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Application of Solar Thermal Energy Storage for Industrial Process Heating

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Abstract

A massive deployment of solar thermal technology is required in those industries which use large quantities of low temperature hot water for the economic operation. With the rise in fuel cost and scarcity now, there is a significant research, development and application in solar industrial process heating. Due to the unavailability of solar energy during non sunny days and diurnal changes throughout the day, storage of thermal energy is inevitable. Recent developments nationally and internationally may rekindle new applications of solar thermal energy use by industry. This paper reviews the application of solar industrial process heating in paper industry.

Introduction

The sun is a spherical hot gaseous matter with a diameter of 1.39 x 10^6 km. The solar energy reaches surface of earth in 8 min and 20 s after leaving the sun which is 1.5 x 10^8 km away. The blackbody temperature of the sun is 5762 K [1]. The core temperature is about 8 x 10^6 to 40 x 10^6 K. The sun is a continuous fusion reactor in which hydrogen is turned into helium. The sun's total energy output is 3.8 x 10^{20} MW. The sun radiates energy in all directions. Only a tiny fraction, 1.7 x 10^{14} kW, of the total radiation emitted falls on the earth surface [1]. The small fraction of energy falling on earth for half an hour is equal to the world energy demand for one year

Heat can be stored in three methods: sensible, latent and thermo-chemical heat storages. The sensible heat storage (SHS) system is simple and a well-developed ancient technology. But in this type of storage the efficiency is less because of low heat storage capacity per unit volume of the storage medium. The heat liberated or absorbed when a substance changes from one phase to another is called the latent heat. These types of materials are called phase change materials. The advantages of Latent heat storage (LHS) systems using phase change material (PCM) as storage medium are high heat storage capacity, small unit size and isothermal behaviour during charging and discharging processes. Very limited number of research work is conducted on the thermal performance of LHS systems employing PCM in various geometries integrated with Solar heating applications. Esen et al. [2] made numerical investigation on the thermal performance of solar water heating systems integrated with cylindrical LHS unit using various PCMs. G.Kumaresan et.al [3] analysed D-Mannitol for use as PCM for latent heat storage system. They found out the melting and decomposition range and its suitability for medium temperature applications around 170ºC. Cheralathan et al. [4] analysed numerically and conducted parametric studies on a PCM encapsulated cool TES system integrated with a refrigeration unit. Effective utilization of solar energy for water heating applications using combined SHS and LHS systems were experimentally verified by Nallusamy et al. [5]. Regin et al. [6] analyzed the melting behaviour of paraffin wax as a phase change material encapsulated in a cylindrical capsule, used in a LHS system with a solar water heating collector. Vikram et al. [7] conducted the experiments by implementing the PCM in the TES tank. The PCM was encapsulated within aluminium cylinders and were packed in beds

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within the tank and was experimented. Though the experiment was successful there was a problem of the PCM (paraffin) on expansion had caused a pressure within the container and had leaked into the HTF within the tank resulting in spoiling the water that was to be used. A. Pasupathuy et.al. [8] Experimentally investigated the thermal performance of PCM incorporated in building roof for heating the room and also compared with the numerical analysis. Velraj.R et.al. [9] Performed the experiments in enhancing heat transfer in a latent heat storage system and found that increase in heat transfer by providing fins inside the container. Comparative studies of SHS and LHS systems have been carried out by Vijay padmaraju et al. [10]. They had performed the experiments using the aluminium cylinders with rubber corks to seal the opening, yet it resulted in leakage of PCM in to the HTF. M.Gajendiran and N.Nallusamy [11] analysed the enhancement of settling tank for Marine Heavy Fuel Oil Systems by the application of thermal energy storage for heating the Heavy Fuel Oil. The objective of the present work involves application of solar industrial process heating in paper industry.

