Briefing paper

Parametric investigations to enhance thermal performance of paraffin through a novel geometrical configuration of shell and tube latent thermal storage system.

Khan, Z., Khan, Z. A. and Tabeshf, K., 2016. Energy conversion and management, 2016, Vol 127, p.355-365.

Research and development in clean energy technologies is a direct response to the need of generating 50% of energy requirements through renewable sources by 2050 as set by the EU initiative. Renewable energy sources have significant potentials to address key issues in terms of depleting natural energy resources, rocketing energy prices and security. Professor Zulfiqar Khan has been leading a portfolio of externally funded two PhDs, two Post Docs and one match funded PhD research project focusing on the development of a comprehensive renewable system to generate (i) heat, (ii) electricity, (iii) novel thermofluids with nano additives, (iv) heat storage for both domestic and commercial applications and (v) a viable business and commercialisation case.

Introduction

Within the above research portfolio one key activity area is to fully understand the Latent Heat Storage (LHS) systems which can store and release surplus thermal energy, and they are used in industry and domestic environments to ensure a steady supply. LHS systems use phase change materials (PCMs) such as paraffin (melting temperature 314.15 Kelvin (K) (41°C) – 317.15K (44°C). As the paraffin changes from solid to liquid phase and back, it absorbs and then releases thermal energy which is captured through surrounding water. LHS systems have been enhanced during this research to more effectively overcome low thermal conductivity and to increase the speed with which energy storage and discharge takes place. The 'shell and tube' heat exchange system performance is enhanced by the addition of metal fins. These developments have increased the surface area and heat transfer by allowing the paraffin to melt faster.

Outline of research

The research team developed a novel two-dimensional computer model and assessment of nano fluids based on a recently completed research project focusing on Flat Plate Solar Energy Collector. Statistical parameters were generated through modelling for:

- The number and orientation of tube passes in the LHS.
- The length and width of the metallic fins.
- The material for the shell, tube and fins.
- The inlet temperature of the HTF (water).

Calculations allowed for a flat plate solar energy collector of length 320mm, cross-sectional diameter

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450mm and thickness 1mm, with fins ranging from 12.7mm – 38mm long and 2mm thick. The calculations determined the thermal performance of each component and variation in order to melt the paraffin over 10 hours.

Key findings and impact

- Increasing the surface area from 9 to 21 tube passes markedly increased the melting and heat transfer rate through heat conduction.
- The longer fin length increased the paraffin melting rate compared to fin thickness due to improved thermal conductivity and heat transfer between the HTF and the PCM.
- A reduction in thermal storage capacity is minimal in longer fins compared to fin thickness.
- Thermal storage capacity and melting rate in the LHS system are increased by 18.06% and 68.8% when the inlet temperature is 323.15K (50°C) and 343.15K (70°C) respectively.
- Copper, aluminium and aluminium 6360 (an aluminium alloy) showed improved conductivity and reduced melting time with paraffin, compared to steel AISI 4340 (a heat treatable low alloy steel), making these better options for shells, tubes and fins.

Conclusion

This study offers a blueprint for a new LHS system with enhanced performance which builds on our existing research. The specific orientation of shell, tube and longitudinal fins in LHS systems has not been reported in the literature before. The computational framework and parametric calculations allow modelling of specific design components to overcome previous issues of low thermal conductivity and slow heat transfer which will improve LHS systems for domestic and industrial use.

Next steps

An optimisation of the system to enhance overall efficiency through nano additives in the new generation of commercially used Thermofluids and address durability issues in terms of corrosion failures is underway. This research will provide a comprehensive cost effective, durable and efficient system to provide clean energy.