Airflow Sciences Corporation

Vehicle Interior Heating and Cooling

Case Study

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Recently, an automotive design group was searching for a better way to evaluate special low-transmittance glass as a means of reducing solar heating of the passenger cabin. When used for vehicle windows, this special glass reflects and absorbs some of the energy radiated by the sun that would otherwise become trapped inside the vehicle. Many different types of glass are available that vary widely in the amount of energy transmission and in cost. The automotive designers were challenged to find the lowest cost glass that satisfied their specific cabin heating criteria.

In the past, the designers were faced with protracted experimental studies to determine what effect each glass type had on cabin temperature. Sets of windows were custom made from the various glass types and installed in the vehicle along with an array of temperature measurement devices. The completed test vehicle was then placed in direct sun or in a special thermal test chamber. By recording the increase in temperature as a function of time, the designers determined temperature curves at perhaps a dozen locations within the vehicle. By averaging these curves, an approximate value was found for the mean cabin temperature as a function of time. This task was repeated for each glass studied.

Because of the high cost of this procedure, the designers had to limit the number of glass types to be evaluated. Furthermore, the time required to complete the test program at times affected the production schedule. Airflow Sciences Corporation (ASC) provided a new approach to the problem which not only reduced the time and expense involved, but also provided much more information.

Instead of utilizing experimental measurements, the test vehicle was recreated entirely on a computer. This ‘numerical model’ included all important interior features such as the instrument panel and seats. The transmission characteristics of the glass windows, provided by the manufacturer, were also input. The simulated sun was positioned at the desired location relative to the vehicle as illustrated in Figure 1.

An advanced Computational Fluid Dynamics program was then employed to simulate the radiative heat transfer from the sun to the vehicle. The interior air velocity and temperature were computed throughout the entire cabin, not at just a few selected points.

In order to visualize the simulation results, consider the two dimensional horizontal display plane through the vehicle indicated in Figure 1. Simulated temperatures are plotted in this same plane in Figure 2. This simulation is for standard window glass after 20 minutes in the sun. The color contours indicate temperature levels and the arrows show the direction of convective air motion.

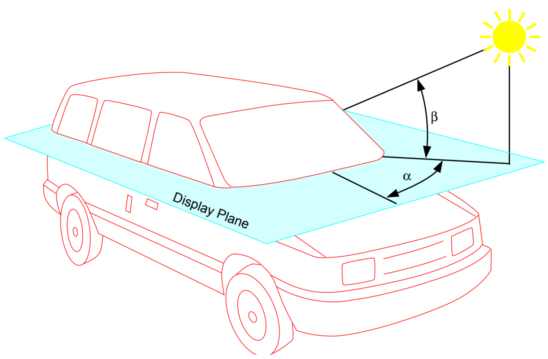

Figure 1 - Sun angles for solar heating calculations

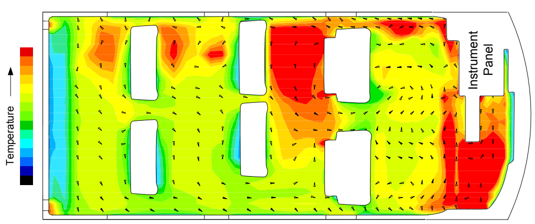

Figure 2 - Temperature profiles for standard glass t=20 min.

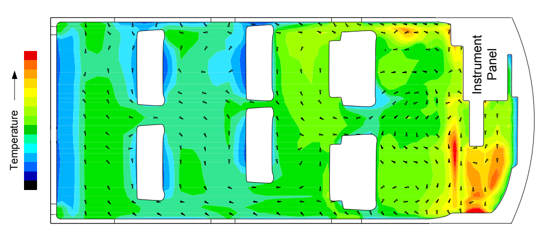

Figure 3 - Temperature profiles for low transmittance glass, t=20 min.

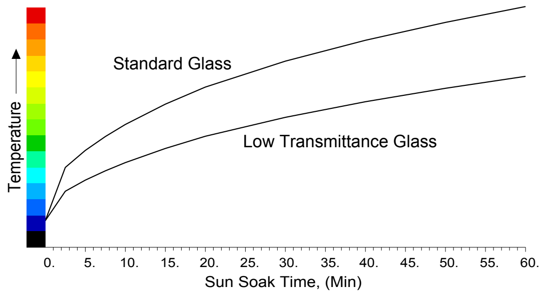

Figure 4 - Average passenger compartment temperature vs. time

With the first numerical model complete, many different glass types were rapidly evaluated by simply changing the few numbers which describe the glass transmission characteristics. One such example, shown in Figure 3, illustrates how low transmittance glass reduces interior temperatures. Given these data, accurate curves of average air temperature vs. time were prepared (Figure 4), allowing the automotive designers to make the most cost-effective glass choice.

Numerical flow simulation affords the opportunity to make significant climate control system performance improvements which otherwise could not be justified due to cost and schedule restrictions. And that translates into a competitive advantage.