"Design Optimization & Analysis of Air Conditioner by using Peltier Effect"

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Abstract - As we know that, the future of the Automobile industry is Electric so, now all automobile companies are working on their Electric vehicle versions. For the comfort of the passenger, AC works on an Electric compressor in EV. But as per the study, EV Compressor consumes more electric energy, which affects battery efficiency and directly on vehicle performance in terms of average Km/charge.

During the study, we are optimizing the design by adding the Peltier's & analysis on the AC unit to achieve the required Airflow by using CFD analysis, material selections study, Design of heat sink, CAE & vibration analysis for AC unit & Peltier unit.

We are trying to integrate this system for Electric Cars as there is no refrigerant used since no compressor is required.

Keywords: AC un

1.Literature Survey –

Pankaj Ratnaparkhi & Nikhil Hajgude has done Design optimization & analysis of the Air Conditioner by using the Peltier effect. The CAD model done in CATIA and Analysis was done in ANSYS under similar loading conditions for parameters like deformation, stress, Normal stress, Simulation done in the Heat load calculation sheet for deciding the Airflow, Performance & capacity, etc. We have compared Conversional AC & Electric Peltier AC for an application of automobile & domestic purposes.

2.Problem Statement-

We had studied the performance of EV vehicles, Where the vehicle runs on battery power. In the same, vehicle for passenger comfort AC/ HVAC unit works on batteries by using.

The electric Compressor is the replacement of the mechanical Compressor.

Normally, The Compressor takes almost 20-25% of total power to perform the AC, And as in EV's compressor works on HV & LV from batteries. So to reduce this consumption in a vehicle is important for Vehicle high / long range.

We are researching to optimize the existing AC system by designing the AC with a Peltier effect.

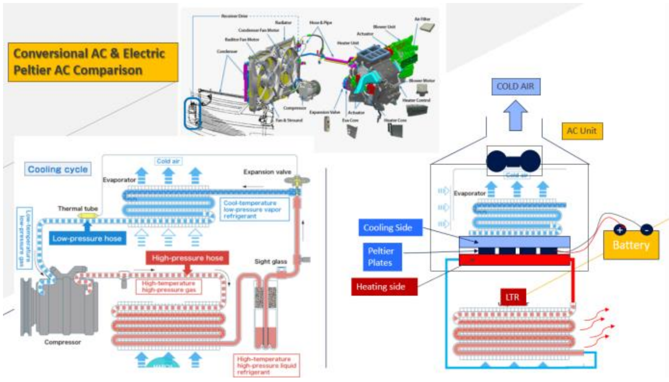

Fig. 1 **Conversional AC & Electric Peltier AC Comparison**

3.Introduction: -

Basic Concept & methodologies used: -

We are designing the AC system & optimizing it by using Peltier plates. We are adding the Peltier plates, Heat sink & cooling tank instate of the Evaporator unit from the existing AC system.

In the Peltier effect, plaiter plates having two faces/surfaces, one gets- cools & one rejects the heats. We are taking the cooling energy from the paltrier & heat energy needs to rejects into the environment.

We designed the Peltier unit with Peltier plates, Heat sink & water tank. The heat sink absorbs the cooling from Peltier & we are allowing the air to pass from these fins/heat sinks. Air will cool & We get a cooling effect.

Same, with that, we need to maintain the heating side of the Peltier. We are allowing the water to pass through these hot side fins of the heat sink. This water gets circulated by using pump & heat rejected by heat exchange i.e low-temperature radiator (LTR).

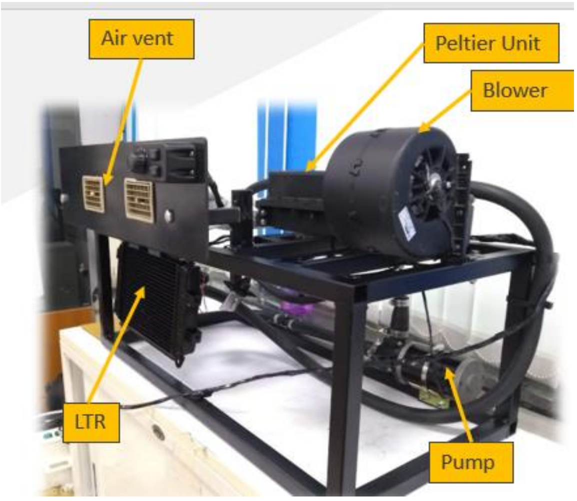

Fig.3 Demo – Bench level AC unit

Computational Fluid Dynamics (CFD) :- For Optimizing the performance & airflow, we are doing Computational Fluid Dynamics (CFD) for our design & as per that we are designing the housings & ducts in CATIA.

