Preliminary study on simulation and validation of the effect of particle loading regarding flow-induced deformation of pleated porous filter media

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Abstract

For modelling aerosol particle filtration, the shape of the pleated porous filter media is used to be assumed as stiff and unchanged during particle loading. With ongoing advances in simulation of fluid-structure interaction, it is now possible to consider the flow-induced deformation of pleated media. By changing the permeability of the porous media, particle loading is modelled. For validation purpose an experimental setup is developed, providing information about the pleated media deformation. Preliminary results show a good correlation between simulation and testing.

Introduction

Enhancing the performance of today's filter elements in automotive applications is challenging, especially in the context of increasing requirements for upcoming filtration tasks. For this purpose, new generations of filter materials are developed. However, a highly efficient filter media and good mechanical stability of the material are not necessarily associated with each other. In certain extreme cases, fluid forces may lead to deformations of the pleated filter structure which may affect the flow field and the particle deposition inside the pleats as well. This kind of generally unintended interference is also known as Fluid-Structure Interaction (FSI).

Therefore, we are focusing on the enhancement of the filter pleat stiffness which is a multi-goal task that cannot only be solved by common "trial-and-error" methods. Furthermore, we want to gain more insight to underlying phenomena and mechanisms which cannot be easily investigated up-to-now. In addition, the permeability of the filter media changes with ongoing particle collection. Thus, the flow-induced forces acting at the porous medium are higher resulting in a larger deformation of the pleated media. Therefore, the interplay of particle loading, fluid forces and deformation of the filter media is of particular interest.

Methodology

In order to study these effects of particle loading on flow-induced deformation of pleated filter media, we enhanced our simulation approach and developed an experimental setup to quantify the deformation of the pleats. Hereby, the pleat shape is measured by laser triangulation method. The optical measuring system is located downstream of the filter element in the flow channel and gives access to characteristic changes of the pleat's shape by flow-induced forces.

Fluid and structural mechanics simulations are performed with ANSYS 16.1 using the system coupling approach. This allows a step-by-step simulation of the pleat deformation (Traut et al., 2014). The mechanical material parameters (E, G, ν) of the porous filter medium have been derived in previous stages of the research project. The domain and the basic setup are shown in figure 1.

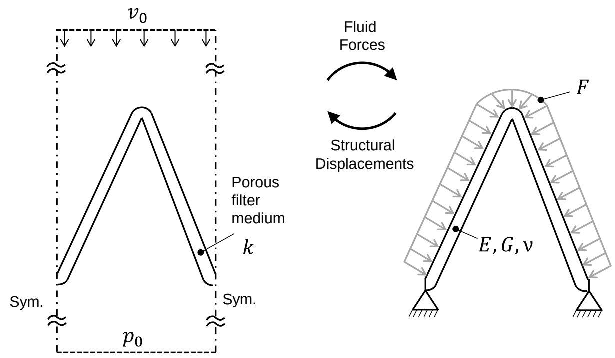

Figure 1. Simulation domain and setup for CFD (left) and FEA (right). Flow induced forces and displacements of the filter structure are transferred.

In this study we focused on the deformation while loading the filter media. For simulation purpose, the loaded filter is rigorous modelled by a decreased media permeability k as derived from flat sheet data.

Results

Preliminary results indicated a good correlation between experimental and simulation data for new and unloaded filter material (Traut et al, 2016). Latest results will be presented and discussed about flow-induced deformation for particle loaded filter media.

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