Thermo-Comfort Cushion & Back Car Seat

Eduardo E. Castillo, Ph.D., Miguel Goenaga, Ph.D., Edwar Romero, Ph.D.
Universidad del Turabo, Puerto Rico, ecastillo@suagm.edu, mgoenaga@suagm.edu, eromero6@suagm.edu

Abstract*– This work explore the possibility to use the thermoelectric technology to create a device to effectively cold or heat the skin of the people in contact with a car seat; in addition, this device must be adaptable to the factory made seat. Initially one thermoelectric device was used with two computers heat sinks and blowers. Three different supply voltages for the blower were analyzed; while the power to the thermoelectric device was kept constant. The results shows no dependence of the air flows, suggesting a blower with lower capacity can be used. The coefficient of performance in the three cases was 0.32 which is still lower that the expected. The use of optimal heat sinks and the improvement of the contact resistances need to be explored.

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I. INTRODUCTION

In recent years the development of the thermoelectric materials has been of great interest because of its well-known advantages such as no moving parts, good stability, high reliability, environmental friendliness, and long operation life [1]–[3]. A thermoelectric device (TED) is a solid state device that converts a temperature difference into voltage or vice versa. TED can be used for cooling systems like water and wine coolers, computers chips, and lasers [4]. Fig. 1 shows a typical TED used as a cooler. Other applications are to generate power by using a heat source like solar radiation, human body or heat wasted from machinery, furnaces, etc [5]. Thermoelectrics used to generate power are based on the Seebeck effect and the ones employed for cooling are based on the Peltier effect [6].

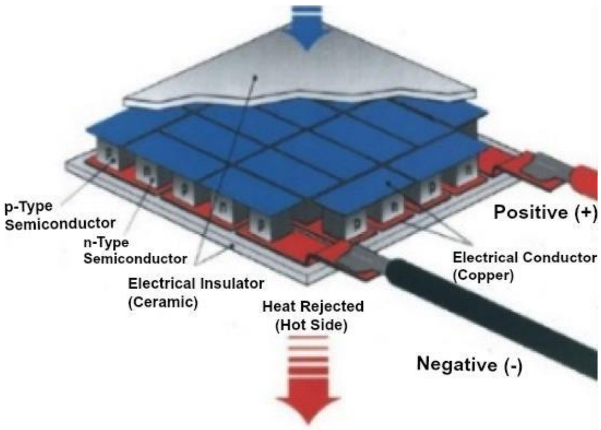

Fig. 1 Setup for a thermoelectric device, composed of two faces that are separated by the thermoelectric material, made up of p and n type semiconductors [7].

The Seebeck effect is the conversion of a temperature difference between two semiconductor materials to an electromotive force (voltage). As seen in Fig. 2, when an n-type and p-type thermoelectric materials are in electrical contact and their edges are exposed to a temperature difference, they generate a voltage. The Seebeck effect varies mainly by the temperature difference and depends on the material of the conductor used. A good example of this effect is the measurement of temperature by a thermocouple where the voltage is measured and correlated with the temperature.

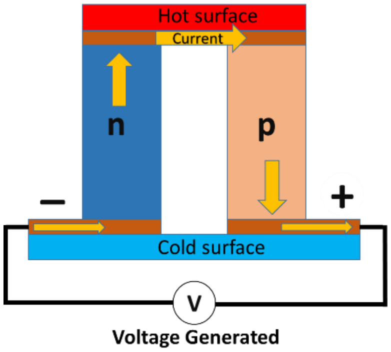

Fig. 2 Seebeck effect.

The Peltier effect is the presence of heating or cooling at the electrified junction of two different conductors. The Peltier effect states that when electric current flows through two dissimilar semiconductors, heat is removed or added at the junction points (see Fig. 3).

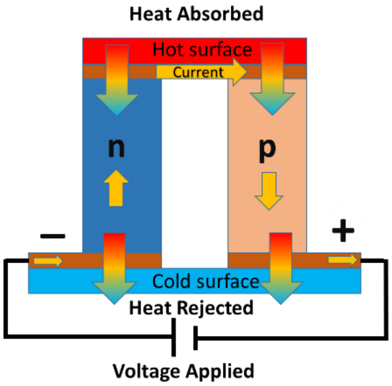

Fig. 3 Peltier effect

The energy conversion efficiency of a thermoelectric material is determined by the dimensionless figure of merit $ZT = -\sigma S^2T/k$, where S is the Seebeck coefficient, T is the absolute temperature, σ is the electrical resistivity, and k is the thermal conductivity. While bulk thermoelectric materials have ZT~1, nanostructured thermoelectric materials have received much attention during the last decade due to their potential for

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enhanced thermoelectric energy conversion efficiency. Most nanostructured materials of high ZT values are films on substrates.

