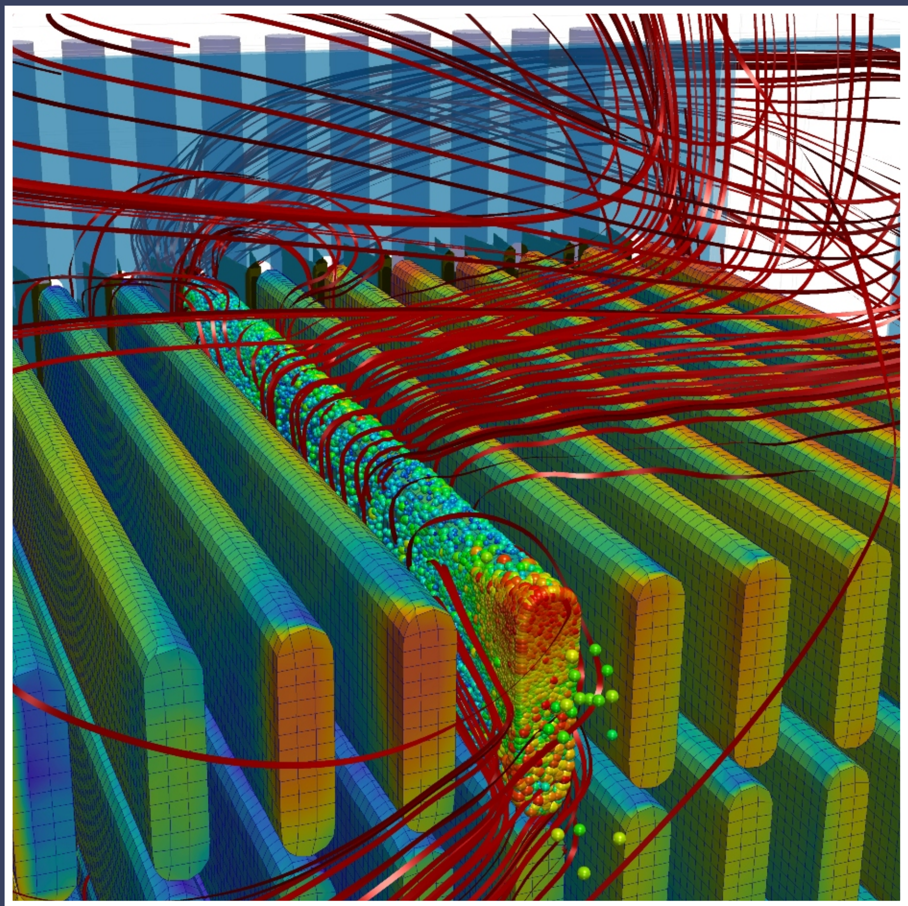
DHCAE Tools

CFD-Solver for filter applications



www.dhcae-tools.com

DHCAE CFD solvers for filter applications

Flow simulations (CFD) are widely used to optimise components and processes. DHCAE has carried out a comprehensive expansion of the renowned CFD toolbox OpenFOAM® specifically for the modelling of filter applications and in order to optimise the inflow and design of filters.

Typical application areas in the development and the production of filters and in plant construction:
The simulation tool can be deployed in every field of filtration of solid particles from gases or liquids with thin filter media in a plant or a unit.

Typical areas for use are:

- **Air filtration processes**, e.g. for exhaust gas purification, purifiers, respiratory protection, air purification
- **Filtration processes for liquids**, e.g. for water purification, sewage processes, oil treatment, fuel purification
- as well as whole plants for air purification or units in which thin-walled filters are used.

