Improving comfort in residential building

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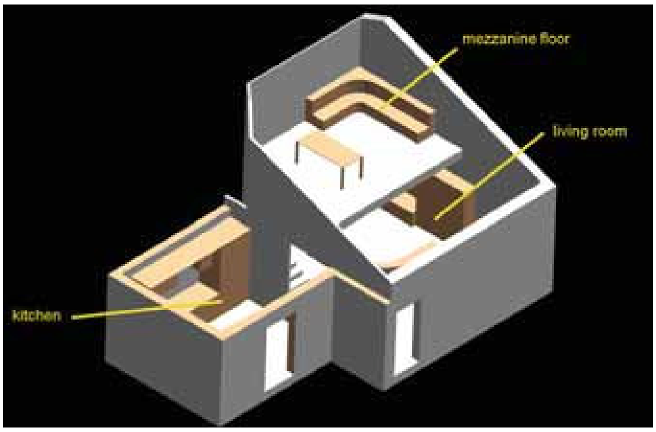
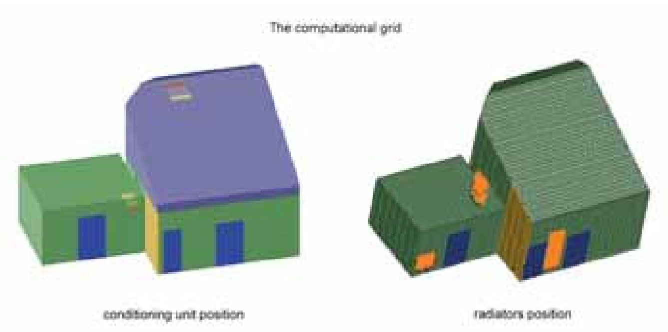




In this article we describe how CFD was used in order to optimize the thermal comfort of a residential building. The objective of the study was to determine whether the arrangement of air-conditioning and heating devices was sufficient to keep the house comfortably cool in the summer and warm in the winter. By ensuring that all devices are properly sized and located, it is possible to minimize the energy costs of operating the system, thereby minimizing both the environmental and economic impact of the development. The methodology described delivers useful design information and is both simple and inexpensive to apply. Pro S3 is a company located in Turin, Italy providing support to industrial companies using advanced design for product innovation.

The building in question is largely open-plan and has an irregular layout. The large living area is split by a mezzanine floor and is joined to the kitchen area without doors. The thermal environment of the resulting large volume occupied zone is difficult to control. The design of the building disrupts the usual insulating near the roof air layer so that the volume is subject to large solar gains through the roof during the summer and large heat loses through the roof during the winter. Economic and environmental constraints restrict the number of air-conditioning units to two and the number of radiators to three.

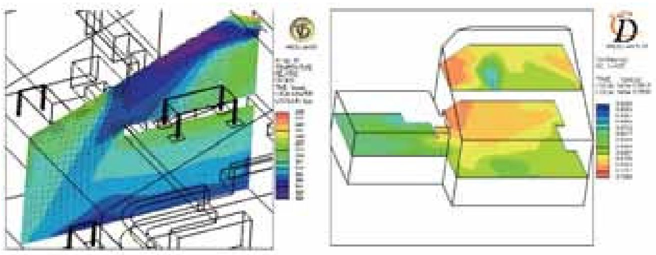
A simple 3D CAD model was constructed from the 2D drawings of the building.

