Experimental Analysis on Fabricated Parabolic Solar Collector with Various Flowing Fluids and Pipe Materials

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Abstract- This work is accomplished on fabricated parabolic solar collector. Numbers of experiments are performed on collector at different operating conditions with tracking mode III. Operating conditions are; copper-water arrangement, copper-engine oil arrangement, mild steel-water arrangement and mild steel-engine oil arrangement at 12:30PM, at 01:30PM, 02:30PM and at 03:30PM. Then fluid outlet temperature, inside/outside pipe surface temperatures, heat transfer rate, instantaneous efficiency, convective heat transfer coefficient, absorbed flux and collector efficient factor are experimentally found. Inlet exergy is also analysed for this solar collector with and without considering Sun's cone angle. Finally this work can be concluded as – If fluid temperature difference decreases then heat gain rate increases by increasing mass flow rate of fluid. When aperture width, pipe length and mass flow rate of fluid increase then inlet exergy increases. Maximum instantaneous efficiency (84.28%) is achieved at 12:30PM with copper-water combination at 0.0166kg/sec flow rate. Maximum and minimum temperature difference (59°C and 3°C) of fluid are found at 12:30PM and at 02:30PM respectively. Maximum inlet exergy (2839.854W) is achieved with 1.75m pipe length and 3.0m aperture width but minimum inlet exergy (858.392W) is found with 0.75 m aperture width and 2.0 m pipe length.

Keywords Parabolic solar collector, solar energy, instantaneous efficiency, collector efficiency factor.

1. Introduction

This research work is related with solar energy. Many research works have been done by researchers in this field because solar energy is the most significant non-conventional sources of energy and it is non-polluting therefore it helps to decreasing the greenhouse effect. This work is done on parabolic solar collector. Parabolic solar collectors are thermal collectors that are curved as parabola in two dimensions but straight in one dimension. The curved surfaces have polished mirrors which reflect solar energy or thermal energy. This solar energy is focused at focus axis of the parabola and then thermal energy is utilized for different purposes; like power plants, chemical industries etc. A simplest layout parabolic solar collector is as shown in figure 1. From layout, mirrors which are assembled with curved surface reflect sunlight on the pipe. Pipe is mounted at focus axis of the parabola and it contains fluid which is heated to high temperature by the use of thermal energy. Many researchers have done lot of work in the field of solar energy. They have optimized solar energy systems with different methods or different ways [2-8]. In this research work parabolic solar collector is fabricated and experiments are performed. Fabricated collector is shown in figure 2. From various tracking modes, mode III tracking mode is chosen in this research work. This mode has focal axis in North-South direction and its orientation is horizontal [1].

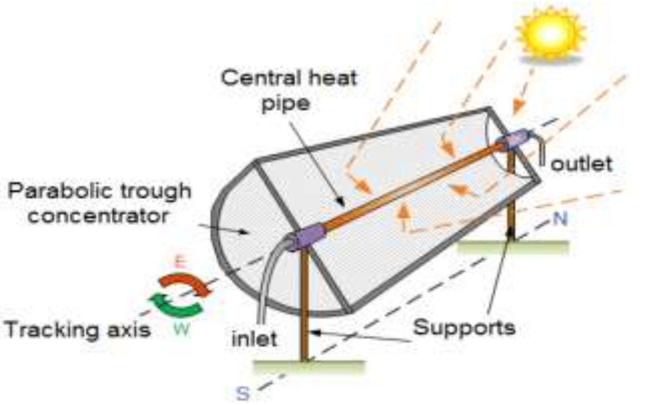

Figure 1 – Schematic layout of cylindrical parabolic solar collector

Figure 2 – Fabricated cylindrical parabolic solar collector with glass plate

In this experimental work, 64 number of experiments are performed with different input parameters or conditions. Here water and engine oil are used as flowing fluids while mild steel and copper are selected as pipe materials. With experiments fluid outlet temperatures, heat transfer rates, instantaneous efficiencies, absorbed fluxes, collector efficient factors and inlet exergies are found. Whole experimental work is done on typical summer months of April and May at Sushila Devi Bansal College of Technology, Indore, Madhya Pradesh, India (Latitude - 22°43'4.51"N and Longitude - 75°49'59.88"E). 12:30PM, 01:30PM, 02:30PM and 03:30PM are selected time intervals on which all observations are taken.

