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No smoke without Jasmine

by Roderic Bunn

Computer simulation of fire and smoke spread is gradually coming of age. 3D real-time computer simulations are available to the design engineer, and development work is moving fast. Roderic Bunn reports on the BRE simulation model, Jasmine.

Models of fire behaviour have been around for a long time. They began with standard mathematical predictions developed in the 1950s, to brine solution models and more recently zonal computer simulations. Today, with the advent of fast computers and megabytes of ram memory, simulation modelling is moving onto a higher plane: the 3D real-time simulation model.

Earlier models of fire and smoke spread made little in the way of assumptions about the way that fires perform. Instead, the models were based on mathematical equations of how much matter would move in and out of wire mesh co-ordinates, in terms of mass, momentum, chemical species etc.

The big breakthrough came with the development of solid modelling, which enables the products of combustion to be modelled in 3D within a building structure.

Developed in conjunction with the software house CHAM, Jasmine (Analysis of Smoke Movement in Enclosures) is now well established as a service through the Fire Research Station (FRS) Fire Technology consultancy, having been progressively developed since the early 1980s.

Simpler zone models provide a quantified picture of a fire situation, for example the estimation of smoke layer depths and temperatures, and the volume of smoke that needs to be removed from an enclosure.

In contrast, the Jasmine 3D field model makes no assumptions about how the smoke will move. Instead, Jasmine solves the dynamic field equations, which describe the heat and mass transfer processes associated with the dispersion of combustion products created by a fire.

Jasmine calculates the convective and radiative heat transfer to solid boundaries in addition to mass and heat flow-rates through ventilation openings, be they natural or forced. Once the 3D geometrical data has been input for a particular type of building, along with the thermal performance of the fabric, the model can be used to start a simulated fire based on a given heat source.

As the fire grows at a given rate, the combustion products will rise in accordance with a convective heat transfer coefficient and the smoke will spread throughout the space.

The effects of cold radiant surfaces are calculated by working out the heat transfer from the hot gases to the cold surfaces, and the influence that has on the smoke itself. The temperature of each surface is dependent on how thick the wall is, and what the thermal properties are.

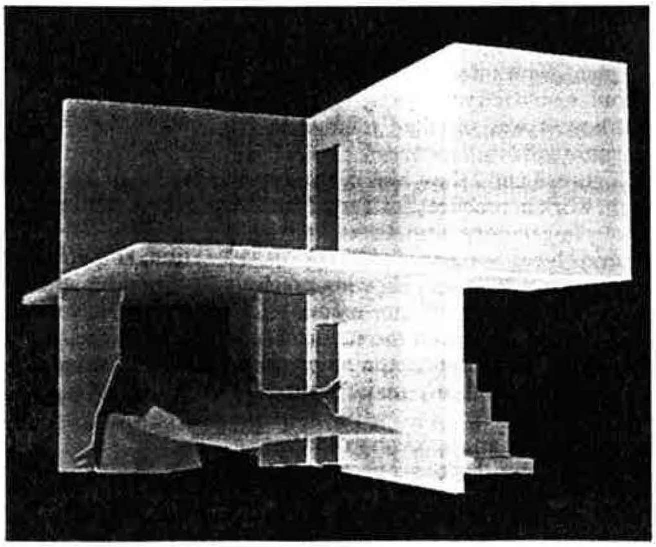


Figure 1: The smoke boundary layer in a model house.

New software guide

The Building Research and Information Association has produced the latest edition of the booklet *Software for building services – a selection guide.*

The ring bound booklet, presented in A5 format, gives information on 369 software packages for building services. Software suppliers are listed alphabetically, with contact names, addresses and telephone numbers.

The selection guide is priced at £25 and can be ordered from BSRIA Publication Sales, Old Bracknell Lane West, Bracknell, Berkshire, RG12 7AH.

Figure 1 shows the results from the latest version of the Jasmine simulation program. Here, the model has been used to demonstrate how smoke will move within an experimental three bedroom house after a fire has started in an armchair.

The smoke layer in the simulation is a snapshot from the Jasmine 3D real-time display. As the smoke spreads throughout the house, the model calculates the position of the lower boundary layer (shown as a grey contour), the temperature of the smoke and its density. The space above the boundary layer is actually composed of dense smoke.

The model will also demonstrate the rate at which the smoke will invade the upper storey and spread throughout the bedrooms. The user can zoom around the building, and watch in detail how the smoke invades the rooms.

Figures 2 and 3 further illustrate how the model has been used to examine the danger of smoke spread through a typical commercial open-plan office, in this instance a dealing floor.

Here, a fire has been started at the far end of the dealing space in a location which, when viewed from the far end of the room, would appear to offer no immediate danger from that vantage point. However, as a cut-out in figure 2 shows, the false ceiling is leaking, allowing smoke and carbon monoxide to spread in the void. Sudden failure of the false ceiling would have catastrophic consequences for anyone in the room.

