A DATA-DRIVEN INVESTIGATION ON VISCOELASTIC FLUID FLOWS

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While the application of data-driven approaches has been already considered as an important tool in fluid mechanics researches for Newtonian fluids, the construction and application of frameworks for non-Newtonian fluids are in early progress stages and remain largely unexplored. It is worth noting that non-Newtonian materials can be found in many different types of applications (e.g. pharmaceutical, petrochemical, food and mineral industries), exhibiting complex mechanical and rheological responses. In this work we have selected one special class of non-Newtonian fluids: the viscoelastic fluids [1].

In this work we discovery reduced-order models in viscoelastic fluid flows using a purely data-driven strategy. We have considered simulation data of an oscillatory problem in order to identify underlying functional form of the nonlinear physics observed in viscoelastic instabilities [2]. In particular, to generate our dataset, we have numerically solved the mass and momentum equations combined with a set of hyperbolic partial differential equations that define the polymeric contribution on the system [3].

The proposed framework combines a viscoelastic proper orthogonal decomposition (POD) with the sparse identification of nonlinear dynamics (SINDy) [4] resulting in a low-dimensional reduced order model. In particular, the inputs used by the SINDy algorithm are the temporal coefficients obtained by the linear reduction POD technique while the output of the process is a dynamical system related to the dataset. In order to select a stable identified dynamical system, we studied different libraries of candidate functions of the time series, as for example, the combination of linear and cubic polynomials in terms of the POD modes. The criteria used to define the models are based on a combination of the sparsity of the system with the numerical stability to integrate the resulting equations.

The identified dynamical system was able to capture the dominant behavior of the leading temporal coefficients. In particular, in order to intepretate the reduced-order model, we have compared the obtained results with the full simulation data in an oscillatory regime. In addition, the accurate reconstruction of the full state from the obtained reduced-order model confirms the successful of our framework to capture the field flow patterns in a complex viscoelastic flow. The current work can be considered as a significant step on the construction of the reduced-order models in non-Newtonian Fluid Mechanics.

References

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