2. Methodology

Experimental analyses are performed on parabolic solar collector with different fluids and with different pipe materials. All observations are taken at fix time intervals and that time instantaneous beam radiations for per unit surface area are; at 12.30 PM - 526.90 W/m^2, at 01.30 PM – 529.0 W/m^2, at 02.30 PM - 537.20 W/m^2 and at 03.30 PM - 472.80 W/m^2 [1]. Following mathematical equations are used for research work. Instantaneous efficiency [1, 3, 5, 7],

$$\eta_{ib} = (Q_u) / (I_b R_b\ W\ L) \quad (1)$$

Here Q_u is rate of heat transfer in Watts, $I_b R_b$ is instantaneous beam radiation on per unit area of the surface in W/m^2, W is aperture width in meters and L is length of the pipe in meters. Useful heat gain rate [1, 3, 4, 7],

$$Q_u = m_f\ C_p\ (T_{fo} - T_{fi}) \quad (2)$$

Here m_f is mass flow rate of fluid which is flowing in the pipe in kg/sec, C_p is specific heat of fluid in J/kgK, T_{fo} and T_{fi} are fluid temperatures at inlet and outlet respectively in Kelvin. Convective heat transfer [1],

$$Q_u = h_f\ A_s\ (T_p - T_{fo}) \quad (3)$$

Here h_f is convective heat transfer coefficient in W/m^{2}K, A_s is surface area of pipe in m^2, T_p and T_{fo} are temperatures of pipe and outlet fluid respectively in Kelvin.

Concentration ratio is the ratio of effective aperture area to pipe surface area. It is represented by C. Here W is aperture width in meters, D_o is pipe outer diameter in meter and L is effective length in meter, Concentration ratio [1, 3, 10],

$$C = \{(W - D_o)\ L\} / \{\pi\ D_o\ L\} \quad (4)$$

Absorbed flux [1],

$$S = \{I_b R_b\ \rho\ \gamma\ (\tau\ \alpha)_b + I_b R_b\ (\tau\ \alpha)_b\ [D_o / (W - D_o)]\} \quad (5)$$

Here ρ is reflectivity of the collector surface, some amount of reflected radiation is intercepted by the pipe which is known as intercept factor and it is denoted by γ, τ is transmissivity and α is absorbtivity. Conductive heat transfer through the pipe [8],

$$Q_u = \{[2\ \pi\ K\ L\ (T_c - T_p)] / [\ln (D_o/D_i)]\} \quad (6)$$

Here K is thermal conductivity of the pipe material in W/mK, T_c are T_p are pipe surface temperature at outlet and inlet respectively in Kelvin. Amount of heat transfer (Q_u) can also be written with overall heat loss coefficient (U_l), concentration ratio (C) and absorbed flux (S) as [1, 12],

$$Q_u = [\ S - (U_l / C)\ (T_p - T_a)]\ (W - D_o)\ L \quad (7)$$

Collector efficiency factor [1],

$$F' = [U_l \{(1 / U_l) + [D_o / (D_i\ h_f)]\}]^{-1} \quad (8)$$

Focus point for cylindrical parabolic collector is found by mathematical equation given below [1, 3].

$$F = (W^2) / (16\ C) \quad (9)$$

Exergy inlet for solar collector is the summation of exergy available in solar radiation and exergy taken by flowing fluid. Exergy analysis for solar collector is calculated by following equations which is given by Petela [9]. Exergy inlet and maximum useful work available from solar radiation are calculated by equations 10, 11 and 12 where equation 11 gives maximum useful work without considering Sun's cone angle but equation 12 give maximum useful work with consideration of Sun's cone angle which is equal to 0.005 radian [11].

$$\Psi_{inlet} = m_f\, C_p\, (T_{fi} - T_{fo}) - m_f\, C_p\, (\ln T_{fi} - \ln T_{fo}) + I_b R_b\, (W\, L_c)\, \Psi \qquad (10)$$

$$\Psi = 1 - (4\, T_0 / 3\, T_s) + (1/3)\, (T_0 / T_s)^4 \qquad (11)$$

$$\Psi' = 1 - (4\, T_0 / 3\, T_s)\, (1 - \cos\mho)^{0.25} + (1/3)(T_0 / T_s)^4 \qquad (12)$$

Here Ψ_{inlet} is exergy at inlet in Watts and Ψ is maximum useful work, T_0 and T_s are ambient temperature and Sun surface temperature (which is near about 5800K) in Kelvin.

Results –

For experimental work, cylindrical parabolic solar collector is fabricated. Important dimensions are; (a) aperture width (W) of the collector is 1.25 m, (b) length of collector and absorber pipe is 2.5 m, (c) inner diameter (D_i) of hollow pipe is 0.028 m, (d) outer diameter (D_o) of hollow pipe is 0.032 m and concentration ratio (C) is 12.12. Assumed values for calculations are - specular reflectivity of glass which is mounted on concentration surface is 0.39, intercept factor for absorber pipe is 0.95, transmissivity and absorptivity are 0.32 and 0.29 respectively. All the experimental results are found with four different combinations; combinations are - copper-water, copper-engine oil, mild steel-engine oil and mild steel-water. Fluid and surface ttemperatures are measured by digital thermometer. Results are shown in tabulated form in tables 1-16 with different time intervals.

