Rheological Interpretation of the Slump Test

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Abstract:
We examine the validity of the slump test for predicting the yield stress of polymeric suspensions and mineral suspensions. First we propose a modification of this test: in order to make measurements on fluids with high yield stress (of the order of several hundreds of Pascal) we add a mass at the sample top. From detailed observations of the slump in time we show that, for polymeric suspensions (hair gel and sewage sludges), two critical stresses can be distinguished which almost exactly correspond to the two critical stresses (respectively corresponding to a regime change and to the asymptotic slump) observed in rheometry during creep tests. Thus the slump test appears as a practiceful and relevant means to determine the intrinsic properties of these fluids. For mineral suspensions it is shown that the flow abruptly stops after a short time, a behaviour in agreement with the results of rheometrical tests carried out by progressively decreasing the applied stress. In that case the slump also appears to significantly depend on the procedure and cannot be related to a single property of the material.

Zusammenfassung:
Wir untersuchen die Gültigkeit des Ausbreitversuches zur Vorhersage der Fliessgrenze von Polymer- und Mineralsuspensionen. Zuerst schlagen wir eine Modifikation dieses Tests vor: um Messungen an Fluiden mit hoher Fliessgrenze (von der Ordnung mehrerer hundert Pascal) vorzunehmen, fügen wir eine Masse am oberen Ende der Probe hinzu. Aus detaillierten Beobachtungen des Ausbreitverhaltens als Funktion der Zeit kann gezeigt werden, dass für Polymersuspensionen (Haargel und Klärschlamm) zwei kritische Spannungen unterschieden werden können, welche fast exakt mit den zwei kritischen Spannungen übereinstimmen, die in einem Rheometer während eines Kriechtests gemessen werden. Somit scheint der Ausbreitversuch für die Bestimmung der intrinsischen Eigenschaften dieser Fluide anwendbar und aussagekräftig zu sein. Für Mineralsuspensionen wiederum kann gezeigt werden, dass die Strömung nach einer kurzen Zeit abrupt endet. Dies stimmt mit den Resultaten von rheometrischen Tests mit kontinuierlicher Erniedrigung der Schubspannung überein. In diesem Fall scheint der Ausbreitungsvorgang wesentlich von der versuchsfuehrung abzuhängen und kann somit nicht mit einer einzigen Materialeigenschaft korreliert werden.

Résumé:
Nous examinons ici la validité du test d'affaissement (slump test) pour prédire le seuil de contrainte de suspensions de polymers et de suspensions minérales. Afin de pouvoir réaliser des mesures avec des fluides à seuil relativement élevés (de l'ordre de plusieurs centaines de Pascal) nous proposons de modifier le test en ajoutant une masse supplémentaire sur la pâte. A partir d'observations détaillées de l'affaissement au cours du temps nous montrons que, pour les suspensions de polymères, deux contraintes critiques peuvent être distinguées (correspondant respectivement à un changement de régime et à l'affaissement asymptotique), qui correspondent presque exactement à celles déterminées en rhéométrie classique à partir de tests de fluages. Ainsi le test d'affaissement constitue un moyen pratique et pertinent pour déterminer les propriétés intrinsèques de ces fluides. Pour les suspensions minérales en revanche l'affaissement s'arrête brutalement après un temps très court. Ce phénomène est associé à la bifurcation de viscosité de ces matériaux à contrainte imposée. En outre pour ces matériaux la contrainte critique associée à l'affaissement dépend des conditions expérimentales et ne peut donc pas représenter une caractéristique rhéologique intrinsèque de ces matériaux.

Key Words: Slump, yield stress, suspensions, polymers, instability

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this critical value it evolves towards a complete stoppage [19 - 20].

At this stage it is hard to interpret completely the results obtained with the mineral suspensions. However they tend to show that their behavior is governed partly by some thixotropy and partly by some instability below a critical shear rate, which explains both our results from slump tests and from rheometry. More precisely there is likely a continuous competition between restructuration and destructuration due to shear; at rest the strength of the material increases, which explains the need to add a larger mass for slump to start as the time of preliminary rest increases; when the stress is sufficiently large, the destructuration becomes more rapid than the restructuration so that the material "liquefies", its viscosity decreases in time and the material rapidly flows; when the stress becomes smaller than a critical value the restructuration becomes more rapid than the destructuration so that the fluid viscosity rapidly increases towards infinity, leading to an abrupt stoppage.

In our context this means that the slump test in its present form is not appropriate for determining an intrinsic property of such fluids, in particular because its result is significantly dependent on previous flow history, and thus on the complete experimental conditions (procedure for mass addition, absence of link between rheometry and slump data, time of rest before starting the test).

CONCLUSION

The slump test appears as a simple but efficient means to determine the two critical yield stresses of (concentrated) polymeric suspensions. The rapid measurement of the slump after the sudden speed decrease provides σ_2, the critical stress corresponding to the transition from a purely viscous to a viscoelastic regime, while the asymptotic slump (after a long time) provides σ_1, i.e. the critical stress corresponding to the transition from a viscoelastic to a purely elastic regime.

For mineral suspensions the slump depends on the experimental conditions (procedure for mass addition, absence of link between rheometry and slump data, time of rest). This tends to prove that this test in its present form is not appropriate for determining an intrinsic property of these fluids, simply because such a property does not exist.

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