DUAL SOURCE HYBRID AND REVERSIBLE HEAT PUMP WITH R32

D. DEL COL
UNIVERSITÀ DI PADOVA

DEVELOPMENT OF A DUAL SOURCE HYBRID AND REVERSIBLE HEAT PUMP WORKING WITH R32

Davide Del Col[1], Marco Azzolin[1], Stefano Bortolin[1], Giulio Busato[2], Alessandro Zerbetto[2]
[1] Dipartimento di Ingegneria Industriale - University of Padova, Via Venezia, 1 – I 35131 Padova, Italy
[2] Hiref Spa, Viale Spagna, 31/33, 35020 Tribano (Padova), Italy

Abstract

The development of new HVAC technologies with low environmental impact at the minimum possible cost is an open task in the refrigeration and air conditioning industry. In the recent years, international agreements and regulations urge for a reduction of the HFCs production and use while achieving high seasonal performance remains a crucial aspect. This work presents the development of an innovative dual source (air and ground) heat pump: it can operate in heating and cooling modes, it has variable speed drives, it is designed and realized in the framework of the European Project GEOTeCH. This unit has been developed with the purpose of using both the air source and the ground source, with the goal of partial saving of drilling investment costs without any penalization in the seasonal performance. On the air side, this prototype has been tested both with a traditional finned coil and an innovative microchannel heat exchanger. To satisfy the new stringent requirements of low global warming impact, the present unit adopts R32 as the working fluid. After presenting the unit, some results from tests in cooling mode using air as external sink are here presented, comparing the performance with the finned coil and that one with the microchannel heat exchanger.

Keywords: R32, dual source, microchannel heat exchanger

Introduction

Ground source heat pumps using shallow (low temperature) geothermal energy can provide high values of seasonal performance factor and they can play an important role in the reduction of indirect carbon dioxide emission. Instead, direct carbon dioxide emissions are the result of the release of HFC refrigerants to the atmosphere and are tackled by new regulations. In Europe, the Regulation (EU) No 517/2014 on fluorinated greenhouse gases (F-gases) foresees the introduction of a HFCs phase-down in the next years, and in October 2016 during the 28th Meeting of the Parties (MOP) in Kigali (Rwanda), 197 countries adopted an amendment to the Montreal Protocol to phase down HFCs. In such a context, a reversible dual source heat pump working with R32 (GWP=675) is here presented. The refrigerant R32 has been studied at University of Padova since the very beginning of this century (Cavallini et al., 2001). The present heat pump has been designed in the framework of the European Project GEOTeCH, which is financed through the Horizon 2020 EC program: it intends to develop new drilling and ground heat exchanger technologies and to realize dual source heat pumps with the aim to significantly contribute to EU energy and environmental policies. Reversible dual source heat pumps give the possibility to exchange heat with air or with water. In the literature, few works can be found on dual source heat pumps (Urchueguía *et al*., 2008; Pardo *et al*. 2010) while further research is needed to improve the control strategy and to investigate the seasonal performance.

Dual Source Heat Pump Prototype

The layout of the reversible dual source heat pump developed and tested in the present project is reported in Fig. 1 (only for the cooling mode). The system is composed of a scroll compressor with variable speed drive, three brazed plate heat exchangers (BPHEs) and a refrigerant-to-air heat exchanger. The three BPHEs are dedicated to: 1. exchange heat with the brine of the ground circuit, 2. production of the water for the heating/cooling system of the building and 3. production of hot domestic water. Two different types of air-to-refrigerant heat exchangers have been installed in the machine: a traditional finned coil heat exchanger and an innovative microchannel heat exchanger which can operate both as the condenser and as the evaporator. The technology of microchannel heat exchangers is used to obtain good performance with a significant reduction of refrigerant charge inside the machine since it is a desirable feature using flammable or mildly flammable refrigerants (R32 is in the A2L class as per AHSRAE designation). This system can run in four different main modes: heating mode (condensation at the BPHE), cooling mode (evaporation at the BPHE); domestic hot water production; full recovery with hot water production and cooling supplying at the same time. Considering, for example, the case when the dual source heat pump is working in cooling mode (Fig. 1), the fluid after being compressed is condensed on the ground side BPHE (using water as secondary fluid and the ground as thermal source) or in the microchannel heat exchanger (using air as secondary fluid) and then, after the expansion valve, it evaporates in the BPHE to the user. In Fig. 2 a picture of the reversible dual source heat pump during the test campaign is reported.

Experimental Results

Experimental tests have been performed at the R&D laboratory of Hiref SpA. Tests have been run in cooling mode with air temperature of 30°C and producing cold water in the temperature range 12-7°C. The subcooling degree at the condenser and the superheating degree at the evaporator have been maintained constant and equal respectively to 1 K and 6 K. During the tests, the compressor speed has been varied to investigate the performance at different thermal loads. Both the finned coil and the minichannel heat exchangers have been tested, at the same working conditions, to compare their performance. As shown in Figs. 3 and 4, during tests, the saturation temperature at the evaporator outlet decreases when the compressor speed is increased and no difference is found between the two configurations since the BPHE installed in the system is the same. Considering the condenser side, the inlet condensation temperature increases when the compressor speed is increased and it is lower for the case of the microchannel heat exchanger. At the same working conditions, the microchannel heat exchanger provides a better performance than the traditional finned coil heat exchanger, leading to an increase of the COP at 80 Hz (calculated including auxiliaries consumption) of about 15%.

