Peltier Portable Refrigerator

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AB STR AC T

Coolers are usually very large and heavy as they consume a lot of electrical energy, so here introducing Peltier based small cooler. It is a small cooler that does not consume too much energy. A small cooler uses a Peltier effect with heat-sink, thermal isolator, supporting frame, switch, screws and joints to get the maximum cooling. The Peltier effect is the phenomenon that a potential difference applied across a thermocouple causes a temperature difference between the junctions of the different materials in the thermocouple. The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material. This phenomenon can be useful when it is necessary to transfer heat from one medium to another on a small scale.

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INTRODUCTION

PELTIER coolers are thermoelectric heat pumps that will produce a temperature gradient that is proportional to an applied current, temperature cycling, or cooling below ambient are required. There are many products using thermoelectric coolers, including CCDcameras (charge coupled device), laser diodes, microprocessors, blood analyzers and portable picnic coolers

The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material. This phenomenon can be useful when it is necessary to transfer heat from one medium to another on a small scale. The Peltier effect is one of three types of thermoelectric effect; the other two are the Seebeck effect and the Thomson effect. Thermoelectric effects have been discovered for more than 40years and many researchers have been concentrating on the investigations of improving the thermoelectric properties of materials [7,8]. In addition, optimizing the structure of thermoelectric devices based on thermal analysis is also an important way to improve the performances of TEG. Consequently, precise, complete description of the thermoelectric coupling process in the thermoelectric devices and analysis of the influence of various factors on the output index are vital for the amelioration of TEG's performance. So far, computation tools have been used to build one-dimensional [9,10] or three-dimensional [11,12] heat transfer model, and the performances of TEG can be obtained by solving electric potential distribution and temperature distribution. More recently, Kossyvakis et al.

Model validation

The proposed simulation models presented in Section 2 are first verified in terms of being complaint with the conservation of energy laws for all energy flow variables. For instance, convective heat transfers at the direct gas cooler and Peltier devices have been verified to equal that by specific enthalpy calculations. After this, the simulation model is then further verified by simulating the same scenario that was presented by Sarkar in [36] and comparing the corresponding COP results. Finally, the 1-D convective heat transfer model is verified in terms of mesh size independence.

Numerical method

A three-dimensional finite element model of the TEG1-127-1.4-1.6 TEG module is built in the commercial software ANSYS AIM. The governing equations mentioned above are solved in association with the boundary conditions. The dimensioning of the TEG module is 40mm×40mm×3.8mm (width×depth×length). And the module is composed of 127 pairs of thermocouples and the size of semiconductor grain is 1.4mm×1.4mm×1.6mm. Electrical connection is established through copper strips. The ceramic plates act as electric insulation and heat conduction. In addition, an external load resistor is electrically coupled with the electrodes of the TEG module in the present model. The grid systems and geometric structures of TEG are displayed in Fig. 1. Four different grids with total elements of grid i=100,984, grid ii=34,820, grid iii=17,779, grid iv=9388 are tested and compared

with each other to seek an appropriate grid system. In the four grid systems, the output power and conversion efficiency versus load resistance are calculated under the temperature of the hot side and cold side are 200°C and 30°C, respectively. The results show that the discrepancies among the curves of grid i, grid ii, grid iii are almost imperceptible. The maximum deviation between the results of grid ii and grid iii is less than 0.5%, while the results of grid iv differs greatly from others, which indicates that the grid iii system with 17,779 elements is proper for the simulation. Therefore, to save computation efforts without loss in accuracy, the grid iii is adapted. The materials' temperature-dependent properties are listed in Table 1. Boundary conditions have been set as follows: the load resistor iselectrically coupled with theelectrodes ofTEG. Constant temperature and convective heat transfer condition are applied directly to the TEG's hot and cold sides.

