Accepted Manuscript

A damped Newton algorithm for computing viscoplastic fluid flows

Pierre Saramito

PII: S0377-0257(16)30062-3
DOI: 10.1016/j.jnnfm.2016.05.007
Reference: JNNFM 3793

To appear in: *Journal of Non-Newtonian Fluid Mechanics*

Received date: 12 November 2015
Revised date: 17 May 2016
Accepted date: 19 May 2016

Please cite this article as: Pierre Saramito, A damped Newton algorithm for computing viscoplastic fluid flows, *Journal of Non-Newtonian Fluid Mechanics* (2016), doi: 10.1016/j.jnnfm.2016.05.007

A damped Newton algorithm for computing viscoplastic fluid flows

Pierre Saramito

CNRS and Lab. J. Kuntzmann, B.P. 53, 38041 Grenoble cedex 9, France

mail: Pierre.Saramito@imag.fr

Abstract – For the first time, a Newton method is proposed for the unregularized viscoplastic fluid flow problem. It leads to a superlinear convergence for Herschel-Bulkley fluids when $0 < n < 1$, where n is the power law index. Performances are enhanced by using the inexact variant of the Newton method and, for solving the Jacobian system, by using an efficient preconditioner based on the regularized problem. A demonstration is provided by computing a viscoplastic flow in a pipe with a square cross section. Comparisons with the augmented Lagrangian algorithm show a dramatic reduction of the required computing time while this new algorithm provides an equivalent accuracy for the prediction of the yield surfaces.

Keywords – viscoplastic fluid ; Bingham model ; Herschel-Bulkley model ; Newton method

Introduction

The numerical resolution of viscoplastic fluid flows is still a challenging task. The augmented Lagrangian method has been introduced in 1969 by Hestenes [20] and Powell [29]. During the 1970s, this approach became popular for solving optimization problems (see e.g. Rockafellar [33]). In 1980, Glowinski [17] and then Fortin and Glowinski [15] proposed to apply it to the solution of the linear Stokes problem and also to others non-linear problems such as Bingham fluid flows. In 1980, Bercovier and Engelman [3] proposed a viscosity function for the regularization of Bingham flow problem. In 1987, another viscosity function was proposed by Papanastasiou [28]. During the 1980s and the 1990s, numerical computations for Bingham flow problems was dominated by the regularization method, perhaps due to its simplicity, while the augmented Lagrangian algorithm leaded not yet convincing results for viscoplastic flow applications. In 1989, Glowinski and le Tallec [18] revisited the augmented Lagrangian method, using new optimization and convex analysis tools, such as subdifferential, but no evidence of the efficiency of this approach to viscoplasticity was showed, while regularization approach becomes more popular in the 1990s with the work of Mitsoulis *et al.* [21] and Wilson and Taylor [44]. In 2001, Saramito and Roquet [41, 35] showed for the first time the efficiency of the augmented Lagrangian algorithm when combined with auto-adaptive mesh methods for capturing accurately the yield surface. In the 2000s, this approach became mature and a healthy competition developed between the regularization approach and the augmented Lagrangian one. Vola, Boscardin and Latché [43] obtained results for a driven cavity flow with the augmented Lagrangian algorithm while Mitsoulis *et al.* [22] presented computation for an expansion flow with regularization and Frigaard *et al.* [23, 16, 31] pointed out some drawbacks of the regularization approach. Finally, at the end of the 2000s decade, the augmented Lagrangian algorithm becomes the most popular way to solve viscoplastic flow problems [24, 12]