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Topology optimization of a reversible crash protection using fluid – structure interaction

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Topology optimization has proven a very successful method for obtaining optimized designs without a priori design considerations for a variety of mechanical problems [1]. This includes among others both solid and fluid mechanical problems. Topology optimization has earlier been applied for crashworthiness applications by the use of truss and frame models [2]. In this work a fluid saturated porous material with spatially varying microstructure is considered and the effect of internal dissipation is utilized.

The goal in this paper is to design auto mobile bumpers or crash barriers where reversible crash protection for impact is needed, meaning that the deceleration limitation does not origin from plasticity. Such an energy absorbing mechanism can be designed using a porous fluid saturated material which in its optimized configuration limits the deceleration during crash due to the dissipation and furthermore regains its original outer shape afterwards due to the elastic skeleton.

The methods used so far in the context of topology optimization of fluid mechanical problems uses the Brinkman formulation where the flow is penalized by introducing less penetrable material which in the limit acts as solid material [3]. This though neglects the stiffness problem and does not allow for designs where the structure and fluid interacts as this requires a well-defined boundary on which the stresses can be evaluated.
In order to include the interaction an alternative approach is used, namely to consider a class II problem, also known as soil-pore interaction in earth-mechanics, where the solid and fluid are inseparable and are represented in the same variables. The problem is transient and the consolidation equations were first introduced by Biot but this work elaborates on the formulation in [4,5].

An interpolation function is introduced for each of the constitutive parameters; stiffness, permeability and hydrostatic pressure dependency in order to use the topology optimization method. These interpolation functions origin from homogenization studies of a prescribed simple micro-structure which can be scaled according to macroscopic density.
By the specification of an objective function such as a prescribed deceleration curve [2] and the use of mathematical programming an optimized crash protector is designed.

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