POLYMER HOLLOW FIBRE HEAT EXCHANGERS

Current developments and applications under an INNOVATE project

David Reay,
David Reay & Associates
(with thanks to the INNOVATE project partners)
Polymer Hollow Fibre Heat Exchanger

http://www.polyhx.com/ is the project web site of the Innovate project

• “This project aims to develop, optimize, and manufacture a novel micro-polymer hollow fibre heat exchangers (PHFHE) for various applications. This light weight PHFHE can reduce the weight by up to 50% compared with traditional metal heat exchangers, leading to at least a 50% cost reduction. The small diameter fibres (<1mm) also have thin walls and large surface areas so heat transfer intensity is significantly increased”
What do the Fibres look like?

Above Random ‘chaotic’ bundles of fibres
RHS Flexible non-chaotised CPHEs, length 750 mm.

Miroslav Raudenský, Ilya Astrouski, Miroslav Dohnal

**Intensification of heat transfer of polymeric hollow fiber heat exchangers by chaotisation**


http://dx.doi.org/10.1016/j.applthermaleng.2016.11.038
Detailed design of hollow fibre module

- 5 bundles of hollow fibre, each contains 100 fibres
- In order to avoid the flow channelling or shielding of adjacent fibres, the fibres in each bundle were compressed from both ends to make them into spindle shapes to allow maximum contact between the air stream and the fibres.
When bundled together at the manifold, many fibres of <1mm diameter can be contained in a 25mm diameter end fitting.
Material properties – PEEK is of interest
Also PAEK – Polyaryletherketone (Victrex)
Materials, header sealing and 3D printing

One application where a gas-liquid PHFHE has potential is as a car radiator. The unit shown developed at Brno University shows the challenge of sealing a header – as in the previous slide.

Victrex PEEK polymer in hollow fibre form is being used in the INNOVATE project – it has a continuous use T of 250deg.C

Victrex, with companies such as HiETA, has a project top develop AM using Victrex.

Applications are seen in:

1. Buildings: hollow membrane fibres for liquid desiccant cooling and non-porous capillaries for air heat recuperation, air heaters and fan-coils;
2. Automotive: car radiators with same thermal power as traditional radiators but 50% lighter;
3. Electronics: heat transfer units for cooling compact electronic devices;
4. Water desalination: air humidification by pervaporation through hollow fibre membranes;
5. Energy Storage: non-porous hollow fibres for encapsulating PCMs can enhance heat transfer for passive cooling and energy storage applications.
6. The use of hollow fibre membranes for carbon capture has been examined in other countries.
The Project Partners reflect the application interests - 1

- Spirax Sarco (Leading the project). The company sees this as a new product opportunity to complement their existing heat exchanger product range.

- EPS. A leading supplier of PCMs (Phase Change Materials) and systems into which they are engineered. Looking at an evaporative cooling system with desiccant inside the fibres.

- Geo Green Power. The company is strong in solar PV and renewable energy for heat generation.
The Project Partners - 2

- PAK Engineering. A heat exchanger company seeing this type of unit as a new product opportunity. In this project it is involved in the construction of the heat exchanger units for tests. Involved in potting of the fibres as shown in the earlier heat exchanger illustrations.
- PAB. This company, highly active in the automotive and aerospace industries, sees application for the heat exchanger in electric vehicles.
- Solar Ready. Working in the energy storage area.
- University of Nottingham. Carrying out tests on evaporative cooling system using the fibres, and also desiccant cooling – examples later
- DRA.
Fig. 14. Three bundles in a box forming heat exchanger typically used in liquid – gas applications.

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Fig. 3. Heat transfer coefficient at outer surface for external flow of air (20 °C) across separated fibers.

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http://dx.doi.org/10.1016/j.applthermaleng.2016.11.038
PHFHEs for Electronics Cooling

• 15th IEEE ITERM Conference; 978-1-4673-8121-5/$31.00 ©2016 IEEE paper by Raudensky et al.