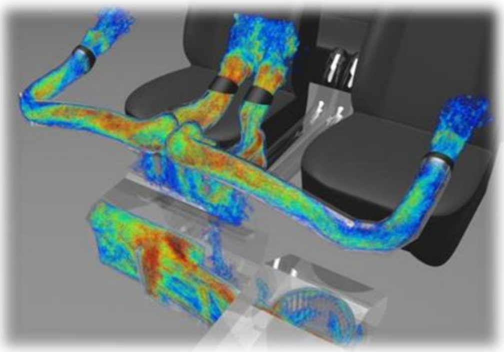

Fig. 4. CFD analysis at vehicle level.

CAE Analysis: - We are integrating the Peltier unit & tank in the AC unit by replacing the Evaporator & fitment done by brackets, snaps & bolts. Also, at the unlit level, for checking all strengths, we are doing CAE analysis.

Noise, Vibration, And Harshness (NVH) :- The computational analysis of automotive noise, vibration, and harshness (NVH) performance is most often done with mode- based finite element procedures. The accuracy of such analyses increases if the associated frequency range is increased to cover a larger fraction of the audible spectrum.

4. Peltier Methodology

Thermoelectric cooling uses the Peltier effect to form a heat flux at the junction of two differing kinds of materials. A Peltier cooler, heater, or thermoelectric apparatus may be a solid-state active apparatus which transfers heat from one side of the device to the opposite , with consumption of electrical energy, counting on the direction of the present . Such an instrument is also called a Peltier device, Peltier apparatus , solid state refrigerator, or thermoelectric cooler (TEC). It are often used either for heating or for cooling,[1] although in practice the most application is cooling. It also can be used as a temperature controller that either heats or cools. This technology is way less commonly applied to refrigeration than vapor-compression refrigeration is. The primary advantages of a Peltier cooler compared to a vapor-compression refrigerator are its lack of moving parts or circulating liquid, very long life, invulnerability to leaks, small size, and flexible shape. Its main disadvantages are high cost for a given cooling capacity and poor power efficiency. Many researchers and corporations attempt to develop Peltier coolers that are cheap and efficient. (See thermoelectric materials.) A Peltier cooler also can be used as a thermoelectric generator. When operated as a cooler, a voltage is applied across the device, and as a result, a difference in temperature will build up between the two sides. When operated as a generator, one side of the device is heated to a temperature greater than the other side, and as a result, a difference in voltage will build up between the 2 sides (the Seebeck effect). However, a well-designed Peltier cooler are getting to be a mediocre thermoelectric generator and therefore the other way around, because of different design and packaging requirements.

4.1 Joule effect:

In the study by Julio-Betancourt and Hooton [20], it's defined because the interaction between a physical phenomenon and therefore the conduction of electrical current where a term phenomenon related to the heating of a conductor through which current flows is associated. Matter offers some resistance to the movement of electrons, which give K.E. to the environment in successive collisions. This energy provided by the electrons dissipates within the sort of heat (eq. 1).

$$Q=I^2R \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: Q is that the heat produced by the present, I is that the current intensity that circulates, R is that the electric resistance of the conductor and t is that the time.

4.4 Seebeck Effect:

Thomas J. Seebeck discovered that during a circuit formed by two homogeneous different metals, A and B, with two unions at different temperatures, T and T + ΔT, an electrical current flow J is established, or, if the circuit may be a thermal voltage (ftem) EAB that depends on the metals utilized in the joint and therefore the temperature difference between the two joints. The diagram of the mentioned configurations is shown in the Fig. 5

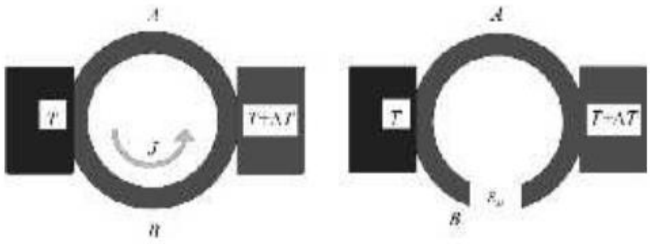

Fig.5 Scheme of the Seebeck effect.

