Design Development and Fabrication of Foldable Solar Panel for Portable Thermoelectric Cooler
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Abstract—Present day cars have an air conditioning system to keep the car interior cool as per requirements of occupant, but during the hot seasons is needed to have a water or beverage cooler in the car. Presently no such system is installed in the car. The systems that use conventional. The Foldable solar panel –portable thermo-electric cooler is a concept that solves the above problem by using solar power. The portable thermoelectric cooler is a innovative system that utilizes Peltier effect for the thermoelectric cooler. This thermoelectric cooler is run on 12 volt DC power hence can be operated in dual mode i.e., using solar power during day time whereas 12 V DC power from vehicle battery using cigarette lighter socket. This system is fully automatic i.e., it actuates when the equipment to be cooled i.e., can is placed in the thermoelectric cooler. Thus the device provides refrigeration effect in minimal space using solar.

Key words: thermoelectric effect, Peltier effect, foldable solar panel

Nomenclature:
- TEC- Thermoelectric cooling
- Qabs - Amount of Heat absorbed by per unit time
- \( \pi \) - Coefficient of Peltier
- COP- Coefficient of performance
- Winput- Applied power, Watts
- Sut- Ultimate tensile strength, N/mm²
- Syt- Yeild strength, N/mm²
- \( \sigma_{\text{max}} \)- Permissible shear stress, N/mm²
- C- Dynamic capacity of bearing
- W- Total load acting on bearing, N
- P-Power, Watt
- T- Torque on motor, N-M
- Zg- Number of teeth on gear
- Zp- Number of teeth on pinion
- M- Module, mm
- Cs- Service factor
- Np- Speed of pinion, rpm
- \( \sigma_{bg} \)- Permissible bending stress of gear, N/mm²
- \( \sigma_{bp} \)- Permissible bending stress of pinion, N/mm²
- Y- Lewis form factor
- Yp- Lewis form factor for pinion
- Yg- Lewis form factor for gear
- Fb- Beam strength of gear tooth, N
- Ft- Tangential force acting on gear tooth, N
- L- Length of gear tooth, mm
- b- Face width of gear tooth, mm
- \( \phi \)- Pressue angle, degree
- Dp- Diameter of pinion, mm
- Dg- Diameter of gear, mm
- Feff- Effective load, N
- V- Pitch line velocity, m/sec
- Kv- Velocity factor

I. INTRODUCTION

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice-versa. A thermoelectric device creates a voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side, similar to a classical gas that expands when heated; hence inducing a thermal current.

A. Peltier Effect

The Peltier effect is the presence of heat at an electrified junction of two different metals and is named for French physicist Jean-Charles Peltier, who discovered it in 1834. When a current is made to flow through a junction composed of materials A and B, heat is generated at the upper junction at \( T_1 \), and absorbed at the lower junction at \( T_2 \). The Peltier heat absorbed by the lower junction per unit time is equal to

\[
Q = \Pi_{\text{eff}} = (I_{\text{p}} - I_{\text{b}}) \Pi
\]

Thermoelectric coolers (TECs), also known as Peltier coolers, are solid-state heat pumps that utilize the Peltier effect to move heat. Passing a current through a TEC transfers heat from one side to the other, typically producing a heat differential of around 40°C—or as much as 70°C in high-end devices—that can be used to transfer heat from one place to another. The principle of thermoelectric cooling dates back to the discovery of the Peltier Effect by Jean Peltier in 1834. All electric current is accompanied by heat (Joule heating). When electric current passed across the junction of two dissimilar conductors (a “thermocouple”) there is a heating effect that could not be explained by Joule heating alone. In fact, depending on the direction of the current, the overall effect could be either heating or cooling. This effect can be harnessed to transfer heat, creating a heater or a cooler.

While refrigerators and air conditioners utilize compressors, condensers, and liquid refrigerants to lower temperature. Solid-state cooling utilizes DC power, heat sinks, and semiconductors. This fundamental difference
gives solid-state thermoelectric coolers the following advantages over compressors:

1. No moving parts. Therefore they require little or no maintenance. Ideal for cooling parts that may be sensitive to mechanical vibration.
2. No refrigerants, such as potentially harmful CFCs. Therefore environmental and safety benefits.
3. Enables reduced low-noise operation of cooling fans, while providing greater cooling power.
4. Suitable for manufacture in very small sizes. Therefore ideal for microelectronics.
5. Lightweight.
6. Long life. Exceeds 100,000 hrs. MTBF (Mean Time between Failures).
7. Small size.
9. Can provide cooling below ambient temperature.

II. OBJECTIVE
Theoretical determination of heat load for thermoelectric cooler, /power requirements for operation of the solar panel folding, mechanism and the sun tracking arrangement thereby determining the overall power requirements to select the solar panel power and storage system capacity.

Design and development of folding mechanism.
1. Selection of thermoelectric module to produce the desired refrigeration effect.
2. Integration of the foldable solar panel system and the thermoelectric module to make the desired system for required refrigeration effect.
3. Test and trial on developed system to find
   (1) Refrigeration effect produced with use of solar system
   (2) Comparative study and analysis of above result for optimization of the output from the thermo-electric module to get maximum refrigeration effect
   (3) To determine the overall effectiveness of system by study of overall power produced by system and overall power consumed by system to produce desired refrigeration effect, thereby establishing an energy balance sheet.