Inlet exergy analyses are also done by considering Sun's cone angle and without considering Sun's cone angle at various operating conditions. After that, inlet exergy results are shown in figures 3, 4, 5 and 6. Inlet exergies at different aperture widths with 0.012kg/sec mass flow rate and 32°C inlet temperature for copper-oil arrangement are shown in figure 3. Inlet exergies at different pipe lengths with 0.0019kg/sec mass flow rate and 32°C inlet temperature for mild steel-water arrangement are shown in figure 4. Inlet exergies at different aperture widths and pipe lengths with 0.0049kg/sec mass flow rate for mild steel-oil arrangement are shown in figure 5. Inlet exergies at different mass flow rates of flowing fluid with 31°C inlet temperature for copper-water arrangement are shown in figure 6.

Table 1 – At 12:30PM with Copper Water combination ($I_b R_b$ 526.90 W/m^2)

	Inlet Parameter					**Outlet Parameter**				
Sr. No.	**m_f (kg/sec)**	**T_{fi} (ºC)**	**T_c (ºC)**	**T_{fo} (ºC)**	**T_p (ºC)**	**Q_u (W)**	**η_{ib} (%)**	**h_f (W/m^{2}K)**	**S (W/m^2)**	**F'**
1	**0.00326**	**31**	**91**	64	90.99	449.68	27.31	75.801	19.401	0.69
2	**0.01163**	**31**	**100**	51	99.98	972.26	59.04	90.313	19.401	0.57
3	**0.0166**	**31**	**95**	51	94.97	1387.76	84.28	143.592	19.401	0.58
4	**0.01247**	**31**	**100**	49	99.98	938.24	56.98	83.731	19.401	0.56

Table 2 – At 01:30PM with Copper Water combination ($I_b R_b$ 529.0 W/m^2)

	Inlet Parameter					**Outlet Parameter**				
Sr. No.	**m_f (kg/sec)**	**T_{fi} (ºC)**	**T_c (ºC)**	**T_{fo} (ºC)**	**T_p (ºC)**	**Q_u (W)**	**η_{ib} (%)**	**h_f (W/m^{2}K)**	**S (W/m^2)**	**F'**
1	**0.01079**	**31**	**94**	52	93.98	947.14	57.29	102.647	19.478	0.59
2	**0.00415**	**31**	**95**	52	94.98	364.28	22.04	38.550	19.478	0.61
3	**0.0165**	**31**	**95**	45	94.98	965.58	58.41	87.897	19.478	0.55
4	**0.00781**	**31**	**98**	49	97.98	587.62	35.55	54.574	19.478	0.58

Table 3 – At 02:30PM with Copper Water combination ($I_b R_b$ 537.2 W/m^2)

Inlet Parameter	**Outlet Parameter**

Sr. No.	m_f (kg/sec)	T_{fi} (ºC)	T_c (ºC)	T_{fo} (ºC)	T_p (ºC)	Q_u (W)	η_{ib} (%)	h_f (W/m²K)	S (W/m²)	F'
1	**0.00279**	**31**	**88**	55	87.99	279.89	16.67	38.595	19.78	0.66
2	**0.01505**	**31**	**88**	38.5	87.99	471.82	28.11	43.37	19.78	0.54
3	**0.01589**	**31**	**80**	37.4	79.99	425.08	25.32	45.408	19.78	0.53
4	**0.00967**	**31**	**52**	40.3	51.98	497.17	29.62	260.322	19.78	0.65

Table 4 – At 03:30PM with Copper Water combination (I_bR_b 472.8 W/m²)

	Inlet Parameter					**Outlet Parameter**				
Sr. No.	m_f (kg/sec)	T_{fi} (ºC)	T_c (ºC)	T_{fo} (ºC)	T_p (ºC)	Q_u (W)	η_{ib} (%)	h_f (W/m²K)	S (W/m²)	F'
1	**0.00615**	**31**	**57**	40.6	56.99	246.78	16.67	68.483	17.409	0.60
2	**0.0099**	**31**	**57**	36.2	56.99	215.186	14.56	47.079	17.409	0.55
3	**0.00331**	**31**	**38.6**	36.4	38.59	74.713	5.06	154.647	17.409	0.48
4	**0.00563**	**31**	**37.8**	35.1	37.79	96.487	6.53	162.704	17.409	0.14

Table 5 – At 12:30PM with Copper Engine Oil combination (I_bR_b 526.90 W/m²)

	Inlet Parameter					**Outlet Parameter**				
Sr. No.	m_f (kg/sec)	T_{fi} (ºC)	T_c (ºC)	T_{fo} (ºC)	T_p (ºC)	Q_u (W)	η_{ib} (%)	h_f (W/m²K)	S (W/m²)	F'
1	**0.0063**	**32**	**132**	67	131.99	350.374	21.28	24.527	19.401	0.63
2	**0.0032**	**32**	**132**	58	131.99	132.205	8.03	8.128	19.401	0.70
3	**0.012**	**32**	**132**	70	131.98	724.584	44.01	53.183	19.401	0.62
4	**0.0072**	**32**	**132**	59	131.99	308.902	18.76	19.254	19.401	0.61

