Computer Models For Fire and Smoke

Model Name: Fire3D

Version: 4.9

Date: 03.09.2013

Classification: Field model

Very Short Description: CFD model to simulate jet and buoyant turbulent diffusion combustion, thermal radiation and spray-flame interactions in compartments and open atmosphere

Modeler(s), Organization(s): Alexander Snegirev, St.-Petersburg State Polytechnic University

User's Guide: N/A

Technical References: Snegirev A.Yu., Marsden J.A., Francis J., and Makhviladze G.M. Numerical studies and experimental observations of whirling flames. International Journal of Heat and Mass Transfer. 2004. Vol. 47. No 12–13. P. 2523–2539 (ISSN 0017 9310).

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Snegirev A., Isaev S. Turbulent Combustion and Thermal Radiation in a Massive Fire // N. Syred and A. Khalatov (eds.) Advanced Combustion and Aerothermal Technologies, p. 197–209, Springer, 2007. (ISBN 978-1-4020-6513-2).

Snegirev A., Lipjainen A., Talalov V. Flame suppression by water sprays: flame-spray interaction regimes and governing criteria / Proc. of the 12th International conference Interflam 2010 (Nottingham, UK, 5-7 July 2010). Interscience Comm., London, 2010. Vol. 1, P. 189–199 (ISBN 978-0-9541216-5-5).

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Snegirev A.Yu. Monte-Carlo Modelling of Radiative Transfer in Unconfined Buoyant Turbulent Diffusion Flames. Computational Thermal Radiation in Participating Media. Proc. of the Eurotherm Seminar 73, April 15–17, 2003, Mons, Belgium, P. 259–270 (ISSN 1248-8313).

Snegirev A.Yu., Makhviladze G.M., Chamchine A.V., Metcalfe P.H., Talalov V.A. Flame Exhaust and External Burning in Enclosure Fire. Fire Safety Science. Proceedings of the Seventh International Symposium (Worcester, USA, 16–21 June 2002), IAFSS, 2003, P. 1179 (ISBN 0-9545348-0-8).

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Validation References: A. Snegirev. Modeling combustion and heat transfer in fires. St.-Petersburg State Polytechnic University, Russia, 2004, 270 P. (In Russian)
Please also see *Technical References* above.

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Model Actively Supported?: Yes

Price: N/A

Necessary Hardware: PC

Computer Language: Delphi Pascal

Size: 4 MB on hard disk (excluding size of the output data)

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Detailed Description:

The model and code Fire3D used in this study solves the transient Navier-Stokes equations for multi-component reacting gas in the low Mach number limit. Either Favre-averaged (URANS version) or filtered (LES version) equations are discretised by means of the finite volume method. Structured non-uniform Cartesian mesh is used, unconfined and enclosed domains are considered. Second-order symmetric differencing is used in the approximations of the diffusion terms and the upwind TVD scheme is employed to approximate the convective terms keeping the order of approximation close to two wherever possible, and yet ensuring that monotonicity of the solution is preserved. A three-layer backward second-order accurate approximation is used for time advancement. A multigrid-accelerated pressure correction technique is applied to couple the pressure and velocity fields in the low Mach number limit and to satisfy the continuity equation.

In LES, the subgrid stress tensor is modelled through the Smagorinsky approach. The contribution to turbulence production due to buoyancy has been approximately taken into account by modifying the conventional Smagorinsky expression for subgrid viscosity.

For turbulent combustion modelling, two approaches are available: the eddy-dissipation concept and the presumed mixture fraction PDF model. In either case, a simplified kinetic description is adopted based on fast irreversible reactions or chemical equilibrium. Probability of local flame extinction due to excessive vapour concentration is approximately accounted for.

Radiative transfer is modelled by the Monte Carlo method. Spectral properties of combustion products (carbon dioxide, water vapour, and soot) are evaluated by means of the weighted-sum-of-gray-gases (WSGG) model. The effect of modelled turbulent fluctuations on radiation emission is approximately taken into account.

Lagrangian approach is applied to model the evaporating spray. Given the gas flow characteristics, multiple discrete droplets are tracked along their trajectories. Droplet velocity changes due to the gravity and drag forces. To make computations feasible, the momentum (as well as mass and energy) conservation equation is considered for a group of similar droplets (parcels). The spray submodel in Fire3D includes the following components: droplet movement, droplet dispersion by turbulence, droplet heating, droplet evaporation, inter-phase exchange, nozzle performance and spray atomization (initial droplet size and velocity distribution), flame extinction, and spray-pool interaction.

Options of conjugate heat transfer in structures and coupling thermal feedback between the incident heat flux and fuel gasification rate are available.