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ANALYSIS OF REFRIGERATION SYSTEM BEHAVIOR USING VARIABLE SPEED COMPRESSOR

Claudia Rosa do Espirito Santo Nobrega
Taynara Geysa Silva do Lago
State University of Campinas, Faculty of Mechanical Engineering, Rua Mendeleiev, 200, Cidade Universitária Zeferino Vaz, Barão Geraldo, Campinas, S. P. Brazil, Postal Code 13083-860
claudiarosa@fem.unicamp.br, taynaragls@fem.unicamp.br
Luiz Felipe Mendes de Moura
State University of Campinas, Faculty of Mechanical Engineering, Rua Mendeleiev, 200, Cidade Universitária Zeferino Vaz, Barão Geraldo, Campinas, S. P. Brazil, Postal Code 13083-860
felipe@fem.unicamp.br

Abstract. *This paper discusses the experimental study of the performance of an air conditioning system for the control of their thermodynamic parameters (physical). Such a system is, at its core, composed of a subsystem of vapor compression refrigeration, and a refrigeration secondary subsystem. In order to evaluate and analyze system behavior with use of variable speed compressor, having as parameter of analysis, coefficient of performance the system and power consumption required by the same for the use of fixed speed compressor and variable speed. The fixed speed compressor is designed to meet the maximum thermal load of the system, the compressor of variable rotation allows adjustment of the rotation from the fluctuation of the same, affording work without loss of coefficient of performance with thermal loads relatively low. The advantages and disadvantages of the variation of the increase / decrease in the rotation for the studied system will be presented at results obtained.*

Keywords: *Systems Compression Vapor, Variable Speed Compressor, Coefficient of performance, Power Consumption*

1. INTRODUCTION

The increased use of refrigeration in food preservation and thermal comfort has grown considerably in recent years, hence the demand for used electricity has increased, reaching representative values on the world stage. Given this reality, the need for reduction in electricity consumption has afforded the incentive to develop more efficient cooling systems in energy use and to provide better performance to systems, aiming at a reduction in energy loss.

The compressor is a part of great importance in the refrigeration system, it is responsible for about 80% of total power consumption, used in the refrigeration system. Studies in variable speed compressors have shown good results in reducing this power consumption, being a good alternative to energy attenuation required by cooling systems.

In the proposed study, the efficiency of a vapor compression refrigeration system is analyzed using a variable speed compressor while keeping evaporation temperature and varying the required thermal load. At the thermal load variations performed will be evaluated: the coefficient of performance, efficiency, degree of superheat, degree of subcooling, the compression power and the power consumed.

According to " Tassou and Qureshi (1994)" the most efficient way to control the refrigeration capacity is by varying the compressor speed, because the refrigeration capacity is adapted to the load. Thus, for conditions of low thermal load of the equipment decreases the compressor speed thus reducing energy and consumption losses." Tassou and Qureshi (1996)" concluded that the variation of compressor speed depends climate. Since, with reduction of the rotation, there is a reduction in friction loss in the compressor and a decrease in compression ratio, which means a decrease of the difference between the condensation temperature and the evaporation of system. The direct consequence of this is an increase in the coefficient of performance and a decreased power consumption of the compressor.

" Lida *et al.* (1982)"performed experimental trials in a refrigeration system with a nominal capacity of 3.0 kW. During the analysis, the compressor speed was varied between 25 Hz and 75 Hz. The results reported an increased energy efficiency of the system with the introduction of a variable speed compressor. In cyclical regimen, the power consumption of the variable speed compressor system was 20% to 26% lower than that obtained with the conventional compressor.

" Aprea and Mastrullo (2002)" has compared the energy performance of a refrigeration system, fitted with EEV and with TEV in permanent and transient conditions. It were considered two situations: departure equalized and non-equalized. The valves were mounted in parallel on the input of an evaporator with forced air convection belonging to a refrigeration system with a water cooled condenser and a semi-hermetic compressor. The tests were performed as refrigerants R22 and R407C. The electronic expansion valve controlling the degree of overheating in evaporator outlet at 10°C. The authors concluded that the EEV and TEV has provided similar performance coefficients in steady state conditions, which did not occur in transient regime, where the EEV provided better performance. According to these authors, the main advantages of EEVs are a rapid response to changes in operating conditions, ease of control of superheat setting (setpoint) and the smallest fluctuations in controlling this variable. Also emphasize that the EEVs are more suitable expansion device mounted to operate in systems with variable speed compressors, despite this observation, they did not studied the effect of the rotation of the compressor.

