EXERGETIC ANALYSIS OF AN AIR CONDITIONING SYSTEM USING R-22 AND R-600a REFRIGERANTS.

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Abstract-- Exergy analysis has been applied to two air conditioning systems which made use of R-22 and R-600a refrigerants in an effort to characterise exergy consumption and to identify areas requiring greater improvements in the systems. The study was conducted by taking temperature and pressure data to perform mass and exergy analysis of the refrigeration system which comprises of the compressor, the condenser, a throttle valve and an evaporator. The coefficient of performance, exergy destruction and exergetic efficiency and inefficiency of the refrigeration systems was determined. Results show that the highest irreversibility occurs in the compressor and the evaporator which have very close values. In the air conditioning system using R-22 refrigerant, the total exergy destroyed was 5.47 kW, with the highest value of 1.76 kW in the evaporator and an inefficiency of 32.16% while the R-600a system had the highest irreversibility in the compressor having 2.28 kW and inefficiency of 30.97%. The R-22 air conditioning system had a COP of 3.08 and had a minimum temperature of 18°C in the delivery air while the COP of R-600a was 4.13, though higher than that of R-22, had a minimum temperature of 21°C. The major energy into the system was through the compressor. The work done in the compressor of the R-22 air conditioning system was found to be 1.104 kJ/s while that of the R-600a system was 1.102 kJ/s.

Keywoeds--- Analysis, Air Conditioning System, Compressor, Efficiency, Evaporator, Exergy, Refrigerants.

1 INTRODUCTION

Tropical climates general pattern is warm temperatures. Depending on the type of tropical climate, humidity is variable with Equatorial climates [1]. Humans are very sensitive to humidity, as the skin relies on the air to get offload moisture. The process of sweating is the body's attempt to keep cool and maintain its current temperature. If air is at 100% relative humidity, sweat will not evaporate into the air causing us to feel hotter than the actual temperature [2].

Humidity control was the problem that originally spurred the need for air conditioning. Air conditioning was first invented as a dehumidification system in 1902 by Willis H. Carrier [3]. Modern air conditioners dehumidify as they cool, solving the problem of humidity control [4].

In tropical regions like Nigeria, the use of air-conditioners has been increasing rapidly. HVAC [Heating, Ventilation, and Air Conditioning] is a term used to fully define an air conditioning system since an air conditioner can at an instance, cool the air in a room, and at another instance (when desired), heat up the air. It is the technology of indoor and vehicular environmental comfort. The rapid growth in the use of air conditioners will represent a challenge for policy makers in the country, who at a minimum must implement policies to improve their efficiency [5]. Even in temperate regions, the use of air conditioners is rapidly growing. In southern Florida, for example, the percentage of homes with air conditioning increased from 5% to 95% in the 40 year period between 1950 and 1990. One of the results has been a huge surge in power demands in the state [5].

These HVAC systems consume large quantities of energy, particularly electricity and represent a key target area for improved energy efficiency [6]. Having an air conditioning unit with high efficiency is highly preferable, that is, an air conditioning system that can quickly regulate the air in a room in a short while, using minimal power to achieve this and also have a minimal effect on the environment in general. Air conditioned buildings often have sealed windows, because open windows would work against the system intended to maintain constant indoor air conditions. The area of application of air conditioning systems extends far beyond just the indoor comfort of domestic homes or possibly commercial buildings such as restaurants, shopping centres and malls.

2 OVERVIEW OF EXERGY

Exergy, is a thermodynamic concept which enables us to articulate what is consumed by all working systems, whether they are man-made systems such as thermo-chemical engines and electricity-driven heat pumps or biological systems such as microbes, plants, and animals including the human body. When we use such expressions as "Energy Consumption", "Energy Saving", and even "Energy Conservation", we implicitly refer to "Energy" as intense energy available from fossil fuels or from condensed uranium. But, it is confusing to use one of the most well- established scientific terms, energy, to mean "to be conserved" and "to be consumed" simultaneously. This is why we need to use the thermodynamic concept, Exergy, to articulate what is consumed [7].
The usable energy in a system is called Exergy, and it can be measured as the total free energies in the system. Exergy is always consumed or destroyed when a process involves a temperature change. The destruction is proportional to the increase in entropy of the system together with the surrounding. The destroyed exergy is termed Anergy. For an isothermal process, exergy and energy are interchangeable terms and there is no anergy.

