Fire zone model MAGIC :

The validation and verification principles

Bernard GAUTIER
6, quai Watier, 78401 CHATOU France

Abstract

This paper present the principles used in the validation and verification of MAGIC (EDF Zone Model for simulation of fire in multi-compartment building). The general problem of validation of zone model is discussed: validation of the sub-model (classic laws, empirical correlation,..) and validation of the global model. Then a short presentation of MAGIC validation is provided: principles, list of references, examples and future prospects.

Zone model approach of fire

A zone model results from the association of various sub-models :

- Integration of classical laws of physics
- energy and mass balance on different layers (homogeneous temperature and concentrations, hydrostatic pressure, Perfect Gas assumption , etc..).
- simplified conduction in walls (1, 2 or 3D) or in some targets
- simplified radiation (semi-transparent assumptions in concave rooms)
- Semi-empirical models which can be found in fire source , plume, ceiling jet, convection heat exchange coefficient, openings and vent, detection, suppression etc..

Due to this nature, we must first say a few words about sub-model validation.

Validation of the sub-models

The General laws are accepted by the scientific community. Empirical models have most of the time been directly obtained from specific experiment, and have been qualified according to it. Both have shown a certain accuracy and validity domain. *(ex: Alpert correlation for ceiling-jet was studied for r/H<3).* The control of the right use of it must be done inside the code (for instance : produce "warnings" when getting out of a validity domain).
So, the sub-model validation has to be considered during the zone-model conception. Nevertheless, a sub-model used outside of its validity domain does not necessarily mean that the global code results will not be acceptable. Moreover it is not possible to deduce the accuracy of a code from its component ones. For those reasons, a global validation process remains always necessary to validate the zone model itself.

Validation of the global zone-model

The objectives of the zone model validation are the accuracy of the calculation data and the validity domain. Both are linked : the acceptable accuracy domain is the validity domain. Accuracy of the code seems impossible to determine theoretically, but it can be displayed by confrontation to experimental fire, and estimated by this means. The criterion of "sufficient" accuracy themselves, can be discussed.
The accuracy of a fire model, observed by comparison to experimental fires, remains quite rough because too many parameters are involved in the fire process, and some complex phenomena (combustion, mass flow, etc..) cannot be completely described. Furthermore, when using the model in a real life risk study, the input control will be much worse and will interfere with the calculation relevance.

Consequently, it is not crucial to get a very high level of accuracy when confronting experimental and numerical results. The most important issues are to show that the code provides realistic quantitative results in its current application field and respects the qualitative tendencies in the fire dynamics and the significant effect of input variations.

In fact, the validation process is mainly demonstrative : it has to prove that, when the input parameters are efficiently controlled, the code results are sufficiently realistic, in the range of the code current application field. To make the demonstration efficient, the way of using the code in this process must be similar to the way it is used for typical fire risk studies.

Validation "code of ethic"

If we had to list the most important issues of a "good" validation process, we would retain :
a- The quality of the reference tests :

To be demonstrative, the tests must be well known, approved and accepted by the scientist community. Of course, the quality of the experiment is the main factor of this acceptance, and has been discussed a lot (ex: ASTM E603)

b- The conditions of the code use:

To enhance the confidence and decrease the user effect, the input of the code during the test must be clearly identified.

Any user modeling choice (fixed exchange coefficient., plume model, etc..) specific to the calculation must be identified, or, as much as possible, avoided.

c - The Field covered by the tests :

The tests should cover the field of application of the code. First building configuration : mall to medium scale compartment configuration, multi-compartment and large scale tests, opened or confined condition for instance. Also, fire parameters: kinds of combustible, heat release rates, etc..

The validation File of MAGIC

MAGIC is EDF code for determinist fire risk studies in NPP. The validation process of the code is based on comparison to real scale fires : about 60 real scale fire tests are available in the base. The file is used to define the validation domain of the code. This includes volumes from 10 to 1300 m^3 (a 200 000 m^3 case is at work), heat release from 100 kW to 2.5 MW (a 60 MW case is at work) , ventilated and post-flashover fires, Mono-compartment and multi-compartment varied configurations, gas burner, liquid pool or solid fires, linear or axisymetrical fire source.

MAGIC has a large validation file, including among others the following references :
- Semi-natural fires in a room: Hognon B. CSTB/ DGRST-CSTE 1980 and Carmier, Curtat, Hognon, Bertin - CNRS - CSTB 1984
- Semi-natural fire in a commercial hall corridor : N. C. Markatox, M.R. Malin "Int J Heat transfer" Vol. 25 n° 1 p. 63-75 BRE/FRS 1986
- Fires in ventilated room: (Alvares N.J., Hasegawa H.K., Lipska.Quin A.E.) Report UCRL-53179, LLNL, Univ. of California, Livermore 1982
- Fire in a compartimented building (Cooper L.Y& al.) J. of Heat Transfer vol. 104 pp 714-749 NBS (1982)
- Real-size tests in multi-compartimented buildings : R.D Peacock, S. Davis, V. Babraukas "Data for room Model Comparisons", Journal of research of the NIST, vol 96, N°4, 1991.
- Control-room tests FM/SNL : S. Nowlen NUREG/CR-4681 1987
- 20-foot separation tests UL/SNL : NUREG/CR-3192 1983
- Large cable fire tests (2 compartiments) EDF-CNPP : CNPP TR 96 5045 P1 -1997
- CTICM Hotel-room : H. Lebotgne Test reprt 96S511 (1996) Linen-room (2 compartments, post-flashover): H. Leborgne TR 97S031 (97) Large hall tests : TR 98-x-406 (97) ; TR 94-R-242 (94)

