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Preface

The necessity for energy efficiency improvement and development of new materials for energy storage and energy generation puts forward a great challenge for the researchers working in the field of energy engineering. Thermal analysis of energy systems plays a major role in optimizing the configuration and make system technically, economically and environmentally sustainable option in the market. The research progress around the world needs to be explored. Hope, the outcome of this conference on Thermal Analysis and Energy Systems (ICTAES-2018) provides a forum to disseminate the research ideas and technologies for the sustainable development. This proceeding contains sixty seven technical papers presented by various research scholars from India and abroad in the field of Thermal Applications of Solar Energy, bio-fuels, thermal and fluid flow analysis, Refrigeration and Air conditioning systems, nano-fluids and materials etc. About thirty selected papers from this conference will be published in Journal of Thermal Analysis and Calorimetry as a special issue. We would like to thank **Dr. Imre Miklos Szilagyi** *the Editor in Chief, Journal of Thermal Analysis and Calorimetry for accepting our request to publish the selected papers in the Journal as a special issue.*

We would like to thank the management of Hindusthan College of Engineering and Technology, Coimbatore for providing an opportunity to organize this event. We would like to thank all the authors for their valuable research contributions to ICTAES2018. Besides, we also express our gratitude to our Principal, Heads of Departments and faculty members for their kind support during every stages of the conference. Further, the work supports provided by all the supporting staff members are recognized. Moreover, the technical experts from Indian and foreign universities are acknowledged. The supports provided by the student voluntaries are highly appreciated.

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About the Conference

The over whelming necessity for energy efficiency improvement, development of newer materials for energy storage and energy generation lay forward a great challenge for the researchers working in the field of energy engineering. Thermal analysis of energy systems is inevitable in optimizing the system configuration and makes it technically, economically and environmentally sustainable in the market. The research progress in the conference theme needs to be explored around the world. The conference on **Thermal Analysis of Energy System**s provides a forum to disseminate the research ideas and technologies for sustainable development. The scope of the conference may include following major topics (but not limited to):

- Thermal Analysis of Energy Conversion Systems
- Thermal Energy Storage
- Micro and Nano-Scale Thermo-Fluids
- Experimental Techniques for Thermal Analysis
- Instrumentation and Measurements in Thermal Analysis
- Thermal Analysis in Heat Transfer Equipment
- Thermal Analysis of Refrigeration and Air-Conditioning Systems
- Novel Photovoltaic Materials and Hybrid Systems
- Thermal Characterization of Energy Materials
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CONTENTS

ANALYSIS OF REFRIGERATION, AIR CONDITIONING AND HEAT PUMP SYSTEMS

Numerical simulation of R290 as possible alternative to R22 in air source heat pumps

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R22 is the widely accepted working fluid in heat pump applications due to its good thermodynamic and thermo-physical properties. However, due to its poor environmental properties, it should be phased out soon. Hence, an energy efficient and environment friendly alternative is proposed in this work. The numerical simulation of air source heat pump has been carried out with R290 as possible alternative to R22. The properties of R290 are compared against standard working fluid R22. The standard energy performance parameters such as, condenser heating capacity, compressor power consumption and coefficient of performance were predicted for the meteorological conditions of Almaty, Kazakhstan. The ambient temperatures were simulated between -20º C and 30º C. The validated simulation model is used for predicting the performance of R290. The simulation results showed that R290 is an energy efficient and environment friendly alternative to phase out R22 in solar assisted heat pumps.

Keywords: Refrigerant; Heat pumps; Cold climates; Kazakhstan

1. Introduction

Heat pump is an energy efficient device due to its capability to deliver more heat output than the work input [1]. The performance of the heat pump systems are improved using renewable energy sources such as, ambient, solar, geothermal and its hybrid forms [2]. However, the use of geothermal energy in heat pumps is more expensive due to its initial investments [3]. Hence, the fast development on solar assisted heat pumps was progressed during last two decades for space heating, water heating, drying and desalination applications [4-6]. Most of the investigations reported on heat pumps are using halogenated refrigerants such as, R22 and R134a due to its good thermodynamic and thermo-physical properties [7]. However, due to its poor environmental properties, R22 and R134a should be phase out soon [8]. Earlier investigations reported that hydroflurocarbons (HFCs) with low global warming, hydrocarbons (HC), HFC/HC mixtures and hydrofluroolefins (HFOs) are good environment friendly substitutes for refrigeration, air conditioning and heat pump applications [9]. At present, the HFC mixtures such, R407C and R410A are the potential substitutes to R22 in heat pump systems [10]. However, such refrigerant mixtures are not possible to use it as drop in substitutes in R22 systems due to its immiscible nature with mineral oil [11]. Hence, stringent flushing of lubricant is essential for retrofitting with HFC refrigerants [12]. The other drawback is mismatch in vapour pressure, which requires modifications in the condenser and evaporators [13]. To overcome these issues, the mixtures composed of HFCs and HCs are preferred to make it miscible with conventional lubricant [14]. The mixture composed of HFC and HC refrigerants behaves like a zeotropic. However, the zeotropic mixtures have composition shift under leakage conditions and non-linear behavior in condensers and evaporators. To overcome these drawbacks, the possibility of using R290 as a viable alternative is assessed in this work. The performance of the ASHP is evaluated for wide range of evaporator temperatures between -30º C and 20º C with condensing temperatures between 35º C and 55º C. The energy performance parameters such as compressor power consumption, condenser heating capacity and coefficient of performance are assessed in this work.