3 METHODOLOGY

The schematic diagram of the basic system is shown in fig 3.1 below

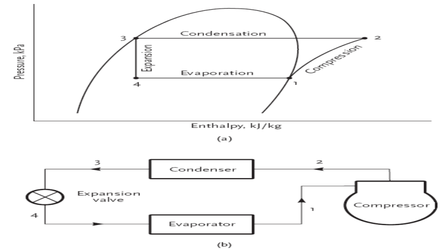

Figure 3.1 Schematic representation of the basic Air Conditioning process SOURCE: CIBSE [24]

3.1 Data Acquisition and Analysis

The air conditioning system utilizes majorly, electrical energy supplied to the compressor and other auxillary componenets not involved in the basic cooling or heating process but necessary for proper functioning of the unit. Data was collected on a per component basis of the four basic components. Datasheets were prepared for the sole purpose of detailed collection of data from the air conditioning systems.

Analysis of the acquired data was carried out in line with the purpose of the project work. Exergy studies were conducted on the two air conditioning systems using different refrigerants to determine the energy consumption pattern and methods of energy optimization in the systems. Typical reference state pressure of 101 kPa was used for the analysis. The entire components are installed in the same environment and therefore have the temperature of the surrounding constant.

3.2 Inefficiency

Exergy study allows a system to be analysed more comprehensively by determining the exergy destroyed in the various components of a system by internal irreversibility and its causes. Inefficiency can be defined as the ratio of the irreversibility or the exergy destruction rate in each section to the irreversibility over all sections [28] [29].

3.3 Exergy Expenditure

The exergy analysis was carried out on each component separately. Exergy accounts for individual process were presented in order to identify major losses and evaluate the potential for further technical improvements in the design and operation of an air conditioning system.

Table 1 Exergy balance of the components of the air conditioning system using different refrigerants at ambient temperature of 297 K

COMPONENT	EXERGY CHANGE ΔE_x (kJ/s)		IRREVERSIBILITY $E_{x,d}$ (kJ/s)		EXERGY INEFFICIENCY I_{ff}		EXERGY EFFICIENCY ψ	
	R-22	R-600a	R-22	R-600a	R-22	R-600a	R-22	R-600a
COMPRESSOR	-1.1182	-1.0997	1.7582	2.277	32.13	30.96	22.62	23.01
CONDENSER	0.3492	0.4552	1.1800	1.3635	21.57	18.54	26.14	27.15
THROTTLE VALVE	-2.9367	0.4102	0.7722	1.4355	14.11	19.52	28.62	26.82
EVAPORATOR	3.7057	0.2342	1.7602	2.2766	32.17	30.96	22.60	23.01
TOTAL	0	0	5.47074	7.3526	100	100	100	100

The exergy efficiency of each component is shown in table 1. From the table, it is clear that the component with the highest efficiency in the system using R-22 refrigerant is the throttle valve with a value of 28.62%, followed by the evaporator and then the condenser. However, the least efficient component is the evaporator. The R-600a system has its highest efficiency in the condenser with a value of 27.15% closely followed by the throttle valve having 26.82% efficiency. In the two air conditioning systems, the compressors both have low efficiencies. A comparison between the two systems is shown in fig 4.2 below.

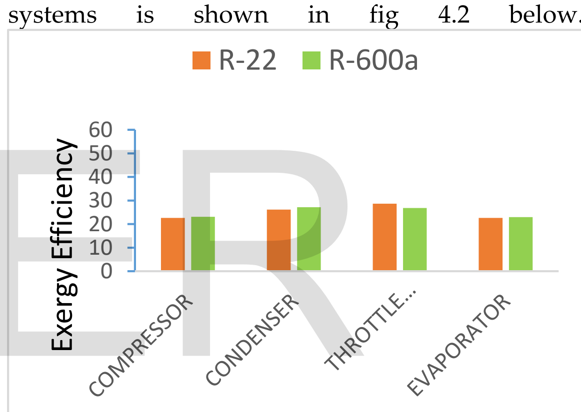

Figure 4.2 Histogram showing exergy efficiency of the components using different refrigerant

4 CONCLUSION

The exergy analysis of two air conditioning systems was conducted using R-22 and R-600a refrigerants. In the air conditioning system using R-22 refrigerant, the total exergy destroyed was 5.47 kW, with the highest value of 1.76 kW in the evaporator. The evaporator also had the highest exergy inefficiency of 32.16%. The basic vapour compression cycle of operation was between 46.48°C and -15°C. In the system using R-600a as its working fluid, the total exergy destroyed was 7.35 kW, with the highest value of 2.28 kW in the compressor. Similar to the R-22 system, the component with the highest exergy destruction rate accounts for the highest inefficiency, the compressor thus having an inefficiency of 30.97%. It has been discovered that for different refrigerants, exergy losses occur at different locations in the basic vapour compression cycle depending on the nature of refrigerant. Also, this analysis has helped to establish the fact that the air conditioning system operates a closed loop owing to the fact that the total change in exergy for all component is zero regardless of the type of refrigerant or the ambient temperature the system may be operating in.

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