

# IMPORTANCE OF CFD SIMULATIONS FOR THE DESIGN OF EFFICIENT FILTERS

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## ABSTRACT

The importance of CFD simulations for the design of efficient filters will be illustrated using the concrete example “automatic transmission filtration”. Thus some specific aspects of this filtration application will be explained preliminary, before the focus is finally related to CFD simulations respectively practical implementation, benefit and future trends. Due to the attention to filtration key factors as pressure drop, filtration efficiency and dirt holding capacity, the emerging expertise should be transferable to other (at least liquid) filtration applications.

## KEYWORDS

CFD Simulation, Liquid Filtration, Filter Design,  
Pressure Drop, Filtration Efficiency, Dirt Holding Capacity, Aeration

## 1. Introduction

IBS FILTRAN is specialized in the field of automatic transmission filtration for the automotive business. In response to the continuously rising demands on transmissions themselves regarding performance, comfort and environmental compatibility, transmissions manufacturers are developing new materials, innovative designs or more complex control units and not least totally new, groundbreaking transmission types.

Filter experts have to identify the changing conditions with the goal to refine transmission requirements to generate their supporting filtration concepts.

	<i>aspects</i>		
<i>level</i>	<i>performance</i>	<i>comfort</i>	<i>environmental</i>
<b>transmission</b> 	<ul style="list-style-type: none"> <li>- high torque</li> <li>- reduction of traction loss</li> <li>- transmission ratio spread</li> <li>- performance per weight</li> </ul>	<ul style="list-style-type: none"> <li>- no sudden movement</li> <li>- reduction of noise</li> <li>- operator control</li> </ul>	<ul style="list-style-type: none"> <li>- effectiveness</li> <li>- lightweight</li> <li>- compact</li> </ul>
<b>type of transmission</b>	conventional stepped automatic, semi-automated continuously variable, double clutch, etc.		
<b>hydraulic</b>	new design, new materials, new concepts, higher pressure, smaller parts, more sensitive parts, higher cleanliness level		
<b>filtration</b> 	<b>suction and pressure filtration</b>		
	<ul style="list-style-type: none"> <li>- <b>less pressure drop</b> (feed of oil at cold start, effectiveness, cavitation)</li> <li>- <b>higher filtration efficiency</b> (cleanliness level, critical particle size)</li> <li>- <b>higher dirt hold capacity</b> (reduction of service intervals, lifetime filters)</li> </ul>		

Figure 1: Dependency between demands on transmissions and filtration concepts

The challenge within the development of filter systems is to find the best compromise between the interacting key factors pressure drop, filtration efficiency and dirt hold capacity.

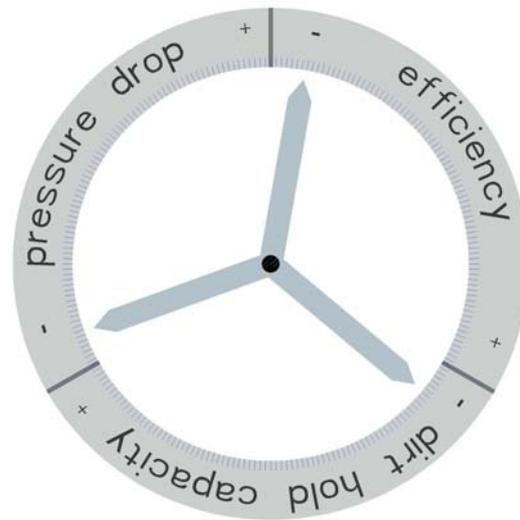


Figure 2: Schematic interaction between the three filtration key factors

The interaction is related to the nature of filter media. For example: the higher the efficiency, the higher the pressure drop or the lower the pressure drop the lower the dirt hold capacity. To generate optimizations for all three factors, it is necessary to develop new filter media types.

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

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

## 2. Implementation of a CFD Simulation Tool

Since 2001, IBS FILTRAN has been using the exclusively developed CFD program SuFiS™, which had been developed by the “Fraunhofer Institut Techno- und Wirtschaftsmathematik - ITWM in Kaiserslautern (Germany)”. The algorithms are specially adjusted for application filtration in automatic transmissions. This enables a faster and more precise calculation “pressure drop as subject to flow rate” for the relatively high viscous media ATF (Automated Transmission Fluid) in comparison to standard CFD programs.

