Research Article

Composite Materials Based on Henequen Fiber as a Thermal Barrier in the Automotive Sector


¹Universidad Tecnológica de San Juan del Río, Col. Vista Hermosa, San Juan del Río, 76800 Querétaro, Mexico
²CONACYT—Universidad Tecnológica de San Juan del Río, Col. Vista Hermosa, San Juan del Río, 76800 Querétaro, Mexico
³Centro de Investigación en Materiales Avanzados, Complejo Industrial Chihuahua, 31091 Chihuahua, Mexico
⁴Universidad de La Salle Bajío, Escuela de Ingeniería, Av. Universidad 602, Col. Lomas del Campestre, 37150 León, Guanajuato, Mexico
⁵Centro de Investigación y Desarrollo Tecnológico en Electroquímica, Parque Tecnológico Querétaro, 76703 Querétaro, Mexico
⁶Centro de Física Aplicada y Tecnología Avanzada, Universidad Nacional Autónoma de México, Boulevard Juriquilla, 76230 Querétaro, Mexico

Correspondence should be addressed to J. M. Olivares-Ramírez; jmolivar01@yahoo.com and A. Doctor; andres_dector@live.com

Received 5 February 2019; Revised 6 March 2019; Accepted 10 March 2019; Published 14 July 2019

Academic Editor: Gang Zhang

Copyright © 2019 J. M. Olivares-Ramírez et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Currently, the automotive industry has made great advances in the incorporation of materials such as carbon fiber in high-performance cars. One of the main problems of these vehicles is warming, which is generated inside due to the heat transfer produced by solar radiation falling on the car, mainly on the roof. This research proposes the preparation of a composite material containing henequen natural fiber as a thermal barrier to be used as the roof of the car. In this research, 35 different laminates of 5 layers were prepared, combining carbon fiber, henequen natural fiber, fiberglass, and additives such as resin + Al₂O₃ or resin + Al. Reference samples were taken from stainless steel and one reference sample was extracted from the roof of the car. Considering the solar radiation and the heat transfer mechanisms, the temperature of the surface exposed to solar radiation was determined. The thermal conductivity of the 37 samples was determined, and the experimental results showed that the thermal conductivity of the steel with which the roof of the car is manufactured was 13.43 W·m⁻¹·K⁻¹ and that of the proposed laminate was 5.22 W·m⁻¹·K⁻¹, achieving a decrease in the thermal conductivity by 61.13%. Using the temperature and thermal conductivity data, the simulation (ANSYS) of the thermal system was performed. The results showed that the temperature inside the car with the carbon steel, which is currently used to manufacture high-performance cars, would be 62.34°C, whereas that inside the car with the proposed laminate would be 44.96°C, achieving a thermal barrier that allows a temperature difference of 17.38°C.

1. Introduction

The current technological breakthrough in many areas of research and industry has opened the need to look for new materials that have greater benefits than the materials that are commonly used in different applications. In this context, researchers from all over the world have innovated different material systems. Composites being one of the most prominent material systems. These composites are made of two or more constituents [1], bringing as a consequence that each composite offers unique advantages by complementing each constituent with another.

For example, the incorporation of polymeric resins, metals, or metal oxides into matrices based on carbon fiber,
fiberglass, and even natural fibers has advantages in hardness, tensile strength, modulus of elasticity, and other mechanical properties. In addition, other properties can be decreased and/or improved such as thermal conductivity, the coefficient of thermal expansion, the coefficient of friction, wear resistance, corrosion, and fatigue resistance [2, 3].

Currently, in the automotive and aeronautical industries, thermomechanical properties have acquired great importance due to the different components used in these systems. In this sense, composites based on graphene, carbon fiber, fiberglass, and natural fibers have explored new applications in these two areas ranging from the manufacture of parts that constitute the external or internal structure of automobiles and aircraft and the electronic application that helps to protect and, at the same time, dissipate the heat [4–11].

Carbon fiber is considered one of the coal-based materials with excellent mechanical properties and chemical stability. Normally, this material contains 92 wt.% of carbon in each of its fibers [12]. These fibers offer very good mechanical and physical properties [13–16], for example, high tension (2–7 GPa) by having a remarkable Young modulus (200–900 GPa), low density (1.75–2.20 g·cm⁻³), low thermal expansion, and excellent electrical conductivity and thermal conductivity (800 W m⁻¹K⁻¹) [8, 17–21]. In addition, carbon fiber is not only four times lighter than steel but also stronger than steel [22]. All these characteristics are the main reason that carbon fiber is used to develop lightweight composites for structural applications in the automotive and aeronautical areas [23–27].