II. METHODOLOGY

This research uses a commercially available car seat pad as is shown in Fig 4, which have internal air circulation ducts and exit holes in the surface in contact with the people. The original design of this pad draws ambient air under the seat and expulse that through the holes in the front of the pad. In that way, the air being conditioned by the air condition unit of the car and present under the seat is circulated near the skin of the people, causing only a slight better comfort. In addition, initially it will take several minutes to cool or heat the air if the car was in a very high or low temperature due to the weather conditions.

Fig. 4 Commercially available car seat pad used to distribute the air [8].

This work proposes to create a system to effectively cool or heat the air before being circulated into the pad. The system with the appropriate cooling/heating system for the air will be located under the seat. The air will enter to the system under the seat and exit from the pad by the holes at the front, enhancing the comfort of the people. The device must also be adaptable to the factory made car seats and the supplied power must to come from the car's battery.

Preliminary Calculations

In order to perform a better design, initially some calculations are necessary to have an idea of the expected results and to setup the appropriate parameters of the system. For this experiment, a thermoelectric device RC 12-6 from Marlow Inc. will be used, which have a ZT= 0.76 [9]. Fig. 5 shows the performance curves of the device from the manufacturer data sheet. That performance was determinate in a nitrogen ambient, a cold side of 27 °C, and with excellent both thermal and electrical contact resistances. According to the graphs, for a supply voltage of 12 V, a current of 4.5 A and 5.0 A will flow through the device, for zero heat transfer rate (Q) or zero temperature difference (ΔT), respectively. In addition, for a current of 4.5 A, approximately 42 W of heat load will be pumped from the cooling side of the TED, under a temperature difference of 10 °C between the cold and hot sides of the TED.

Then, the temperature drop, ΔT_c, in the cold air stream can be calculated from (1); assuming: 1) negligible thermal resistance at the heat sinks, 2) the total heat load, Q_c, of the TED is coming only from the air, 3) 20 CFM of cold air flow, $\dot{V}$, and 4) standard air density, ρ, of 1.2 kg/m^3.

$$Q_c = \rho \dot{V} \Delta T_c \tag{1}$$

Using the mentioned data, a temperature drop in the cold air stream of 3.6 °C was calculated. That will by the maximum temperature drop expected. However, actual conditions like the contact thermal resistant and experimental conditions will decrease the value significantly.

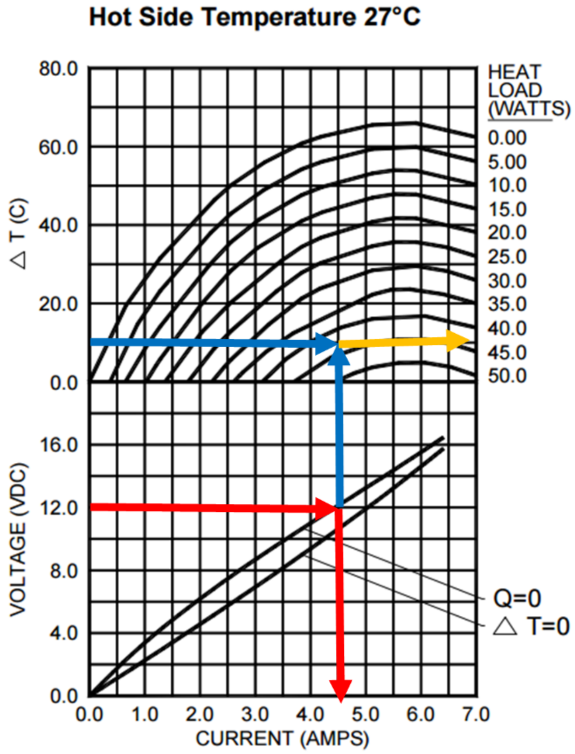


Fig. 5 Manufacturer data for the thermoelectric device RC 12-6 [9].

