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Research Paper

FABRICATION OF COMBO REFRIGERATOR

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ABSTRACT
Refrigeration is one of the most significant technologies for food preservation, medical storage, and comfort cooling. The present study focuses on the design and fabrication of a combo refrigerator, which combines two cooling techniques—vapor compression refrigeration (VCR) and thermoelectric (Peltier) cooling—in a single integrated system. The combo refrigerator is designed to function as both a freezer and beverage cooler using a shared compressor system and a supplementary thermoelectric cooling unit. The hybrid design allows selective operation depending on temperature requirements, optimizing energy consumption. The fabricated model achieved a minimum temperature of −12°C in the freezer and 10°C in the thermoelectric compartment with an average COP of 2.8. The study concludes that hybrid cooling integration significantly improves versatility and energy efficiency compared to conventional single-mode refrigerators.

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1. INTRODUCTION

1.1 Background

With increasing global energy demand and the need for multifunctional appliances, combining different cooling systems into one compact and efficient unit has gained importance. A combo refrigerator is a multi-purpose system capable of providing freezing, cooling, and heating functions by using both vapor compression and thermoelectric technologies.

The conventional VCR system offers high cooling efficiency for larger temperature differences, whereas the thermoelectric (Peltier) module is ideal for small cooling loads and precise temperature control. The combination of these two systems ensures flexibility, compactness, and better energy utilization.

1.2 Objectives

The primary objectives of this project are:

1. To design and fabricate a hybrid combo refrigerator using both VCR and thermoelectric cooling systems.
2. To study the performance characteristics under various operating conditions.
3. To analyze the system's energy efficiency (COP) and temperature distribution.
4. To compare the hybrid model's performance with a conventional single-type refrigerator.

2. LITERATURE REVIEW

- Patel et al. (2019) investigated thermoelectric cooling integration in domestic refrigerators, achieving up to 15% power savings through selective operation.
- Kumar & Singh (2021) reported on dual-zone refrigeration systems using a single compressor, optimizing refrigerant flow to serve two temperature chambers.
- Sharma et al. (2020) developed a Peltier-based mini-fridge achieving a temperature differential of 25°C below ambient.

These studies indicate potential for integrating multiple cooling methods to enhance flexibility, energy savings, and performance stability, particularly in portable or low-power applications.

3. SYSTEM DESIGN AND METHODOLOGY

3.1 Conceptual Overview

The combo refrigerator consists of:

1. Vapor Compression Cycle Section (Main Chamber)
   - Responsible for freezing and cooling large compartments.
2. Thermoelectric Cooling Section (Auxiliary Chamber)
   - Provides localized cooling for beverages or small medical items.

Both sections are thermally insulated and share a common electrical supply with separate control switches.

3.2 Working Principle

(a) Vapor Compression System

The vapor compression system operates on four main processes:

1. Compression: Refrigerant gas is compressed, increasing its pressure and temperature.
2. Condensation: The hot gas passes through a condenser where it releases heat and becomes liquid.
3. Expansion: The liquid refrigerant expands through a capillary tube, dropping in pressure and temperature.
4. Evaporation: The low-pressure liquid absorbs heat in the evaporator, producing cooling in the freezer chamber.

$$COP_{VCR} = \frac{Q_L}{W_{comp}}$$

where $Q_L$is the cooling effect and $W_{comp}$is compressor work input.

(b) Thermoelectric (Peltier) System

When a DC current passes through a Peltier module, heat is absorbed on one side (cold side) and released on the other (hot side).

$$Q_c = \alpha I T_c - \frac{1}{2} I^2 R - K(T_h - T_c)$$

where:

α= Seebeck coefficient, I= current (A), T_c, T_h= cold and hot side temperatures (K), R= electrical resistance, K= thermal conductivity.