On the contrary, fiberglass has been widely used and studied for a long time as a matrix in the manufacture of composites. One of its main advantages is the cost due to the high demand for use.

It has not been the same case for the use of natural fibers in the formation of composites, since this case is relatively new and is still being explored by researchers in the area. However, the purpose of adding natural fibers in the formation of composites has been quite attractive because it considerably reduces the density of materials with excellent mechanical properties and chemical stability. Normally, this material contains 92 wt.% of carbon in each of its fibers [12]. These fibers offer very good mechanical and physical properties [13–16], for example, high tension (2–7 GPa) by having a remarkable Young modulus (200–900 GPa), low density (1.75–2.20 g·cm⁻³), low thermal expansion, and excellent electrical conductivity and thermal conductivity (800 W m⁻¹K⁻¹) [8, 17–21]. In addition, carbon fiber is not only four times lighter than steel but also stronger than steel [22]. All these characteristics are the main reason that carbon fiber is used to develop lightweight composites for structural applications in the automotive and aeronautical areas [23–27].

On the contrary, fiberglass has been widely used and studied for a long time as a matrix in the manufacture of composites. One of its main advantages is the cost due to the high demand for use.

It has not been the same case for the use of natural fibers in the formation of composites, since this case is relatively new and is still being explored by researchers in the area. However, the purpose of adding natural fibers in the formation of composites has been quite attractive because it considerably reduces the density of materials with excellent mechanical properties and chemical stability. Normally, this material contains 92 wt.% of carbon in each of its fibers [12]. These fibers offer very good mechanical and physical properties [13–16], for example, high tension (2–7 GPa) by having a remarkable Young modulus (200–900 GPa), low density (1.75–2.20 g·cm⁻³), low thermal expansion, and excellent electrical conductivity and thermal conductivity (800 W m⁻¹K⁻¹) [8, 17–21]. In addition, carbon fiber is not only four times lighter than steel but also stronger than steel [22]. All these characteristics are the main reason that carbon fiber is used to develop lightweight composites for structural applications in the automotive and aeronautical areas [23–27].

Carbon fiber is considered one of the coal-based materials with excellent mechanical properties and chemical stability. Normally, this material contains 92 wt.% of carbon in each of its fibers [12]. These fibers offer very good mechanical and physical properties [13–16], for example, high tension (2–7 GPa) by having a remarkable Young modulus (200–900 GPa), low density (1.75–2.20 g·cm⁻³), low thermal expansion, and excellent electrical conductivity and thermal conductivity (800 W m⁻¹K⁻¹) [8, 17–21]. In addition, carbon fiber is not only four times lighter than steel but also stronger than steel [22]. All these characteristics are the main reason that carbon fiber is used to develop lightweight composites for structural applications in the automotive and aeronautical areas [23–27].

On the contrary, fiberglass has been widely used and studied for a long time as a matrix in the manufacture of composites. One of its main advantages is the cost due to the high demand for use.

It has not been the same case for the use of natural fibers in the formation of composites, since this case is relatively new and is still being explored by researchers in the area. However, the purpose of adding natural fibers in the formation of composites has been quite attractive because it considerably reduces the density of materials with excellent mechanical properties and chemical stability. Normally, this material contains 92 wt.% of carbon in each of its fibers [12]. These fibers offer very good mechanical and physical properties [13–16], for example, high tension (2–7 GPa) by having a remarkable Young modulus (200–900 GPa), low density (1.75–2.20 g·cm⁻³), low thermal expansion, and excellent electrical conductivity and thermal conductivity (800 W m⁻¹K⁻¹) [8, 17–21]. In addition, carbon fiber is not only four times lighter than steel but also stronger than steel [22]. All these characteristics are the main reason that carbon fiber is used to develop lightweight composites for structural applications in the automotive and aeronautical areas [23–27].

On the contrary, fiberglass has been widely used and studied for a long time as a matrix in the manufacture of composites. One of its main advantages is the cost due to the high demand for use.