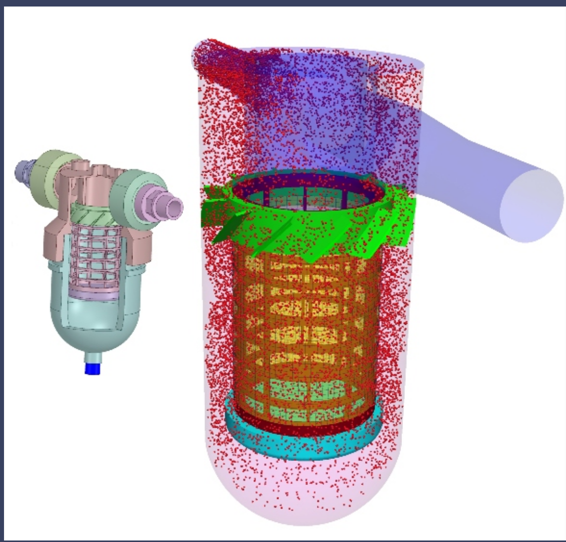
Your benefits from filter modelling:

Already in the development, the inflow on the filter can be optimised without building a prototype. This leads to a

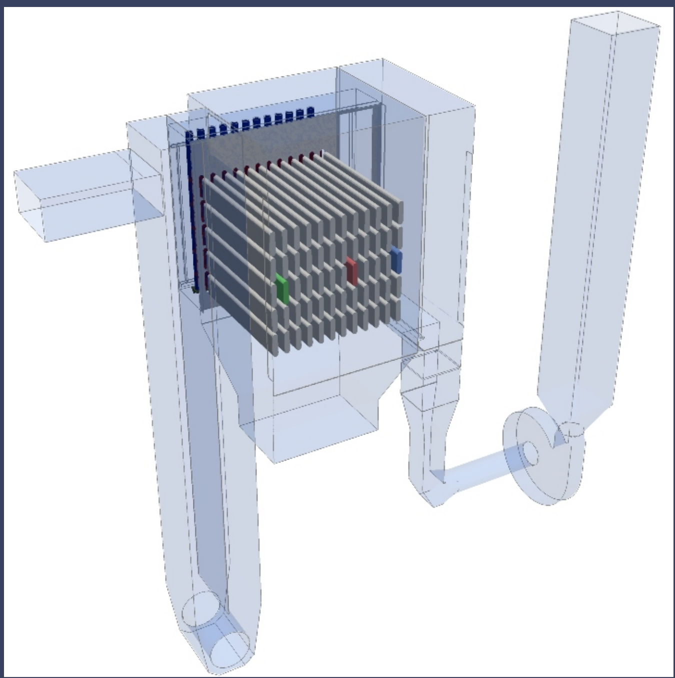
- higher filter efficiency,
- better utilisation of the filter material and
- an energetic process optimisation due to a lower pressure loss.

Modelling approach

The utilised modelling is based on the so-called Euler-Lagrange approach, that takes account of the continuous flow and the dispersed solid particles. In the calculation tool, especially the reaction of the particles on the filter is considered, e.g. the continuous shift of the flow into zones with lower resistance.



Water filter



Filter plant for air purification

The utilised modelling covers a broad spectrum of application cases:

The particles can have

- different sizes (considering size distributions),
- a diverging trajectory from the continuous flow (e.g. due to its inertia, turbulent dispersion, gravity or other forces).

The continuous phase of the transfer medium can be a gas or a liquid. Both single filters and a multitude of filters with different features (as e.g. different resistance characteristics) can be simulated.

DHCAE Tools' extensions for filter applications based on OpenFOAM® technology

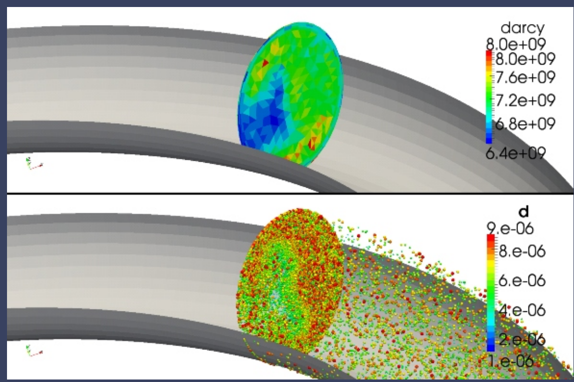
The OpenFOAM® basic system was adapted by DHCAE Tools with specific model extensions for the requirements of the industry for filter development and production. These extensions for the filter industry were already carried out by DHCAE Tools in the adapted solvers and are fully available for you as packages.