Table 6 – At 01:30PM with Copper Engine Oil combination (I_bR_b 529.0 W/m²)

	Inlet Parameter					**Outlet Parameter**				
Sr. No.	m_f (kg/sec)	T_{fi} (ºC)	T_c (ºC)	T_{fo} (ºC)	T_p (ºC)	Q_u (W)	η_{ib} (%)	h_f (W/m²K)	S (W/m²)	F'
1	**0.0058**	**32**	**129**	79	128.98	433.161	26.20	39.421	19.478	0.68
2	**0.0013**	**38**	**129**	74	128.99	74.365	4.5	6.152	19.478	0.89
3	**0.0102**	**38**	**127**	64.2	126.99	424.644	25.69	30.768	19.478	0.62
4	**0.0025**	**38**	**127**	64	126.99	103.285	6.25	7.459	19.478	0.77

Table 7 – At 02:30PM with Copper Engine Oil combination (I_bR_b 537.2 W/m²)

	Inlet Parameter					**Outlet Parameter**				
Sr. No.	m_f (kg/sec)	T_{fi} (ºC)	T_c (ºC)	T_{fo} (ºC)	T_p (ºC)	Q_u (W)	η_{ib} (%)	h_f (W/m²K)	S (W/m²)	F'

1	**0.0034**	**32**	**62**	55	61.99	124.26	7.4	80.796	19.78	0.87
2	**0.00659**	**32**	**68**	65	67.98	345.56	20.58	525.278	19.78	0.92
3	**0.0066**	**32**	**65**	63	64.98	325.109	19.37	742.154	19.78	0.94
4	**0.025**	**32**	**55**	50	54.96	715.05	42.59	652.595	19.78	0.79

Table 8 – At 03:30PM with Copper Engine Oil combination (I_bR_b 472.8 W/m^2)

	Inlet Parameter				**Outlet Parameter**					
Sr. No.	**m_f (kg/sec)**	**T_{fi} (ºC)**	**T_c (ºC)**	**T_{fo} (ºC)**	**T_p (ºC)**	**Q_u (W)**	**η_{ib} (%)**	**h_f (W/m^{2}K)**	**S (W/m^2)**	**F'**
1	**0.0043**	**32**	**55**	38	54.99	40.996	2.77	10.972	17.409	0.77
2	**0.00218**	**32**	**52**	40	51.99	27.712	1.88	10.507	17.409	0.56
3	**0.0073**	**32**	**55**	35	54.99	34.799	2.36	7.916	17.409	0.62
4	**0.008**	**32**	**52**	42	51.99	127.12	8.6	57.852	17.409	0.71

Table 9 – At 12:30PM with Mild Steel Water combination (I_bR_b 526.90 W/m^2)

	Inlet Parameter				**Outlet Parameter**					
Sr. No.	**m_f (kg/sec)**	**T_{fi} (ºC)**	**T_c (ºC)**	**T_{fo} (ºC)**	**T_p (ºC)**	**Q_u (W)**	**η_{ib} (%)**	**h_f (W/m^{2}K)**	**S (W/m^2)**	**F'**
1	**0.00544**	**32**	**48**	45	47.99	305.93	18.58	465.04	19.401	0.81
2	**0.0084**	**32**	**41**	38	40.99	210.672	12.79	319.917	19.401	0.58
3	**0.0382**	**32**	**40.5**	36	40.48	638.704	38.79	647.758	19.401	0.38
4	**0.0586**	**32**	**39.5**	36	39.47	979.792	59.51	1281.303	19.401	0.31

Table 10 – At 01:30PM with Mild Steel Water combination (I_bR_b 529.0 W/m^2)

	Inlet Parameter				**Outlet Parameter**					
Sr. No.	**m_f (kg/sec)**	**T_{fi} (ºC)**	**T_c (ºC)**	**T_{fo} (ºC)**	**T_p (ºC)**	**Q_u (W)**	**η_{ib} (%)**	**h_f (W/m^{2}K)**	**S (W/m^2)**	**F'**
1	**0.016**	**32**	**60**	45	59.94	869.44	52.59	264.023	19.478	0.61
2	**0.0011**	**32**	**58**	43	57.99	50.578	3.06	15.342	19.478	0.89
3	**0.0023**	**32**	**43.4**	40.4	43.37	80.758	4.89	122.554	19.478	0.87
4	**0.0013**	**32**	**40**	38.4	39.98	34.778	2.1	98.953	19.478	0.64

Table 11 – At 02:30PM with Mild Steel Water combination (I_bR_b 537.2 W/m^2)

	Inlet Parameter				**Outlet Parameter**					
Sr. No.	**m_f (kg/sec)**	**T_{fi} (ºC)**	**T_c (ºC)**	**T_{fo} (ºC)**	**T_p (ºC)**	**Q_u (W)**	**η_{ib} (%)**	**h_f (W/m^{2}K)**	**S (W/m^2)**	**F'**
1	**0.0019**	**32**	**107**	54	106.94	174.724	10.41	15.00	19.78	0.67
2	**0.0188**	**32**	**55**	44	54.69	943.008	56.17	390.738	19.78	0.62