Experimental Setup

Initially, a proof of concept experiment has been prepared with non-optimal configuration. The idea is to prepare the measurement system and to validate the theoretical calculations. For now, only one cooling/heating channel is being tested without being connected to the car seat pad. Then, as a second step, this channel will be connected to the pad to determinate the flow and pressure drops and the actual temperature of the blowing air near to the people. Finally, the design will include the optimization of the heat sink, TED capacity and channel configuration.

A schematic of the proof of concept system is shown in Fig 6, where two blowers will force ambient air into the cooling and heating channels of the box. Air will pass through a heat sink where is cooled and then the air goes to the pad. In a similar way, air is circulated through the hot channel where is heated by the other heat sink and then is returned to the cabin. Changing the polarity of the TED will exchange its hot and cold surfaces. In that way, the upper channel in Fig. 6 will carry the heated air stream, which will goes to the pad, enabling the heating function of the device.

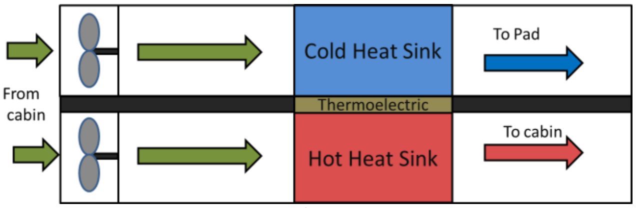


Fig. 6 Schematic of the cooling/heating system

A picture of the actual system can be seen in Fig 7. As is shown in the picture, the system consists of:

1. Four thermocouples type T were used to measure the temperature of the inlet and exit of the hot and cold air streams.
2. Two centrifugal blowers model BFB 1012H
3. Thermoelectric device RC 12-6 from Marlow Inc.
4. Two computer heat sinks. Material: 6063 aluminum alloy; with dimensions: 50×36×35 mm^3 for width, deep and tall, respectively.
5. A power supply model WV-12V, with a capacity of 12 V and 20A, to power the thermoelectric module.
6. A power supply Keithley 2030G-30-1 to power the centrifugal blowers.
7. A NI cDAQ-9174 chassis with a NI-9211 thermocouple module.

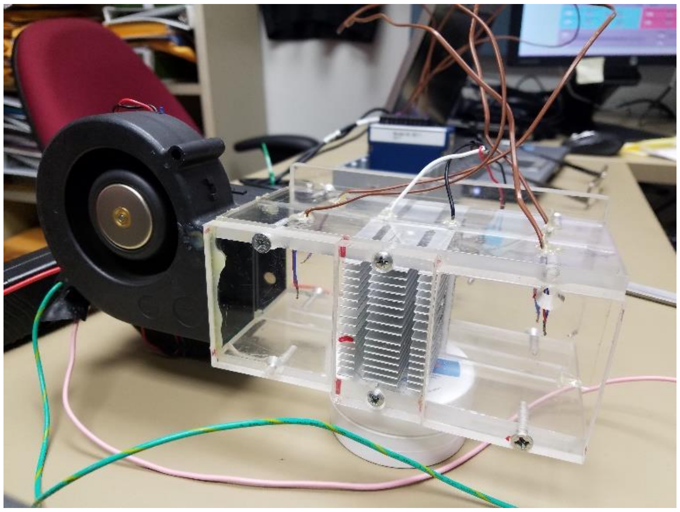


Fig. 7 Picture of the proof of concept system.

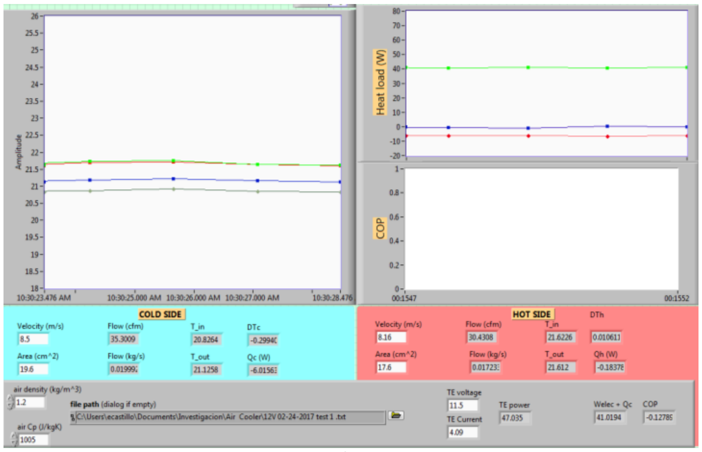
The channels were made in acrylic as in show in Fig. 7, and the dimensions (36×51×153 mm^3 for high, width and long, respectively) were chosen to exactly accommodate the bundle of the cold and hot heat sinks with the TED in the middle. Thermal grease was used in the contact areas between the TED and the heat sinks to improve the thermal contact resistance, and also a slight pressure was made with the screws of the cover of the bundle.

