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Review

A review on polymer heat exchangers for HVAC&R applications

C. T'Joen[a,*], Y. Park[b], Q. Wang[c], A. Sommers[d], X. Han[c], A. Jacobi[b]

[a]Department of Flow, Heat and Combustion Mechanics, Ghent University—UGent, Sint-Pietersnieuwstraat 41, 9000 Gent, Belgium
[b]Department of Mechanical Science and Engineering, University of Illinois, 1206 West Green Street, Urbana, IL 61801, USA
[c]Institute of Refrigeration and Cryogenics, College of Mechanical and Energy Engineering, Zhejiang University, No. 38 Zheda Road, Hangzhou 310027, PR China
[d]Department of Mechanical & Manufacturing Engineering, Miami University, 650 East High Street, Oxford, OH 45056, USA

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ABSTRACT

Because of their low thermal conductivity, polymers are not commonly considered as a material to construct heat exchangers, except for specific applications, e.g. heat recovery from solvent laden streams, where exotic alloys are required to prevent corrosion. In this review the material properties of polymers are examined, as well as the current state of the art of polymer matrix composites. It is shown that these materials do hold promise for use in the construction of heat exchangers in HVAC&R applications, but that a considerable amount of research is still required into material properties and life-time behavior. A successful application of polymers or polymer matrix composites is based on careful material selection and modification of the design to fully exploit the material properties, as is demonstrated through a series of examples.

Echangeurs de chaleur en polymère pour les applications dans le chauffage, la ventilation, le conditionnement d'air et le froid : état de l'art

Mots clés : Échangeur de chaleur ; Conditionnement d'air ; Froid ; Enquête ; Matériau ; Polymère ; Additif ; Exemple ; Technologie

* *Corresponding author*. Tel.: +32 9 264 3355; fax: +32 9 254 3575.
E-mail address: Christophe.tjoen@ugent.be (C. T'Joen).
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1. Introduction

In air-conditioning, refrigeration, and energy-recovery applications, heat exchangers are very important to the overall efficiency, cost, and size of the system. Currently, these applications rely heavily on fin-and-tube or plate-fin heat exchanger designs, often constructed using copper, aluminum, or steel. A large amount of technical literature can be found to enhance the heat transfer of these conventional designs. However, the operating limitations of metallic heat exchangers in some applications have created the need to develop alternative designs using other materials. One of these materials is polymers. Much of the initial interest in the development of polymer heat exchangers was stimulated by their ability to handle liquids and gases (i.e. single and two-phase duties), their resistance to fouling and corrosion, and their possible use in both humidification and dehumidification systems. Perhaps most importantly, the use of polymers offers substantial weight, volume, space, and cost savings which can provide a competitive edge over heat exchangers manufactured from more exotic metallic alloys. In this review, a survey of the literature is presented describing the current state of the art on the use of polymers and polymer matrix composites (PMCs). To explore the potential of these materials, the property data are first presented and compared to the conventional materials.

2. Material properties of polymers and polymer matrix composites (PMCs)

2.1. Monolithic polymers

Polymers are large organic molecules consisting of a series of repeating units, called *monomers*, connected to each other. A polymer is primarily made out of hydrogen and carbon atoms, arranged in long chains. Naturally occurring polymers include wood, rubber, and cotton; however, a vast number of synthetic polymers also exist. These can be categorized in several different ways. One classic distinction considers the behavior of the polymer when it is heated and subsequently cooled down. *Thermoplastics* are polymers that soften when heated and become firm again when cooled. Heating and cooling may be repeated. *Thermosets* are plastics that soften when heated and can be molded, but harden permanently. They will decompose when reheated.

When considering new heat exchanger designs, both the thermal and mechanical properties are important. Standards and codes (ASTM, ASHRAE, ARI, etc.) impose minimal mechanical requirements for materials used in HVAC&R applications such as creep behavior over time to ensure a minimal life expectancy, e.g. at least 10 years (Raman et al., 2000). For many of these materials, this data are not readily available, indicating a need for further research. The most important property data include the thermal conductivity, specific heat capacity, maximum operating temperature (thermoplastics soften on heating), coefficient of thermal expansion, ultimate tensile strength, tensile modulus, and density. A brief list of some of the commonly cited polymers and their material properties are presented in Tables 1 and 2. The data were compiled using both an online database (Matweb©, http://www.matweb.com) and technical publications. In the following paragraphs, brief material descriptions are presented taken from technical papers (Reay, 1989; Deronzier and Bertolini, 1997; Wharry, 2002; Zaheed and Jachuck, 2004).

Fluoropolymers are corrosion resistant to most chemicals due to their chemical structure, as discussed by Wharry (2002). The upper temperature operating limits of the polyvinylidene difluoride (PVDF) and ethylene tetrafluorethylene (ETFE) are severely restricted. This is critical in heating applications where thermal margins of safety are important. PVDF swells in ketones, dissolves in polar solvents, and is not generally recommended for applications where it is in direct contact with bases. It is suitable, however, for heat recovery processes involving acids, processes aimed at reducing pollution emissions, and flue gas cleaning purposes. Its service temperature ranges from −1.6 to 154 °C. Teflon (PTFE) is chemically resistant to everything except molten alkali metals and fluorine. Teflon can withstand temperatures up to 204 °C. It is widely used in bromine recovery systems, metal pickling, plating solutions, and deionized water heating. Teflon is also well known for its non-stick properties, as in non-sticking cooking pans.

Liquid crystal polymers (LCPs) combine the material properties of both polymers and liquid crystals. Reay (1989) believed that these materials might be useful at temperatures in excess of 300 °C due to the self-reinforcing characteristics and the good creep resistance. Deronzier and Bertolini (1997) presented pure LCP property data showing a good chemical resistance to organic solvents, acids and bases, very high tensile strength and modulus, and a very low coefficient of thermal expansion-characteristics that are attractive for heat exchanger manufacturing. By using fillers (e.g. glass fibers and silica powder), the mechanical properties can be further enhanced.

Polypropylene (PP) is non-toxic, non-staining, and exhibits excellent corrosion resistance. It has a significant application in mechanical vapor compression desalination units.

Table 1 – List of common polymers: thermoplastics and thermosets.

Thermoplastics	Thermosets
Fluoroplastics (PTFE, ETFE etc.)	Epoxy
Liquid crystal polymer (LCP)	Phenolic resins
Polyamide (PA or nylon)	Polyester resins
Polyethylene terephthalate (PET)	
Polycarbonate (PC)	
Low density polyethylene (LDPE)	
Polyetheretherketone (PEEK)	
Polypropylene (PP)	
Polystyrene (PS)	
Polysulfone (PSU)	
Polyvinyl chloride (PVC)	
Polyvinylidene difluoride (PVDF)	
Polyphenylsulfone (PPSU)	
Ionomer	