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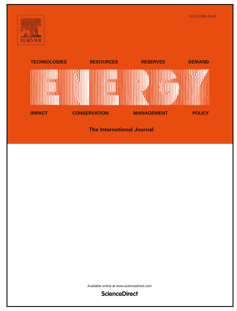

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Theoretical Analysis and Experimental Investigation of Material Compatibility between Refrigerants and Polymers

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Abstract

A new generation of refrigerants, the hydrofluoroolefines, has been introduced within the last years. These fluids have a significantly smaller Global Warming Potential compared to the state-of-the-art fluids, which are within the class of hydrofluorocarbons. The hydrofluoroolefines are unsaturated molecules consisting of double-bonded carbon atoms. Especially, compared to hydrofluorocarbons, which are saturated molecules, the interaction with polymers might differ. Therefore, this study investigates the compatibility between polymers and refrigerants, which are commonly used as working fluids in Organic Rankine Cycles or refrigeration units. The compatibility is evaluated due to a theoretical analysis of the relevant mechanisms of the fluid-polymer interaction and an experimental study. The investigated refrigerants are two state-of-the-art fluids, namely R245fa and R134a, as well as three next-generation refrigerants R1233zd-E, R1234yf and R1234ze-E. In addition, two blends, namely R450A and R513A, as well as a lubricant polyolester are investigated. The polymers comprise six elastomers and two thermoplastics, more specifically, two different compositions of ethylene-propylene-diene rubber, two compositions of fluororubber, chlorobutadiene rubber, nitrile-butadiene rubber, polytetrafluoroethylene and polypropylene. The material compatibility is evaluated by changes in volume, weight, Shore hardness as well as in small load hardness. Summing up, 64 different fluid-polymer combinations are tested at two different temperature levels.

Keywords:
Material compatibility, Polymer, Refrigerant, Swelling test, Organic Rankine Cycle, ORC, Low GWP working fluid, Refrigeration, Chemical stability

1. Introduction

The rapid technical and economic development in many countries, especially in emerging markets such as the Asia-Pacific region or Latin America and the increasing world population leads to a continuously growing energy demand. The primary energy consumption has increased by more than 50 % within the last 20 years, leading to a significant increase in greenhouse gas emissions of approximately 50 % within the same period [1]. Nevertheless, the goal of the Paris Agreement of the UN framework convention on climate change from 2015 is to limit the increase in the global average temperature to 2 K above preindustrial levels [2]. Therefore, considerable efforts to increase the energy efficiency on the demand side, to increase the share of renewable energy sources for power and heat production or to improve the use of waste or low-temperature heat sources are being made to reduce the global greenhouse gas emissions. In this context, refrigerants are of great importance due to their widespread use in industry, refrigeration and power generation. Within the last years, a new generation of refrigerants, the hydrofluoroolefines (HFO), has been introduced, that has a significantly smaller Global Warming Potential (GWP), compared to the state-of-the-art working fluids, which are within the class of hydrofluorocarbons (HFC). Especially due to legislative acts such as the F-Gas regulation [3] or the MAC-directive [4], the application of these working fluids is highly encouraged.

From a thermodynamic point of view, the HFO can be applied to existing and novel Organic Rankine Cycle (ORC) systems and refrigeration units [5–11]. However, the compatibility of the fluids with the construction materials within the system is often not investigated in depth. In this context, special focus should be put on polymers because they tend to swell when exposed to certain refrigerants [12]. Within ORC plants and refrigeration units, polymers are applied i.e. as sealing materials or as component materials in components. Some prominent examples are the rotary shaft seal of open-drive compressors, expanders or pumps as well as the diaphragm in positive displacement pumps, which are often applied to experimental ORC test rigs [13]. The broad range of applications leads to different requirements on the materials. For example, moderate swelling of a static seal such as an O-ring is acceptable, while a

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