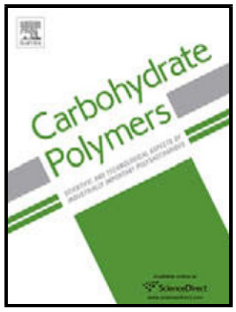

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PII: S0144-8617(15)00932-7
DOI: http://dx.doi.org/doi:10.1016/j.carbpol.2015.09.067
Reference: CARP 10369

To appear in:

Received date: 23-5-2015
Revised date: 7-9-2015
Accepted date: 21-9-2015

Please cite this article as: Szopinski, D., Handge, U. A., Kulicke, W.-M., Abetz, V., and Luinstra, G. A.,Extensional Flow Behavior of Aqueous Guar Gum Derivative Solutions by Capillary Breakup Elongational Rheometry (CaBER), *Carbohydrate Polymers* (2015), http://dx.doi.org/10.1016/j.carbpol.2015.09.067

Extensional Flow Behavior of Aqueous Guar Gum Derivative Solutions by Capillary Breakup Elongational Rheometry (CaBER)

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Abstract

The extensional rheological properties of aqueous ionic carboxymethyl hydroxypropyl guar gum (CMHPG) and non-ionic hydroxypropyl guar gum (HPG) solutions between the semi-dilute solution state and the concentrated network solution state were investigated by capillary breakup elongational rheometry (CaBER). Carboxymethylated guar gum derivatives show an instable filament formation in deionized water. The ratio of elongational relaxation time λ_E over the shear relaxation time λ_S follows a power law of $\lambda_E / \lambda_S \sim \left(c \cdot [\eta]\right)^{-2}$. The difference of the relaxation times in shear and elongation can be related to the loss of entanglements and superstructures in elongational flows at higher strains.

Keywords

Extensional flow; capillary breakup elongational rheometry (CaBER); guar gum derivatives; relaxation times

1 Introduction

Guar gum is a natural, water-soluble polysaccharide from the endosperm of the guar bean (*cyamopsis tetragonoloba*). This carbohydrate polymer consists of a linear backbone of β-1,4 linked D-mannopyranosyl units and randomly, in pairs and triplets arranged α-1,6 linked D-galactopyranosyl units as sidechains (Dea & Morrison, 1975; Hoffman & Svensson, 1978; McCleary, Clark, Dea, & Rees, 1985). The water-thickening properties are considered to result from the high molar mass (1000-2000 kg·mol^{-1} (Vijayendran & Bone, 1984) and the formation of superstructures in aqueous solutions. The latter are putative segment-segment interactions of the unbranched part of the backbone and are commonly referred to as “hyperentanglements” (Coycoolea, Morris, & Gidley, 1995; Morris, Cutler, Ross-Murphy, Ress, & Price, 1981; Wientjes, Duits, Jongschaap & Mellema, 2000; Szopinski, Kulicke, & Luinstra, 2015) according to a first hypothesis.

Carboxymethylation (CM) and hydroxypropylation (HP) of native guar gum result in derivatives with enhanced thermal stability and solubility in water. These ionic and non-ionic derivatives (Fig. 1) find use on an industrial scale in food, agriculture and/or textile applications and as additives for fracturing fluids in oil recovery operations (Tizzotti et al., 2010; Kesevan & Prud’homme, 1992; Zhang & Zhou, 2006).

We recently published structure-property relationships of aqueous CMHPG solutions in steady state and oscillatory shear flow (Szopinski et al., 2015). A further insight can be gained by the additional determination of the extensional flow behavior of aqueous guar gum derivative