THERMAL PERFORMANCES OF NANO CARBON-CHROMIUM OXIDE COATED FINS AND EXTERNAL REFLECTOR INTEGRATED SOLAR HEATING DEVICE

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Abstract : Solar collector is used to match the demand and supply of hot water. It is essential to improve the thermal performance of solar collectors with nano-structured fins and external reflectors. It is also essential to estimate the thermal performance of solar collectors with nano-structured fins and external reflectors so as to study their suitability in application sectors. In the present investigation, the solar heating systems with nano-structured fins and external reflectors of different materials of reflectors were tested. The experimental results showed that the temperature elevation of working fluid ranged between 19.9 and 30.3 0C with the corresponding thermal performance variation of 32 to 41% in the aluminium reflector based heating device. The experimental results also showed that the temperature elevation of working fluid varied from 24.3 to 31.1 0C with the corresponding thermal performance variation of 31 to 44% in the stainless steel reflector based heating device. The experimental results also revealed that the minimum temperature elevation was 24.0 0C and the maximum temperature elevation of working fluid was 32.2 0C with the thermal efficiency variation of 35 to 46% in the anodized metal reflector integrated heating device. As the nano-structured fins and anodized metal reflector integrated heating device had the highest efficiency, it could be concluded that the solar heating devices with nano-structured fins and anodized metal reflectors would be effectively used in the application sectors.

Index Terms - **Solar heating device – Nano-structured fins – External reflectors – Thermal enhancements – Thermal performances**

I. INTRODUCTION

The glass cover, fin and insulator are integrated together to form solar collector. The reflector can be additionally integrated to the solar collector so as to have improved thermal performances (Garg and Prakash, 1997, Soteris A. Kalogirou, 2004). In the present research investigation, the research works have been conducted in connection with sizes of integral elements, materials of integral elements and dimensions of solar collectors. The research works have also been conducted in connection with structural, optical and thermal properties of the concerned individual components. The research works have as well been conducted in connection with assessment of thermal characteristics and estimation of efficacy of solar collector (John A. Duffe, William A. Beckman, 1980). The materials, research methodologies and research outcomes have been recorded in this research paper for the benefits of researchers, manufacturers and end users.

II. MATERIALS AND METHODS

In the present research, the nano carbon and nano chromium oxide were procured. They were mixed in optimized proportions in black emulsion and they were stirred by using mechanical stirrer. The prepared absorption solution was spray coated on metal plate (Uma Maheswari and Jeba Rajasekhar, 2015). The mixture of nano carbon and chromium oxide power was characterized and the diffractogram was generated.

Before the experimentation on thermo – syphon domestic solar fluid heating device, it was kept to get exposed to varied weather conditions for two days with the daily solar irradiance that was more than 18 MJ/m^2 on the plane of solar collector. The experimentation on thermo - syphon domestic solar hot fluid device was conducted during sun-shine hours for a stipulated period of seven days. The total duration required for each cycle of the test was seven hour, which comprised 3.5 hour before solar noon and 3.5 hour after solar noon (Nayak et al., 2005, MNRE, 2007). Based on not only the measured data obtained during day time test but also the formula presented as equation 1, the efficiency parameter of the solar hot fluid device was evaluated.

$$\eta_{system} = \frac{(MC)_s (T_{sfd} - T_{std})}{A_c \int_{t_1}^{t_2} G_t \, dt}$$

Efficiency (day time) ----- (1)

Where,

η	Efficiency of solar hot fluid device averaged over the test period (%)
$(MC)_s$	Thermal capacitance of the fluid in the storage tank (J/K)
T_{sfd}	Storage temperature at the end of the day-test (^{0} C)
T_{std}	Storage temperature at the start of day test (^{0} C)
G_t	Solar irradiance on the inclined plane of the Solar Collector (W/m^2)

The solar fluid heating device with variations in materials of external reflectors was the test sample and the thermal performances of the device were estimated in the present research (BIS, 2003, MNRE, 2007).

III. RESULTS AND DISCUSSION

In the present investigation, the sizes of the solar heating device were measured. In addition, the solar hot fluid device with nano-structured fins and without reflectors was tested. Subsequently, the solar hot fluid device with nano-structured fins, aluminium reflector, stainless steel reflector and anodized metal reflector was tested (Soteris A. Kalogirou, 2009). The incident solar radiation was monitored by using Class 1 Pyranometer, the ambient temperature was recorded by using Stevenson screen and the working fluid temperature was recorded by using Pt_{1000} thermometer (BIS, 2003). The recorded parameters during experimentation on components and solar heating device have been presented in tables.