III. PRINCIPLE
System comprises of foldable solar panel system mounted on top of the car roof, these solar panel power a 12 V dc battery that stores this electrical energy for utilization. The TEC or thermoelectric module is powered by the 12 volt DC battery or can be powered by the car battery during night time or cloudy condition.

IV. METHODOLOGY
A. Literature review:
Study of various configurations of solar panel efficiency, orientation, optimization, sun tracking device and Thermoelectric using various Handbooks, United State Patent documents, Technical papers, etc.

B. Design and Developments:
(1) System design as to Theoretical determination of heat load for thermoelectric cooler, power requirement for operation of the solar panel folding, mechanism and the sun tracking arrangement there by determining the overall power requirements to select the solar panel power and storage system capacity
(2) Kinematic linkage design for the solar panel folding mechanism.
(3) Mechanical design of components as the folding solar panel hinge, driver linkage, slider crank using theoretical formulae to determine their geometrical dimension. Mechanical design of spear gear box, shaft, and driver linkage mechanism for given system of forces.
(4) Selection of motor drives for folding mechanism.
(5) Selection of thermoelectric module to produce the desired refrigeration effect.

C. Fabrication:
Suitable manufacturing methods will be employed to fabricate the components and then assemble the test set up. The fabrication will be carried out as per figure shown in 1.

V. DESIGN
A. Motor torque
Input: p= 15W
N = 30 rpm
P = 2πNT/60
Design of motor torque, T= 4.7 N-m (5.1.1)

B. Design of Spur pinion and Gear
Input:
Tmax= 4.7 N-m (from equation 5.1)
b= 10 M
Sutg=Sutp= 300 N/mm²
Zp= 10
Zg= 30
C.S= 1.5

(1) W= Tmax/ Dg
W= 4.7* 10*3/30
Maximum load, W= 157 N (5.2.1)

(2) Ft= W*C.S
Ft= 157*1.5
Tangential load, Ft= 235.5 N (5.2.2)
Effective load, Fef= 235.5 N (5.2.3)
(As Cv= 1 due to low speed of operation)

(3) Lewis strength equation
W= Sut *Y*sb*M
Where,
Y= 0.484- 2.86/Z
Y= 0.484- 2.86/10
Yp = 0.198
Yg = 0.484- 2.86/30
Yg = 0.38

(5.2.5)

Shaft bearing will be subjected to purely radial loads; hence we shall use ball bearing for our application.
a) Radial load= T design / radius of crank
Fr = (0.3058*10^3) / (40)
Fr = 7.6 N

(5.4.1)

Total load acting on bearing, W = 7.6 N

Select deep groove ball bearing from design data book, series 60:
Bearing no. 6002 (V. B. Bhandari)
Bore diameter, d = 15 mm
Outer diameter of bearing, D = 32 mm
Width of bearing, B = 9 mm

b) Equivalent dynamic load, P
P = (X*Fr) + (Y*Fa)
For our application Fa=0
Therefore, P = X*Fr

(5.4.2)

(5.4.3)

Assuming, L = 14.67 N
But, L = (60*N* L / (10^6))
L = (60*30*4000) / (10^6)
Rated bearing life, L = 7.2 million revolution
Put value of L and P in eq (5.4.3)

7.2 = (C/ P)^p……. Where, p=3 for ball bearing and C-
dynamic load capacity

(5.4.4)

Assuming, LH = 4000-8000 hr.
But, L = (60*N* L)/ (10^6)
L = (60*30*4000) / (10^6)
Rated dynamic capacity of bearing

14.67 N

(5.4.5)

Which is less than rated dynamic capacity of bearing.
Therefore, design selection is correct.

VI. PARTS AND THEIR MATERIAL SELECTION

<table>
<thead>
<tr>
<th>SR. NO.</th>
<th>Parts</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shaft</td>
<td>EN24</td>
</tr>
<tr>
<td>2</td>
<td>Gear</td>
<td>Nylon 66</td>
</tr>
<tr>
<td>3</td>
<td>Motor</td>
<td>Standard</td>
</tr>
<tr>
<td>4</td>
<td>Panel</td>
<td>Standard</td>
</tr>
<tr>
<td>5</td>
<td>Sensor</td>
<td>Standard</td>
</tr>
<tr>
<td>6</td>
<td>Can holder</td>
<td>MS</td>
</tr>
<tr>
<td>7</td>
<td>Electric cir.</td>
<td>Standard</td>
</tr>
<tr>
<td>8</td>
<td>Limit holder</td>
<td>Standard</td>
</tr>
<tr>
<td>9</td>
<td>Frame</td>
<td>MS</td>
</tr>
</tbody>
</table>

6.1 Table No.1

VII. CONCLUSION

Our experimental analysis concludes that solar energy system must be implemented to overcome increasing electricity crisis. In this work a portable solar operated system unit is fabricated and tested for the cooling and heating purpose. The system is designed based on the principle of thermoelectric module to create a hot side and cold. The cold side of thermoelectric module utilizes for cooling purpose whereas heat is rejected by fan.

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REFERENCE