More detailed information regarding background and structure of the software kernel of SuFiS™, are published in the paper „On a new challenge for CFD simulation in filtration“ [O.Iliev – ITWM].

The approach of a filter calculation using CFD software can be roughly described as follows:

1. Segmentation of a 3D-CAD model into different cells
2. Classification of the cells regarding „solid” (filter housing), “fluid” (flow area) and “porous” (filter medium)
3. Definition of boundary conditions (flow rate, viscosity, density, porosity, etc.)
4. Calculation in an iterative way
5. Generation of test results regarding requested parameters (pressure drop)
6. Visualization of the test results (pressure distribution or vectors of flow)

Calibration and validation between calculated and experimental results, are most important for a successful usage of CFD programs in general. For example, the accuracy of a filter calculation is highly depending 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 the real boundary conditions. Another method to determine the porosity number is the micro structure analysis, in turn, based on simulation. Nevertheless the validation has to be done on the experimental side. The implementation of CFD software in filtration business will generate a relatively high amount of laboratory effort.

**3. Benefit of the usage a CFD Simulation Tool**

Although the implementation of a CFD simulation tool is causing extra charge related to the need of experimental studies, the benefit will be enormous, from the time when all needed parameters are correctly determined.

The following chart compares the traditional way of filter design optimization to the new CFD analysis approach:

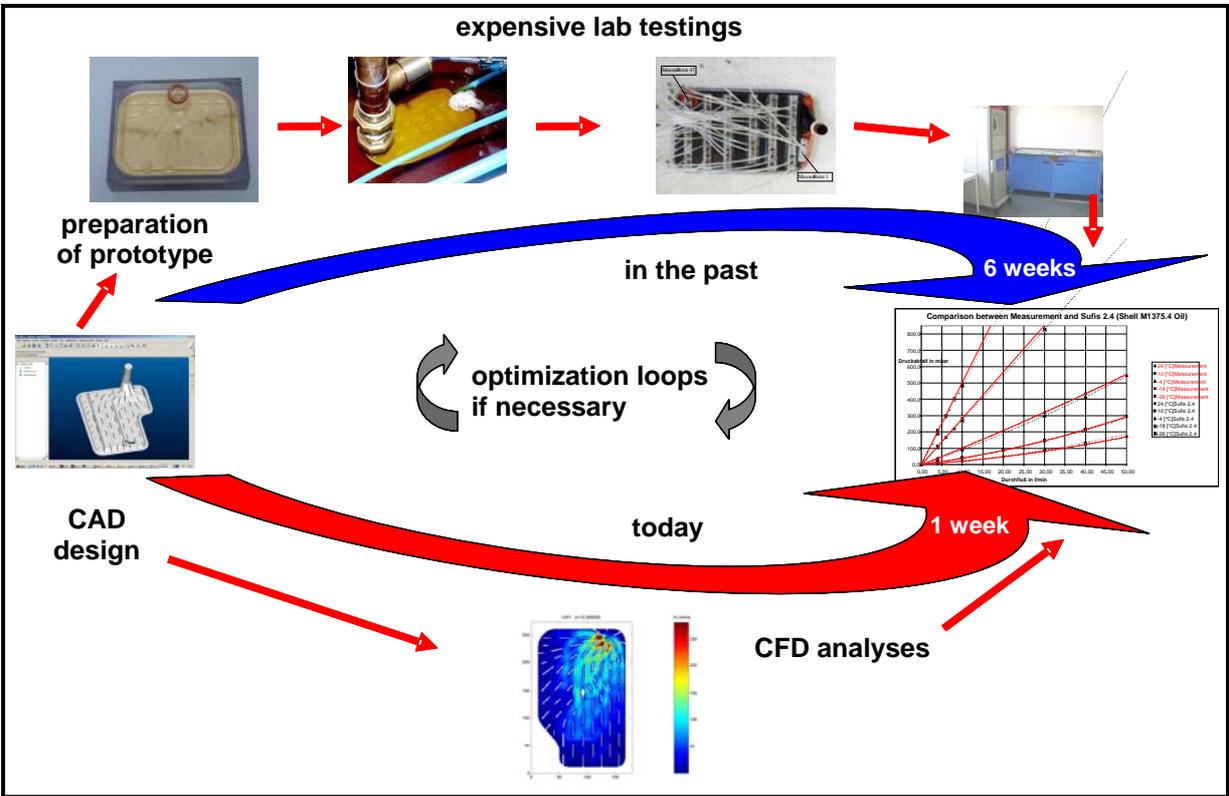


Figure 3: Reduction of development effort based on usage of CFD simulation tool

The decreasing product life cycle and the cost pressure basing on higher competition on a global market are aggravating circumstances in the automotive business. The filter industry, as development partner, is highly recommended to optimize their operating efficiency and capability regarding development, design and production.