The exit area of the two air streams was divided into three equal parts, and the air velocity was measured in each part by an HHF81 anemometer. Then, the average velocity, and volumetric flow in the channel were calculated. The data for the three supply voltages in the blowers is shown Table 1. The flow in the two channels are no exactly equal under the same air velocity due to small differences in the actual channels dimensions.

Table 1 Flow characterization for three voltages supply in the blowers: 6, 9 and 12 V.

Voltage (V)	6	9	12
Hot air velocity (m/s)	5.1	6.9	8.2
Cold air velocity (m/s)	4.8	6.9	8.5
Hot air flow (CFM)	19	26	32
Cold air flow (CFM)	20	29	37
Current (A)	0.7	1.2	1.8
Power (W)	3.9	10.5	21.1

A LabView code was prepared to evaluate the performance of the system, as is shown in Fig. 8. The temperature of the cold and hot air streams at the inlet and exit was tracked in real time since the system was turned on. Also, the electrical power consumed by the TED and by the blowers was tracked. The code also calculates the heat transfer rate from/to the air and the coefficient of performance (COP) of the system.



COLD SIDE

Velocity (m/s): 8.5
Flow (cfm): 35.3009
T_in: 20.8264
DTc: -0.2994
Area (cm^2): 19.6
Flow (kg/s): 0.01999
T_out: 21.1258
Qc (W): -6.0156

HOT SIDE

Velocity (m/s): 8.16
Flow (cfm): 30.4308
T_in: 21.6226
DTh: 0.01061
Area (cm^2): 17.6
Flow (kg/s): 0.0172
T_out: 21.612
Qh (W): -0.1837

air density (kg/m^3): 1.2
air Cp (J/kgK): 1005
file path (dialog if empty): C:\Users\ecastillo\Documents\Investigacion\Air Cooler\12V 02-24-2017 test 1 .txt
TE voltage: 11.5
TE Current: 4.09
TE power: 47.035
Welec + Qc: 41.0194
COP: -0.1278

Fig. 8 Front Panel of the LabView code

III. Results

As was mentioned before, three different voltages (6, 9 and 12 V) were used in the blowers under the same power applied to the TED. The purpose for that was to test the influence of the blower capacity (CFM) on the temperatures and COP of the system. In a future study, the power applied to the TED will also be analyzed. Fig. 9 shows the temperature behavior of the inlet and outlet of both air streams, for the 12 V case. Initially, the temperature was measured with the blowers and the TED off. That approach is to analyze the initial temperatures and any offset in the system.

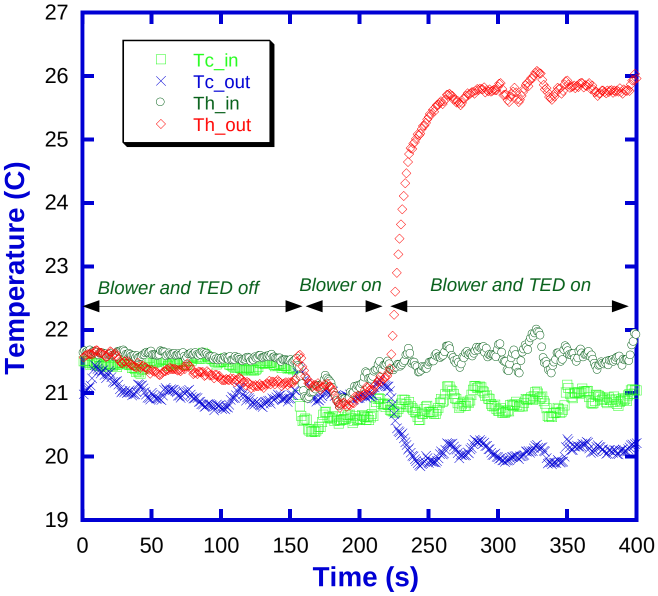


Fig. 9 Temperature profile for 12 V of power supply in the blower. T_c and T_h are the temperatures of the cold and hot air streams, respectively.

