A hybridizable mass-conserving stress-yielding method for incompressible flow

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In computational fluid dynamics, the proper treatment of the incompressibility constraint on the fluid velocity is an age-old subject of discussion. A relatively recent twist in this topic, arising from a series of developments by multiple authors, is the treatment of the incompressibility constraint using the Sobolev space H(div), the space of vector fields whose components and divergence are square integrable. With this as a starting point, we proceed to discuss a natural Sobolev space for viscous fluid stresses to pair with H(div) velocities. Simple new matrix finite elements for viscous stresses are developed. They have shear continuity and can be seen as arising from a nonstandard Sobolev space H(curl div). The resulting method, called the Mass-Conserving Stress-yielding (MCS) method, produces optimal order approximations for viscous stresses, velocity, pressure, and vorticity, is exactly mass conserving, and is pressure robust. Moreover, the method uses only facet-based coupling (i.e., without any vertex or edge degrees of freedom in three dimensions) and is amenable to straightforward hybridization. This is joint work with Philip Lederer and Joachim Schöberl.

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