Filter model: Load-dependent resistance

The filter is assigned by a geometry or mesh face. This allows a simple setup in the CAD system and poses a much lower requirement to the mesh generation than a volume based setup. Based on this approach, two solution procedures exist:

- The user can model the complete pressure loss caused by the clean filter and the particle to the face or
- The base resistance of the clean filter can be assigned to an automatically detected volume zone before and behind the filter. The pressure increase caused by the particle will still be modelled by face in the middle.

With these options, a wide range of filter types with different characteristics, in particular high or low base resistance, can be investigated numerically efficiently.



Filter patch

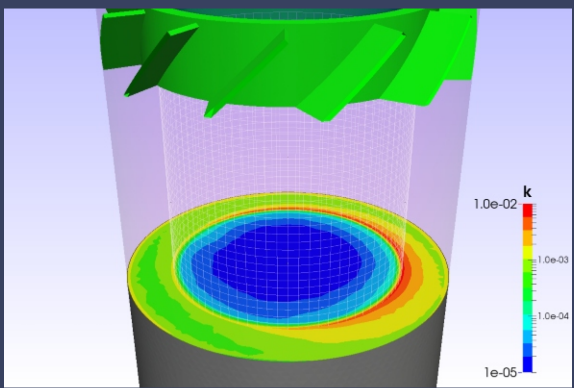
Features of filter regions

For the following modelling, in each of these regions are saved:

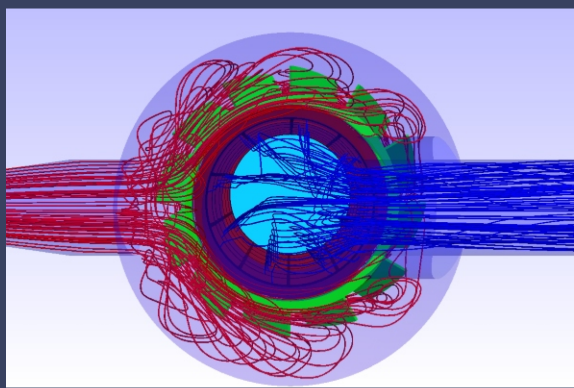
- Local particle load (e.g. mass per cubic metres)
- Number of particle hits for the evaluation of the statistical reliability of the results
- Darcy & Forchheimer initial values
- Variable Darcy & Forchheimer values, depending on their filter load
    - Mass
    - Particle size
    - Period of the load

Core functionality

- The simulation takes into account the variable local resistances on the filter regions.
- Different resistance characteristics are available.
- Several different sorts of particles can be entered into the system that interact with the filter differently (e.g. also very small particles can pass the filter).
- The flow can be diverted when passing through the filter, so that the fluid flows out surface normally.
- The turbulence can be dampened when passing the filter.



Turbulence damping in filter

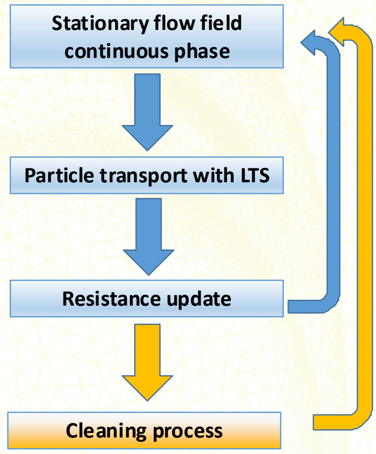


Flow re-direction at higher resistance

The solution procedure

General iteration process

The deposition model on filter regions with particle transport is integrated into an iteration process with the continuous phase. By this, the interaction of the continuous phase with one or several filters can be considered.



1. In the first step, in calculation with the filter solver, the flow field of the continuous phase is solved. Here, the pressure and velocity fields for the unloaded filter are calculated.
2. Afterwards, a small number of particles is added, and the end position of the particles is calculated. This position can be the adhesion to the filter or also its deposition in the housing.
3. The particles deposited on the filter increase the resistance locally according to a given characteristic.
4. In an iterative loop, the reaction on the continuous phase, e.g. a shift of the flow, is calculated. The newly added particles increase the resistance at their new deposition place further. The iterative process between local increase of resistance and flow shift is continued until the total number of required particle mass was added.
5. Also the cleaning process, which is usual with some filtration processes, can be considered when starting from a new initial state.