Implementation of Solar TES system for feed water heating

From a number of studies on industrial heat demand, several industrial sectors have been identified with favourable conditions for the application of solar energy. In this work implementation of TES system for feed water heating (Fig.2) in the paper industry with production capacity of 65 Tons per day of Kraft paper is analysed. The process involves grinding the wet pulp, pressing and drying with the help of steam. Wood fired boiler (Fig.1) is used for generating steam required for the process. After grinding the pulp it is passed through rollers, where the excess water is squeezed out and it is passed through heating rollers and drying drums (Fig.3), where the paper is dried to final stage.

Process details. The steam used for drying is saturated steam which is fed to the set of rollers and to the drying drums of 4 numbers. The condensate collected is used as feed water along with makeup water.

Table 1: Process Details

Process	Parameters
Feed water initial temperature before mixing with condensate	30-34[º C].
Feed water temperature after mixing with condensate	60-75 [º C]
Flow rate of feed water	5000 [L/Hr]
Capacity of feed water tank	20 [m^3].
Quality of condensate	Condensate mixed with Flash steam
Temp of condensate	@ [98 º C].
Steam temp at boiler	165 [º C], (Saturated steam)
Capacity of boiler	5000 [Kg/Hr]
Steam Pressure	9 [Kg/ cm^2]
Flow rate of steam	4 - 5 [T/Hr]
Usage of steam	4 - 5 [T/Hr] @ 3-4 [kg/ cm^2]
Fire wood consumption	@1.5 [T/ Hr]
Cost of fire wood	Rs. 3.00/- per kg
Make up water required @ 30%	1500 [L/Hr]

System designed. The system is designed for heating the makeup feed water of 1500 L/Hr. Solar flat plate collectors (Fig.4) connected to TES tank are used for heating the feed water. Paraffin-Type II is selected as Phase Change material (PCM) and water is selected as sensible heat storage (SHS) material.

Solar energy is to be used for heating the makeup water quantity of 1500 L/Hr, to a temperature around 60 º C.

Makeup water required = 1500 L/Hr

Solar energy available per day = 6 Hrs

Solar energy

Energy available from Solar flat plate collector = 400 J/s = 1440 kJ/Hr

For 6 hours = 8640 kJ

Total solar collector area required = 523 m^2

Total number of solar panels (Area of $2m^2$) = 523/2 = 262 panels.

The Makeup water required for 24 Hrs = 1500 x 24 = 36000 Litres = 36 Tons.

Energy requirement for heating 36 Tons

$Q= m\, c_p\, \Delta T$ = 36000x 4.18 x (65-30) = 5266800 kJ = 5266 MJ

The TES system stores 75% and 25% of energy in PCM and SHS (water) respectively

Mass of PCM (m_{PCM}) required, $Q_{PCM} = m_s\, cp_s\, \Delta Ts + m_s \times LHF + m_L\, cp_L\, \Delta T_L$.

5266800 kJ = m_s x 1850 × (60-30) + m_s × 213000 + m_L x 2384 x (65-60)

$m_{PCM} = (m_s + m_L)$ = 18000 x 0.75= 13500 kg of PCM.

Mass of water (m_{SHS}) required, $Q_{SHS} = m_{SHS} \times 4182 \times (65-30)$

m_{SHS} = 36000 x 0.25 = 9000 kg of water.

Where, m_{PCM} is mass of the PCM, m_s is the mass of solid PCM, m_L is the mass of the liquid PCM, LHF is the latent heat of fusion, cp_s and cp_L are specific heats of solid and liquid PCM respectively, m_{SHS} is the mass of water.