3	**0.0105**	**32**	**50**	40	49.86	351.12	20.92	159.857	19.78	0.59
4	**0.00298**	**32**	**46**	37	45.97	62.282	3.71	31.488	19.78	0.96

Table 12 – At 03:30PM with Mild Steel Water combination (I_bR_b 472.8 W/m^2)

	Inlet Parameter					**Outlet Parameter**				
Sr. No.	**m_f**	**T_{fi}**	**T_c**	**T_{fo}**	**T_p**	**Q_u**	**η_{ib}**	**h_f**	**S**	**F'**
	(kg/sec)	**(ºC)**	**(ºC)**	**(ºC)**	**(ºC)**	**(W)**	**(%)**	**(W/m²K)**	**(W/m²)**	
1	**0.00214**	**32**	**48**	40	47.97	71.562	4.84	40.707	17.409	0.83
2	**0.0087**	**32**	**41**	36	40.95	145.464	9.85	132.44	17.409	0.49
3	**0.00828**	**32**	**44**	37	43.94	173.052	11.71	112.538	17.409	0.55
4	**0.00281**	**32**	**40.3**	37.5	40.27	64.602	4.37	105.006	17.409	0.82

Table 13 – At 12:30PM with Mild Steel Engine Oil combination (I_bR_b 526.90 W/m^2)

	Inlet Parameter					**Outlet Parameter**				
Sr. No.	**m_f**	**T_{fi}**	**T_c**	**T_{fo}**	**T_p**	**Q_u**	**η_{ib}**	**h_f**	**S**	**F'**
	(kg/sec)	**(ºC)**	**(ºC)**	**(ºC)**	**(ºC)**	**(W)**	**(%)**	**(W/m²K)**	**(W/m²)**	
1	**0.0024**	**33**	**134**	92	133.4	225.002	13.66	24.376	19.401	0.76
2	**0.0164**	**33**	**106**	76	105.97	1120.563	68.05	170.073	19.401	0.71
3	**0.0091**	**33**	**84**	55	83.9	318.118	19.32	49.919	19.401	0.66
4	**0.0086**	**33**	**74**	68	73.97	478.289	29.05	363.275	19.401	0.87

Table 14 – At 01:30PM with Mild Steel Engine Oil combination (I_bR_b 529.0 W/m^2)

	Inlet Parameter					**Outlet Parameter**				
Sr. No.	**m_f**	**T_{fi}**	**T_c**	**T_{fo}**	**T_p**	**Q_u**	**η_{ib}**	**h_f**	**S**	**F'**
	(kg/sec)	**(ºC)**	**(ºC)**	**(ºC)**	**(ºC)**	**(W)**	**(%)**	**(W/m²K)**	**(W/m²)**	
1	**0.0046**	**52**	**88**	60	87.973	58.475	3.54	9.502	19.478	0.99
2	**0.015**	**41**	**70**	63.5	69.8	536.288	32.44	376.004	19.478	0.85
3	**0.0064**	**42**	**68**	57	67.94	152.544	9.23	63.109	19.478	0.82
4	**0.013**	**32**	**66**	45	65.89	268.541	16.24	58.195	19.478	0.63

Table 15 – At 02:30PM with Mild Steel Engine Oil combination (I_bR_b 537.2 W/m^2)

	Inlet Parameter					**Outlet Parameter**				
Sr. No.	**m_f**	**T_{fi}**	**T_c**	**T_{fo}**	**T_p**	**Q_u**	**η_{ib}**	**h_f**	**S**	**F'**
	(kg/sec)	**(ºC)**	**(ºC)**	**(ºC)**	**(ºC)**	**(W)**	**(%)**	**(W/m²K)**	**(W/m²)**	
1	**0.0019**	**32**	**64**	57	63.97	75.478	4.5	49.07	19.78	0.95
2	**0.0049**	**32**	**75**	50	74.94	140.15	8.35	25.508	19.78	0.72
3	**0.0105**	**32**	**55**	36	54.973	66.738	3.98	15.981	19.78	0.9
4	**0.0142**	**32**	**48**	35	47.973	67.691	4.03	23.692	19.78	0.87

Table 16 – At 03:30PM with Mild Steel Engine Oil combination (I_bR_b 472.8 W/m^2)

	Inlet Parameter			Outlet Parameter						
Sr. No.	**m_f (kg/sec)**	**T_{fi} (°C)**	**T_c (°C)**	**T_{fo} (°C)**	**T_p (°C)**	**Q_u (W)**	**$Ŋ_{ib}$ (%)**	**h_f (W/m^{2}K)**	**S (W/m^2)**	**F'**
1	**0.0056**	**42**	**56**	49	55.97	62.289	4.22	40.49	17.409	0.95
2	**0.0032**	**41**	**47**	45	46.998	20.339	1.38	46.267	17.409	0.74
3	**0.015**	**32**	**55**	36	54.974	95.34	6.45	22.832	17.409	0.67
4	**0.0083**	**38**	**45**	44	44.98	79.132	5.36	360.74	17.409	0.96