A stable and fast calculation

In these iteration processes, a great number of measures for the acceleration of stabilisation and calculation was integrated:

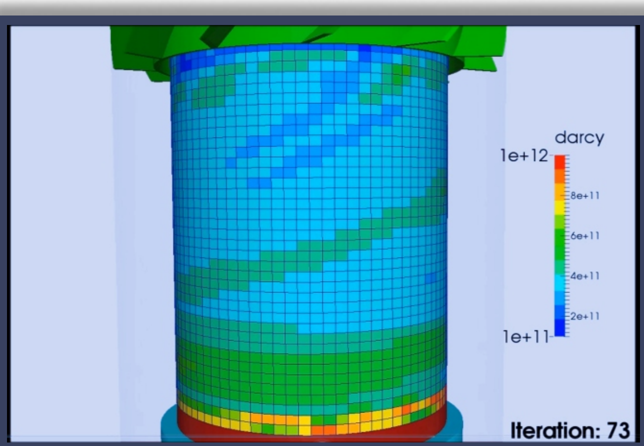
- Filter stabilisation (e.g. by local under relaxation)
- Optimised parallel calculation of the particle transport
- Different options for iteration control with coupling

Your entry data for the calculation are:

- Inflow velocity in the continuous phase, e.g. a gas or fluid volume flow with material value (viscosity, density)
- Particle density, quantity and size or also size distribution
- The characteristic features of your filter, e.g. the basic resistance in an unloaded state and the increase of the resistance with particle load, as determined in the test stand

Result of the simulation:

- The local load of the filter as mass or mass percentage
- The local resistances
- The pressures and streamlines for the continuous phase
- The gradual shift of the flow through local increase of resistance at the filter during a cycle



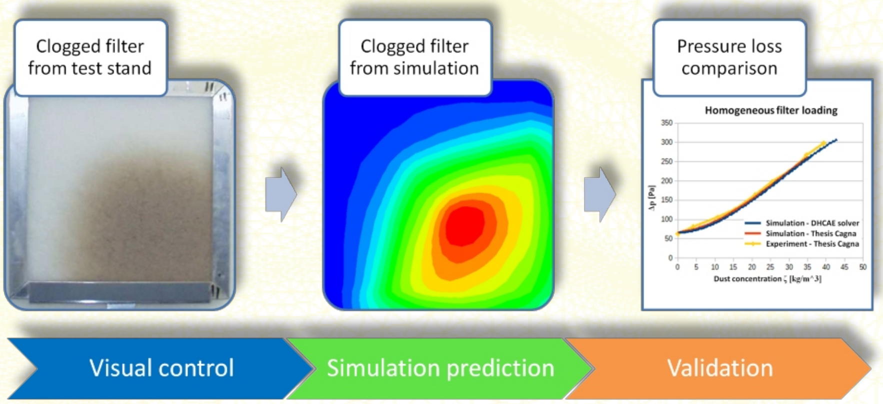
Local resistance at the filter

Validation performed on real world plants

The modelling approaches at the filter element were validated by the reproduction of literature dates.

Verification with sources from literature

The partial models developed here were verified with examples from the literature. The work of Michele Cagna (Cagna, 2003) served for this verification. Here, the local particle distribution, the increase of resistance and the flow shift were replicated both numerically and experimentally under laboratory conditions.



The pressure increase for the homogenous particle load could be reproduced exactly so that the correct realisation of the model is proven. At the same time the particle deposition in the case of an inhomogeneous loading could be replicated excellently.

[1] Cagna, M. (2003). Numerische Modellierung des zeitlichen Verhaltens von Strömungen in der Umgebung von Tiefenfiltern. Dissertation, Universität Karlsruhe.

