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TRANSIENT MODELING AND SIMULATION OF A VAPOR COMPRESSION SYSTEM FOR COMPARISON OF REFRIGERANTS FLUIDS

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Abstract. *This work develops a simplified transient mathematical model, which applies the mass and energy conservation principles to the components of compression vapor system. The developed model was used to compare the performance of the system when the R12 was substituted by R134a, Ammonia and R600a. A computer application was then developed to predict the response of principles components, i.e., condenser, evaporator, compressor and expansion valve. The model assigns thermodynamic control volumes to each component, therefore uniform properties are assumed within them, which yields a thirteen ordinary differential equations system, that are integrated in time using the adaptive time step Runge-Kutta Fehlberg fourth-fifth order method. The simulation of the system started with the temperature on equilibrium of 30 ° C and to evaluate the efficiency of the system with each refrigerants was used the COP and compressor power. The R134a was the best fluid for the of vapor compression refrigeration systems simulated in this work*

Keywords: *Refrigerating system; Refrigerant; R12; Efficiency.*

1. INTRODUCTION (TIMES NEW ROMAN, BOLD, SIZE 10)

Cooling in industrial processes, air-conditioning of buildings and refrigeration of perishable products are common practices throughout the world (Dahmani ,*et al.*, 2011). For these refrigeration and air-conditioning systems, the vapor compression systems are the most used (Karamangil ,*et al.*, 2010).

In the 30s, the industry of refrigeration developed the "freons" and it thought to have discovered the ideal working fluids for vapor compression systems. It was the beginning of an era dominated by the type chlorofluorocarbon refrigerants (CFCs), which stood out the R11 and R12. But, in 1974, Molina and Rowland discovered that the element chloro of the CFCs could destroy the ozone layer terrestrial. Then, the Montreal Protocol, established in 1987, has stipulated that the CFCs would be banned until 2010, in developing countries such as Brazil (Arini, 2008). In the 80s, the hydrochlorofluorocarbons (HCFCs) emerged with substitutes for CFCs. Between these substitutes' fluids, the most famous was the R-22 (Arini, 2008, McCulloch, 2006). However, the HCFCs are also greenhouse gases, then their production and consumption are controlled under the Montreal Protocol and will be reduced progressively towards phase out in 2040 (McCulloch, 2006).

The problems of the depletion of ozone layer and increase in global warming caused scientists to investigate more environmentally friendly refrigerants than HFC refrigerants for the protection of the environment such as hydrocarbon (HC) refrigerants of propane, isobutene, n-butane, or hydrocarbon mixtures as working fluids in refrigeration and air-conditioning systems (Dalkilic, 2010). Recently, the ozone depleting potential (ODP) and global warming potential (GWP) have become the most important criteria in the development of new refrigerants (Dalkilic and Wongwises, 2010). Marques ,*et al.* (2009) showed the Table 1 that it exhibition the environmental impact of some refrigerants.

Table 1. The environmental impact of some refrigerants

REFRIGERANTE		ODP	GWP	lifetime in atmosphere (years)
R-12	Diclorodifluormetano(CFC)	0,820	10600	100
R-22	Clorodifluormetano(HCFC)	0,034	1900	11,8
R-134a	1,1,1,2Tetrafluoretano (HFC)	0	1600	13,6
R-600a	Isobutano	0	< 3	< 1
R-717	Ammonia	0	0	*

* uninformed

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Many investigations have been conducted in the research into substitutes for CFC12 and CFC22. This work develops a simplified transient mathematical model of vapor compression refrigeration system and the computational simulation of model was used to compare the process of substituting of R12 by other refrigerants.

2. MATHEMATICAL MODEL

Simplified transient mathematical model applied the mass and energy conservation principles to the components of compression vapor system. A computer application was then developed to predict the response of principles components, i.e., condenser, evaporator, compressor and expansion valve. The model assigns thermodynamic control volumes to each component, therefore uniform properties are assumed within them, which yields a thirteen ordinary differential equations system, that are integrated in time using the adaptive time step Runge-Kutta Fehlberg fourth-fifth order method. The first simulation of the system was used the thermodynamic properties of R12. With the same mathematical model of compression vapor system was performed new simulations, in which the thermodynamic properties of R12 were replaced by the thermodynamic properties of R134a, Ammonia and R600a.