Results and discussion

The potential distributions when the hot side is 200°C and the cold side is 30°C are shown in Fig. 3(a). As can be seen, the direction of the potential growth is in line with the series of the thermoelements. The voltage across the load resistor is equal to TEG's positive and negative electrode voltages. Fig. 3(b) shows the temperature distributions for the corresponding conditions. As shown in Fig. 3(b), the internal temperature drop of the TEG model mainly occurs in the thermoelements. Fig. 4 presents the measured and simulated open-circuit voltage, internal resistance and output power of the TEG. The test temperature range and the results deviation are present in Table 2. The open-circuit voltage and internal resistance curves present linear behavior, whereas the output power increases parabolically with the increase of the temperature gradient between the two sides of the generator. The maximum relative deviation is less than 6%, which indicates that the numerical results present very good agreement with the experimental results. The contact thermal resistance caused by the gap between the module and heat exchanger may be one of the reasons for the deviations. The variations of the output power and conversion efficiency with load resistance, when the temperature of hot side is 200°C and that of the cold side is 30°C, are shown in Fig. 5. It can be seen that the output power and conversion efficiency increase initially and decrease afterward as the load resistance increases. The output power reached its maximum value (4.7W) as the load resistance is 3.6 Ω, and the conversion efficiency reached the maximum value (4.5%) when the load resistance is 4.5 Ω. As shown in Fig. 4(b), the internal resistance value of TEG is 3.5 Ω when working in this same temperature range. For lithium batteries, it is generally known that the highest output power is obtained when the load resistor is equal to the battery resistance, whereas the TEG does not comply with this rule. The inconsistency of the load and internal resistance when output power of TEG reaches the maximum is due to the Peltier effects produced by carrier transport, which increases the heat flow from the hot side to the cold side. Although the temperature of the TEG's cold and hot sides is kept constant, the additional heat flow makes the temperature difference between the ceramic plates and the semiconductor grains increase, which result in a reduction in the effective temperature difference of the TEG (the temperature difference between the hot end and the cold end of the thermoelements). Thus, increasing load resistance and decreasing current will lead to an increase in the voltage of TEG. Also, the output power increases correspondingly. Consequently, when output power of TEG reaches the maximum, the load resistance is greater than the internal resistance.

Peltier effect

The Peltier effect can be used to create a refrigerator that is compact and has no circulating fluid or moving parts. Such refrigerators are useful in applications where their advantages outweigh the disadvantage of their very low efficiency. The Peltier effect is also used by many thermal cyclers, laboratory devices used to amplify DNA by the polymerase chain reaction (PCR). PCR requires the cyclic heating and cooling of samples to specified temperatures. The inclusion of many thermocouples in a small space enables many samples to be amplified in parallel.

Peltier effect

The Peltier effect bears the name of Jean-Charles Peltier, a French physicist who in 1834 discovered the calorific effect of an electric current at the junction of two different metals. When a current is made to flow through the circuit, heat is evolved at the upper junction (at T2), and absorbed at the lower junction (at T1). The Peltier heat absorbed by the lower junction per unit.

where π is the Peltier coefficient ΠAB of the entire thermocouple, and ΠA and ΠB are the coefficients of each material. p-type silicon typically has a positive Peltier coefficient (though not above ~550 K), and n-type silicon is typically negative.

The Peltier coefficients represent how much heat current is carried per unit charge through a given material. Since charge current must be continuous across a junction, the associated heat flow will develop a discontinuity if ΠA and ΠB are different. This causes a non-zero divergence at the junction and so heat must accumulate or deplete there, depending on the sign of the current.

Another way to understand how this effect could cool a junction is to note that when electrons flow from a region of high density to a region of low density, this "expansion" causes cooling (as with an ideal gas).

The carriers are attempting to return to the electron equilibrium that existed before the current was applied by absorbing energy at one connector and releasing it at the other. The individual couples can be connected in series to enhance the effect.

An interesting consequence of this effect is that the direction of heat transfer is controlled by the polarity of the current; reversing the polarity will change the direction of transfer and thus the sign of the heat absorbed/evolved.

A Peltier cooler/heater or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other. Peltier cooling is also called thermoelectric cooling (TEC).

Thermoelectric cooling

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junction of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other side against the temperature gradient (from cold to hot), with consumption of electrical energy. Such an instrument is also called a Peltier device, Peltier heat pump, solid state refrigerator, or thermoelectric cooler (TEC). Because heating can be achieved more easily and economically by many other methods, Peltier devices are mostly used for cooling. However, when a single device is to be used for both heating and cooling, a Peltier device may be desirable. Simply connecting it to a DC voltage will cause one side to cool, while the other side warms. The effectiveness of the pump at moving the heat away from the cold side is dependent upon the amount of current provided and how well the heat can be removed from the hot side.

A Peltier cooler is the opposite of a thermoelectric generator. In a Peltier cooler, electric power is used to generate a temperature difference between the two sides of the device; while in a thermoelectric generator, a temperature difference between the two sides is used to generate electric power. The operation of both is closely related (both are manifestations of the thermoelectric effect), and therefore the devices are generally constructed from similar materials using similar designs.

Thermoelectric junctions are generally only around 5–10% as efficient as the ideal refrigerator (Carnot cycle), compared with 40–60% achieved by conventional compression cycle systems (reverse Rankine systems using compression/expansion). Due to the relatively low efficiency, thermoelectric cooling is generally only used in environments where the solid-state nature (no moving parts, maintenance-free) outweighs pure efficiency.

Peltier (thermoelectric) cooler 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.

Uses

Peltier devices are commonly used in camping and portable coolers and for cooling electronic components and small instruments. Some electronic equipment intended for military use in the field is thermoelectrically cooled. The cooling effect of Peltier heat pumps can also be used to extract water from the air in dehumidifiers.