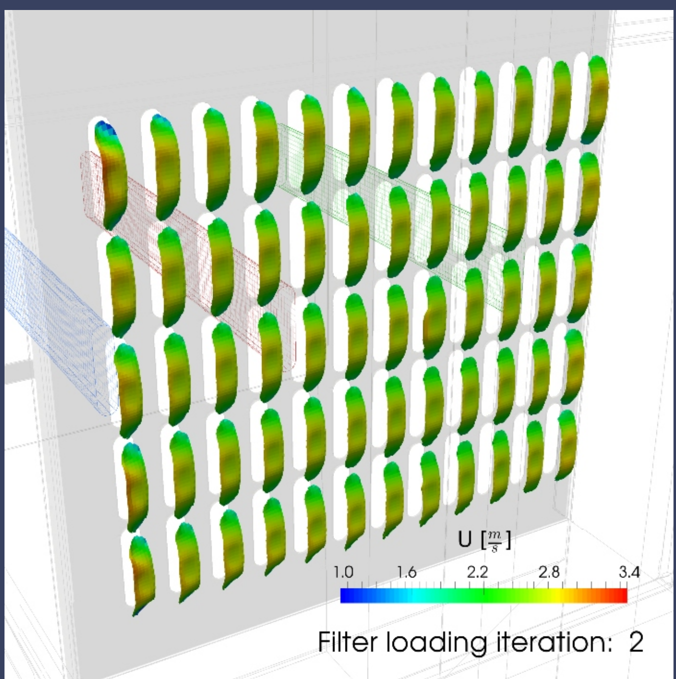
Validation performed on real world plants

Furthermore, we have a testing plant with 60 pocket filters and filter cleaning by pressure surge for the explicit use for validation purposes at our disposal.

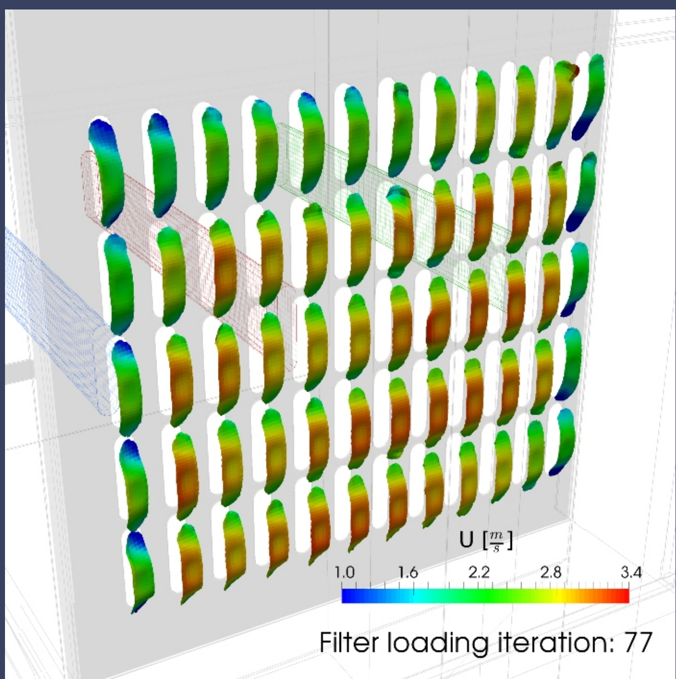
Here, numeric models are validated and additional effects, e.g. the influence of fluid structure interactions, are examined thoroughly in the frame of master theses. The new knowledge obtained and the collected experiences are directly integrated into further software development.

Flow shift caused by increased filter resistance during particle load

Measuring the filter flow velocities showed that the outer bag filters were clogged with particles first. The gas flow shifted more and more to the inner bag filters of the filter block. The increasing velocities through the inner filters and the decreasing flow through the outer filters where reproduced by the simulation. Therefore the continuous flow shift could be proved.



Flow shift at filter elements: During the early particle load cycles outer filter elements are passed stronger

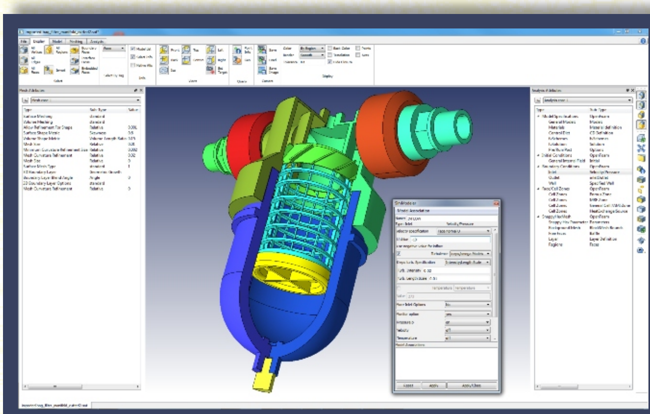


During the later particle load cycles the resistance at the outer filter is increased and the flow shifts to inner filter elements