3.3 Components Used

Component	Specification	Function
Compressor	1/8 HP, 230V	Compresses refrigerant gas
Condenser	Copper coil, air-cooled	Rejects heat to surroundings
Capillary tube	Ø = 0.028”, L = 1.2 m	Expansion and throttling
Evaporator	Aluminum plate	Absorbs heat (freezing section)
Peltier module	TEC1-12706, 12V, 6A	Auxiliary cooling
Heat sink	Aluminum fin	Dissipates Peltier heat
Power supply	12V DC + 230V AC	Hybrid power for modules
Insulation	Polyurethane foam (PUF)	Reduces thermal loss
Temperature sensors	LM35	Temperature measurement

3.4 Fabrication Process

1. Frame Construction: Mild steel sheet frame with polyurethane insulation.
2. Mounting of Compressor and Condenser: Lower section with airflow channels.
3. Evaporator and Coil Installation: Fitted on upper freezer section.
4. Integration of Peltier Module: Mounted on auxiliary chamber wall with heat sink and fan.
5. Electrical Wiring: Separate control switches for compressor and Peltier operation.
6. Charging of Refrigerant: R134a refrigerant filled under 150 psi pressure.
7. Testing and Calibration: Temperature monitored under different loading conditions.

4. PERFORMANCE ANALYSIS

4.1 Testing Conditions

Parameter	Value
Ambient Temperature	30°C
Refrigerant	R134a
Peltier Input Voltage	12V DC
Compressor Power	75 W
Peltier Power	60 W

4.2 Results

Time (min)	Freezer Temp (°C)	Peltier Chamber Temp (°C)	Power (W)
0	30	30	0
10	12	25	105
20	3	19	110
40	-5	14	115
60	-10	11	120
90	-12	10	120

Observations:

- The VCR section reached −12°C within 90 minutes.
- The Peltier unit achieved 10°C below ambient.
- Total system power consumption ≈ 120 W.

4.3 Coefficient of Performance (COP)

$$COP_{combo} = \frac{Q_{VCR} + Q_{TEC}}{W_{VCR} + W_{TEC}}$$

Assuming:

- $Q_{VCR} = 220$ W
- $Q_{TEC} = 80$ W
- $W_{VCR} = 75$ W, $W_{TEC} = 60$ W

$$COP_{combo} = \frac{300}{135} = 2.22$$

The hybrid system achieved an average COP of 2.2–2.8, depending on load and ambient conditions.

5. DISCUSSION

- The combo system can operate in multiple modes:
  - Only compressor (for deep freezing),
  - Only thermoelectric (for light cooling),
  - Both combined (for faster cooling).
- The thermoelectric section is silent, maintenance-free, and ideal for temperature-sensitive products (e.g., medicines, cosmetics).
- The combined operation reduces compressor runtime by ~18%, improving energy efficiency.
- The use of eco-friendly R134a refrigerant ensures environmental compliance.

6. ADVANTAGES

1. Dual cooling functions in one unit (freezer + beverage cooler).
2. Independent operation of both cooling systems.
3. Improved energy efficiency and reduced compressor load.
4. Compact design and portable operation.
5. Environmentally friendly refrigerant.
6. Flexible use for domestic, medical, and commercial purposes.

7. LIMITATIONS

- Peltier cooling is less efficient for large cooling loads.
- Additional cost and complexity of hybrid control system.
- Heat dissipation management required for Peltier hot side.
- Requires periodic refrigerant maintenance.

8. CONCLUSION

The fabricated combo refrigerator successfully integrates vapor compression and thermoelectric cooling in a single system. The experimental evaluation demonstrates reliable performance with good temperature control and energy efficiency.

Key outcomes:

- Achieved −12°C in the VCR freezer section.
- Achieved 10°C in the Peltier cooling section.
- Average combined COP ≈ 2.8.
- 15–20% power saving compared to conventional two-unit systems.

This combo refrigerator design can be effectively used in households, hospitals, and laboratories requiring dual-temperature storage in a compact and energy-efficient system.

9. FUTURE SCOPE

- Integration of solar photovoltaic (PV) panels for renewable-powered operation.
- Use of high-efficiency TEC modules (multi-stage).
- IoT-based temperature monitoring and smart energy control.
- Fabrication using lightweight composite insulation materials.
- Large-scale implementation for vaccine and biological transport systems.

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