It has not been the same case for the use of natural fibers in the formation of composites, since this case is relatively new and is still being explored by researchers in the area. However, the purpose of adding natural fibers in the formation of composites has been quite attractive because it considerably reduces the density of materials with excellent mechanical properties and chemical stability. Normally, this material contains 92 wt.% of carbon in each of its fibers [12]. These fibers offer very good mechanical and physical properties [13–16], for example, high tension (2–7 GPa) by having a remarkable Young modulus (200–900 GPa), low density (1.75–2.20 g·cm⁻³), low thermal expansion, and excellent electrical conductivity and thermal conductivity (800 W m⁻¹K⁻¹) [8, 17–21]. In addition, carbon fiber is not only four times lighter than steel but also stronger than steel [22]. All these characteristics are the main reason that carbon fiber is used to develop lightweight composites for structural applications in the automotive and aeronautical areas [23–27].

On the contrary, fiberglass has been widely used and studied for a long time as a matrix in the manufacture of composites. One of its main advantages is the cost due to the high demand for use.

It has not been the same case for the use of natural fibers in the formation of composites, since this case is relatively new and is still being explored by researchers in the area. However, the purpose of adding natural fibers in the formation of composites has been quite attractive because it considerably reduces the density of materials with excellent mechanical properties and chemical stability. Normally, this material contains 92 wt.% of carbon in each of its fibers [12]. These fibers offer very good mechanical and physical properties [13–16], for example, high tension (2–7 GPa) by having a remarkable Young modulus (200–900 GPa), low density (1.75–2.20 g·cm⁻³), low thermal expansion, and excellent electrical conductivity and thermal conductivity (800 W m⁻¹K⁻¹) [8, 17–21]. In addition, carbon fiber is not only four times lighter than steel but also stronger than steel [22]. All these characteristics are the main reason that carbon fiber is used to develop lightweight composites for structural applications in the automotive and aeronautical areas [23–27].

On the contrary, fiberglass has been widely used and studied for a long time as a matrix in the manufacture of composites. One of its main advantages is the cost due to the high demand for use.

It has not been the same case for the use of natural fibers in the formation of composites, since this case is relatively new and is still being explored by researchers in the area. However, the purpose of adding natural fibers in the formation of composites has been quite attractive because it considerably reduces the density of materials with excellent mechanical properties and chemical stability. Normally, this material contains 92 wt.% of carbon in each of its fibers [12]. These fibers offer very good mechanical and physical properties [13–16], for example, high tension (2–7 GPa) by having a remarkable Young modulus (200–900 GPa), low density (1.75–2.20 g·cm⁻³), low thermal expansion, and excellent electrical conductivity and thermal conductivity (800 W m⁻¹K⁻¹) [8, 17–21]. In addition, carbon fiber is not only four times lighter than steel but also stronger than steel [22]. All these characteristics are the main reason that carbon fiber is used to develop lightweight composites for structural applications in the automotive and aeronautical areas [23–27].

On the contrary, fiberglass has been widely used and studied for a long time as a matrix in the manufacture of composites. One of its main advantages is the cost due to the high demand for use.

It has not been the same case for the use of natural fibers in the formation of composites, since this case is relatively new and is still being explored by researchers in the area. However, the purpose of adding natural fibers in the formation of composites has been quite attractive because it considerably reduces the density of materials with excellent mechanical properties and chemical stability. Normally, this material contains 92 wt.% of carbon in each of its fibers [12]. These fibers offer very good mechanical and physical properties [13–16], for example, high tension (2–7 GPa) by having a remarkable Young modulus (200–900 GPa), low density (1.75–2.20 g·cm⁻³), low thermal expansion, and excellent electrical conductivity and thermal conductivity (800 W m⁻¹K⁻¹) [8, 17–21]. In addition, carbon fiber is not only four times lighter than steel but also stronger than steel [22]. All these characteristics are the main reason that carbon fiber is used to develop lightweight composites for structural applications in the automotive and aeronautical areas [23–27].

On the contrary, fiberglass has been widely used and studied for a long time as a matrix in the manufacture of composites. One of its main advantages is the cost due to the high demand for use.
In order to know the temperatures of the hot surface of each laminate, thermographies were made in these surfaces.