But not only reduction in development time and costs is an important point by using a CFD program – for example, the visualization tool of a CFD simulation tool enables “a look into each corner of a filter”, which is often hard or even impossible to realize in practice. In addition the possibility of choosing boundary conditions, which are not available for experimental testing (e.g. different porosity of filter media) expands the “playground” in filter development.

#### 4. Examples of the usage of a CFD Simulation Tool

Attached are some examples of practical applications regarding filter design:

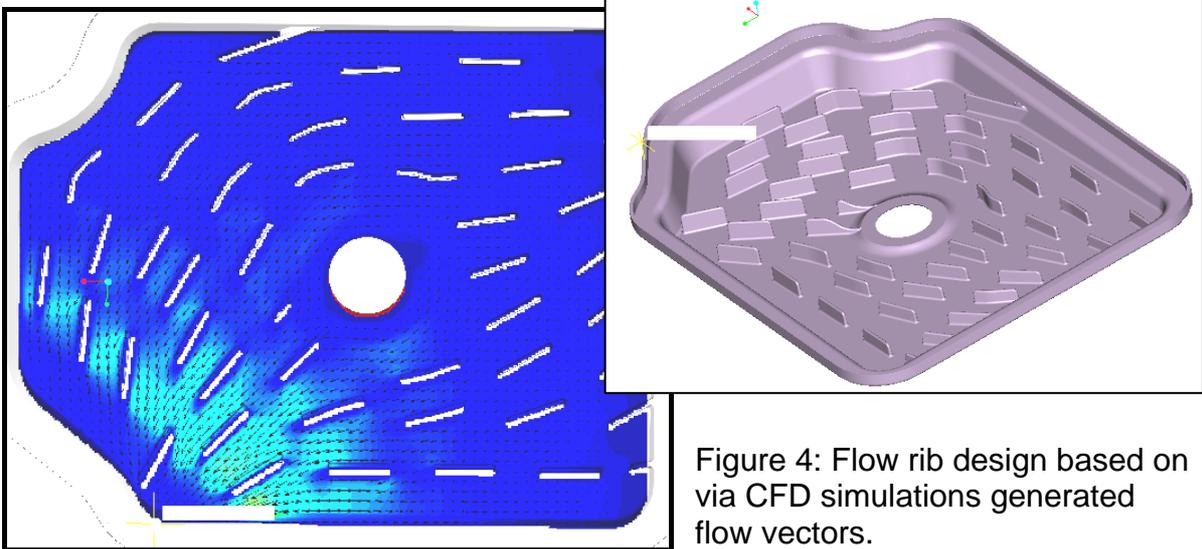


Figure 4: Flow rib design based on via CFD simulations generated flow vectors.