All simulation of the system started with the temperature on equilibrium of 30 ° C and to evaluate the efficiency of the system with each refrigerants was used the COP (coefficient of performance) and compressor power (WCP)

3. RESULTS

Although not directly related to the efficiency, the first measure of performance of the refrigeration system was the temperature profile, during the simulation, for each refrigerant examined, as shown in Fig. 1. This analysis measured the temperature of the refrigerated chamber (Controlled ambient) and the temperature variation on both sides of the compressor and the evaporator, that is, on the air side and the refrigerant side of these components.

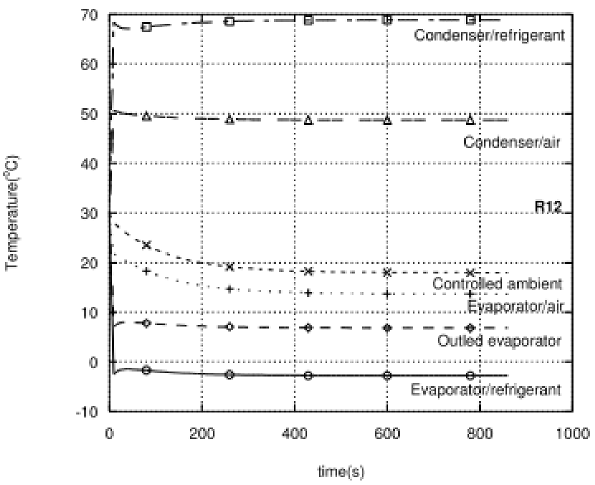

Figure 1a. Fluid R12

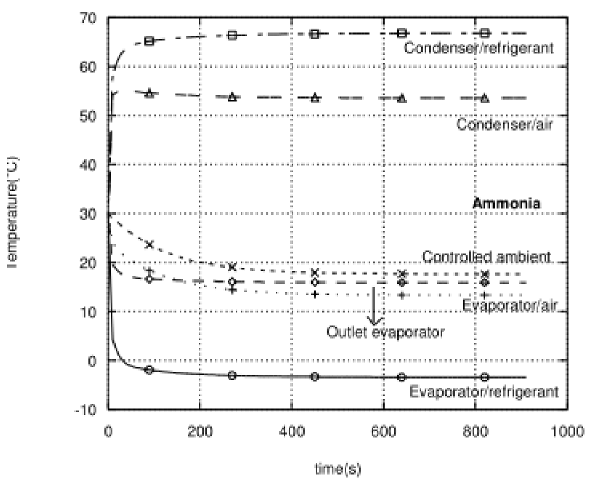

Figure 1b. Fluid Ammonia

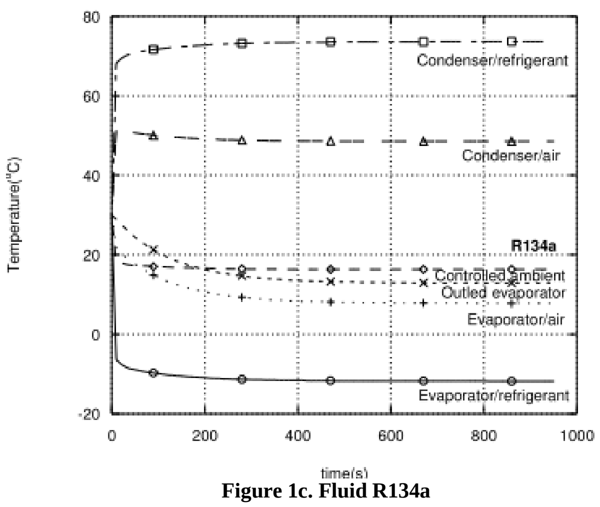

Figure 1c. Fluid R134a

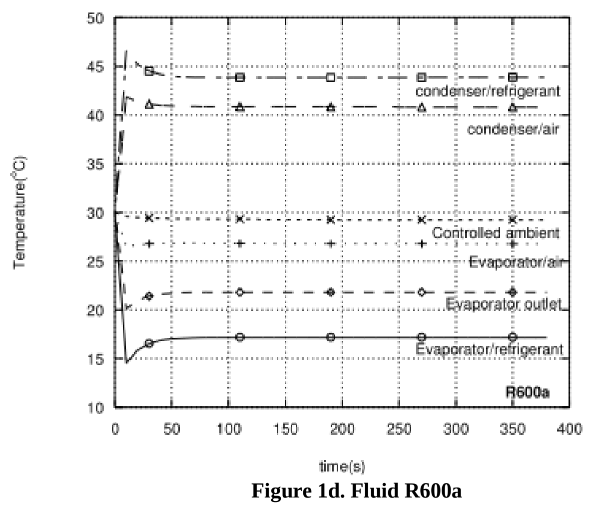

Figure 1d. Fluid R600a

Figure 1. Temperature profile of the components of the refrigeration system, during the simulation, for each refrigerant examined.