2.4. Simulation. In the present investigation, ANSYS workbench was used in “Steady-State Thermal” module to quantify the thermal behavior of the system.

The thermal behavior is analyzed by conservation of energy (from the first law of thermodynamics for a control volume) applied to this system as well as any system with heat transfer or energy exchange. The element equation for the analysis [51] is as follows:

\[ [K][T] = [Q], \tag{1} \]

where \([K]\) is the thermal conductivity matrix, \([T]\) is the column vector of nodal temperatures, and \([Q]\) is the column vector of nodal heat fluxes. The complete system is represented in Figure 1(a). The surfaces considered to have the greatest

<table>
<thead>
<tr>
<th>Additive</th>
<th>Laminates</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF CF CF CF CF CF 14</td>
<td>CF CF CF CF CF CF 15</td>
<td>Al2O3</td>
</tr>
<tr>
<td>CF CF NHF CF NHF CF 16</td>
<td>NHF CF NHF CF NHF CF 17</td>
<td>Al</td>
</tr>
<tr>
<td>CF CF GF CF CF CF 18</td>
<td>CF CF GF CF CF CF 19</td>
<td></td>
</tr>
<tr>
<td>GF CF CF GF CF GF 20</td>
<td>GF CF CF NHF GF GF 21</td>
<td></td>
</tr>
<tr>
<td>NHF CF GF CF NHF GF 22</td>
<td>NHF CF GF CF NHF GF 23</td>
<td></td>
</tr>
<tr>
<td>GF NHF CF NHF GF GF 24</td>
<td>GF NHF CF NHF GF GF 25</td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>CF CF CF CF CF 26</td>
<td>Al2O3</td>
</tr>
<tr>
<td>CF CF NHF CF CF CF 27</td>
<td>CF CF NHF CF CF CF 28</td>
<td>Al</td>
</tr>
<tr>
<td>CF CF NHF CF NHF CF 29</td>
<td>CF CF NHF CF NHF CF 30</td>
<td></td>
</tr>
<tr>
<td>GF CF CF GF CF GF 31</td>
<td>GF CF CF NHF GF GF 32</td>
<td></td>
</tr>
<tr>
<td>NHF CF GF CF NHF GF 33</td>
<td>NHF CF GF CF NHF GF 34</td>
<td></td>
</tr>
<tr>
<td>GF NHF CF NHF GF GF 35</td>
<td>GF NHF CF NHF GF GF 36</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Laminate configuration: carbon fiber (CF), glass fiber (GF), and natural henequen fiber (NHF).

In Figure 1, a mesh is shown which consists of three parts: (a) system surfaces, (b) surfaces considered for heat transfer, and (c) mesh volume.
interaction in heat transfer are those shown in Figure 1(b). In the systems to be evaluated, two materials are built: The first one is shown in Figure 1(b), which is representative of the laminate constructed with CF or GF or NHF, and its input variable for the simulation was the thermal conductivity obtained experimentally. The second is the air that surrounds the laminate, and its thermal conductivity was obtained from the ANSYS database. Finally, in Figure 1(c), the meshing of the...
system is shown considering a body sizing of $8 \times 10^{-2}$ m for the bonnet, roof, and both rear doors, $6 \times 10^{-2}$ m for both front doors and boot, and $7 \times 10^{-2}$ m for air.

### 3. Results and Discussion

The solar radiation was 981 W·m$^{-2}$ at an ambient temperature of 32.2°C, which is relatively high. The surface temperature of the car increases due to solar radiation, and the temperature was particularly high considering that May 31, 2018, was one of the hottest days. Then, the main heat transfer is by convection, considering steady state, unidirectional flow, and a convective constant of air of 20.5 W·m$^{-2}$·K$^{-1}$. So, on the basis of these data, the theoretical temperature on the surface was 80°C.