CastNet integration

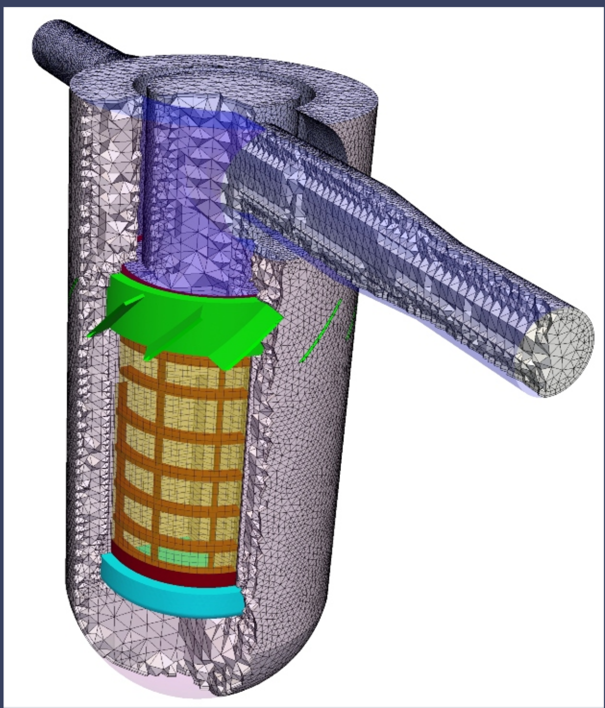
For the work with the filter solver, the user can choose between two options:

- The text-file based work, as usual under OpenFOAM®. This working method is suited for advanced OpenFOAM® users, or if you have already integrated a CFD workflow for OpenFOAM® in your company.
- Alternatively, you can define your filter calculation case in CastNet: CastNet is a pre-processing and calculation control system for the open source CFD/FEA systems OpenFOAM® and CalculiX developed by DHCAE Tools. By specific adaptations and extensions of OpenFOAM® for filter applications, DHCAE Tools created a cost-efficient, reliable and stable calculation tool for the filter industry.



CastNet modelling environment

If you have, besides filters, other application fields in the area of flow simulation or structural mechanics, you can model these with CastNet as well: The whole functional range is available for you.



Hybrid mesh for filters

Meshing for filter applications

In CastNet, models from your CAD system can be saved in the high-quality CAD kernel format and are available there for meshing and definition of the solver settings.

The meshing technologies provided by CastNet allow the consideration of different requirements for mesh generation:

- In hybrid meshing, details and pressure jumps can be solved especially well by prism layers on the filters. Hexahedron-core grids lead to reliable and stable results. Near-wall regions are meshed with prism boundary layers.
- Alternatively, mesh generation with snappyHexMesh is available in CastNet. With only a few minutes of definition effort, also very large, hexahedral-dominant grids for complex filter arrangements can be generated on several CPU kernels in parallel.

Modelling for filter applications

Modelling for filter applications is made especially easy for the user:

- The filter regions can directly be selected in the CAD model.
- The definition of the filter parameters and the solver features in the coupling of the particles with the continuous phase is directly carried out in the GUI.
- By prefabricated or self-produced templates, the calculation case is defined with just a few clicks.
- The whole process with all result files is integrated into the automatic workflow.