" Carvajal (2004)", analysed the control of the variable rotational speed to reduce refrigerant flow to the compressor in response to the refrigeration conditions part load, thus reducing the consumption of electricity compared to the same fixed speed compressor.

" Kizilkan (2011)" concluded that an advantage of the variable speed compressor refrigeration systems is the possibility of modifying the equipment refrigeration capacity, because of this the performance of the refrigerating system can be improved for operation at the optimum frequency of the compressor, changing the machine speed to certain condition thermal loading.

2. EXPERIMENTAL APPARATUS AND DATA PROCESSING

The experimental apparatus used in this study consists of two subsystems: vapor compression refrigeration subsystem composed of condenser, evaporator, compressor and thermostatic expansion valve, that utilize refrigerant R-134a, and secondary subsystem consists variable speed pump, and fancoil which works with alcohol as a secondary fluid. The workbench was instrumented with temperature sensors, pressure and volumetric flow. The diagram is presented in Fig. 1.

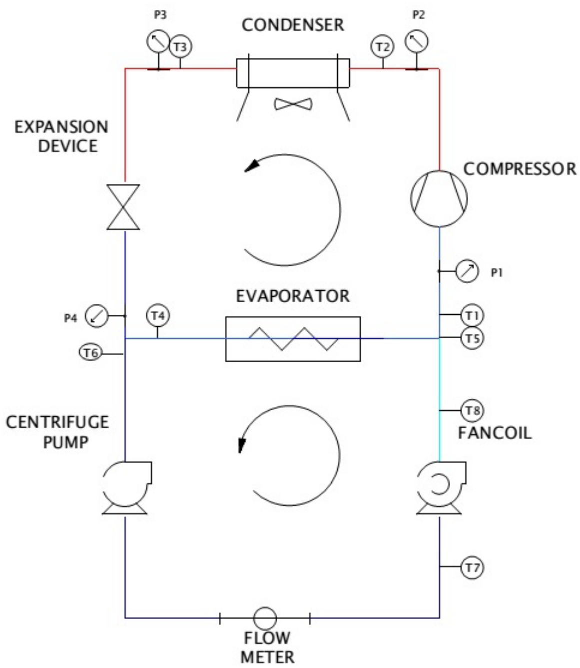

Figure 1. Test stand configuration

2.1 Secondary fluid subsystem

The secondary fluid subsystem comprises: a pump with variable speed control 0-3450 rpm and flow from 5 to 40 liters/min, promotes the circulation of ethyl alcohol by evaporator, removing heat from same and thus supplying heat capacity for air conditioning. The secondary refrigerant circulates through the fan coil removing the environmental heat load to be cooled. The capacity of the heat exchanger of the air conditioning system is 600 W.

2.2 Subsystem of refrigeration compression vapor

The refrigeration subsystem by vapor compression consists of the following components: evaporator is a heat exchanger with countercurrent flow of concentric tubes, condenser is a gas-liquid heat exchanger with capacity of 3 / 4 hp, thermostatic expansion valve and variable rotation compressor connected to the frequency inverter with a capacity of 69 to 578 W.

The variable speed compressor used for the experiment is equal to Fig. 2.

Figure 2. Variable speed compressor

2.3 Measuring instrument and data acquisition

To perform the monitoring of temperature, were used 06 thermoresistance type PT100 with a temperature measurement in the range of -259.35°C to 961.78°C , 02 thermocouple type T with an operating range -60°C to 370°C and for monitoring pressures were used pressure transducers WIKA gage Transmitter ECO-1, having a precision as shown respectively 1°C and 0.01bar. The data acquisition was carried out by datalogger of NOVUS AUTOMATION. It is an equipment acquisition and recording of analog variables. It operates as an electronic data recorder, storing the information acquired in its internal memory for later analysis. The table 1 shows the summary of the related uncertainties.

Table 1. Uncertainties

Variables	**Uncertainty**
COP (Real)	$\pm 0,08$ a $\pm 0,09$
Thermal load	$\pm 17,52$ a $\pm 40,86$ [W]
Consumed power	$\pm 1,19$ a $\pm 2,18$ [W]
Efficiency	$\pm 2,11$ a $\pm 1,79$ [%]

3. RESULTS AND DISCUSSION

3.1 Analysis varying the thermal loading and the compressor speed

This section presents the results of variations of the compressor and Thermal load, evaluating the COP (Real), consumed power and efficiency.