2. Description of air source heat pump cycle

The detailed configuration of an air source heat pump and pressure-enthalpy diagram are shown in the Figure 1-3. The ASHP consists of a R22 based hermetically sealed reciprocating compressor, a compact type heat exchanger – water cooled condenser, a liquid receiver, a sealed type refrigerant drier, a sight glass, a thermostatic expansion device, ambient source evaporator. Experiments are conducted in Almaty (latitude of 43.25 ^{o}N, longitude of 76.91 ^{o}E). During the experiment the following parameters will be taken into account: ambient temperature and wind velocity. Kazakhstan belongs to the continental climatic regions, characterized by cold winters and hot summers. Kazakhstan is one of the leading countries in the Central Asian region with the average annual solar radiation potential. Annual duration of sunshine is 2200-3000 hours, and the estimated capacity of 1300-1700 kW per 1 m^2 per year, which exceeds that of Europe.

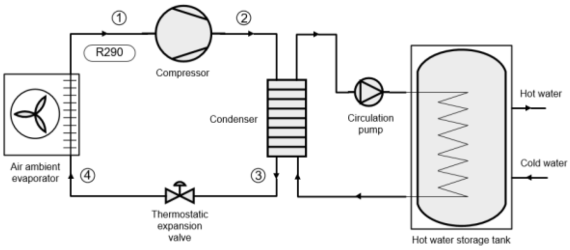

Fig. 1. Schematic diagram of air source heat pump

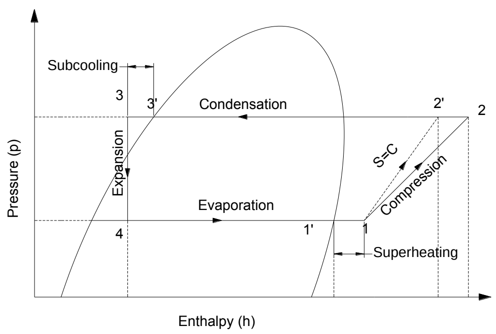

Fig. 2. Pressure enthalpy representation of air source heat pump

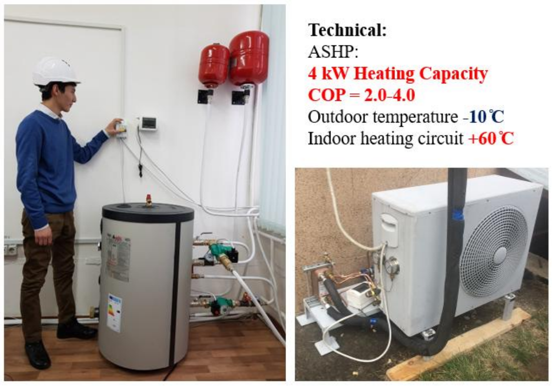

Fig. 3. Experimental setup of air source heat pump

3. Mathematical model

R22 and R290 refrigerants undergo a change of the three phases: superheat, saturated and sub-cooling in their respectively exothermic procedure. Regarding to the cold climate conditions -20º C and 30º C both refrigerants has a small enough boiling points (ºC). Hence, for cold climatic conditions condenser and evaporator operating mode will change respectively. In this paper assessment of air source heat pump operation with two different refrigerants R22 and R290 in the temperature range -20º C and 30º C is conducted.

Figure 2 shows the pressure-enthalpy diagram of a ASHP cycle [15]. The processes 1-2, 2-3, 3-4 and 4-1 represent compression, condensation, expansion and evaporation, respectively. The points 1, 2, 3 and 4 represent the thermodynamic state of the refrigerant at the compressor inlet (superheated vapor at the evaporator pressure), compressor outlet (superheated vapor at the condenser pressure), condenser outlet (subcooled liquid at the condenser pressure) and the two-phase fluid at the evaporator pressure.

Mathematical model (1)-(6) to predict the thermal performance of ASHP for cold climate conditions based on the following assumptions [16-17]:

1) steady state processes within the system;
2) no pressure losses in the suction and delivery valves (pressure changes in compressor, expansion valve and heat exchangers (both condenser and solar collector));
3) isentropic efficiency and volumetric efficiency of the compressor are assumed as 85%;
4) 4 ^{o}C sub cooling in the condenser and 6 ^{o}C super heating in the solar collector;

According to these in the following relations are formulated. Heating capacity has been estimated by the formula:

$$Q_{hc} = m_r \cdot (h_3 - h_2) \qquad (1)$$

where h_2 and h_3 inlet and outlet refrigerant enthalpy of condenser, respectively. Mass flow rate of the refrigerant:

$$m_r = \frac{\eta_\upsilon V_h r}{60 \cdot \upsilon_1} \qquad (2)$$

where η_υ - is the volumetric efficiency ($\eta_\upsilon = 0.85$), V_h - theoretical displacement of ($V_h = 18.27$ cm^3/rev), r - rotational speed of compressor, υ_1 - specific volume at the compressor suction.

