PERFORMANCE INDICATORS FOR SOLAR PIPES WITH PHASE CHANGE STORAGE.

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Thermal energy storage in solar systems using latent heat attracted a great deal of interest. Latent heat provides an efficient high energy density and a constant release temperature from the thermal storage. In most systems, a heat transfer fluid is utilized to transport heat from the collectors to the Phase Change Materials (PCM) during the energy storage mode of operation and back to the load in the energy release mode.

The proposed solution is to use a solar pipe that consists of two concentric pipes with the space in between them filled with PCM. Solar radiation is absorbed directly by the outer surface and then transmitted to the PCM where it stored as sensible and latent heat. Energy release is by exchanging heat with water passing through the inner tube [1].The main advantage of the solar pipe is in the low energy space storage, no need for circulating pump and the direct energy absorption and release.

In order to evaluate the performance of the solar pipe, indicators such as the fusion time of the PCM (β_m) and solidification time due to energy release (β_s) are suggested. The fusion time is defined as the time required by the PCM within a standard solar pipe system to change from a solid at temperature of $T_s = 20$ °C into liquid when the solar pipe is free of load. The solidification time is defined as the time required by 1 m^2 of standard solar pipe system to totally solidified when a mass flow rate of 10 kg/min of water with initial temperature of $T_i = 20$ °C absorbed heat in the inner tube.

The indicators were calculate by numerical simulation that is suitable for this kind of moving boundary problems. The numerical simulation is based of an explicit finite difference method that enables precise interface tracking and capable of solving this small Stefan number problem. This simulation is a refinement of the Springer and Olson [2] solution at the interface vicinity. A full description of the method is given in [3].

The melting times of the solar pipe are of order of few hours and they increase with the fusion temperature T_f. This increase of the melting time in spite of the fact that all the systems have an identical latent heat capacity, is due to sensible heat and energy losses. The fusion time for an insulated system (minimum melting time) is an order of magnitude smaller than the actual melting time.

The solidification time is determined during the energy release process and the outward motion of the interface between the solid and the liquid phase becomes a function of both time and axial location along the solar pipe.

In order of finding the solidification time indicator, the outer surface is thermally insulated while water flowing inside the inner tube. The water heats as a result of energy release of from the PCM during the solidification process. The lowest possible solidification time (for a given heat transfer coefficient - h_l is achieved when an infinite flow rate flows through the inner surface such that the inner boundary temperature does not increase in the longitudinal direction.

The outlet temperature drops sharply within short time (order of minutes) and maintain at the same level of temperature. The solidification times are of order of few minutes and are larger for large melting temperature.

Future development could concentrate on size optimization and materials improving in order of achieving better performance.

References

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