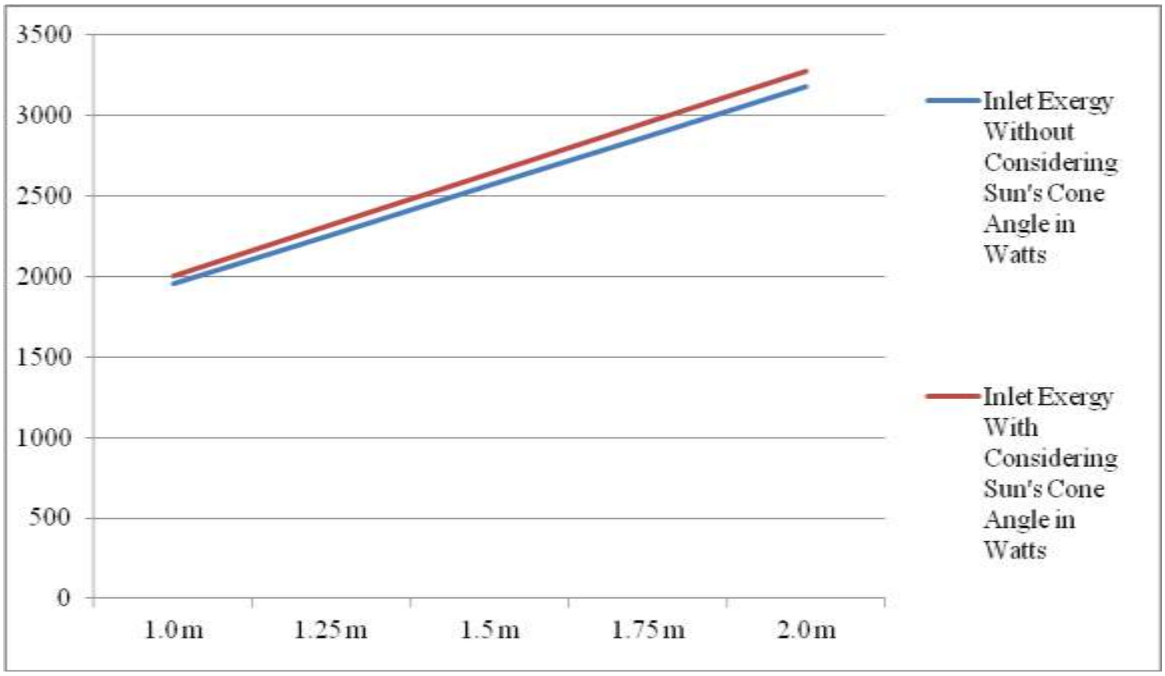

Figure 3 – Inlet exergy curves with different aperture widths for copper-oil arrangement