Peltier elements are a common component in thermal cyclers, used for the synthesis of DNA by polymerase chain reaction (PCR), a common molecular biological technique which requires the rapid heating and cooling of the reaction mixture for denaturation, primer annealing and
enzymatic synthesis cycles.

The effect is used in satellites and spacecraft to counter the effect of direct sunlight on one side of a craft by dissipating the heat over the cold shaded side, whereupon the heat is dissipated by thermal radiation into space.

Photon detectors such as CCDs in astronomical telescopes or very high-end digital cameras are often cooled down with Peltier elements. This reduces dark counts due to thermal noise. A dark count is the event that a pixel gives a signal although it has not received a photon but rather mistook a thermal fluctuation for one. On digital photos taken at low light these occur as speckles (or "pixel noise").

Thermoelectric coolers can be used to cool computer components to keep temperatures within design limits without the noise of a fan, or to maintain stable functioning when overclocking. In fiber optic applications, where the wavelength of a laser or a component is highly dependent on temperature, Peltier coolers are used along with a thermistor in a feedback loop to maintain a constant temperature and thereby stabilize the wavelength of the device. A Peltier cooler with a heat sink or waterblock can cool a chip to well below ambient temperature.

Peltier devices are used in USB drink coolers/chillers, one of the latest addition to USB gadgets/toys. These devices are powered directly from the USB port and are said to keep drinks chilled, some can even keep drinks warm. The effectiveness of these devices, however, is highly questionable. The available power from a USB socket is very limited (maximum of 500 mA at 5 VDC for most situations, although high-power ports providing 1 amp or more do exist) so cooling or heating will be minimal (5-10% of 2.5 W).

Thermoelectric materials

Thermoelectric materials show the thermoelectric effect in a strong and/or convenient form. The thermoelectric effect refers to phenomena in which a temperature difference creates an electric potential or electric potential creates a temperature difference: Specifically, the Seebeck effect (temperature->current), Peltier effect (current->temperature), and Thomson effect (conductor heating/cooling). While all materials have a nonzero thermoelectric effect, in most materials it is too small to be useful. However, low cost materials that have a sufficiently strong thermoelectric effect (and other required properties) could be used.

CONCLUSION

A THREE-DIMENSIONAL TEG MODEL IS ESTABLISHED WHICH CONSISTS OF 127 PAIRS OF THERMOCOUPLES. TEMPERATURE DEPENDENT MATERIAL PROPERTIES WERE CONSIDERED IN THE ﬁNITE-ELEMENT MODEL, AND AN EXPERIMENTAL TEG SYSTEM IS BUILT UP TO VERIFY THE ACCURACY OF THE MODEL. THE OPEN CIRCUIT VOLTAGE, INTERNAL RESISTANCE AND OUTPUT POWER HAVE BEEN STUDIED BY COMPUTATIONAL AND EXPERIMENTAL METHODS. IN SUMMARY, THE SIMULATION RESULTS ARE IN GOOD AGREEMENT WITH THE EXPERIMENTAL DATA AND THE MAXIMUM DEVIATION IS LESS THAN 6%, WHICH PROVED THE ACCURACY OF THE PRESENT NUMERICAL MODEL. BASED ON THIS MODEL, THE INﬂUENCES OF PELTIER EﬀECT ON PERFORMANCES, TEMPERATURE DISTRIBUTION, AND EQUIVALENT THERMAL CONDUCTIVITY HAVEBEENINVESTIGATED. THEFOLLOWING CONCLUSIONS WERE REACHED: (1) THE LOAD RESISTANCE AND THE INTERNAL RESISTANCE ARE INCONSISTENT WHEN THE OUTPUT POWER OF TEG REACHES THE MAXIMUM. (2) THE HEAT ﬂOW IN TEG INCREASED BY 30.2% DUE TO THE PELTIER EﬀECTS. CONSEQUENTLY, THE EQUIVALENT THERMAL CONDUCTIVITY INCREASED BY 30.2% DUE TO THE INCREASE OF HEAT ﬂOW. (3) THE INﬂUENCE OF PELTIER EﬀECTS ON THE EﬀECTIVE temperature difference is limited when the temperature at the boundary is constant. (4) for convective heat transfer boundaries, the numerical results showed that the effective temperature difference was raised by 13.6°c (a 10.2% increase) and the maximum output power was raised by 0.59w (a 14.8% increase) for the TEG model with fin height of 100mm (Hfin5) compared with that without fins (Hfin1) when the output power reaches the maximum value. (5) the radio of load resistance to internal resistance increases from 1.14 to 1.34. the results of the model showed that the temperature distributions of TEG module are deeply influenced by the peltier effect. as a consequence, the influence of the peltier effect cannot be neglected in the study of heat transfer performance, especially when the heat transfer condition at the hot side is weak or the internal resistance of the TEG module is low.

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