Fig. 1. Boiler plant

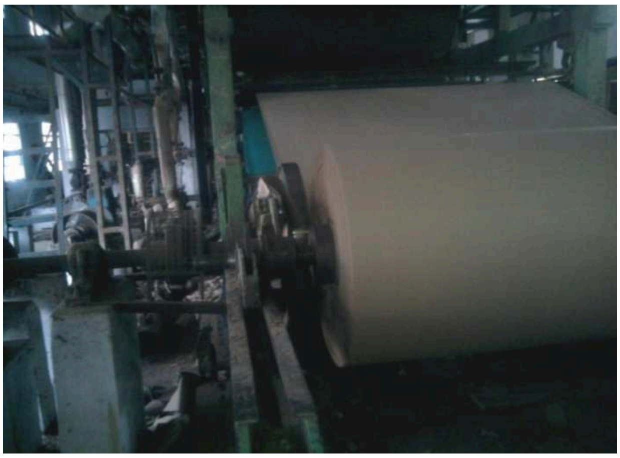

Fig. 3.Paper rolling and drying process

Fig. 2. Feed water tank

Fig. 4. Solar collectors

Results and discussion

The quantity of makeup water required is 1500 Litres (30 % of the total water). The fire wood consumed is 1500kg/Hour. The cost involved in operating the boiler plant with conventional heating is around Rs. 4500/- per Hour. With the application of TES system for heating the makeup water of 1500 Litres, the cost of fire wood is reduced by 30 %. The cost saved from the firewood is Rs.1350/- per Hour. Thus annual savings of Rs.118.2 Lakhs can be made. In addition to running cost reduction, this also reduces the carbon emission generated by firing the boiler with wood.

Conclusion

The implementation of industrial process heating associated with solar thermal energy storage system in a paper industry with production capacity of 65 Tons per day of Kraft paper is analysed. The system is designed to heat the makeup feed water of 1500 L/Hr. Heat collected by solar flat plate collectors is used for heating the makeup feed water and also stored in the TES tank for usage during non-sun shine hours. From the design calculations, the number of solar panels, quantity of PCM and SHS material were decided. It is obvious that the operating cost and thus the production cost of the Kraft paper unit is reduced.

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References

[1] International Energy Agency Technology, Solar Heating and Cooling, http:// www.iea.org/techno/iaresults.asp

[2] M. Esen, A. Durmu, 1998. Geometric design of solar-aided latent heat store depending on various parameters and phase change materials. Solar Energy 62(1), 19-28.

[3] G. Kumaresan, R.Velraj and S.Inian, 2011. Thermal analysis of D-Mannitol for use as latent heat storage. Journal of Applied Sciences 11(16): 3044-3048.

[4] M. Cheralathan, R. Velraj, S. Renganarayanan, Heat transfer and parametric studies of an encapsulated phase change material based cool thermal energy storage system, Journal of Zhejiang University Science 7 (2006) 1886e1895.

[5] N. Nallusamy, S. Sampath, R. Velraj, 2006. Study on performance of a packed bed latent heat thermal energy storage unit integrated with solar water heating system. J. Zhejiang Univ Science A 7(8), 1422-1430.

[6] A.F. Regin, S.C. Solanki, J.S. Saini, 2006. Latent heat thermal energy storage system using cylindrical capsule: Numerical and experimental investigations. Renewable Energy 31, 2025-2041

[7] D. Vikram, S. Kaushik, V. Prashant, N. Nallusamy, 2006, An improvement in the solar water heating system by thermal storage using phase change materials, Proceedings of ISEC-2006, ISEC2006-99090, Irvine, CA.

[8] Experimental investigation and numerical simulation analysis on the thermal performance of a building roof incorporating phase change material (PCM) for thermal management, Applied Thermal Engineering 28 (2008) 556–565.

[9] Velraj R., Seeniraj R.V., Hafner B., Faber C. and Schwarzer K. (1999), 'Heat transfer enhancement in a latent heat storage system', Solar Energy, Vol. 65, No. 3, pp.171-180.

[10] S.A.Vijay padmaraju, M.Viginesh, N.Nallusamy, 2008, Comparitive study of sensible and latent heat storage systems integrated with solar water heating unit, Proceedings of ICREPQ'08, ICREPQ'08-218, Santander, Spain. [11] M.Gajendiran, N.Nallusamy 'Application of solar heating system integrated with thermal energy storage unit for the enhancement of Settling tank for Marine Heavy Fuel Oil Systems'.TRESAT-2012, Sathyabama University.

[11] M.Gajendiran, N.Nallusamy 'Application of solar heating system integrated with thermal energy storage unit for the enhancement of Settling tank for Marine Heavy Fuel Oil Systems'.TRESAT-2012, Sathyabama University.

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