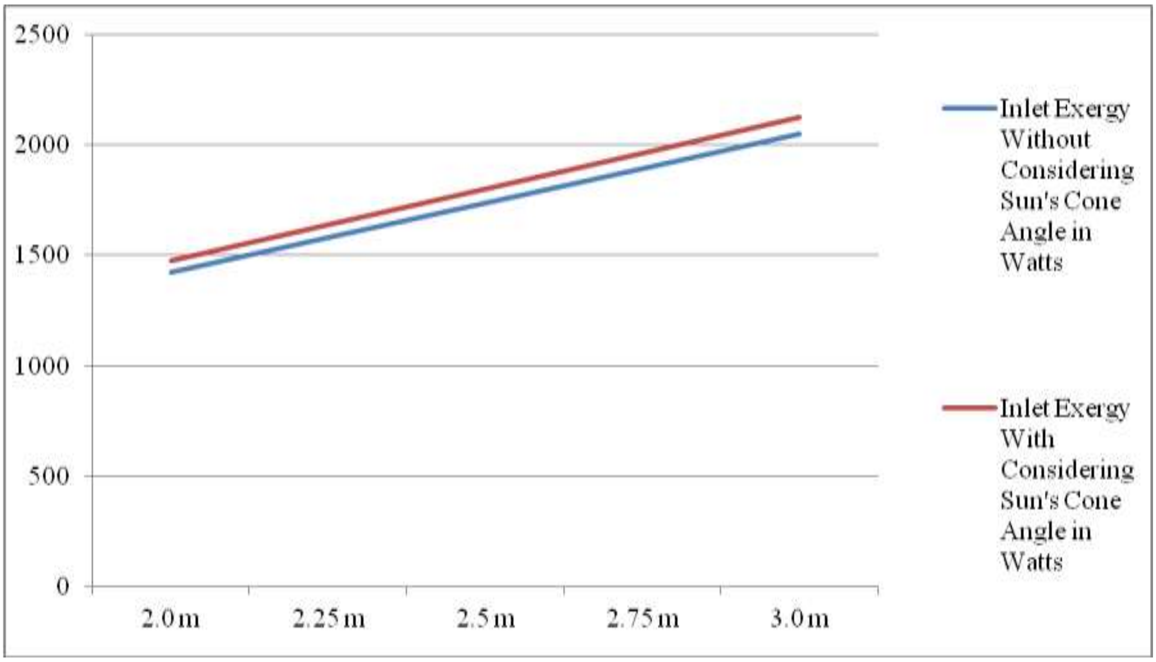

Figure 4 – Inlet exergy curves with different pipe lengths for mild steel-water arrangement

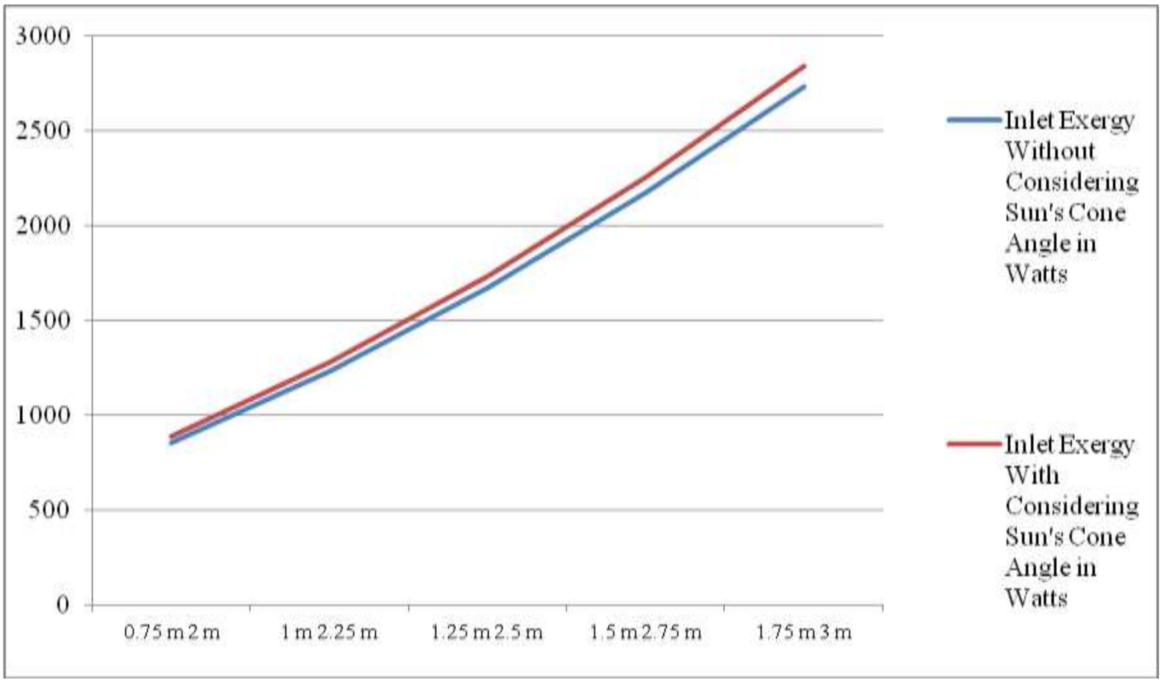

Figure 5 – Inlet exergy curves with different aperture widths and pipe lengths for mild steel-oil arrangement

Figure 6 – Inlet exergy curves with different mass flow rates for copper-water arrangement