For the determination of the thermal behavior of the laminates, each laminate was exposed to the hot surface (80°C, the theoretical value of the surface), on the back part of the laminate, and the temperature values of the upper part of the surface are shown in Figure 2. Figure 2(a) shows the results of the thermal behavior for the laminates described in Section 2, with all the possible combinations of laminates (Table 1). It was considered that the heat transfer of the experiment was by conduction. Figure 2(b) shows the thermal behavior, considering all laminates manufactured with CF, NHF, and the reference laminates (samples 36 and 37). The highest heat transfer was found in samples 1, 25, and 14, which were laminates manufactured only with CF. The highest thermal resistance that was the objective of the investigation was present in samples 15, 27, and 28 that did not contain additives (Al$_2$O$_3$ or Al). The additive Al$_2$O$_3$ increases the thermal conductivity more than the Al, as with sample 1 (containing Al$_2$O$_3$) a temperature of 70.04°C and with sample 14 (containing Al) a temperature of 69.4°C were recorded. By grouping the results of the CF, NHF, and GF laminates (Figure 2(c)), the one with the highest thermal resistance is sample 34, which contains laminated GF at the ends. Again, the observed phenomenon was that the Al$_2$O$_3$ additive improved thermal conductivity. Figure 2(d) is for CF and GF laminates, where the highest thermal resistance was for sample 6, which contained three layers of CF and two layers of GF.

Figure 2(e) shows the thermal behavior considering that all the laminates contained the additive Al$_2$O$_3$. The results show that the greater the number of CF layers, the greater the thermal conductivity (sample 1) and that the best thermal barrier is the combination of sample 13 that contains CF, GF, and NHF. Now, grouping the laminates containing Al (Figure 2(f)) confirms that the highest thermal conductivity occurs in laminates containing CF (sample 14) and the highest thermal resistance occurs with CF, GF, and NHF laminates (sample 24). Considering the laminates that were embedded only in the resin (Figure 2(g)), the highest thermal resistance is present in sample 28. If the materials that exceed the thermal conductivity of stainless steel are considered (Figure 2(h)), the laminate of sample 1 would be indicated to simulate. The best laminates that behave as a thermal barrier, taken as reference sample 36 (Figure 2(i)), were samples 28, 27, and 34. Sample 34 contains glass fibers, and then it would be advisable not to consider this as a more ecological laminate than that containing only CF and NHF. The results of the thermal conductivity are shown in Table 2, which correspond to the laminates that are considered as thermal barriers shown in Figure 2(i).

The simulated temperature profiles are shown in Figure 3, considering the conductivity results for samples 5, 17, 28, 31, 36, and 37, with the results of the average temperature on the upper surface, given each sample at 120s.

In the processing of data for decision making, there are simulation tools that are very important to use, before building a final prototype. Sample 37 recorded an experimental temperature average of 73.92°C at 120 s (Figure 2), and the results of the simulation (Figure 3(a)) show a temperature of 73.87°C, close to the experimental value. For samples 36, 17, 31, 5, and 28, the experimental temperatures were 66.73°C, 63.20°C, 61.02°C, 59.20°C, and 51.79°C (Figure 2), respectively. The temperatures obtained in the simulation were 67.12°C, 63.66°C, 61.22°C, 59.37°C, and 51.53°C, respectively. Also, the values for the simulations were very close to those of the experimental ones. Considering the material from which the roof of a car is manufactured, the internal temperature would be 62.34°C (Figure 3(a)). If the material used was stainless steel (sample 36), the air inside the car would be 57.09°C (Figure 3(b)). The temperature decreases to 54.40°C (Figure 3(c)), when using NHF/CF/NHF/CF/NHF mixed with Al due to the insertion of the NHF. In the case of having a laminate of GF/CF/GF/GF/GF, the temperature was 52.51°C (Figure 3(d)) by the insertion of the GF. Then, having an additive of Al$_2$O$_3$ in a CF/CF/GF/CF/GF laminate allows having a temperature of 51.06°C (Figure 3(e)).

