthy, Influence of crescent shaped absorber in water desalting system, Desalination, 398 (2016) 208–213.
[9] A.M. Manokar, K.K. Murugavel, G. Esakkimuthu, Different parameters affecting the rate of evaporation and condensation on passive solar still–A review, Renew. Sustain. Energy Revs., 38 (2014) 309–322.
[10] S. Varun Raj, A. MuthuManokar, Design and analysis of solar still, Mater. Today Proc., 4(8) (2017) 9179–9185.
[11] R. Sathyamurthy, P.K. Nagarajan, M. Edwin, B. Madhu, S.A. El-Agouz, A. Ahsan, D. Mageshbabu, Experimental investigations on conventional solar still with sand heat energy storage, Int. J. Heat Technol.,34(4) (2016) 597–603.
[12] K.K. Murugavel, P. Anburaj, R.S. Hanson, T. Elango, Progresses in inclined type solar stills, Renew. Sustain. Energy Rev., 20 (2013) 364–377.
[13] A.K. Kaviti, A. Yadav, A. Shukla, Inclined solar still designs: A review, Renew. Sustain. Energy Rev., 54 (2016) 429–451.
[14] M.S. Sodha, Ashvini Kumar, G.N. Tiwari, R.C. Tyagi, Simple multiple wick solar still: analysis and performance, Solar Energy, 26(2) (1981) 127–131.
[15] H. Tanaka, Tilted wick solar still with flat plate bottom reflector, Desalination, 273 (2011) 405–413.
[16] S.B. Sadineni, R.H.C.K. Halford, R.F. Boehm, Theory and experimental investigation of a weir-type inclined solar still, Energy, 33 (2008) 71–80.

[17] P. Anburaj, R.S. Hansen, K.K. Murugavel, Performance of an inclined solar still with rectangular grooves and ridges, Appl. Solar Energy, 49 (2013) 22–26.
[18] R.S. Hansen, C.S. Narayanan, K.K. Murugavel, Performance analysis on inclined solar still with different new wick materials and wire mesh, Desalination, 358 (2015) 1–8.
[19] H.S. Aybar, F. Egelioğlu, U. Atikol, An experimental study on an inclined solar water distillation system, Desalination, 180 (2005) 285–289.
[20] H.Ş. Aybar, Mathematical modeling of an inclined solar water distillation system, Desalination, 190 (2006) 63–70.
[21] S.A. El-Agouz, Y.A.F. El-Samadony, A.E. Kabeel, Performance evaluation of a continuous flow inclined solar still desalination system, Energy Convers. Manage., 101 (2015) 606–615.
[22] R. Sathyamurthy, D.H. Samuel, P.K. Nagarajan, Theoretical analysis of inclined solar still with baffle plates for improving the fresh water yield, Process Safety Environ. Protect., 101 (2016) 93–107.
[23] P.K. Nagarajan, S.A. El-Agouz, H.S. DG, M. Edwin, B. Madhu, R. Sathyamurthy, R. Bharathwaaj, Analysis of an inclined solar still with baffles for improving the yield of fresh water, Process Safety Environ. Protect., 105 (2017) 326–337.
[24] R. Sathyamurthy, P.K. Nagarajan, S.A. El-Agouz, V. Jaiganesh, P.S. Khanna, Experimental investigation on a semi-circular trough-absorber solar still with baffles for fresh water production, Energy Convers. Manage., 97 (2015) 235–242.
[25] P. Naveen Kumar, D.G. Harris Samuel, P.K. Nagarajan, R. Sathyamurthy, Theoretical analysis of a triangular pyramid solar still integrated to an inclined solar still with baffles, Int. J. Ambient Energy, 38(7) (2017) 694–700.
[26] P.N. Kumar, A.M. Manokar, B. Madhu, A.E.T. Kabeel, T. Arunkumar, H. Panchal, R. Sathyamurthy, Experimental investigation on the effect of water mass in triangular pyramid solar still integrated to inclined solar still, Groundwater Sustain. Develop., 5 (2017) 229–234.
[27] H. Panchal, Y. Taamneh, R. Sathyamurthy, A.E. Kabeel, S.A. El-Agouz, P. Naveen Kumar, A. Muthu Manokar, T. Arunkumar, D. Mageshbabu, R. Bharathwaaj, Economic and exergy investigation of triangular pyramid solar still integrated to inclined solar still with baffles, Int. J. Ambient Energy, (2017) DOI: 10.1080/01430750.2017.1422143.