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The Fig. 1a and the Fig. 1b show that in the systems with Fluid R12 and Ammonia the temperature of the refrigerated chamber (Controlled ambient) reduced 10 °C, after 3 minutes of simulation. These temperatures were kept below 20 ° C during the simulation. The graph of Fig. 1c, simulated system with R134a, it is observed that the curve of the temperature of the refrigerated chamber (Controlled ambient) has a higher decay rate curve of the Ammonia and R12, an 50% less time to reach 20 °C, thus showing a better efficiency of the refrigeration. The system R-600, Fig. 1d, showed the lowest performance in cooled chamber and the temperature was maintained near 30 °C throughout the simulation period.

To measure the efficiency of a refrigeration cycle vapor is used the coefficient of performance, COP, which is an important parameter in the analysis of cooling systems. It coefficient relates the desired effect of cooling the power consumed by evaluating the ability to remove heat cycle of the power consumed by the compressor (Medeiros; Barbosa, 2009). The COP in each instant of simulation was shown in Fig. 2. To draw this graph, we used data condensing pressure and evaporating fluid investigated

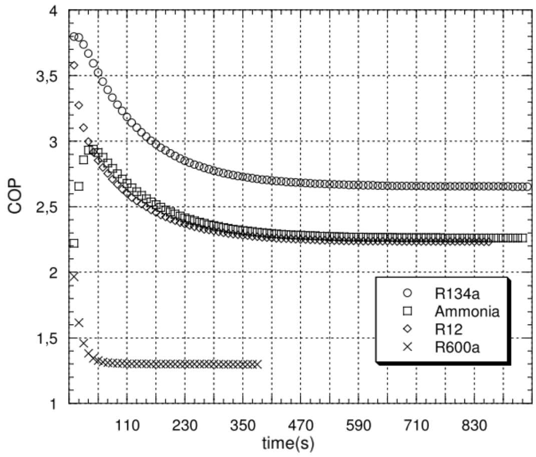

Figure 2. COP of each refrigeration system simulation with R12, R134a, Ammonia and R600a.

Evaluating the Fig.2, it is clear that the COP of the refrigeration system with R600a was 1.3 and this COP was the lowest value among all fluids analyzed, during the simulation. The COP was nearly invariable between the systems with Ammonia and R-12 and the simulation resulted in coefficient of performance with value 2.2. However the simulated system with R-134a showed the best value with COP about 3.2, showing that the system with this fluid have the better performance.

The compressor power (WCP) for the four simulations of the refrigeration system was showed on Fig. 3

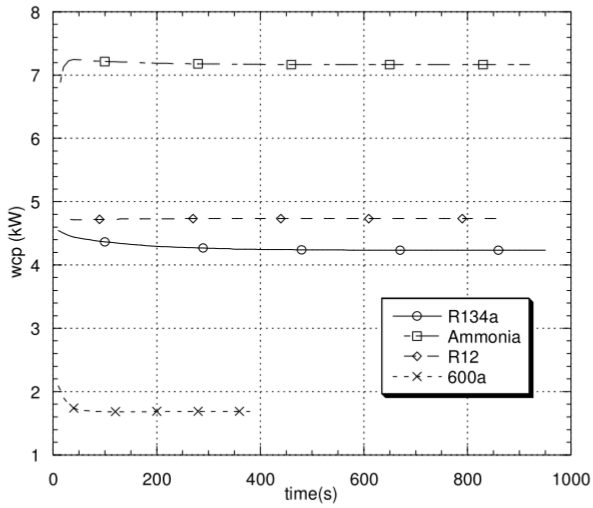

Figure 4 show that the simulated system with R600a has consumed the least amount of energy, because it required approximately 2.6 kW compressor power. However, the system simulated with R600a didn't reduce the temperature of the cooling chamber, as shown in Figure 1d. The systems with R12 and R134a have similar energy cost, because the compressor power was between 4 and 5 kW.

Among the refrigerants analyzed, the R134a was the best fluid for the of vapor compression refrigeration systems simulated in this work. This is because, the simulated system with R134a was cooled camera in the shortest time, presented the best COP and consume less energy than the systems with R12 and Ammonia. However, through this

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simulation, it is clear that the ideal refrigeration cycles should not be strictly applied in real systems refrigeration, because physical considerations, as expansion isenthalpic expansion valve and compressor isentropic compression, were considerate.

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