Contribution ID: **8** Type: **Oral Presentation**

Adjoint-based topology optimization of porous structures

Tuesday, 31 May 2022 14:20 (15 minutes)

Conventional filters consist of one or more layers of filter material, which are either woven or composed of tangled fibers. The quality of the separation results almost only from the density of the fiber arrangement. Due to the manufacturing process, compromises between separation and pressure loss that are in the opposite relationship to each other are inevitable.
The possibilities of additively manufacturing filters and the use of numerical modeling and simulation in combination with adjoint-based topology optimization extend the conventional parametric filter media development options. The cross section of conventional fibers is always round. During the adjoint process completely new shapes adapted to the flow and the media used, are generated and then realized by 3D printing. This leads to new fiber geometries with both increased separation efficiencies and decreased pressure drops. The aim of this work is to optimize simultaneously two normally opposing variables by using the complex non-linear relationships between the different separation mechanisms. In a gas-particle system, for example, impaction, interception and Brownian diffusion are the main separation mechanisms.
In numerical modeling and simulation, a flow region is generated and divided into volume elements (meshing). The conservation equations are solved for each volume element. An initial geometry is presented to the flow solver, the adjoint solver calculates the sensitivities depending on a change of the design variables (mesh). The mesh deformation adjusts the generated mesh in the direction of the sensitivities.
The adjoint method is used to determine the effect of a change in the design variable of an objective function. A simple algorithm is introduced that combines both sensitivities of the cost functions (pressure drop and separation efficiency). While the optimization of the pressure loss has been state of the art for a long time, we propose a substitute function for the separation efficiency.
A cost function for the adjoint solver has to be continuously differentiable. Depending on the deposition mechanism, different parts of the surface are responsible for the deposition. These are optimized accordingly. For example increasing the surface normal to the flow direction, the separation efficiency by inertia increases. The resistance coefficients for pressure and shear stress are used as functions to influence the separation performance accordingly. Especially the combination of force coefficients for pressure and pressure loss have been identified as effective for the case considered. A pressure loss of 3.9 % combined with an increase in total filtration efficiency of 2 % could be realized in only one deformation step for a gas-particle system.

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Time Block A (09:00-12:00 CET)

Participation

In person

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Session Classification: MS22

Track Classification: (MS22) Manufactured Porous Materials for Industrial Applications