The relation between the item, EAB, and the temperature difference between the joints ΔT, defines the Seebeck coefficient in eq. (2)-(3).

$$\alpha = \frac{\partial E_A}{\partial}$$

$$\alpha = \alpha - \alpha$$

Where: αA and αB are respectively the absolute thermoelectric powers of A and B and are characteristics of each metal.

In general, αAB is not constant, but depends on the temperature T.

4.5. Peltier Effect :

Thermoelectric coolers operate by the Peltier effect (which also goes by the more general name thermoelectric effect). The device has two sides, and when a DC current flows through the device, it brings heat from one side to the opposite, in order that one side gets cooler while the other gets hotter. The "hot" side is attached to a conductor in order that it remains at ambient temperature, while the cool side goes below temperature. In special applications, multiple coolers are often cascaded together for lower temperature, but overall efficiency drops significantly.

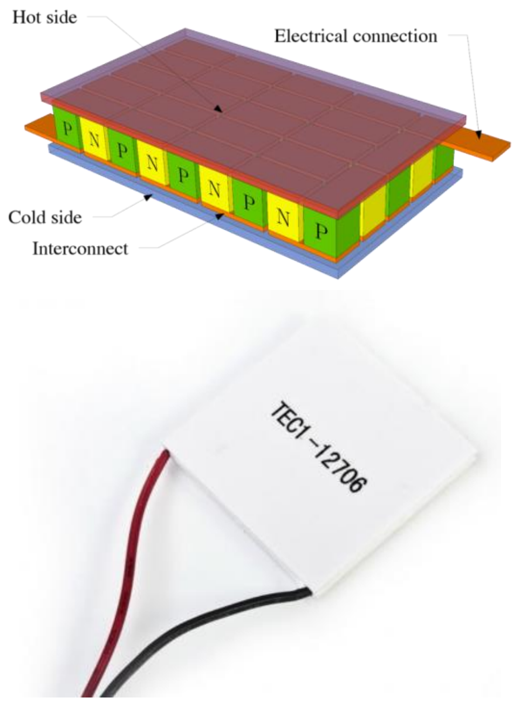

Fig.3 Construction of Peltier

4.6 Peltier Construction:

Two unique semiconductors, one n-type and one p-type, are used because they have to possess different electron densities. The alternating p & semiconductor device pillars are placed thermally in parallel to every other and electrically serial then joined with a thermally conducting plate on all sides, usually ceramic removing the necessity for a separate insulator. The cooling ability of the entire unit is then proportional to the entire cross section of all the pillars, many are connected electrically serial to scale back the present needed to practical levels. The length of the pillars may be a balance between longer pillars which can have a greater thermal resistance between the edges and permit a lower temperature to be reached but produce more resistive heating, and shorter pillars which can have a greater electrical efficiency but let more heat leak from the recent to cold side by thermal conduction. for giant temperature differences longer pillars are far less efficient than stacking separate, progressively larger modules, the modules get larger as each layer must remove both the warmth moved by the above layer and therefore the waste heat of the layer.

4.7 Materials:

Requirements for thermoelectric materials:

- Narrow band-gap semiconductors because of room-temperature operation;
- High electrical conductivity (to reduce electrical resistance, source of waste heat);

- Low thermal conductivity (so that heat doesn't come back from the hot side to the cool side); this usually translates to heavy elements.
- Large unit cell, complex structure; Highly anisotropic or highly symmetric;

5. Electric Air Conditioning by using Peltier:

5.1 Introduction:

As we know that the future of the Automobile industry is Electric so, now all automobile companies are working on their Electric vehicle versions. For the comfort of the passenger, AC works on an Electric compressor in EV. But as per the study EV Compressor consumes more electric energy, which affects battery efficiency and directly on vehicle performance in the terms of average Km/charge.

So, we are trying to integrate this system for Electric Cars, As there is no refrigerant used since no compressor is required.