MAGIC Code quality assurance

In accordance with the code Quality Assurance process, a selection of about 20 tests from the validation file is used systematically to guarantee no regression of new versions. Any difference between versions must be justified in the validation report. The code is always in standard conditions when launching the reference tests. The validation process report is part of the documentation and the tests can be easily re-played by the user.
At this point it is important to underline the differences between verification and validation of the code : the verification of the code specification consists in controlling the respect of sub-model specifications, the different parts (user interface functionalities, calculation options, etc..). It is a different task than validation, also done through the MAGIC code Assurance Quality process. This aspect must not be neglected because the validation tests are not necessary covering all the code possibilities.

Direct comparison of numerical and experimental data

The model necessary input for comparison are : the building materials and configuration, boundary conditions, the combustible properties and location and the mass loss rate scenario.

The commonly available data for comparison are (in decreasing frequency) : local temperatures, average temperatures, heat exchanges on targets obtained on fluxmeters, interface height (which estimation may follow different point of view) gas velocities, species concentrations (O_2, CO_2, CO, C_nH_m NOx, SOx,..), pressure, mass flow through openings.

The first comparison is generally done on gas temperature and fluxes, considering at less the range and delay of the peaks. Those variables represent the thermal boundary condition for the

materials to protect. Nevertheless, they are not easy to obtain, being very unstable, linked to mass flows and radiation. In some cases it seems that internal temperature of targets could be an interesting alternative to develop. The other measurements are less frequent, some like pressure or mass flows are rarely provided.
The comparison is first a "visual" analysis of differences. Numerical analysis can be done, based on relative difference *(ex: (Tmes-Tcalc)/ (Tmes-To) as a error percentage).* Sensitivity to input variation has been done in the process of qualifying the physic model adjustments.

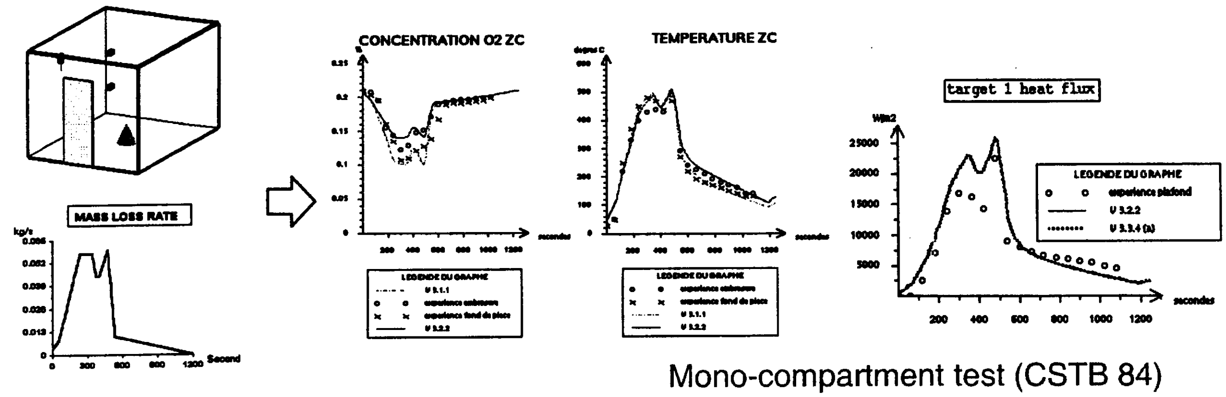

figure 1: comparison of numerical and experimental data

Future prospects

The validation process of code MAGIC is in constant progress. The file is to be reinforced by tests focusing targets temperature. Those variables fluctuate less than gas temperature and are more relevant for risk studies (dysfunction, ignition). Tests are to be done in 2002. Pressure measurement and interaction with ventilation system will be studied through specific tests, also programmed in 2002. The next field of investigation should concern fire suppression effect and complex multi-room configurations : horizontal openings and duck-board.

Conclusion of EDF experience

The validation file is the key of code acceptance. Comparison to real-size and a large field of experiment data is the only way to guarantee an efficient demonstration of the code efficiency. The experimental tests and measurement must be of good quality, available to and accepted by the scientific community. At last, the process of code validation must be independent of modeling choices and available to the final user.
The results obtained with MAGIC on a selection of experimental data has allowed us to get confident for its use in a large range of volumes, heat release and configurations.