PREDICTION OF ZERO SHEAR VISCOITY OF POLY (VINY CLORIDE) PLASTISOLS

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ABSTRACT:
The rheological behaviour of PVC plastisols composed of a blend of suspension and micro-suspension resins in different proportions was investigated. The present work was mainly focused on the variation of the zero shear viscosity versus the concentration of the extender resin. Hence, the packing fraction \( \Phi_m \) was evaluated using the Krieger-Dougherty equation. These experiments confirmed the major influence of particle size distribution concerning the decrease of viscosity for concentrated suspensions. In addition, a model based on the porosity model developed by Ouchiyama et al. (Ouchiyama N, Tanaka T: Porosity estimation for random packings of spherical particle”, Ind. Eng. Chem. Fundam. 23 (1984) 490-493) to predict the packing fraction in the case of multimodal lattices was successfully applied to our PVC plastisols formulations.

ZUSAMMENFASSUNG:

RÉSUMÉ:
Le comportement rhéologique de plastisols de PVC composés d’un mélange de suspensions et de micro-sus- pensions de résines dans différentes proportions a été étudié. Ce travail est principalement centré sur la varia- tion de la viscosité de cisaillement à vitesse nulle en fonction de la concentration en résine. A partir de celle-ci, la fraction volumique pour le compactage \( \Phi_m \) a été évaluée en utilisant l’équation de Krieger-Dougherty. Ces expériences ont confirmé l’influence majeure de la distribution en taille des particules sur la diminution de la viscosité pour les suspensions concentrées. De plus, un modèle basé sur le modèle de porosité développé par Ouchiyama et al. (Ouchiyama N, Tanaka T: Porosity estimation for random packings of spherical particles”, Ind. Eng. Chem. Fundam. 23 (1984) 490-493) afin de prédire la fraction volumique de package dans le cas de réseaux multimodes, a été appliqué avec succès à nos formulations de plastisols de PVC.

KEY WORDS: PVC plastisols, rheology, particles size distribution, maximum packing fraction

1 INTRODUCTION

Predicting the evolution of the viscosity of PVC plastisols is extremely difficult. This complex rhe- ological behaviour results from the physics of particles in suspension whose complexity is enhanced by the complexity of PVC plastisols for- mulations (origin of PVC; mineral fillers; surfactants ...). Particles of PVC are subject to different types of interactions (Van der Waals, brownian, electrostatic) but cannot be considered as solid particles because interactions with plasticisers lead to their swelling upon heating and conse- quently, completely modify their apparent vol- ume fraction [1]. Yet, the fluidity of plastisol before its gelification governs its stability and easiness of processing. Therefore, it would be interesting to be able to predict it and as results adjust it if needed.

Rheological studies performed on standard lattices [2 - 23] are a solid source of documents for the more fundamental study of the rheology


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In order to predict the intrinsic viscosity ranging between 3.6 and 4.5. In order to predict $[\eta]_0$ of the mixtures, we assumed that

$$[\eta]_0 = [\eta]_{0,\text{resinB}} + [\eta]_{0,\text{resinA}} \Phi_{\text{m}}$$

where $[\eta]_{0,\text{resinB}} = 4$ and $[\eta]_{0,\text{resinA}} = 4.5$. Table 3 summarizes the values of intrinsic viscosity evaluated owing to experimental results and calculated from Eq. 7. These values are very close, consequently we regard our evaluation of intrinsic viscosity as correct.

Finally, figures 10 shows the prediction of the model considering tri-modal population. The values of viscosity are well evaluated for the diluted mixtures $\Phi<40\%$ where the PSD distribution does not play a dominating role. The predictions are also correct for the concentrated mixtures as long as the value of $\Phi$ remains lower than its optimal value (around 95 %) given by Pishvaei’s model and which corresponds to a minimum of viscosity. However, the re-increase of viscosity is not well modelled: it takes place for too large $\Phi$, and is carried out in a too abrupt way. The problem comes, as already underlined, from the fact that the tri-modal model predicts a maximum $\Phi_m$ for a too high value of $\Phi$. The difficulty of the modelling of the packing term due to uncertainty on individual $\Phi_m$ is thus not reflected on values of viscosity but on the ratio of extender which leads to the lowest viscosity for a concentration $\Phi$. However the region of lowest viscosity can be predicted precisely enough all the more so as our system is poly-disperse.

**CONCLUSIONS**

We initially checked that the Krieger-Dougherty equation was applicable to PVC plastisols. From this equation and experimental results, we have then determined the packing parameter of two different PVC resins. The knowledge of the packing parameters and the size distributions of particles, allowed us to use the model of Pishvaei et al. [3] to evaluate the packing fraction $\Phi_m$ of poly-modal mixtures.

From the knowledge of the packing term, we finally go up with the values of zero shear viscosity and thus confirm that beyond a critical concentration $\Phi > 30\%$ and for a ratio $\delta$ ranging between 0.07 and 0.5, there is an optimal fraction in large particles $\Phi_g$ between 40 and 70 % for which the viscosity is minimal. Results are compatible with those of the literature relating to lattices and prove that PVC are particular suspensions which obey nevertheless the general laws of dispersions.

This work also underlines that a relatively broad and polydisperse distribution can be modelled in first approximation by a system made up of N monodisperse systems centred around a well defined size. However, this work highlights the faults of the model of Pishvaei [3] since it requires the knowledge of parameters which are difficult to predict, in particular $\Phi_m$, in intrinsic viscosity of the mono-modal populations.

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