5.2 Components For AC unit:

For the designing the Electric AC unit below some components are used:

- Peltier Plates
- Fan Blower
- Heat Sink

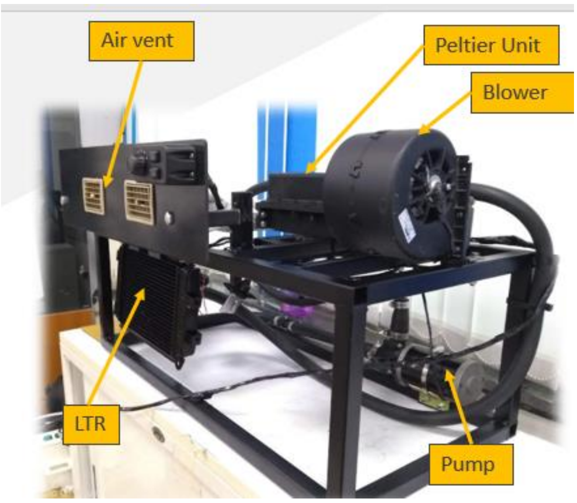

Fig. 5. Bech level Concept design

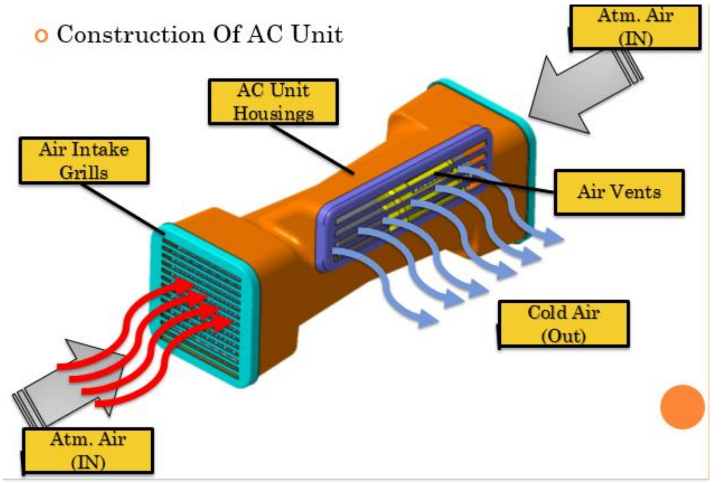

Fig. 6. Basic CAD Concept of AC unit.

- Low Temperature heat exchanger
- Water pump
- Water tank
- Plastic casing etc.

4.3 DESIGN DETAILS:

As we know that, the future of the Automobile industry is Electric so, now all automobile companies are working on their Electric vehicle versions. For the comfort of the passenger, AC works on an Electric compressor in EV. But as per the study, EV Compressor consumes more electric energy, which affects battery efficiency and directly on vehicle performance in terms of average Km/charge.

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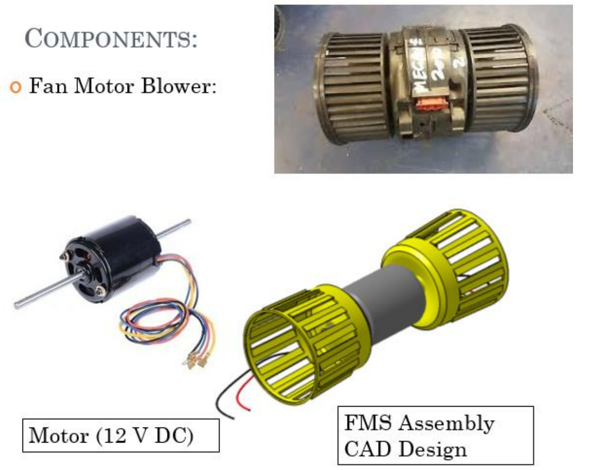
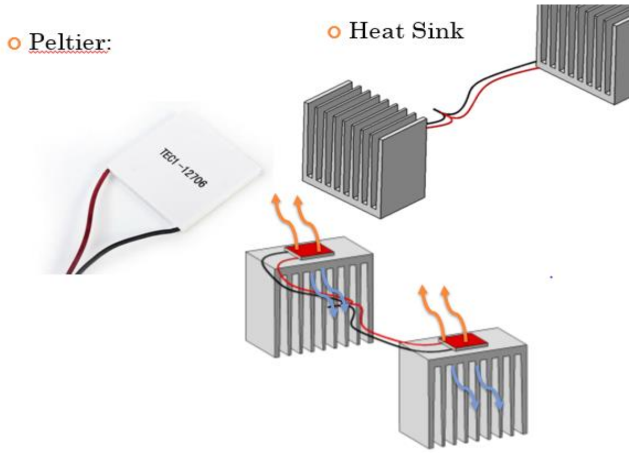
5.4 Components for Peltier AC.





