**Editorial for Virtual Special Issue on “Polymer Degradation in Turbulent Drag Reduction”**

This is the fourth virtual special issue of the Journal of Non-Newtonian Fluid Mechanics. Here we discuss issues around turbulent drag reduction (DR) by polymer additives and, in particular, their degradation (and “de-aggregation”) caused by this turbulent motion. The special issue is centred about the review of Edson Soares [1], which we are very pleased to publish in the Journal of Non-Newtonian Fluid Mechanics. Turbulent drag reduction by polymer additives has fascinated many of us in the Non-Newtonian Fluid Mechanics community, and undoubtedly will continue to do so, for a long time. Coupled with the manifest potential practical applications of being able to reduce turbulent drag by up to 80% - and the concomitant energy reductions this would imply for pumping costs for example – is that this phenomenon can be observed at such dilute conditions that it is often the *only* non-Newtonian characteristic that can be observed: viscometric measurements often being unable, *using current rheometers*, to differentiate such solutions from their solvent (often water). For example, in a too little known JNNFM paper from 1983, Oliver and Bakhtiyarov [2] were able to measure turbulent drag reduction with polymer concentration as low as 0.02 ppm i.e. 20 parts polymer per billion of solvent. Unfortunately, for the majority of very effective drag-reducing polymeric additives (i.e. high molecular weight, linear and flexible molecules) it was quickly found that in recirculating systems the drag-reducing effectiveness can quite rapidly degrade, limiting practical application, and such effects are at the heart of the current review [1]. Despite such degradation effects, turbulent drag reduction by polymer additives has continued to remain a key topic of interest in *JNNFM* with important contributions across the decades. Starting in the 80s with Kowalik et al. [3] who looked to use interpolymer associations to increase the polymers’ resistance to degradation in turbulent flows, then in the 90s where modelling approaches began to take off leading to ground-breaking Direct Numerical Simulations using realistic constitutive equations [4] and advanced experiments where attempts were made to relate drag reduction to apparent extensional viscosity estimates [5]. Following this in the 2000s where the first attempts to produce self-consistent simple two-equation models [6,7] which would enable routine computation in complex geometries (this follows very early work [8] also on this topic and the three works side-by-side demonstrate the enormous progress in modelling DR over this time) and Particle Image Velocimetry (PIV) were used to investigate the flowfield [9]. To emphasize the long-standing interest of this subject we have decided to include not only the 9 JNNFM references cited in this review, but also a number of fundamental drag-reduction papers discussed above [2-9] and also other key contributions of relevance that were not referred to but which have appeared in JNNFM since its inception over 40 years ago. Relatedly, the problem of convective heat transfer reduction that accompanies the well-known drag reduction phenomenon is a fascinating issue which has not received nearly as much attention as the reduction in drag itself and we therefore also include the seminal paper of Matthys [10] who probed such effects whilst paying attention to degradation effects (both mechanical *and* thermal).

As the review discusses in detail, polymer degradation is now known to be related to molecular scission where the long molecule typically breaks near its centre effectively reducing the molecular weight to half of its initial value. In a laminar flow the polymer needs to be fully stretched to achieve this – and therefore extensional kinematics are required [11] but concentration and molecular weight are also important [12] – but in turbulent flows the polymers are mainly stretched by structures which impart a local transient extension which appears to have a similar effect to steady-state pure extension in laminar flow. Gel permeation chromatography (GPC) is often used to study this phenomenon and Moussa et al. [13] studied the effects of different solvents on the degradation of polyisobutylene (PIB) in a turbulent flow whereas in a later study Liberatore et al. [14] such GPC measurements were combined with detailed measurements of the flowfield using PIV and rheo-optical measurements.

Soares [1] also discusses the transient nature of drag reduction and it was his own important contributions which helped to first elucidate these effects such that they could be investigated independently of polymer degradation (which can itself be, of course, in the early stages a “transient” until the molecular weight reaches an equilibrium with the turbulent stresses it is exposed to). These experimental works [15-16] made use of a double concentric cylinder device coupled to a rheometer such that they could provide extremely good temporal and drag (actually torque) resolution. They show that in the early stages the drag actually *increases* -presumed due to a near instantaneous increase of the extensional viscosity - followed by a period (called the “development time”) where the drag reduction increases until reaching a maximum plateau. As also shown by Kalashnikov [17], who studied a turbulent flow of polyethylene oxide and PIB solutions in a similar rotating apparatus, this drag reduction plateau starts to decrease only after a certain period of time, when the number of degraded molecules is sufficiently large. Finally, after this period of constant drag reduction, the degree of DR falls as degradation and de-aggregation processes occur before a steady-state asymptotic degree of drag reduction is reached (which, as degradation does not proceed indefinitely, the ultimate value of drag reduction even after many hundreds of hours of shearing is usually not zero see e.g. [18]). Such transient effects have also been studied numerically using DNS of the FENE-P model [19] and the same qualitative features reproduced. There appear to be differences between flexible [15] and more rigid [16] molecules. In general, rigid molecules such as xanthan gum [20] and, more recently, diutan gum [21] appear more resilient to degradation than more flexible molecules. Indeed, the diutan gum [21] degradation and de-aggregation phenomena appear not to be significant.

Finally, the majority of degradation studies to date have been experimental and little work has been done in how to incorporate degradation effects into modelling efforts, a noticeable exception being the paper of Pereira et al. [22]. We hope this virtual special issue – and the new review at its core which itself suggests a number of open questions – will encourage more work in this area.

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