Viscoelastic Behavior of Disperse Systems with Silicone Oil and Different Fillers

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Received: 23.4.2002, Final version:23.9.2003

Abstract:
The rheological behavior of model suspensions with the silicone oil M20000 and different concentrations of Cab-o-sil TS 720 resp. Durcal 5 are compared. The increase of the Cab-o-sil concentration changes the flow behavior of the suspension from shear-thinning, to pseudoplastic, and to plastic flow behavior. The first normal stress difference rises at the same time at certain shear rate. The disperse systems with Durcal 5 keep the structural viscous behavior of the silicone oil even with a filler concentration of 40.5 wt%. The dependence of the first normal stress difference on shear rate represents for suspensions with Durcal 5 only one straight line with a slope of $n = 2$. The normal stress has double the amount of the silicone oil M20000 at given shear rate and is independent of the used Durcal 5 concentration. It was established that suspensions with the silicone oil M20000 have a first normal stress difference that can, depending on the filler type, either increase (with Cab-o-sil TS 720) or decrease (with Durcal 5) at certain shear stress with increasing filler concentration. It is to be supposed that the decrease of the normal stress at a given shear stress, with increasing Durcal concentration, is a softening effect, caused by the filler.

Zusammenfassung:
Die rheologischen Eigenschaften von Modellsuspensionen mit dem Silikonöl M20000 und verschiedene Konzentrationen von Cab-o-sil TS 720, sowie Durcal 5, werden verglichen. Die Erhöhung der Cab-o-sil Konzentration verändert die Fliesseigenschaften der Suspension von strukturviskosem zu pseudoplastischem und plastischem Fliessverhalten. Die erste Normalspannungsdifferenz steigt dabei bei gleicher Schergeschwindigkeit. Die dispersen Systeme mit Durcal 5 behalten das strukturviskoses Fliessverhalten vom Silikonöl sogar bei einer Konzentration von 40.5%. Die Abhängigkeit der ersten Normalspannungsdifferenz von der Schergeschwindigkeit stellt bei den Suspensionen mit Durcal 5 eine Gerade mit einer Steigung von $n = 2$ dar. Die Normalspannung hat bei gleicher Schergeschwindigkeit einen doppelt so hohen Wert wie diejenige des Silikonöls und ist unabhängig von der Durcal-Konzentration. Es wurde festgestellt, dass Suspensionen mit dem Silikonöl M20000 eine erste Normalspannungsdifferenz haben, die mit steigender Füllstoffkonzentration bei einer bestimmten Schubspannung, je nach Füllstoff-Art entweder steigen (Cab-o-sil TS 720) oder abnehmen (Durcal 5) kann. Es ist anzunehmen, dass die Abnahme der ersten Normalspannungsdifferenz bei einer bestimmten Scherspannung (mit der Erhöhung der Durcal-Konzentration) auf einen Weichmacher-Effekt des Füllstoffes zurückzuführen ist.

Résumé:
Le comportement rhéologique de suspensions modèles contenant de l'huile de silicone M20000 et différentes concentrations de Cab-o-sil TS 720 resp. Durcal 5 est comparé. L'augmentation de la concentration en Cab-o-sil modifie le comportement en écoulement: on passe d'un comportement rhéoamincissant à un comportement pseudo plastique, et finalement à un comportement plastique. La première différence de contraintes normales augmente simultanément à une certaine vitesse de cisaillement. Les dispersions avec Durcal 5 conservent le comportement visqueux structurel de l'huile de silicone, même à une concentration en charge de 40,5% en poids. La variation de la première différence de contraintes normales en fonction de la vitesse de cisaillement pour les suspensions avec Durcal 5 présente simplement une ligne droite avec une pente n=2. La contrainte normale est le double de celle de l'huile de silicone M20000 pour une vitesse de cisaillement identique et ne dépend pas de la concentration en Durcal 5 utilisée. Il est démontré que les suspensions avec l'huile de silicone M20000 possèdent une première différence de contraintes normales qui peut, suivant le type de charge, soit augmenter (cas du Cab-o-sil TS 720), soit décroître (cas du Durcal 5) à une certaine contrainte de cisaillement, avec l'augmentation de la concentration en charge. On suppose que la chute de la contrainte normale accompagnant l'augmentation de la concentration en Durcal, à une contrainte de cisaillement donnée, est un effet de ramollissement causé par la charge.