The "Figure 3" show the COP's behavior and thermal load as a function of rotation compressor. The COP varied from 3.39 to 3.72 in the worked speed range, the thermal load removed by the refrigeration system increases along the speed variation by rotation of 2,300 rpm, while for the variations described above since value of the thermal load remained the same considering the error range found.

It is observed in "Fig. 4", the consumed power is directly related to the variation of the rotation and the same is in line with the thermal load required by the system, gradually increasing. Shows the variable speed compressor to adjust the heat load required by the system with the use of an adequate control of the involved variables.

It is verified in "Fig. 5", the refrigeration system efficiency remained above 70 % for all required thermal loads, this occurred due to the adjustment performed by the compressor to the required loads.

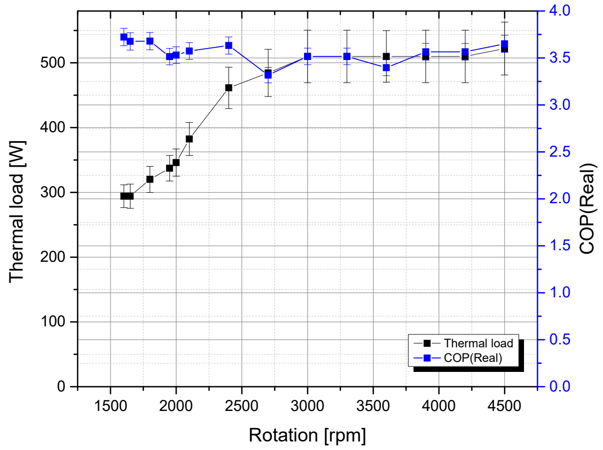

Figure 3. Thermal load and COP in function of the rotation

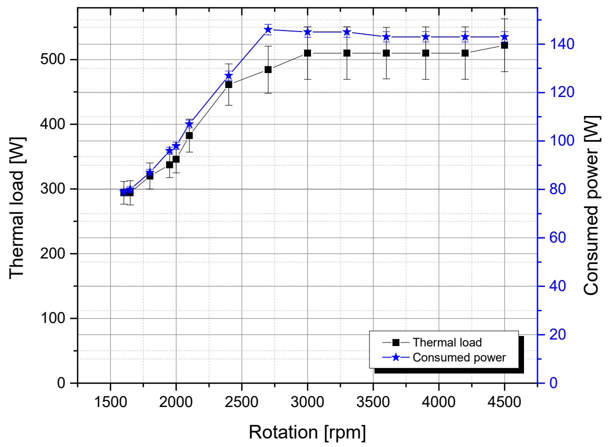

Figure 4. Thermal load and consumed power in function of the rotation

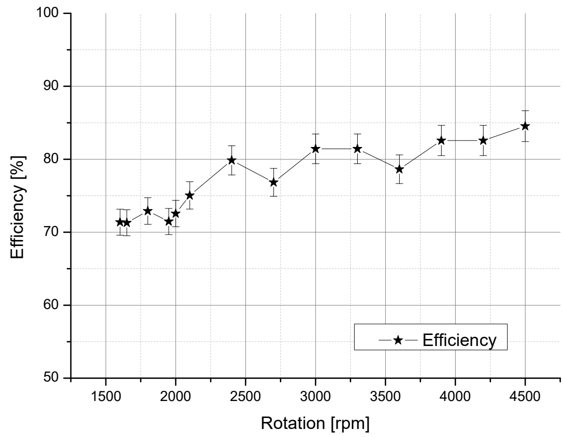

Figure 5. Efficiency in function of the rotation

3.2 Compared compressor rotation fixed x variable rotation

In this section we present a comparison of the compressor use with variable speed and fixed speed for developed Thermal loads for the experiment performed.

The "Figure 6" shows the efficiency for the compressor with variable rotation speed and fixed, it was observed that the efficiency appears when adjusted for rotating the thermal load required to efficiency remained at an efficiency for both low range and the high thermal loads, since for fixed speed there was an increase only in high Thermal loads.