Table 1 Specifications of solar fin

Description of solar fin	**Materials and dimensions of solar fin**
Material	Aluminium
Thickness of material	0.20 mm
Breadth of material	1000 mm
Length of material	2000 mm
Coating on solar fin	Nano carbon and chromium oxide coating

Table 2 Thermal performance of solar fluid heating device (Nano-structured fin and Aluminium reflector based device)

Day	Storage Tank Temperature (^{0}C)			Ambient temperature (^{0}C)	Solar radiation (W/m^2)	Wind speed (m/s)	Efficiency (%)
	Initial	Final	δt				
1	30.0	60.3	30.3	28.4	596.4	0.4	41
2	35.1	62.5	27.4	28.1	590.7	0.3	40
3	40.1	65.9	25.8	27.9	597.3	0.3	37
4	45.1	70.3	25.2	27.8	601.2	0.5	33
5	50.1	73.6	23.5	27.7	589.4	0.4	36
6	55.1	76.7	21.6	28.0	597.3	0.4	30
7	60.1	80.0	19.9	28.0	583.2	0.4	32

Table 3 Thermal performance of solar fluid heating device (Nano-structured fin and Stainless steel reflector based device)

Day	Storage Tank Temperature (^{0}C)			Ambient temperature (^{0}C)	Solar radiation (W/m^2)	Wind speed (m/s)	Efficiency (%)
	Initial	Final	δt				
1	30.1	61.2	31.1	28.4	585.4	0.2	44
2	35.1	63.4	28.3	28.5	572.3	0.3	43
3	40.0	67.2	27.2	27.9	600.4	0.3	36
4	45.1	72.3	27.2	27.8	606.3	0.4	38
5	50.1	75.6	25.5	28.0	590.1	0.2	35
6	55.1	79.4	24.3	28.4	578.3	0.2	31
7	60.0	84.4	24.4	27.9	590.4	0.2	37

Table 4 Thermal performance of solar fluid heating device (Nano-structured fin and Anodized metal reflector based device)

Day	Storage Tank Temperature (^{0}C)			Ambient temperature (^{0}C)	Solar radiation (W/m^2)	Wind speed (m/s)	Efficiency (%)
	Initial	Final	δt				
1	30.1	62.3	32.2	27.8	598.3	0.4	46
2	35.0	63.9	28.9	29.4	587.4	0.4	43
3	40.0	71.2	31.2	27.8	612.4	0.3	37
4	45.0	73.5	28.5	28.2	603.5	0.3	39
5	50.1	76.4	26.3	28.3	580.5	0.3	36
6	55.1	79.6	24.5	21.9	593.2	0.3	35
7	60.0	74.0	24.0	24.6	587.4	0.2	38

The carbon nano particles and chromium nano particles exhibited intense diffraction peaks. From the XRD spectrum, the crystallite size was estimated as 54.8 nm using the Debye-Scherrer formula (Chattopadhyay and Banerjee, 2012). As the crystallite size was in nano range, the optical absorption in the solar fin would be relatively higher than that of the usual fin and hence the thermal performance of the solar heating device.

The experimental results showed that the thermal efficiency of fluid heating device without reflector was relatively lower than that of the solar fluid heating devices with external reflectors. The usage of external reflectors could have caused the augmentation of incident solar radiation on the solar collector. As the incident solar radiation was increased, the absorption of the solar radiation would have been increased. As the absorption of solar radiation was augmented, the heat transfer to the working fluid and thermal performance of solar fluid heating collector would have also been augmented (Tiwari et al., 1985, Soteris A. Kalogirou, 2006).

It was found that the temperature elevation of working fluid ranged between 19.9 and 30.3 ^{0}C with the corresponding thermal performance variation of 32 to 41% in the aluminium reflector based solar collector. It was also found that the temperature elevation of working fluid varied from 24.3 to 31.1 ^{0}C with the corresponding thermal performance variation of 31 to 44% in the stainless steel reflector coupled solar heating device. At the same time, it was also found that the minimum temperature elevation was 24.0 ^{0}C and the maximum temperature elevation of working fluid was 32.2 ^{0}C with the thermal efficiency variation of 35 to 46% in the anodized metal reflector integrated solar heating device.

The experimental results of the present investigation revealed that the alumium reflector integrated hot water device had the relatively lower thermal performance than that of the stainless steel reflector integrated hot fluid device. The results also revealed that the stainless steel reflector integrated hot water system had the relatively lower thermal performance than that of the anodized reflector integrated hot fluid device. The enhancement of thermal performance could be correlated with the enhancement in the dimensions of reflectors, materials of reflectors and reflectivity of reflectors (Ahmed Kadhim Hussein, 2016, Sekar et al., 2012, Vasantha Malliga and Jeba Rajasekhar, 2017, Dnyaneshwar Malwad and Vinod Tungikar, 2020). So, it could be stated that the nano-structured fin and anodized metal based external reflector would be used so as to have relatively higher thermal performance of solar heating device in the utilisation sectors.

IV.CONCLUSION

It could be concluded that nano-structured fin and reflector of suitable material would be utilized in solar collector on the basis of the requirement of temperature enhancement of working fluid and thermal performance enhancement of solar collector in the application sectors

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