A single bundle of fibres (amongst others) has been tested in a gas-liquid configuration under natural convection conditions.

It is suggested that bundles of fibres could be used in electronic enclosures for heat extraction.
Experimental testing of shell and tube PHFHE at University of Nottingham
Performance of prototypes in liquid-liquid duty

13th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics
POLYMER HOLLOW FIBRE SHELL AND TUBE HEAT EXCHANGER FOR LIQUIDS-LIQUID APPLICATIONS
Amir Amini 1* Tereza Brozova 2, Miroslav Raudensky 2, Jeremy Miller 1
1 Spirax Sarco Ltd, Technology Centre, Runnings Road, Kingsditch Industrial Estate, Cheltenham, Gloucester, GL51 9NQ, UK
2 Heat Transfer and Fluid Flow Laboratory, Brno University of Technology, 616 69 Brno, Technicka 2, Czech Republic
* Corresponding author E-mail: amir.amini@uk.spiraxsarco.com
Organic Rankine Cycle unit with Polymer HX

• Low temperature heat recovery.
• Design of a 20 kW regenerative ORC adopting commercial plastic heat exchangers.
• Electricity cost comparable with ORC modules with typical carbon steel components.
• Economic benefit from plastic evaporator adoption with corrosive heat source media.

ORC units are often used for heat recovery from aggressive streams, so a polymer unit that is corrosion-resistant is useful.

Applied Energy Volume 154, 15 September 2015, Pages 882–890
Scale-up of PEEK hollow fiber membrane contactor for post-combustion CO2 capture

Shiguang Lia et al.

From Gas Technology Institute, 1700 S. Mount Prospect Road, Des Plaines, IL 60018, USA & Air Liquide Advanced Separations, 35A Cabot Road, Woburn, MA 01801, USA

http://dx.doi.org/10.1016/j.memsci.2017.01.014
Comparison of PHFHE with other types (UoN data) for building heat recovery

A compact metal heat exchanger with wall thickness of 0.4 mm, a plate heat exchanger with 0.4 mm thickness, and a PEEK plate heat exchanger are chosen for comparisons. We can see from the figure that PHFHE modules generally demonstrate higher volumetric HTC values (about 2–8 times) compared with conventional metal and plastic heat exchangers. Despite the relatively low overall heat transfer coefficients, the large surface area to volume ratio of PHFHEs offers a controlling performance factor on a volumetric basis. For instance, for PHFHE module 3 (fibre number = 400), the CUV values are about 7 times higher than the compact tubular heat exchanger, and 1.5 times higher than the metal plate heat exchanger. However, the values used for the metal heat exchangers already represent the cutting edge of current technology, while the packing/manufacturing technology for the PHFHEs are currently only subjected to laboratory testing conditions. Optimisation should give even better performance.

Conclusions

• The proposed PHFHE product will be non-corrosive, flexible, 100% recyclable and, most importantly, 50% lighter than traditional metal heat exchangers. This will in turn lead to major system weight savings at the same or better thermodynamic performance. Other advantages of micro-PHFHE includes low friction in fluid flow and suitability for mass production and ease of moulding. This PHFHE is suitable for applications across the built environment, transport and clean technology sectors. The markets include:

  • **Automotive vehicles** which are equipped with PHFHE product will benefit from improved thermal performance. This will lead to better vehicle indoor comfort with reduced vehicle weight. The owner of such kind of vehicles will hence enjoy better thermal comfort with reduced fuel costs.

  • **The owners and occupiers of buildings**, in which the air conditioning/ heat recovery system is equipped with PHFHE products stand to benefit from improved indoor thermal comfort, less occupation space of the AC system, and lower fuel bills.

  • **PHFHE products designer, installers and contractors** benefit as the costs and disruption associated with installing and commissioning the product to be significantly lower than what is currently attainable. This, combined with the proposed product functionality and flexibility, will increase the quality of service they are able to offer.
Additional references


