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Spatial-temporal Phenomena in the Flows of Multi-component Materials

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Abstract:
Measuring the rheological properties of multi-component (and multi-phase) systems meets with many special problems which are absent in flows of homogeneous materials. Such complex fluids have inherent structure and all the peculiarities of their behavior are determined by stress-induced temporal-spatial structure rearrangements. This paper is a review devoted to the physical origin and classification of problems encountered in the flow of multi-component materials. Stress-driven phenomena can be related to phase transformations (the formation of a new phase in polymerization, crystallization, amorphous phase separation), molecular and structure orientation, and various forms of self-organization. Some of these time effects are considered to be thixotropic phenomena. Thixotropy of multi-component matters leads to absence of an upper Newtonian plateau, time (rate)-dependence of yield stress and the layered flow in the range of high shear rates. The flow of such matters can lead to the formation of spatially divided structures with different properties and displacement of structures at the macroscopic level that excludes traditional measures of their rheological properties. In addition, the flow of multi-component systems is accompanied by the appearance of anisotropy of their properties. It is emphasized that the stressdriven evolution of rheological properties are not taken into account in the existing widely used constitutive equations.

Key words:
multi-component matter, rheological properties, thixotropy, flow curve, anisotropy, stress-induced transitions, shear banding, self-organization, yielding, Newtonian viscosity

1 INTRODUCTION

There are a lot of publications – original papers, reviews, monographs, textbooks, manuals, software and so on – devoted to fundamental principles, corrections, and applied methods for measuring the rheological properties of fluids [1–4]. Generally speaking, they are based on the conservation equations and, surely, the results of calculations are correct within the limits of the assumptions used. The main assumption is the concept that we are dealing with homogeneous media with properties which are constant or continuously changing in space. These general approaches are applied to very different materials including multi-component and multiphase fluids assuming however that it is possible to average the properties of such systems at some volume which is negligibly small in comparison with the total volume of a measuring cell.

Meanwhile, the latter can be untrue: volumes of parts of a matter under study can be rather large and there are many cases when jump-like spatial-temporal changes of rheological properties of a sample can be met. In these specific cases, it should be understood what is really measured when spatial-temporal phenomena in the flows of multi-component (multiphase) materials occur and one expect (possible false) that their rheological properties are measured. This publication addresses this issue and its goal is to discuss and classify different real situations when this question arises. The earlier review devoted to self-organization in the flow of complex fluids was published in [5]. This review touches several important aspects of the problem not discussed below and covers new literature sources appeared during last 5 years. In particularly, the movement of supermolecular structures as single objects in heterogeneous media is discussed It also seems necessary to discuss the problem of spatial-temporal heterogeneity in the flow of multi-component (complex) fluids with respect to using rheological constitutive equation for such cases. It is emphasized that

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