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A porous media flow model for simulating flow of non-Newtonian bone cement inside a deformable vertebra in the context of vertebroplasty

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Vertebroplasty is a medical procedure in which a “bone cement” is injected into the porous interior of a damaged or fractured vertebra in order to restore its structural strength. While the procedure is fairly successful and provides near-instant relief, sometimes the bone cement might leak out of the vertebra resulting into complications like pulmonary embolism, paralysis, etc. To mitigate the risk of cement leakage, simulations could serve as a useful tool for practitioners to decide the best operating parameters for each patient. However, in order to simulate the procedure, there are many aspects that need to be modelled, e.g. the interior porous geometry, the non-Newtonian behaviour of the bone cement, the curing phenomenon, the displacement of the present bone marrow, etc.

In this work, we use the Theory of Porous Media as the modelling framework, since it is essentially a porous media flow process. Upon this framework, suitable constitutive models are used for the non-Newtonian rheology of the bone cement and the bone marrow, e.g. the Carreau-Yesuda model, to which additionally upscaling is applied using Cannella model and the average viscosity model. The solid deformation problem is solved using the Finite Element approach, while the discretization for the flow problem is carried out using the Box-discretization technique, essentially resulting in a mixed Finite Element - Finite Volume discretization. Furthermore, experiments are carried out in order to characterize the non-Newtonian and curing behaviour of the bone cement. A benchmark injection experiment using aluminium foam is employed in order to validate the simulation results using experimental data. This is then used for trial and comparison of various constitutive models in order to choose the most suitable for this application. This whole modelling setup can be further upgraded to include thermal interactions for studying the temperature, or even to include fractures, possibilities for which will be presented in the outlook.

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References

Time Block Preference

Time Block B (14:00-17:00 CET)

Participation

Unsure

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