As is show in the graph, initially with the power off, the inlet temperatures are different to the outlet temperatures. That is because the outlet chamber is more exposed to the room ambient than the inlet part, as is shown in Fig. 7. Then, the blowers were turned on, and all the temperatures decrease due to the chilling effect of the air circulation. That chilling effect will be similar to the one experimented in the original design of the car seat pad as was mentioned before. Finally, the TED was turned on and the outlets temperatures changed very fast until reach the steady state.

Fig. 10 shows the temperature difference between the inlet and outlet for the cold air stream (ΔT_c) and for the hot air stream (ΔT_h), for the case of 12 V. Positive and negative values indicate cooling and heating the air streams, respectively. The first 230 seconds, approximately, shown the behavior before the TED were turned on, as was mentioned before. For this case the cooling effect was 0.83 ºC while the heating effect was 4.22 ºC.

Fig. 11 shows the cooling load for the three voltages. As it can see, the steady cooling load is approximately the same for the three cases, suggesting that we can use a blower with a smaller capacity. But, the pressure drop in the car seat pad will reduce the flow, requiring a blower with a high capacity and that will be considered in a future study.

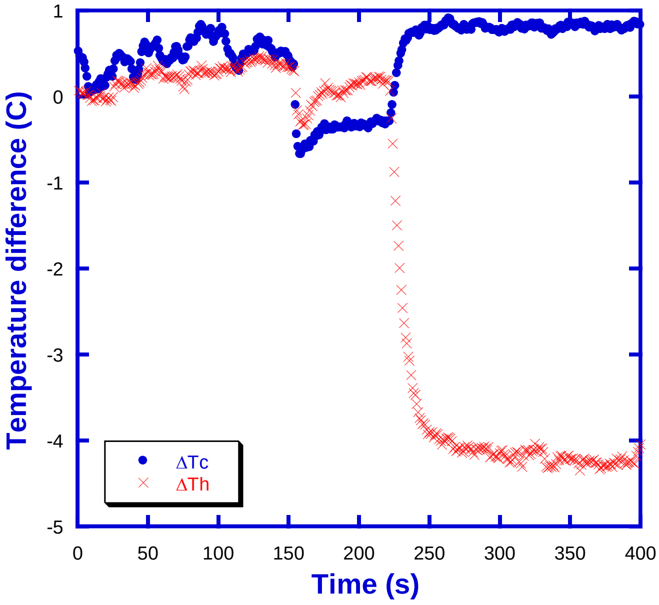


Fig. 10 Temperature profile for 12 V in the blower. T_c and T_h are the temperatures of the cold and hot air streams, respectively. Negative values mean heating.

Because the power applied to the TED was the same and the cooling load was almost the same, the COP based on the TED power was approximately 0.32 for all the cases. This lower that the COP founded in the literature of 0.5-0.8 [1], [10]. Then, this system need to be optimized, which will be the goal for futures studies.

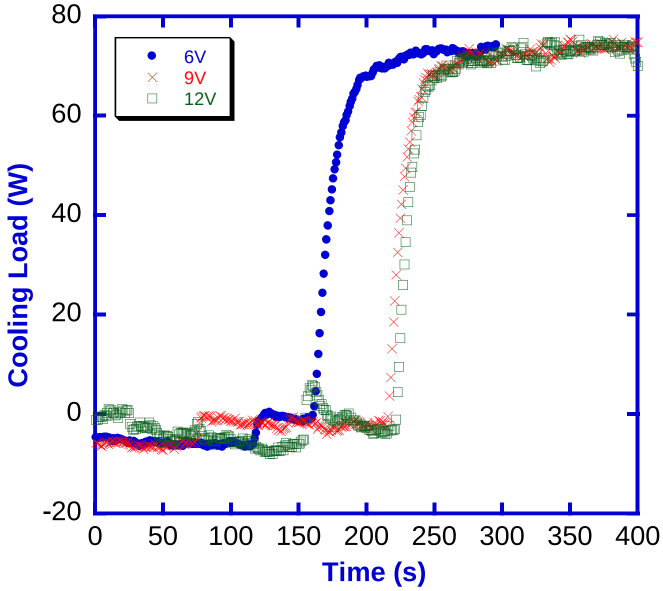


Fig. 11 Cooling load measured in the cold air stream for the three cases.