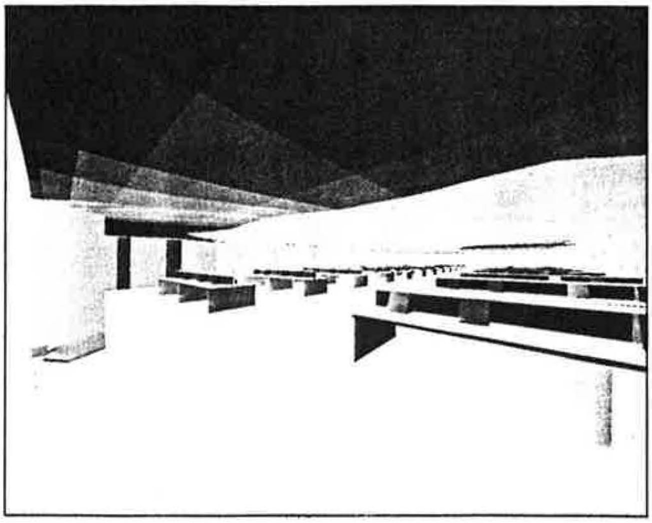
A considerable amount of time has been spent validating this software and in improving the basic physics within it, particularly in respect to the elements of combustion chemistry and the effects of cold radiant surfaces. According to Geoff Cox, Head of Fire Dynamics at FRS, there are many areas which need further work to make the program more robust.

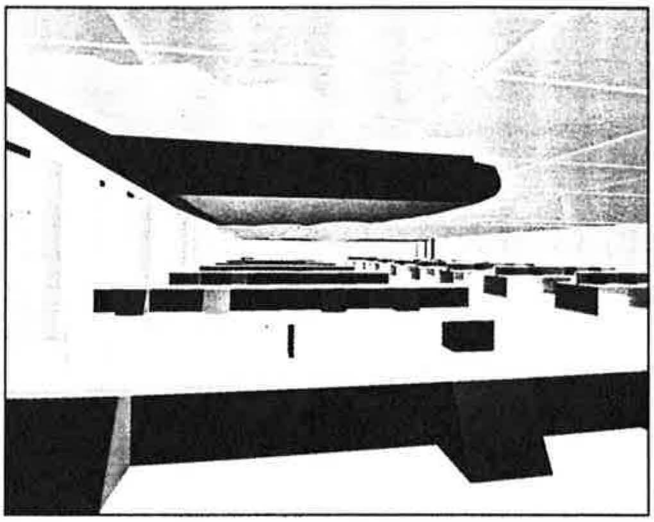
"The main difficulty is in describing the product source and the rate at which fire will spread," he says. "Some materials like petrol or alcohol are easy to model compared to wood laminates and adhesives etc. The arrangement of these materials in a room will also affect how the fire will grow."

There are, he stresses, considerable complexities in modelling reality. "As far as our treatment of the actual fire is concerned, we are still someway off being able to calculate that many fundamentals. But what we can do is to model the nature of a fire for different ventilation systems, different levels of pre-fire stratification and different lengths of escape route."

Graduating to 3D field models from wire mesh models or 2D zone models has revealed a considerable amount of information, says Cox. Mistakes in building geometry, like steps missing from a flight of stairs, are much easier to pick up on a 3D solid model. Also, jets of smoke moving into odd little areas are visible that would otherwise be lost by merely studying numerical output or looking at a single plane of interest.

The Jasmine research team are also looking at how sprinklers affect fire and smoke spread. Although the model is not yet sufficiently robust to be conclusive, early work suggests that sprinkler behaviour is not simple.





Figures 2 and 3: The Jasmine computer simulation of a fire that has penetrated a false ceiling above a large open plan office. The cut-out section shows the progress of smoke through the ceiling plenum.

However, what Cox and his team have discovered is that the sprinkler droplets can become entrained into the hot gases before they get a chance to reach the fire. But Cox is at pains to point out that modelling the character of sprinkler droplets is very difficult.

"We made some assumptions on the effects of sprinklers on a design fire and then saw what the effects were on smoke spread," explains Cox. "What we found was that the hazard contour retreats for a while and then advances again. But we are still trying to model the consequences of the water droplets falling through the smoke particles and imparting momentum to them and dragging them down.

"Clearly more work needs to be done on the dynamics of the droplets before we can determine what impact the water will have on the smoke layer," he says.

"Similarly one has to be careful when designing smoke evacuation systems," warns Cox. "When you take smoke out of the top of an atrium, you have to replace it with something. If the air comes into the space as a high velocity jet, the smoke will be blown all over the floor of the atrium and possibly envelop the people."

Although Jasmine is available to building services designers for simulation modelling on actual structures, a commercial product is years away, simply because of the model's complexity.

"These models are very difficult to use for non-experts," he says. "Calculations can also take a week to run. The computing power to run Jasmine's numerical calculations requires a memory four times the speed of a proprietary 486 machine.

"One of the main problems we have is importing the geometrical features of the building," adds Cox. "At present we do that in a relatively crude way. If we could import that data from the building designer it would make life a lot easier."

For more information on the Jasmine system, contact the BRE Technical consultancy, Fire Research Station, Borehamwood, Hertfordshire.

Fire models digest

Recent progress in fire science and the development of computer hardware now means that a variety of tools can be exploited in fire protection for buildings.

The fire research station has taken a leading role in this field. BRE Digest 367 *Fire modelling* introduces the concept of computer modelling of fires.

Modelling techniques have long played a part in fire simulation but the development of powerful computers has led to rapid progress in numerical fire modelling. Using such techniques offers those involved in building control, design, fire science and fire safety engineering the ability to predict the consequences of fire and plan suitable fire protection strategies.

The digest explains about growth and spread of fire and the two basic types of theoretical computer models. Zone models are related closely to established traditional methods and field models exploit new techniques to study smoke movement.

Copies of BRE Digest 367 *Fire modelling* are available from the BRE Bookshop, BRE, Garston, Watford or from the Fire Research Station Lib-rary, Borehamwood, Herts, WD6 2BL, price £3.50 (post free).