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Numerical Methods for Viscoelastic Fluid Flows

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Abstract

Many synthetic fluids, still as some natural fluids, show complicated rheological behavior during which viscoelasticity may be a relevant fluid property. Over the last forty years, machine physics (CR), the appliance of machine fluid dynamics (CFD) to fluids with non-Newtonian physics, has developed into a mature discipline, that at the same time helps to grasp a good vary of physical phenomena whereas conjointly providing helpful tools for engineering style. Metallic element refers to flow simulations with fluids that area unit delineated by non-Newtonian models, additional complicated than the generalized Newtonian fluid, since specific techniques to deal with the inherent numerical difficulties related to the complicated constituent equations area unit required albeit the simulations area unit geared toward a hydraulics perspective.

In the late 1970s, at a time once Newtonian CFD had already began to take place into competitor industrial merchandise, the big scatter of numerical results for a similar elastic non-Newtonian flow issues and therefore the corresponding conflicting physical interpretations of information, that were pretty much related to the shortage of accuracy and convergence difficulties succeeding from the questionable high–Weissenberg range drawback (HWNP), LED to the institution of a series of standard workshops that introduced correct benchmarks and centered analysis efforts within the field. The biyearly International Workshop on Numerical strategies in Non-Newtonian Flows started in 1979 in Rhode Island, USA, and had its nineteenth edition in 2019, in Peso prosecuting officer Régua, Portugal. The start of the 21st century saw vital progress in attempt the HWNP through a more robust understanding of its causes and therefore the succeeding development of varied acceptable numerical techniques. chromium |Cr| atomic range 24 metallic element metal might finally be employed in unknown territory within the Weissenberg range (Wi)–Reynolds number (Re) space, therefore changing into a lot of correct and trustworthy tool, only if the adequate essential equation is chosen for the actual fluid and flow below investigation.

The relevance of this last point should be emphasized. If we take for granted the description of structurally simple fluids as Newtonian, in all possible flows, the description of complex fluids is often incomplete, except for very limited simple flow kinematics. Therefore, numerical or analytical flow descriptions in many real flows will be qualitative at most. In this review, we do not address the difficulties associated with the proper rheological characterization of real fluids by adequate constitutive equations, an important area of research on its own; rather, we assume that the adopted model adequately describes the intended fluid properties. Therefore, the numerical methods discussed here are for constitutive equations at the same level of description as the equations governing the conservation of mass and momentum, i.e., at the continuum level, also called macroscopic-scale level. Nevertheless, at the end of this review, we provide some references for methods relying on mesoscopic-scale-level fluid descriptions.

An early textbook, written by Crochet et al. (1984), discussed numerical methods for viscoelastic fluid flows based on the finite-element method (FEM) and finite-difference method (FDM). The enormous progress over the following two decades was covered by Owens & Phillips (2002), but the finite-volume method (FVM) was not addressed in detail. The FVM is a relative latecomer to CR and its extension for viscoelastic fluids has been presented. But further developments and new computational tools have become available since then. Therefore, this review focuses essentially on the state of the art, leaning toward the FVM, while providing potential future lines of research in numerical methods and new applications in viscoelastic fluid flow simulations.

Keywords: Computational rheology finite-volume method • Viscoelastic flows • High–Weissenberg number problem • Benchmark flows • Numerical stabilization methods

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