Design of an Anisokinetic Probe for Sampling Radioactive Particles From Ducts of Nuclear Facilities

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Abstract

The International Standard ISO 2889 focuses on monitoring the activity concentrations and activity releases of radioactive substances in air in ducts and stacks of nuclear facilities. It also provides performance-based criteria for the design and use of air-sampling equipment, including probes, transport lines, sample collectors, sample monitoring instruments and gas flow measuring methods.

A shrouded nozzle sampling probe (McFarland et al., 1989) is basically a nozzle fitted with a flow decelerator. It is less susceptible to off-design sampling conditions (e.g. off-angle flow direction, flow turbulence, changes in sampling flow rate or changes in the free-stream velocity) and it has lower wall losses than an unshrouded nozzle (Chandra and McFarland, 1995).

A sampling nozzle should have well-defined geometrical and aerodynamical features and the transmission ratio (ratio of the aerosol particle concentration at the nozzle outlet to that in the free stream) must be within the range of 0,80 to 1,30 for an aerosol with a particle aerodynamic diameter of 10 µm.

The aim of this study is to design a new concept of shrouded probe that meets the ISO 2889 requirements and it is suitable for small-ducts installation. In order to reduce the construction costs they have been considered standard stainless steel welding fittings manufactured according to ASME/ANSI specifications.

In particular, with the numerical simulations, they have been firstly evaluated the capabilities of the numerical model to reproduce the available experimental data for a commercial shrouded probe and secondly they have been investigated the performances of the new concept design.

The 3D simulations have been performed with COMSOL Multiphysics® version 5.1 (Heat Transfer and Particle Tracing Modules). The simulations are based on the following segregated steps: fluid flow study (single-phase incompressible turbulent k-eps-wall function) and time dependent transport of particles (Lagrangian approach). The trajectories of particles in the flow field are simulated including such effects as inertia, drag, gravity and turbulent diffusion. Computations are carried out for free stream velocities in the range of 2 to 25 m/s and for particle size of 5, 10 and 15 aerodynamic equivalent diameter.

The results presented in this study confirm the capability of COMSOL Multiphysics® as a multiphysics simulation tool.

The development of this work has allowed us to obtain useful indications for the design of the new concept probe.

Reference

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Figures used in the abstract

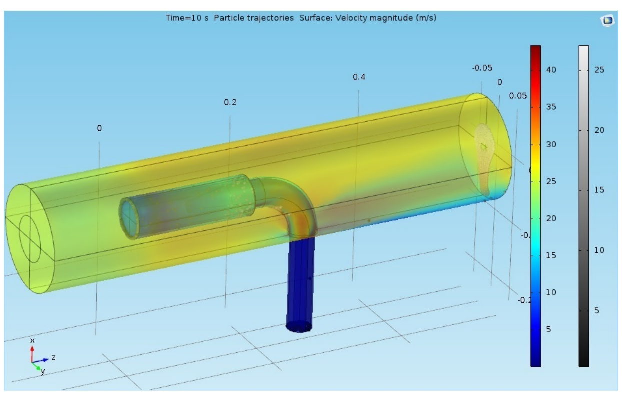

Figure 1

Figure 2

Figure 3

Figure 4