Finally, Table 2 summarizes the cases analyzed for different applied voltage to the blower. It can be seen that as the voltage increases the temperature difference in both flows decreases. That is because the mass air flow increases and there is not enough time to allow a bigger heat transfer in the heat sinks. The cooling load is almost constant for these cases studied as well as the coefficient of performance, suggesting that a blower with less capacity can be used.

Table 2 Summarize of the results for the three voltages analyzed.

Blower Voltage (V)	**6**	**9**	**12**
Hot flow (cfm)	19	26	32
Cold flow (cfm)	20	29	37
Cold Temp. diference (C)	1.30	1.01	0.83
Hot Temp. diference (C)	6.70	5.02	4.22
Cooling Load (W)	16	17	17
Heating Load (W)	72	72	75
Cooling COP	0.31	0.32	0.32

IV. CONCLUSIONS

In this work, the performance of a cooler/heater device for a car seat pad was analyzed. The results showed a very fast response of the device to cool or heat the air flowing to the pad, which is one of the advantages of the proposed system, compared with air condition of the car under extreme temperature. For an ideal case with 20 CFM, the predicted temperature difference (3.6°C) was about three times the measured one, for the cooling load. That will be due to the high thermal resistances in the heat sinks and the actual heat losses.

Also, the coefficient of performance was almost constant for the studied cases, suggesting that a blower smaller blower can be used.

V. FUTURE WORK

This work was the initial step of the research, where a proof of concept setup was developed, including the measurement system. Next steps will be:

- Test the setup for different power applied to the TED.
- Test this setup with the car seat pad to test the actual temperature of the air close blowing at the exit holes.
- Test an optimize the heat sink for a better heat transfer rate with less energy losses
- Use a TED with bigger cooling load. That will include taller TE elements inside the TED, bigger area or in a cascade configuration.

REFERENCES

[1] L. E. Bell, “Cooling, heating, generating power, and recovering waste heat with thermoelectric systems,” *Sci.*, vol. 321, no. 5895, pp. 1457–1461, Sep. 2008.

[2] G. Chen, “Nanoscale heat transfer and nanostructured,” *IEEE Trans. Compon. Packag. Technol.*, vol. 29, no. 2, pp. 238–246, 2006.

[3] D. Kraemer, B. Poudel, H.-P. Feng, J. C. Caylor, B. Yu, X. Yan, Y. Ma, X. Wang, D. Wang, A. Muto, K. McEnaney, M. Chiesa, Z. Ren, and G. Chen, “High-performance flat-panel solar thermoelectric generators with high thermal concentration.,” *Nat. Mater.*, vol. 10, no. 7, pp. 532–538, 2011.

[4] H. Xi, L. Luo, and G. Fraisse, “Development and applications of solar-based thermoelectric technologies,” *Renew. Sustain. Energy Rev.*, vol. 11, no. 5, pp. 923–936, Jun. 2007.

[5] R. Amatya and R. J. Ram, “Solar thermoelectric generator for micropower applications,” *J. Electron. Mater.*, vol. 39, no. 9, pp. 1735–1740, 2010.

[6] E. E. Castillo, C. L. Hapenciuc, and T. Borca-Tasciuc, “Thermoelectric characterization by transient Harman method under nonideal contact and boundary conditions,” *Rev. Sci. Instrum.*, vol. 81, pp. 1–10, 2010.

[7] “https://www.thermtest.com/thermo-electric.”

[8] “https://viotek.com/shop/viotek-cooling-car-seat-cushions-v2/.”

[9] “http://www.marlow.com/thermoelectric-coolers/single-stage/rc12-6-01ls.html.”

[10] H. S. Choi, S. Yun, and K. i. Whang, “Development of a temperature-controlled car-seat system utilizing thermoelectric device,” *Appl. Therm. Eng.*, vol. 27, no. 17–18, pp. 2841–2849, 2007.