Modelling of wearable cooling system based on vapour compression refrigeration cycle

NAVEENKUMAR KALLANGATTU SUDHAKARAN (Student ID-2125636K)
SUPERVISOR - Dr. ZHIBIN YU

Introduction
A wearable cooling system is designed to provide a safer and effective working environment for hazardous duty workers by means of reducing the thermal stress developed in the elevated temperature working environment. Vapour compression refrigeration system is the most promising technology among the other refrigeration technologies, due to the extended operating hours, relatively low system weight and high performance. Heat dissipation to the environment, miniaturization of components and a reliable power source selection are the major challenges in the development of a portable cooling system. A portable cooling system with high levels of compactness, lightweight and high energy efficiency are the essential part of the design criteria.

Importance
Hyperthermia is a form of heat stroke normally occurs when a human body is exposed to a temperature of above 40°C. Heat Exhaustion, sunburn, dehydration are some of the results due to working in a hot environment for an extended time.

Thermodynamic Cycle
Refrigeration is the process of transfer of the heat from a lower temperature region to a higher temperature region. Theoretical thermodynamic cycles consist of non-deceptive and frictionless processes. In the refrigeration cycle, the circulating fluid is compressed, cooled and then expanded during the refrigeration process. During the expansion process the working fluid absorbs heat from its surroundings and provides refrigeration and the cyclic process repeated.

Reversed Carnot cycle
Reversed Carnot cycle is the most efficient cycle operates between two specified temperature levels. The reverse Carnot cycle has the highest theoretical COP. In reverse Carnot cycle working, the heat is absorbed from the low temperature reservoir (evaporator) and the heat is rejected to the high temperature reservoir (condenser). In reversed Carnot cycle the process is completed with the help of an external work to operate the compressor and the turbine.

Coefficient of performance(COP) = 9.9 \( (T_e = 24^\circ\text{C} \text{ & } T_c = 54^\circ\text{C}) \)

Vapour Compression Refrigeration Cycle
In a vapour compression refrigeration system, the low pressure high temperature refrigerant vapour is compressed in the compressor to produce high pressure, high temperature vapour refrigerant. This high pressure, high temperature refrigerant vapour enters into the condenser where it is converted into high pressure liquid due to the condensation process and then passes through the expansion valve. In expansion valve where the refrigerant pressure is controlled to the required level. The low pressure, low temperature refrigerant enters into the evaporator from the expansion valve where it absorbs the heat from the surroundings and converted into high temperature, low pressure vapour refrigerant and the cycle repeat.

Selection of Refrigerant
The thermodynamic efficiency of the refrigeration system depends upon the working temperatures, but, based on the type of refrigerant used, the refrigeration system has been designed. Refrigerant R134a is a single component HFC refrigerant (Terafluorohane), volatile liquid with ethereal and faint sweetish odor. R134a is considered to be for this project.

Design calculation of the vapour compression refrigeration system
Coefficient of performance (COP) = 7.45 \( (T_e = 24^\circ\text{C} \text{ & } T_c = 54^\circ\text{C}) \)
Mass flow rate of the refrigerant, \( m = 0.0033\text{kg/s} \)
Power input to the compressor, \( W_c = 0.059\text{ KW} \)
Heat rejection from the Condenser, \( Q_c = 0.514\text{ KW} \)

Wearable cooling system
The cooling system is working based on the vapour compression refrigeration cycle and the model builds as a backpack configuration. A wearable cooling system is designed using for an elevated ambient temperature and operated by a hermetic compressor powered by lithium ion rechargeable batteries. A wearable cooling system is designed with a total weight of 4.485 Kg.

Components used for the wearable cooling system are,
Compressor - Aspen miniature rotary BLDC compressor
Condenser - SANHUA micro-channel heat exchanger
Expansion valve - Parker Thermostatic C(E) Series Expansion Valves
Evaporator - Polymer coil mounted cooling vest
Power - Lithium ion rechargeable battery

Further consideration
Small scale compressor reliability and efficiency, reduced noise and vibration, ability to handle varying workload and availability at a low cost

Reference
• “Recent developments in vapour compression technologies for small scale refrigeration applications” by Jader R. Barbosa, Jr.,
• Refrigeration lecture notes by Dr. Zhibin Yu ,University of Glasgow