Simulation of filtration applications

Advanced CFD simulations for the design of efficient filters are playing a greater role, but exactly what advantages can this high-tech process realize?

IBS Filtran specializes in the field of automatic transmission filtration for the automotive sector. In response to the rising demands on the transmissions themselves regarding performance, comfort, and environmental compatibilities, manufacturers are continuously developing new materials, innovative designs, and more complex control units, as well as advanced transmission types.

Filter experts have to identify any changing conditions in order to refine the transmission requirements to generate supporting filtration concepts. The key challenge in the development of filter systems is to find the best compromise between the interacting key factors, such as pressure drop, filtration efficiency, and dirt hold capacity.

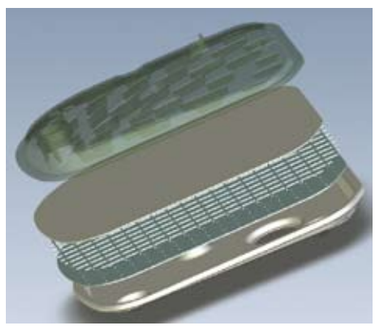
The actual interaction is related to the nature of filter media. For example, the higher the efficiency, the higher the pressure drop will be. Likewise, the lower the pressure drop, the lower the dirt hold capacity will be. To optimize all three factors, new filter media types must be developed.

The pressure drop of a filter consists of pressure differential related to the filter media and the filter geometry (housing). The optimization of the pressure drop in the filter geometry can be realized without many consequences to the other factors.

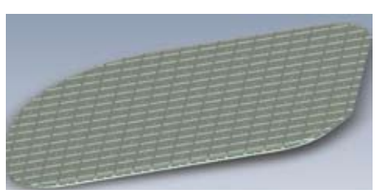
The optimization of the sub-item pressure drop of filter geometry could be considered as a typical application area for CFD simulations. Because of the existence of a filter media inside the filter housing, the CFD software has to work not only with solid or liquid cells, but it also has to deal with porous cells related to the filter media.

Since 2001, IBS Filtran has been working with the CFD program SuFiS, which was developed by Fraunhofer-Institut für Techno-und Wirtschaftsmathematik (ITWM) in Kaiserslautern, Germany, in collaboration with IBS Filtran. The algorithms of this system enabled the calculation of the pressure drop and velocity distribution inside real filter applications. Consequently, the resulting figures could be calibrated and validated between calculated and experimental results.

Above: An all-new pressure filter system with full plastic housing and adapter subcomponents that are lightweight

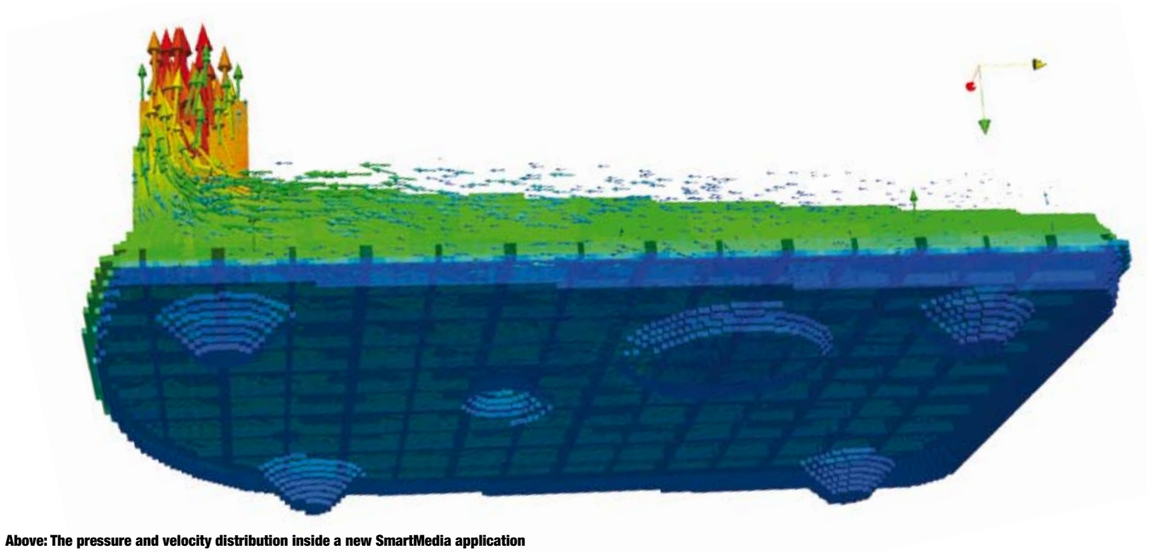


Above and below: The automotive industry is demanding new smart media filters are developed that can find the optimal balance between various factors, such as pressure drops filtration efficiency and dirt hold capacity



This is the most important aspect for the successful use of CFD programs. For example, the accuracy of a filter calculation is highly dependent on the applied porosity value of the filter medium. The porosity number for a filter medium can be identified by special laboratory tests, which should consider real boundary conditions. Another method to determine the porosity number is the micro structure analysis, which in turn is based on simulation. Nevertheless, the validation has to be done on the experimental side. Taking this into account, the implementation of CFD software in the filtration business will generate a relatively high amount of laboratory effort.