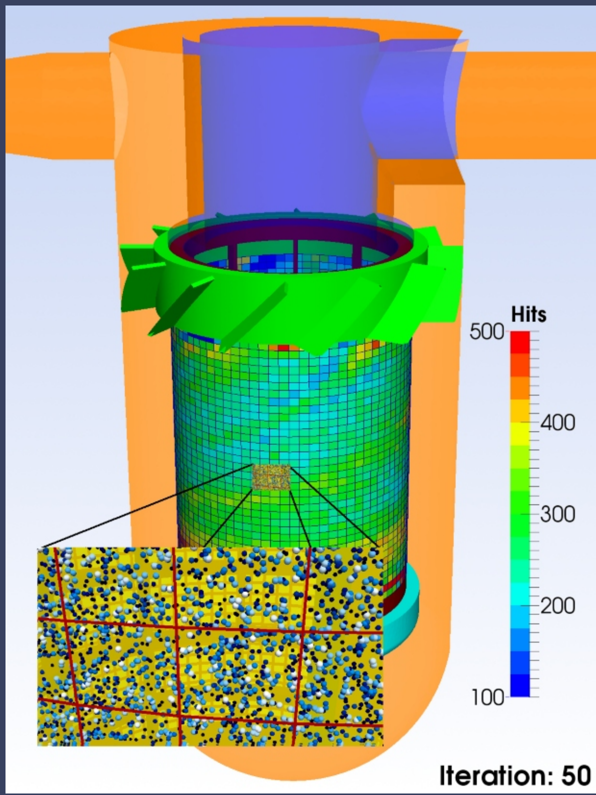
Customized packages according your needs

Support and adaptation included:

A support and adaptation package is always included in the package for the filter solver. By this, we adapt the solving possibilities of the tools to your specific requirements. If you need, for example, a special form of loading characteristic for your filters, it will be provided by us immediately. We also support you with the usage of the solver.

Training

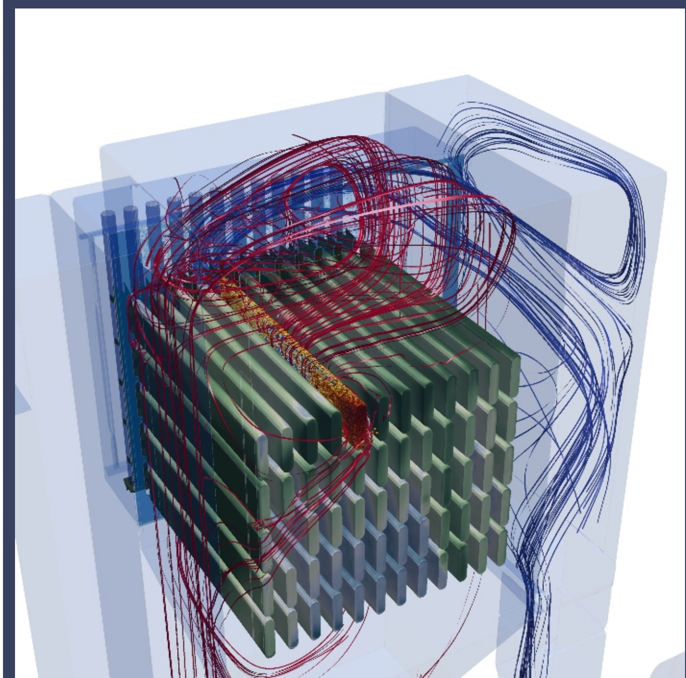
We train you directly in the usage of the filter solver or general CFD with OpenFOAM® depending on your needs. Other CFD problems besides the filter application can of course be investigated as well with the solver package. We offer regular courses in our office in Krefeld as well as on-site training targeting your applications.



Water filter with particle separation

A test environment is available for you:

For a test of the filter simulation, a comfortable test environment with examples is available for you via the Internet. Here, you can directly test your filter application and evaluate, which hardware resources will be required by you later.



Filter test plant: Colour on filters according particle load

Simulation environment:

If desired, you can also receive the complete system (incl. OpenFOAM® installation). We recommend a Linux workstation as simulation environment.

Alternatively, you can use the solver in a complete Windows environment based on the OpenFOAM® port BlueCFD.

Furthermore, we provide a direct cloud access from the monitoring GUI to carry out calculations on external computer centres. Here you find on-demand hardware resources according your job size to conduct fast simulations without blocking your local machine.

The OpenFOAM® source codes are of course included in the scope of delivery.

Scientific funding programme

The Federal Ministry of Economics and Technology funds our innovative developments for filter modelling with a promotion in the „ZIM programme" (central innovation programme for medium-sized companies).

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DHCAE Tools GmbH

Address: Alte Rather Str. 207 47802 Krefeld, Germany
Phone: +49 2151 9490-200 Fax: +49 2151 9490-209
Website: www.dhcae-tools.com Email: info@dhcae-tools.de