Innovative CFD Simulation of Ultraviolet Disinfection

atg UV Technology designs and manufactures ultraviolet (UV) disinfection systems for a wide variety of applications. Wilde Analysis has worked with atg on the development of innovative CFD-based modelling methods, based on **ANSYS Fluent**, to improve simulation accuracy and efficiency. This has enabled atg to accelerate the development and optimisation of new products, in addition to equipment validation.

Company

Based in the North West of England, atg UV Technology are industry experts in the design, production & maintenance of ultraviolet disinfection & treatment systems for municipal, industrial, petrochemical and aquatic applications. They serve an international customer base, including many large blue chip organisations and government controlled agencies across a broad range of market sectors, and have supplied thousands of UV systems worldwide.

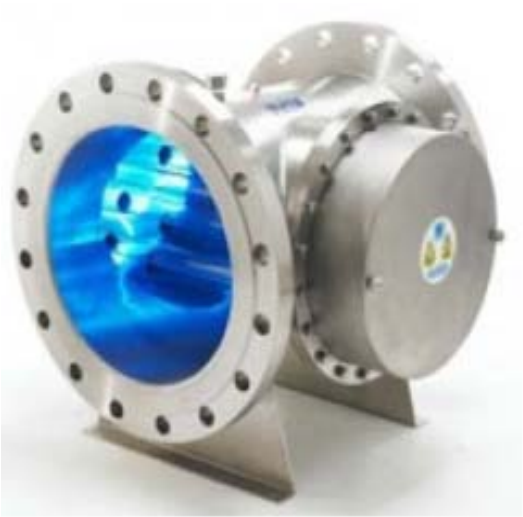

Fig1: Typical example of a cross-flow UV

Background

UV disinfection is becoming an increasingly attractive alternative to chemical treatments (chlorination and ozonation), because:

- It is effective at inactivating most viruses, spores, and cysts
- It avoids the need to generate, transport or store toxic or corrosive chemicals

Fig 2: The benefits of UV disinfection in leisure facilities such as swimming pools are now widely recognised.

- It leaves no residual harmful effect for humans or aquatic life
- It is user-friendly for operators
- It requires both a shorter contact time and less space than the alternatives.

Applications of UV disinfection include: potable and wastewater treatment; aquaculture applications such as fish farming and hatcheries; HVAC where pathogens could build up in air conditioning systems; swimming pools, where chlorine can be an irritant; and marine applications such as ballast water treatment.
A typical UV disinfection process works by passing

> “Thank you for the **very speedy delivery** on our project. In general, I find **Wilde very responsive to our needs** and this is very much appreciated.

contaminated water over one or more ultraviolet lamps. The proportion of micro-organisms killed by the radiation depends on the received dose. This, in turn, depends on the distribution of radiation intensity, the flow pattern, the water quality and the target micro-organism.

Within the industry, fluid dynamics simulation (CFD) has become a vital tool in the design and optimisation of these systems. The basic technique for tackling this multiphysics problem, involving flow, radiation and dose-response kinetics is well-established and gives reasonably good agreement with measured data.

Challenge

The conventional modelling approach involves tracking a set of particles released from the inlet and calculating the average concentration from all of them. Whilst useful, this approach suffers from two shortcomings. Firstly, it takes no account of the fact that UV light covers a range of wavelengths, each of which is emitted with a different distribution for different lamp types, absorbed differently in the quartz and the water, and inactivates a different proportion of the population. Secondly, information relating dose distribution to individual particle trajectories, though available in principle, is difficult to obtain. The various methods of extracting this information are painstaking and time-consuming; additionally, trajectories of interest become obscured and are therefore difficult to identify.

Solution

Wilde Analysis, in conjunction with atg UV, has developed special CFD modelling strategies to overcome both of these issues. The spectral content issue has been addressed by using a multi-band representation of the discrete ordinates radiation model in **ANSYS Fluent**. Here, the flexibility of this powerful software enables irradiation boundary conditions to be applied in each waveband according to lamp emission spectrum data. Furthermore, UV intensity can be attenuated in the quartz and the water by means of its spectral distribution of absorption coefficients and the impact on pathogen inactivation taken care of by means of "germicidal weighting" factors across wavebands.

The requirement to understand where the UV is and, more importantly, is not rendering pathogens inactive has been addressed by reformulating the dose-response relationship as a source term for a user scalar, representing concentration ratio. The resulting visual insights can quickly help to identify design improvement strategies.

Fig 3: Trajectories of interest are obscured amidst a tangle of "coloured spaghetti" In the conventional simulation approach.

Business Benefits

The project focused on refining CFD modelling techniques for UV disinfection in order that simulation can be applied productively at atg UV. Extending traditional particle-tracking techniques to account for spectral content and also providing a completely, new more flexible alternative to the particle-tracking method, have been shown to be highly effective for both the validation and optimisation of equipment.

As atg UV continues to develop their design and analysis capabilities, Wilde Analysis has helped the company realise the benefits of simulation, including:

- Gaining confidence in optimising new product designs through simulation-derived insight
- Evaluating and fine-tuning the disinfection performance of a system prior to acceptance testing
- Significantly reducing the volume of expensive physical acceptance tests by using CFD results whenever possible.