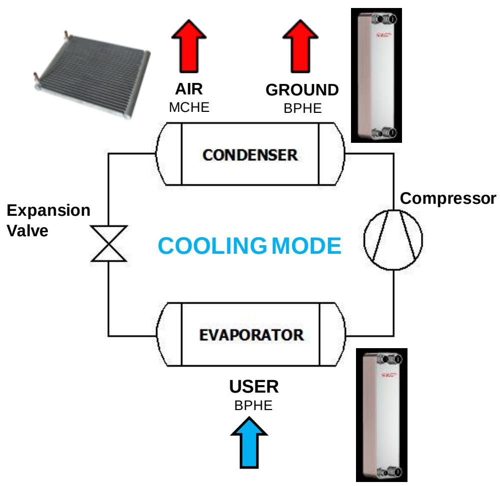

Figure 1: Layout of the reversible dual source heat pump when operating in cooling mode.

Figure 2: Picture of the reversible dual source heat pump during tests performed at Hiref.

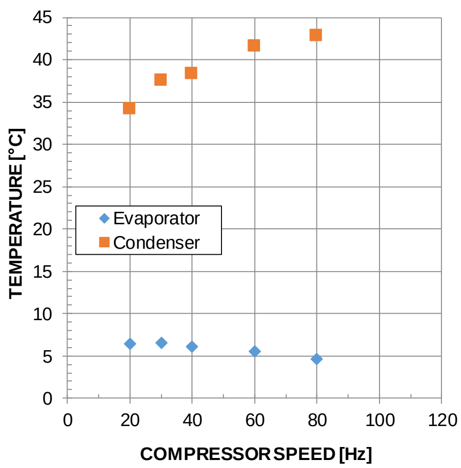

Fig. 3. Evaporation and condensation temperatures during tests performed in cooling mode at varying compressor speed. A finned coil heat exchanger is used as condenser.

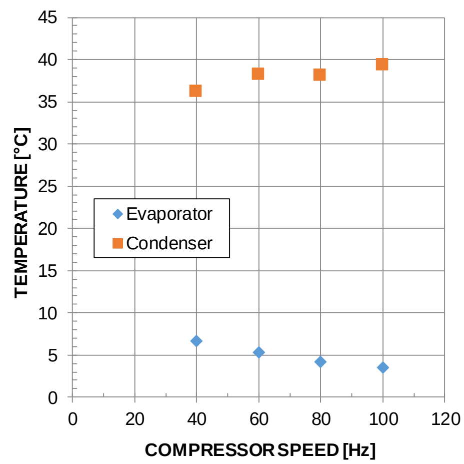

Fig. 4. Evaporation and condensation temperatures during tests in cooling mode when varying compressor speed. A microchannel heat exchanger is used as condenser.

Condenser Charge Evaluation

A model of the reversible dual-source heat pump has been developed at the University of Padova and it has been used to estimate the specific refrigerant charge [g kW^{-1}] trapped in the finned coil and in the microchannel heat exchanger when they work as condenser. In fact, during operation, most of the refrigerant charge lies inside the condenser. In the model of the heat pump, the heat exchangers are discretized into several elements and in each element proper correlations have been applied to evaluate the local heat transfer coefficient and the pressure drop. The local void fraction is calculated with the Rouhani (1978) correlation. A case has been studied considering air temperature of 35°C, air velocity of 1.6 m s^{-1}, heat flow rate at the condenser of 11 kW and subcooling of 1 K. Results predict a reduction of the refrigerant charge in the condenser of about 40% with respect to the finned tube heat exchanger.

Summary

An innovative dual source heat pump working with refrigerant R32 has been presented. Depending on the control strategy, both ground and air can be used as sources/sinks, allowing a reduced size of the borehole heat exchangers. The machine can also operate in full recovery mode with simultaneous production of cooling and hot water. A conventional finned coil heat exchanger and a microchannel heat exchanger have been installed in the heat pump. When working in cooling mode, a better performance of the heat pump and a reduction of the refrigerant charge trapped in the condenser have been achieved with the microchannel heat exchanger.

Acknowledgement

The authors acknowledge the support of the European project GEOTeCH (www.geotech-project.eu/) which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 656889.

References

Cavallini A., Censi G., Del Col D., Doretti L., Longo G.A., Rossetto L., 2001, Experimental investigation on condensation heat transfer and pressure drop of new HFC refrigerants (R134a, R125, R32, R410A, R236ea) in a horizontal smooth tube, Int. Journal of Refrigeration, 24, 73-87.

Pardo, N., Montero, A., Martos, J., Urchueguia, J.F., 2010. Optimization of hybrid - ground coupled and air source - heat pump systems in combination with thermal storage, Appl. Therm. Eng., 30, pp. 1073-1077.

Rouhani, S.Z., 1978. Chapter 12: steady-state void fraction and pressure drop in water-cooled reactors. In: Ginoux, J.J. (Ed.), Two-Phase Flows and Heat Transfer with Application to Nuclear Reactor Design Problems, Washington, pp. 241-327.

Urchueguia, J.F., Zacares, M., Corberan, J.M., Montero, A., Martos, J., Witte, H., 2008. Comparison between the energy performance of a ground coupled water to water heat pump system and an air to water heat pump system for heating and cooling in typical conditions of the European Mediterranean coast, Energy Conversion and Management, 49, pp. 2917-2923.