6. Performance & design calculations:

6.1 AC Unit Performance & Design specifications:

1	Target: in kw Capacity	0.5 to 1 Kw
2	Air Flow	200 m3/hr
3	Temp. Peltier side	3 deg.
4	Grill level Velocity	10 m/s
5	Nose level velocity	2.5 m/s
6	A single stage thermoelectric cooler will typically produce a maximal temperature at cold sides 1 to 3 deg.	
7	A common 40 mm x 40 mm can generate 60 W or more, that is, 4W/cm^2 or more, requiring powerful radiator to move the heat way.	

Table -3.1: Design specifications & AC performance.

Heat Load calculations:

From Heat load calculation we get the requirement of cooling in Cabin i.e.

Q Heat load = Q Peltier

Overall heat transfer coefficient	$1/U = 1/h_0 + (t/k)_{sheet} + (t/k)_{insu} + 1/h_i$
h_0 is assumed to be constant (W/m^{2}k)	7
h_i is assumed to be constant (W/m^{2}k)	21
Heat transfer (W)	Q = U A Δt
Δt for sheet metal	(Skin temperature - In cab temperature)

Outside skin temperature	Surface area	Sheet metal thickness	Insulation thickness	$K_{sheet\ metal}$	$K_{insulation}$	U	Q
(°C)	(m^2)	(mm)	(mm)	W/mk	W/mk	W/m^{2}k	W

Peltier Load:

Peltier (thermoelectric) performance is a function of ambient temperature, hot and cold side heat exchanger (heat sink) performance, thermal load, Peltier module (thermopile) geometry, and Peltier electrical parameters.

The amount of heat that can be moved is proportional to the current and time.

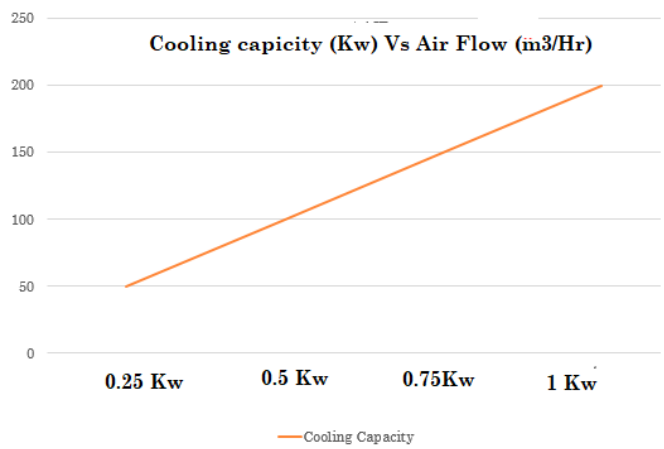
$Q = PIt$, where P is the Peltier coefficient, I is the current, and t is the time.

The Peltier coefficient depends on temperature and the materials the cooler is made of. Magnitude of 10 Watt per Ampere is common. But this is offset by two phenomena:

- According to Ohm's law, a Peltier module will produce wasted heat itself,

$Q_{waste} = RI^2t$, where R is the resistance.

Cooling Vs Air flow graph:-



Graph 1. Cooling Capacity VS Air flow

7. CONCLUSIONS & FUTURE SCOPE

From the Environmental point of view, this system is Eco-friendly as it involves the Peltier module which is not responsible for OZONE Layer Depletion. In this way, we can conclude technically that, higher COP can be obtained at low power input, thereby it reduces the energy consumption rate. It offers the following advantages with respect to the air conditioner:

- The primary advantages of a Peltier cooler compared to a vapor-compression refrigerator are its lack of moving parts or circulating liquid, very long life, invulnerability to leaks, small size, and flexible shape.
- Eco-friendly.
- Low Cost.
- Safety as no gas used.

7.1 Future Scope:

- Applicable for all Electric Vehicle where mechanical compressor is removed.
- Applicable for Domestic use as portable AC.
- From the Environmental point of view this system is Eco-friendly.

8. ACKNOWLEDGEMENT

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