Fire-induced airborne release of radioactive particles: development and validation of a phenomenological model

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In the nuclear industry, assessing the potential release of radioactive particles during an accident is of critical importance in the field of nuclear safety. One of the critical scenarios being considered is the fire of a contaminated glove box. In such a case, it is difficult to assess the source term of particles being released to the gas phase.

Previous works on this topic identified some specific phenomena in the case of polymethyl methacrylate (PMMA) fuel with particle deposits (Ouf *et al.*, 2013), especially a very intense particle emission at the onset of thermal degradation of the polymer. This "flash of emission" could be linked to the bubbling behaviour of this polymer, but the lack of *in-situ* observation technique limited the characterization of this emission.

In this work, we present first phenomenological description of the airborne release of particles deposited on PMMA samples during their thermal degradation. For this purpose, optical analyses (PIV and high frequency ombroscopy) have been carried out at the surface of contaminated polymer sheets. The bubbles flux and diameter have been measured according to these diagnostics while their release efficiency has been quantified by scanning electron microscopy of the samples surface prior and after thermal degradation. Trapping of particles inside the melted polymer has been also analysed with a specific protocol. Considering these developments, we have proposed a phenomenological description of the fire-induced airborne release mechanism for PMMA surface (see figure 1).

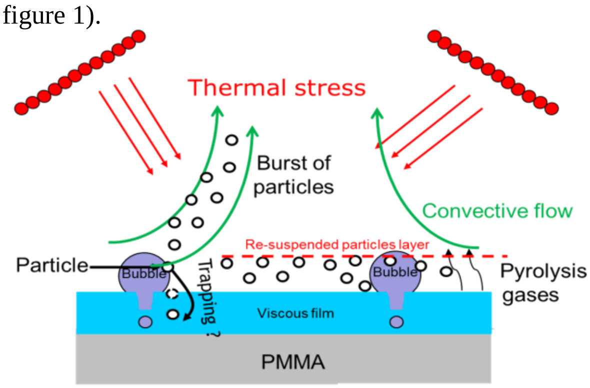

Figure 1: Illustration of the phenomenon involved during fire-induced airborne release for PMMA

According to this description, a theoretical model has been developed (Delcour, 2014). The bubble flux, size and capillary trapping of particles in the polymer are computed according to physico-chemical properties of PMMA evaluated during thermal degradation with the Thermakin model (Stoliarov et al., 2009). Particle release efficiency of each bubble bursting has been fixed in the model to its experimental value (60 %).

For validation purpose, an experimental test bench has been developed specifically for airborne release fraction (ARF) measurement. Released particles have been sampled on cellulose membranes with an isokinetic probe and ARF has been determined by ICP-MS/AES. Experiments have been conducted for alumina and tungsten carbides particles of different size (0.1 to 10 µm) with radiative heat fluxes ranging from 15 to 45 kW/m².

As shown on figure 2, a reasonable agreement is reported between experimental and modelled ARF values. The size distribution and density of particles have been also identified as influencing parameters on the airborne release fraction. Recent developments on the influence of surface concentration will be also presented in this work.

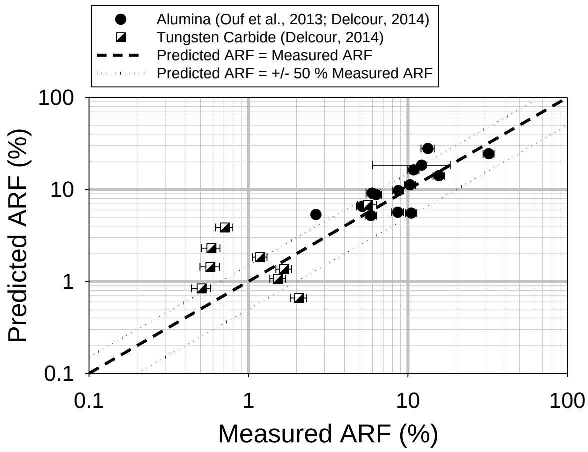

Figure 2: Comparison between measured and predicted ARF

Delcour, S. (2014). PhD thesis Ecole Nationale Supérieure des Mines de Paris.

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