Key Words: filler type, first normal stress difference, flow behavior

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The three dimensional structure of disperse systems with Cab-o-sil TS 720 will be better with increasing concentration of the thixotropic agent. The first normal stress difference, that is responsible for the elastic behavior, i.e. for the strengthening of the structure of the suspension, increases correspondingly at certain shear stress.

Durcal 5 decreases the first normal stress difference of the suspensions with increasing concentration. It seems that calcium carbonate particles do not interact with the liquid phase. Durcal 5 works as a kind of lubricant for the silicone oil molecules. It is to be supposed that the decrease of the normal stress of these suspensions at a given shear stress with increasing filler concentration is a softening effect, caused by the filler.

It seems that the first normal stress difference can increase or decreases with increasing filler concentration depending on the filler type used. From our measurements and literature dates, one can assume the existence of two kinds of suspensions with a viscoelastic fluid, depending on the filler type:

- Suspensions with calcium carbonate [7, 8, 18, 19] and titanium dioxide [18, 20], where the first normal stress difference decreases at given shear stress with increasing filler concentration. These suspensions have silicone oil or polymer melts as viscoelastic flow phase.
- Suspensions with glass beads [24] or thixotropic agents [16, 17] in silicone oil, where the first normal stress difference increases at given shear stress with increasing filler concentration.

4 SUMMARY

Model suspensions with the silicone oil M20000 and different concentrations of Cab-o-sil TS 720 or Durcal 5 were prepared and the rheological behavior compared. These suspensions have very different rheological behavior. The increase of the Cab-o-sil TS 720 concentration leads to change of the flow behavior of the fluid – from structural-viscous (M20000, 1 and 3 wt% Cab-o-sil TS 720) to pseudoplastic (5 wt%) and finally to plastic (7 wt% Cab-o-sol TS 720) flow behavior. The investigated suspensions with Durcal 5 (calcium carbonate) keep the structural viscous flow behavior of the silicone oil M20'000 even with a filler concentration of 40.5 wt% Durcal 5. The first normal stress difference of the suspensions with Cab-o-sil TS 720 has higher values at certain shear rate as the silicone oil M20000. The dependence of the first normal stress difference on shear rate represents for suspensions with Durcal 5 only one straight line with a slope of $n = 2$. The first normal stress difference of these suspensions has double the amount of the silicone oil M20'000 at given shear rate and is independent of the used Durcal 5 concentration. These facts can be used to predict the first normal stress difference of these suspensions from the first normal stress difference of the silicone oil.

It was established that suspensions with the silicone oil M20000 have a first normal stress difference that can either decrease (Durcal 5 in the silicone oil M20000) or increase (Cab-o-sil TS 720 in the silicone oil M20'000) at certain shear stress with increasing filler concentration. The dependence of the first normal stress difference on shear stress for the systems with 3, 5, and 7 wt% Cab-o-sil TS 720 shows three regions. The slope of the first region is $n = 1$. The destruction of the thixotropic agent structure begins in the second transition region and is already completed in the third region. The slope of the third straight line section is $n_3 = 2$, independent of the thixotropic agent concentration present. The third straight line section is nearly identical with the first normal stress difference of the silicone oil M20000. The first normal stress difference of the suspensions with silicone oil and Durcal 5 decrease at a certain shear stress with increasing filler concentration. The increase of the Durcal concentration causes a parallel movement of the straight lines with a slope of $n = 2$ to higher shear stresses.

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