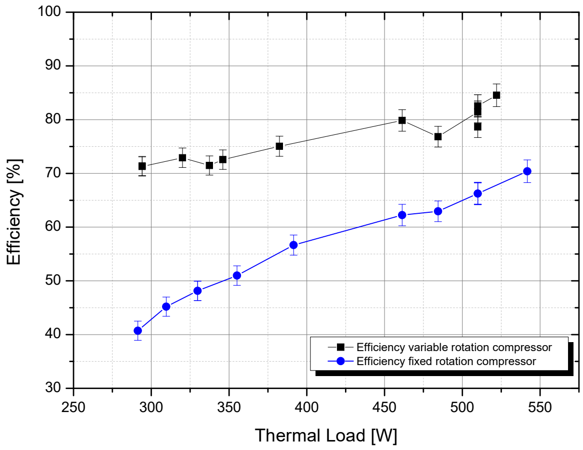

Figure 6. Eficiency of the rotation fixed and rotation variable in function of the rotation

In the "Figure 7" presented is possible to observe that the COP (Real) for variable speed compressor remained in all thermal loads, but when used with fixed rotation was possible to have the highest COP (Real) for larger thermal loads requested the system studied. The COP with fixed speed compressor is lower for all thermal load range analyzed compared to the variable speed compressor.

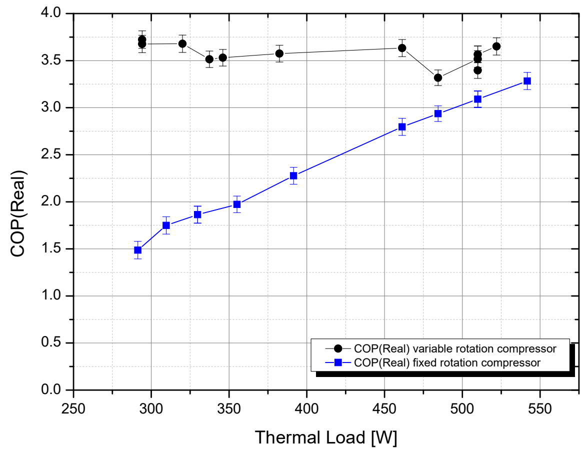

Figure 7. COP (Real) of the rotation fixed and rotation variable in function of the thermal Load

It is observed from the "Fig. 8" that the power consumption increases with increasing thermal load to the compressor with variable speed, however the fixed for rotation power consumed remained high even for low thermal loads.

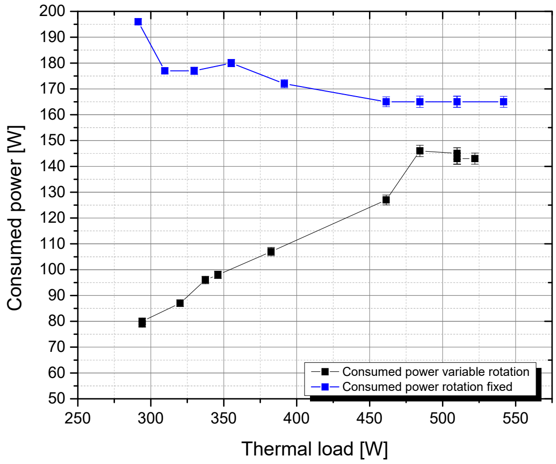

Figure 8. Consumed power rotation fixed and rotation variable in function of the rotation

4. CONCLUSION

This experimental study examined the performance and effect of the changes made in the compressor rotational speed of the vapor compression refrigeration system using R-134a as the refrigerant, to evaluate the COP and power consumption by opting for the use of variable expansion device, thermostatic expansion valve.

Initially it was observed system behavior setting the evaporating pressure of 0.24 MPa. The system presented a COP without many changes, with higher rates for low speeds, made possible by the low compressor power consumption in relation to developed thermal load.

For comparison, the use of compressor variable and fixed speed, it is observed that the efficiency of the compressor using a variable speed has always remained higher than that obtained when the compressor was subjected to the same conditions fixed speed.

The use of variable speed compressor was extended to the system a working range without sacrificing performance of the same, being able to vary the speed according to the need of the thermal load, which means that the compressor provides a setting for it to decrease or increase its rotation without harming the efficiency parameters. This system is an alternative to reduce power consumption and system optimization, which in turn brings greater energy efficiency, using the appropriate expansion system.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

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