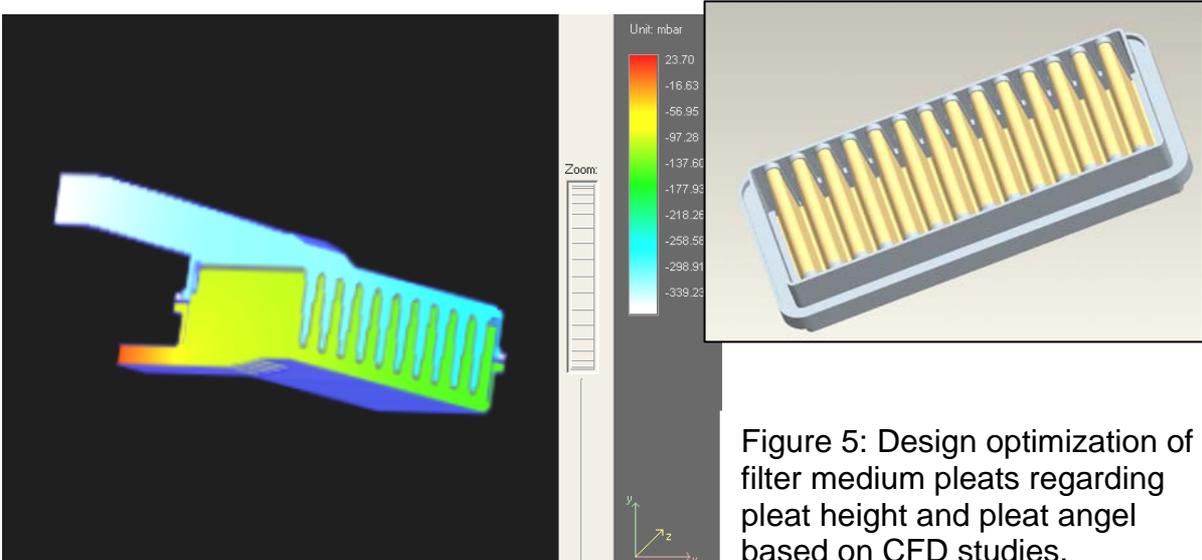


Figure 5: Design optimization of filter medium pleats regarding pleat height and pleat angel based on CFD studies.

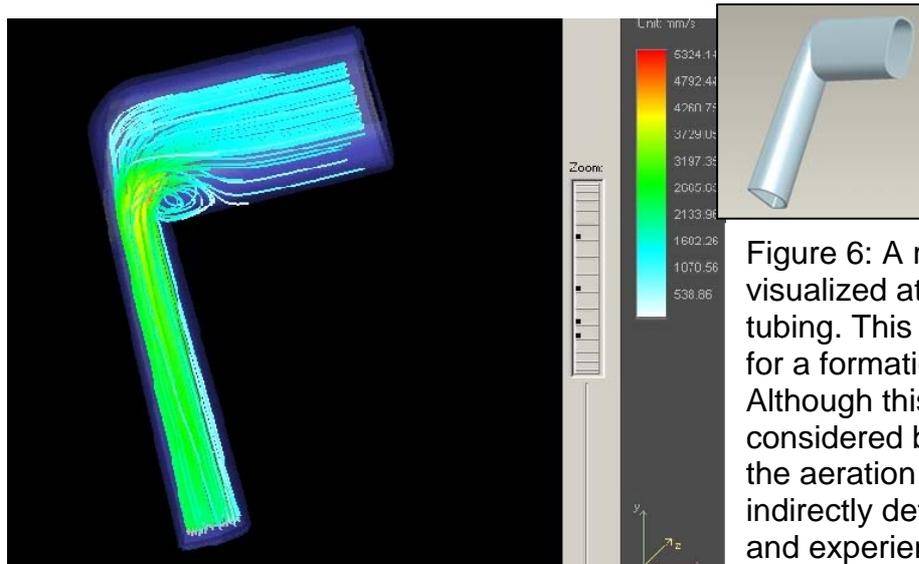


Figure 6: A rotating flow is visualized at the one-quarter tubing. This could be an indication for a formation of air bubbles. Although this simulation did not considered bonded gas in the fluid, the aeration problem can be indirectly detected based on CFD and experiences.

#### 4. Future trends in CFD Simulation Tools for the filtration business

Advantaged by the enormous enhancements in computer hardware, the CFD software is even more applicable. The need of “supercomputers” is a requirement of past times. Actual standard PC’s provide already enough computing power to generate simulation test results in an acceptable time. In future, this development will generate further advantages regarding simulation time or respectively accuracy. The relevance of the investment in computer hardware related to the implementation of CFD software will turn to be nearly irrelevant.

The actual available CFD-Software is capable to determine accurately pressure drop vs. flow rate in filter applications. Added visualization tools are placing filter designers in a position of better understanding the complex fluid dynamic situation.

IBS FILTRAN will focus their future development in conducting sub-tools to the existing CFD program SuFiS™, which will be able to simulate also other filtration key-factors as ‘filtration efficiency’ and ‘dirt hold capacity’. The strategic goal is to create a simulation tool, which providing a complete overview about all relevant parameters in filter performance.

Instead of this macroscopic view, others (special filter media suppliers) are developing in a microscopically analysis like ‘flow simulations’ or ‘particle separation’ in porous media. It is supposable, that these components will be able to integrate into the macroscopically structure.

Another approach would be the combination of CFD and FEM analysis, also presenting a helpful tool in filter design.

Finally it can be mentioned, that it is not a question if CFD simulation tools will capture the filtration business market, the question is, what kind of sub-tools will be able to be adapted, in order to gain the most efficient simulation tool.