After successful implementation of the first SuFiS version it was possible to simulate one of the three key factors describing a filter (pressure drop). To simulate an entire filter, it is necessary to implement the efficiency and loading of the porous media. IBS Filtran and ITWM decided to continue with the development of SuFiS. To do so, the behavior of the filter over time had to be determined. In other words, it is key to know the concentration and distribution of particles inside the oil volume and filtering media over

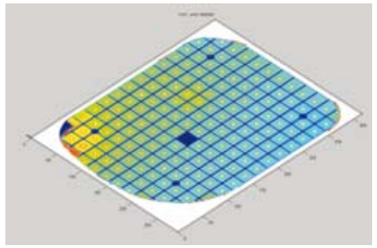


Above: The pressure and velocity distribution inside a new SmartMedia application

a certain period of time. Because the loading and efficiency is velocity dependent, the flow field and pressure distribution also has to be recalculated over time. Having overcome several engineering hurdles, the two partners now have a stable working version of SuFiS.

When determining the validation and generation of input parameters, the effort is by far higher than for the pressure calculation only. For example, for calibration and validation of the efficiency solver ISO 16889 and the Transmission Filtration Effectiveness Method (TFEM) is used. The results achieved by the new SuFiS version are very promising and for the first time it is possible to predict an ISO 16889 efficiency test or TFEM test in a real filter environment. Furthermore, one possibility of the new SuFiS is to compute the efficiency from combinations of filtering media inside a real filter housing, which is more or less impossible without such a tool.

Although the implementation of a CFD simulation tool causes extra charge related to the need of experimental studies, the benefit



Above: Velocity distribution of a SmartMedia application

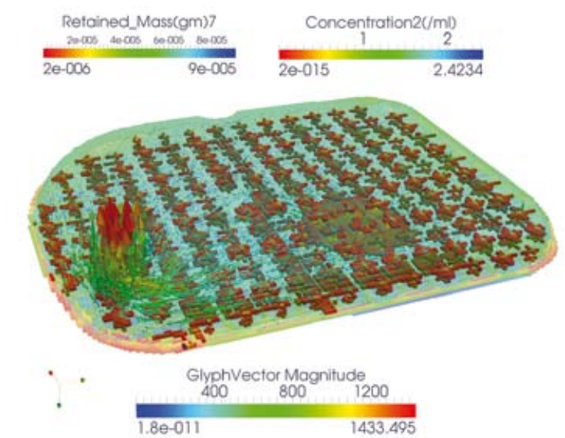
at the end will be enormous, and especially at the time when all needed parameters are correctly determined.

The decreasing lifecycle of products, and cost pressures based on increasing competition, are aggravating circumstances in the automotive industry. The filter industry provides great development partners to help optimize operating efficiency and capabilities.

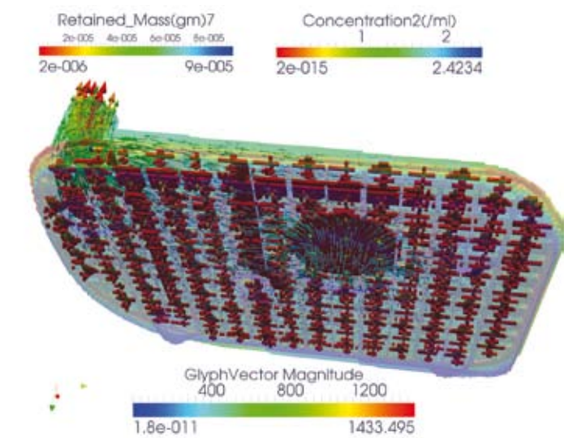
But reducing time and cutting on costs are not the only benefits when using a CFD program. For example, the visualization tool of a CFD package enables the engineer to look into each corner of a filter, which is often difficult or in some cases even impossible to realize. In addition, the possibility of choosing boundary conditions, which are not available for experimental testing (such as different porosity of filter media, different particle distribution and concentration of oil volume) expand the scope of filter development.

Added visualization tools place the filter designer in a position to better understand the complex fluid dynamic situation. To get an idea what is possible some examples are shown in the illustrations above and below.

Instead of this macroscopic view, other manufacturers are developing microscopically analysis flow simulations or particle separation in porous media. It is possible that these parts will be able to integrate into the macroscopically structure of SuFiS. Another approach would be the connection of CFD and FEM analysis, which would be also a helpful tool in filter design. ***TTi***



Above: Vector field and retained mass inside dual layer porous for particle concentration



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