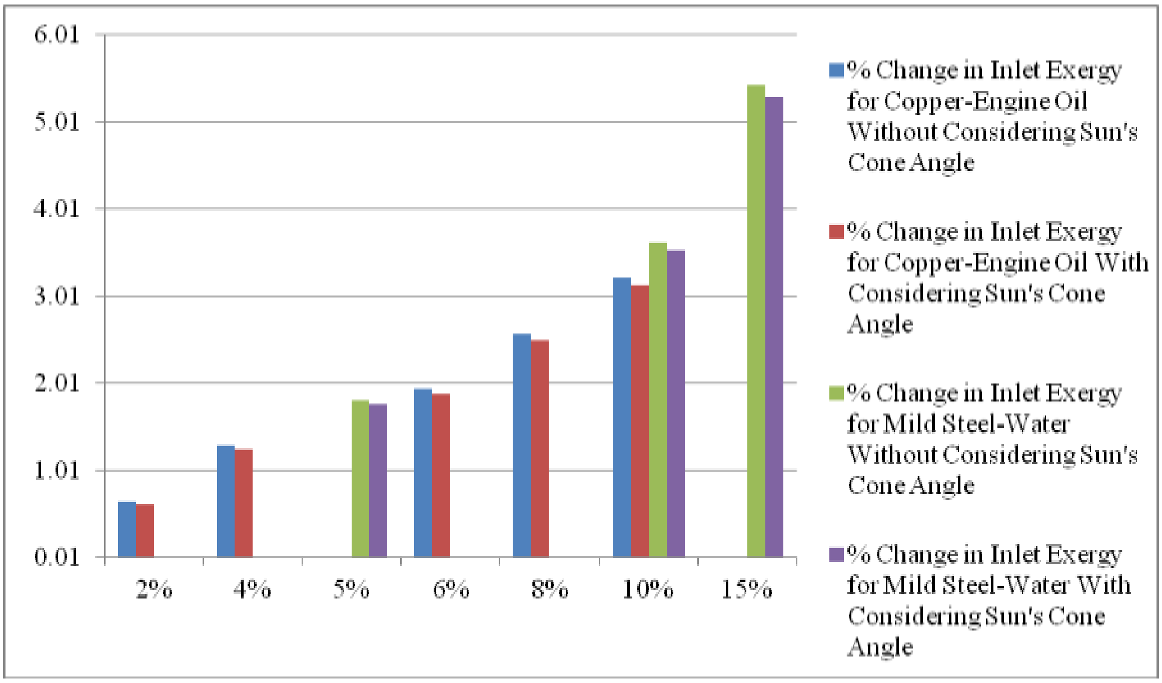

Figure 7 – Inlet exergy v/s change in flow rates

Conclusion –

Cylindrical parabolic solar collector is fabricated and then experimental analyses are done with various combinations/arrangements. Various arrangements are – (1) copper pipe and engine oil as flowing fluid, (2) copper pipe and water as flowing fluid, (3) mild steel pipe and engine oil as flowing fluid and (4) mild steel pipe and water as flowing fluid. All experimental results are taken at 12:30PM, at 01:30PM, at 02:30PM and at 03:30PM. Experimental results are compared and then concluded as – maximum temperature difference (59°C) of flowing fluid is achieved at 12:30PM with mild steel-engine oil arrangement when flow rate is 0.0024kg/sec but minimum temperature differences (3°C) are found at 02:30PM and at 03:30PM with mild steel-engine oil and copper-engine oil arrangements when flow rates are 0.0142kg/sec and 0.0073kg/sec respectively. When engine oil flows through mild steel pipe with rate of 0.0046kg/sec at 01:30PM then near about one collector efficiency factor is found. Minimum inlet exergy (with and without Sun's cone angle) is found at minimum dimensions of experimental setup (0.75 m aperture width and 2.0 m pipe length) but maximum inlet exergy (with and without Sun's cone angle) is achieved with bigger dimensions of collector (example 1.75m pipe length and 3.0m aperture width). When flow rate of engine oil through copper pipe increases with 2%, 4%, 6%, 8% and 10% then inlet exergy (without considering Sun's cone angle) increases with 0.65%, 1.29%, 1.94%, 2.58% and 3.22% respectively. And when flow rate of engine oil through copper pipe increases with 2%, 4%, 6%, 8% and 10% then inlet exergy (with considering Sun's cone angle) also increases with 0.62%, 1.25%, 1.88%, 2.51% and 3.14% respectively. When flow rate of water through mild steel pipe increases with 5%, 10% and 15% then inlet exergy (without considering Sun's cone angle) increases with 1.81%, 3.63% and 5.44% respectively. And when flow rate of water through mild steel increases with 5%, 10% and 15% then inlet exergy (with considering Sun's cone angle) also increases with 1.76%, 3.53% and 5.30% respectively. Maximum instantaneous efficiency of the collector is found at 12:30PM with copper-water arrangement when flow rate is 0.0166kg/sec. It means this arrangement is best arrangement.

List of Symbols, Abbreviations, Nomenclatures –

A_s = *Surface area of pipe* (m^2)

C_p = *Specific heat for flowing fluid (J/kg-K)*

F' = Collector efficiency factor

h_f = *Convective heat transfer coefficient* (W/m^2K)

I_bR_b = *Instantaneous/hourly beam radiation on a surface* (W/m^2)

K = Thermal conductivity of the material (W/mK)

L_c = *Characteristic length of pipe (metre)*

m_f - *Mass flow rate of flowing fluid (kg/s)*

Qu = Heat transfer rate (W)

S = Absorbed flux (W/m^2)

T_{fo}, T_{fi} = *Outlet and inlet fluid temperatures (K)*

T_c, T_p = *Outlet and inlet surface temperatures of pipe material (K)*

T_a = *Ambient temperature (K)*

U_l = *Overall heat loss coefficient* (W/m^2K)

W = Aperture width (m)

η_{ib} = *Instantaneous efficiency (%)*

ϒ = Intercept factor

α = *Absorbtivity of the pipe material*

τ = Transmissivity of the pipe material

ρ = Specular reflectivity on the concentrator surface

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