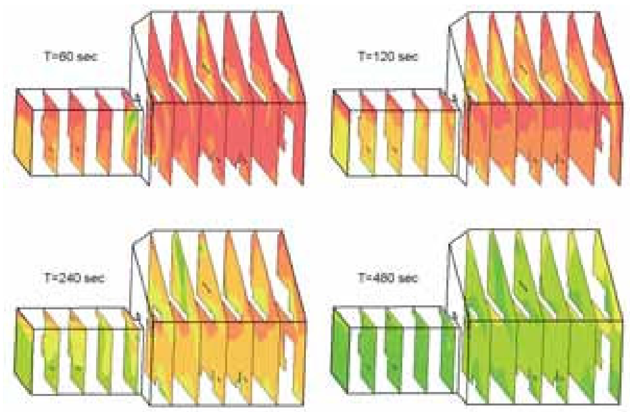
Representative, low detail, furniture is included in the model in order to determine how much influence it has on the predicted thermal environment. The computational mesh was constructed automatically from the CAD model using trimmed cell technology. Air conditioning units are simulated using coupled pairs of inlet and outlet boundary conditions, controlled via user coding. The mass flow and the temperature of the air entering the room are calculated from the air-conditioning unit data sheet. The radiators are simulated using baffle cells with an exchange area that is equivalent to those of the real heaters.

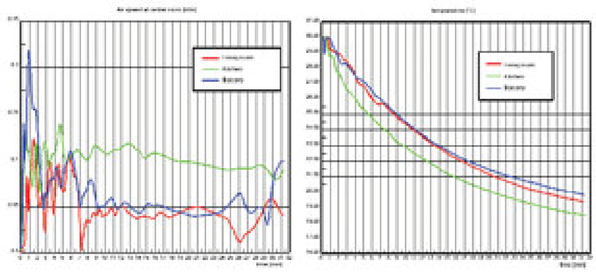
Appropriate levels of thermal resistance are applied to the windows, walls and roof. Adiabatic boundary conditions are prescribed at all internal walls.

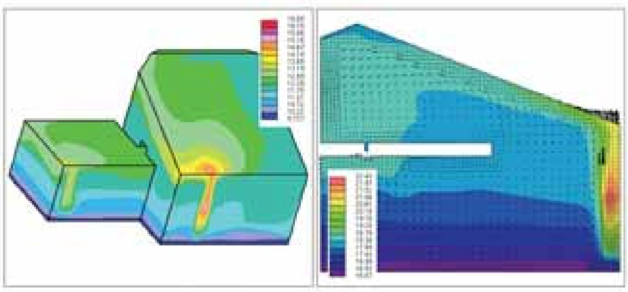
The analysis

Several calculations were performed. The initial simulations were used to tune the modeling parameters to optimize the convergence ➲









	External air temp. [°C]	Initial internal air temp. [°C]	Conditioned air temp. [m3/min]	Conditioned air flow rate [°C]	Radiators surface temp. [m2]	Total radiators exchange surface
Summer conditioning	40	30	15	28	-	-
Winter heating	5	5	-	-	60	25

behavior of subsequent calculations. In order to accurately model the effects of buoyancy, a transient solution method was employed, using a pressure correction under-relaxation factor of 0.8, double precision and a small time step. Temperatures were monitored at the head height of a typical occupant in a number of locations. Simulations were performed for both winter and summer scenarios.

The summer conditioning results

One of the major aims of these analyses is to verify if the air-conditioning unit placed in the mezzanine floor of the living room can adequately cool the whole room. The analysis clearly shows that if this unit is placed strategically, it can contribute dramatically to the comfort of the occupants of the lower living room level. The results also demonstrated, however, that the area beneath the mezzanine balcony is exposed to relatively stale air, when compared with other areas of the building.

The winter heating results

The results from the winter heating scenarios were easier to predict. There is a great difference in temperature between the lower level and the mezzanine floor. The mezzanine level is heated excessively by the large buoyant plume generated by the heater in the open area away from the balcony.

Conclusions

These analyses clearly show that, even in a relatively simple building geometry such as this, it is possible to predict interesting thermal effects that might not have otherwise been apparent until the house was built. A practical methodology has been defined that is reusable for other similar cases. With parametric CAD and STAR-CD's automatic meshing tools, it is possible to generate a good computational mesh in a small amount of time. Recalculating the simulations with air-conditioning units and radiators in different positions takes just a few hours. The complete analysis with animated gifs can be seen on our web site: www.pros3.it ■