### Table 2: Thermal conductivities of the laminates, inferior to the thermal conductivity of sample 36.

<table>
<thead>
<tr>
<th>Sample</th>
<th>K/W·m$^{-1}$·K$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.41</td>
</tr>
<tr>
<td>5</td>
<td>7.13</td>
</tr>
<tr>
<td>11</td>
<td>7.09</td>
</tr>
<tr>
<td>12</td>
<td>9.17</td>
</tr>
<tr>
<td>13</td>
<td>6.69</td>
</tr>
<tr>
<td>15</td>
<td>27.58</td>
</tr>
<tr>
<td>17</td>
<td>9.58</td>
</tr>
<tr>
<td>19</td>
<td>12.66</td>
</tr>
<tr>
<td>20</td>
<td>7.88</td>
</tr>
<tr>
<td>22</td>
<td>11.44</td>
</tr>
<tr>
<td>24</td>
<td>7.47</td>
</tr>
<tr>
<td>26</td>
<td>7.90</td>
</tr>
<tr>
<td>27</td>
<td>6.41</td>
</tr>
<tr>
<td>28</td>
<td>5.22</td>
</tr>
<tr>
<td>29</td>
<td>10.02</td>
</tr>
<tr>
<td>31</td>
<td>8.26</td>
</tr>
<tr>
<td>32</td>
<td>9.40</td>
</tr>
<tr>
<td>33</td>
<td>6.77</td>
</tr>
<tr>
<td>34</td>
<td>6.60</td>
</tr>
<tr>
<td>35</td>
<td>7.41</td>
</tr>
<tr>
<td>36</td>
<td>12.90</td>
</tr>
<tr>
<td>37</td>
<td>13.43</td>
</tr>
</tbody>
</table>

*Better thermal barrier.*
Finally, the best thermal barrier was the laminate built with NHF/CF/NHF/CF/NHF (Figure 3(f)), registering an operating temperature of 44.96°C due to the NHF; that is, it allows generating a temperature difference of 17.37°C inside the car.

© The morphology of the materials used is shown in Figure 4(a), where the best thermal barrier was obtained with sample 28 that was formed with NHF/CF/NHF/CF/NHF, as shown in Figure 4(b). The evaluation of morphology was made using scanning electron microscopy as shown in Figure 4(c). The three white parts (edges and center) are NHF, and the dark part in the center of the NHF is the CF, which are homogeneously integrated into a piece. Increasing the magnification to 300x, the NHF is shown in Figure 4(d), and the results of the elemental composition were obtained by energy-dispersive X-ray spectroscopy (EDS). The NHF has an elongated laminar morphology, similar to the CF shown in Figure 4(e). The lamination of the roof was formed by Fe (87.28 wt.%) and C (12.72 wt.%).

4. Conclusions

The interesting finding is that the carbon fiber laminates either combined with resin + Al₂O₃, resin + Al, or only resin always remain above sample 36, highlighting the property of thermal conductivity of carbon fiber. On the contrary, as regards the thermal behavior of the GF, it was observed that a third of the nine laminates have better thermal behavior than sample 36. Therefore, in this case, GF did not act as a thermal barrier in this composite. It can be seen that, of the three laminates with higher thermal conductivity, only sample 36 (CF/GF/CF/GF/CF) was combined with resin. These results show that including the additive (resin + Al or resin + Al₂O₃) did not contribute significantly to the thermal conductivity of the material.

The thermal barrier obtained was made with NHF/CF/NHF/CF/NHF (sample 28), which only added resin, and presented an experimental thermal conductivity of 5.22 W·m⁻¹·K⁻¹. This is 61.13% lower than the conductivity of the material with which the roof of a car is formed (sample 37). Thus, the material that provides the characteristic thermal barrier was the NHF.

The simulation of the process of heat transfer allows deducing that, if the roof of a car is manufactured with the proposed compound (sample 28), there would be a decrease in temperature from 62.34°C to 44.24°C. This implies that the proposed compound significantly lowers the internal temperature of the car by 29.03%. This temperature difference could have an effect on fuel savings by lowering the use of air.

Figure 3: Temperature profiles (°C) for (a) reference sample 37 and (b) sample 36 and for the laminates considered as thermal barriers: (c) sample *17, (d) sample *31, (e) sample *5, and (f) sample *28.
conditioning for a shorter period to keep a comfortable temperature since the heat to be removed would be 29.03% lower.

In general, the current manufacturing process of a car roof is through a hydraulic process and high precision molds. However, the composite material manufacturing process, that is, proposed in this research, requires less economic and energy investments.

Data Availability

No data were used to support this study.
Conflicts of Interest
The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments
The authors thank Iván Josué Valencia Gómez, José Carlos Ramírez Baltazar, and Francisco Javier Cruz Pérez for technical support. The authors thank CONACYT for financial support through “Catedra CONACyT” project (513) and FOMIX project (279788).

References


Submit your manuscripts at
www.hindawi.com