Power consumption has been found by the following relation:

$$Q_{pc} = \frac{m_r \cdot (h_2 - h_1)}{\eta_\upsilon^{\ 2}} \qquad (3)$$

where h_1 and h_2 inlet and outlet refrigerant enthalpy of compressor, respectively.

Accordingly, coefficient of performance (COP) has been calculated by

$$COP = \frac{Q_{hc}}{Q_{pc}} \qquad (4)$$

Heat gain by air ambient evaporator is calculated by

$$Q_{amb} = m_r \cdot (h_1 - h_4) \qquad (5)$$

where h_4 and h_1 inlet and outlet refrigerant enthalpy of air ambient evaporator, respectively.

In Table 1 the two refrigerant properties are performed.

Table1. Refrigerant properties

Refrigerant	R22	R290
Molecular weight (g/mol)	86.46	44.1
Critical temperature (°C)	96.14	96.7
Critical pressure (kPa)	4990	4248
Critical density (kg/m^3)	562.0	367.2
Boiling point (°C)	-40.9	-42.1
Flammability	No	Yes(2.2-9.6%)
Virulence	No	No
ODP	0.05	0
GWP	1700	20

4. Results and discussion

The standard energy performance parameters such as, condenser heating capacity, compressor power consumption and coefficient of performance were predicted for the meteorological conditions of Almaty, Kazakhstan. Figures 4-6 shows heating capacities of two kinds of refrigerants depending on environment temperature variation from -20º C to 30º C.

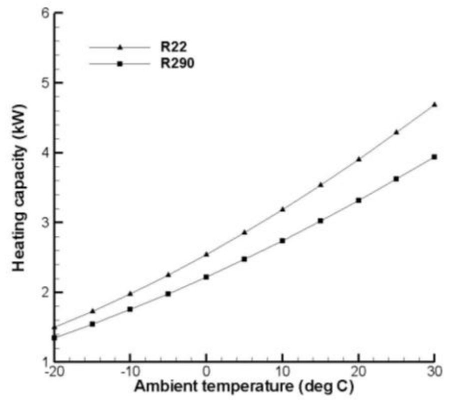

Fig. 4. Heating capacity vers. ambient temperature

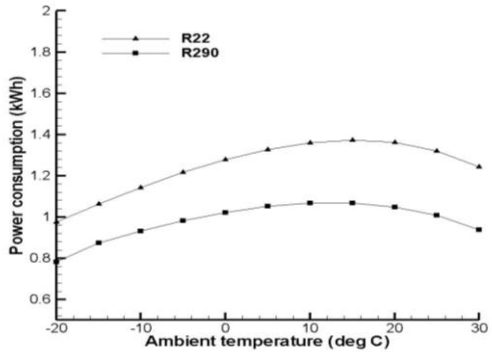

Fig. 5. Power consumption vers. ambient temperature

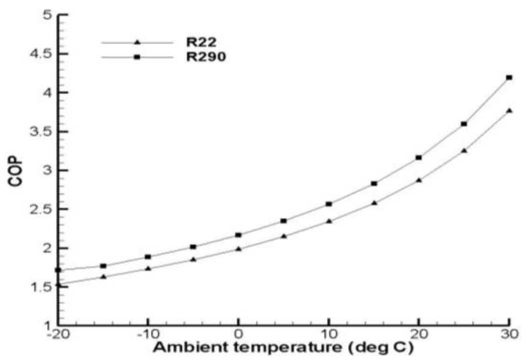

Fig. 6. COP vers. ambient temperature

According to Figures 4-5 heating capacity and power consumption for R290 is lower than that of R22 at all corresponding outdoor ambient temperatures. As it can be seen from Figure 5 required power consumption for compressor during minus ambient temperature is more for both refrigerants. However, coefficient of performance of R290 is higher than that of R22 (Figure 6). Also Figure 6 shows that in cold ambient temperatures COP is growing slowly. At the example ambient temperature of -20° C, the heating capacity of R22 was 7% higher than that of R290. Accordingly the power consumption of R22 was also 18.5% higher than that of R290. The results show that R290 exhibits better heating performance, especially in low temperature conditions.

5. Conclusion

Numerical simulation of R290 as possible alternative to R22 in air source heat pump under meteorological conditions of Almaty, Kazakhstan has been conducted. Calculated results show that R290 exhibits better coefficient of performance comparing to R22, particularly, for cold climate conditions. In terms of the environmental impact of R290 is better than R22. ODP of R290 is 0 and GWP 20, whereas ODP of R22 is 0.05 and GWP 1700.

6. Acknowledgements

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