Petroleum & Coal
ISSN 1337-7027

Available online at www.vurup.sk/pc

Petroleum & Coal 46 (2), 47-54, 2004

Study of suspension stability*

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Received 16 August 2004;received in revised form 18 October 2004; accepted 28 October 2004

Abstract

Suspensions often occur both in nature and in industry. Ready solutions of suspensions find wide applications in various branches of industry, beginning with chemical, through metallurgy, food industry and many others.
Results of studies on stability of suspensions that may be applied in pharmaceutical industry are presented in this paper. The effect of various types of thickening agents on viscosity and stability of systems was investigated. Some rheological parameters were measured and attempts were made to describe them by models available in the literature.

Key words: suspensions, stability, rheology

Introduction

Suspensions are included into the group of disperse systems. They consist of a continuous phase, which is a liquid, and a disperse phase, which is formed from solid particles. Stability of this system can be maintained only in the presence of a thickening agent.
Suspensions often occur both in nature and in industry. Ready solutions of suspensions find wide applications in various branches of industry, beginning with chemical, through metallurgy, food industry and many others. They are very frequently encountered on a pharmaceutical market in the form of syrups and a variety of mixtures for external use. Despite extensive research dedicated to the problems of suspensions, still many studies are carried out to improve the quality of existing systems and to devise new ones that will satisfy growing quality and marketing demands.
There are many factors that determine the quality of suspensions, some, however, have a basic significance in this respect – stability of a suspension being such a desirable property. In the case of certain systems we tend to use mixtures as stable as possible (drugs), in other cases the aim is to separate a solid phase from the suspension (sewage treatment).
Results of investigations on the effect of particle properties and various types of thickeners on rheological parameters of suspensions to be applied in the pharmaceutical industry, are presented in this study.

EXPERIMENTAL

Investigations were carried out in the pharmaceutical plant “Polfa Lodz”. In the experiments the following media were used; as a thickening agent: hydroxyl-ethylcellulose (0.3-0 g/100 ml H_2O) – Fig. 1, xanthane gum (0.05-0.5 g/100 ml H_2O), – Fig. 2, carboxymethylcellulose (0.3 g/100 ml H_2O) – Fig. 2,. Suspended substances were Sucralfat (2; 6; 10 g/100 ml H_2O) and basic magnesium carbonate (2; 6; 10 g/100 ml H_2O). Sucralfat is the basic aluminium salt of saccharase octosulphate with anti-ulcer action. To ensure suspension stability the following preservatives were used: Chlorhexidinum (0.03 g/100 ml H_2O), Nipagina “P” (0.05 g/100 ml H_2O) and Nipagina “M” (0.1 g/100 ml H_2O) [5].

Viscosity was measured with a rotary rheometer Rheotec RC 20 (Haake, Germany). It can be controlled both manually and by a computer. Investigations were made in the system of set shear rate constants. Sedimentation curves were determined by means of a Sartorius sedimentation balance.

Figure. 1. Photograph of hydroxyethylcellulose, magnification × 6oo [4]

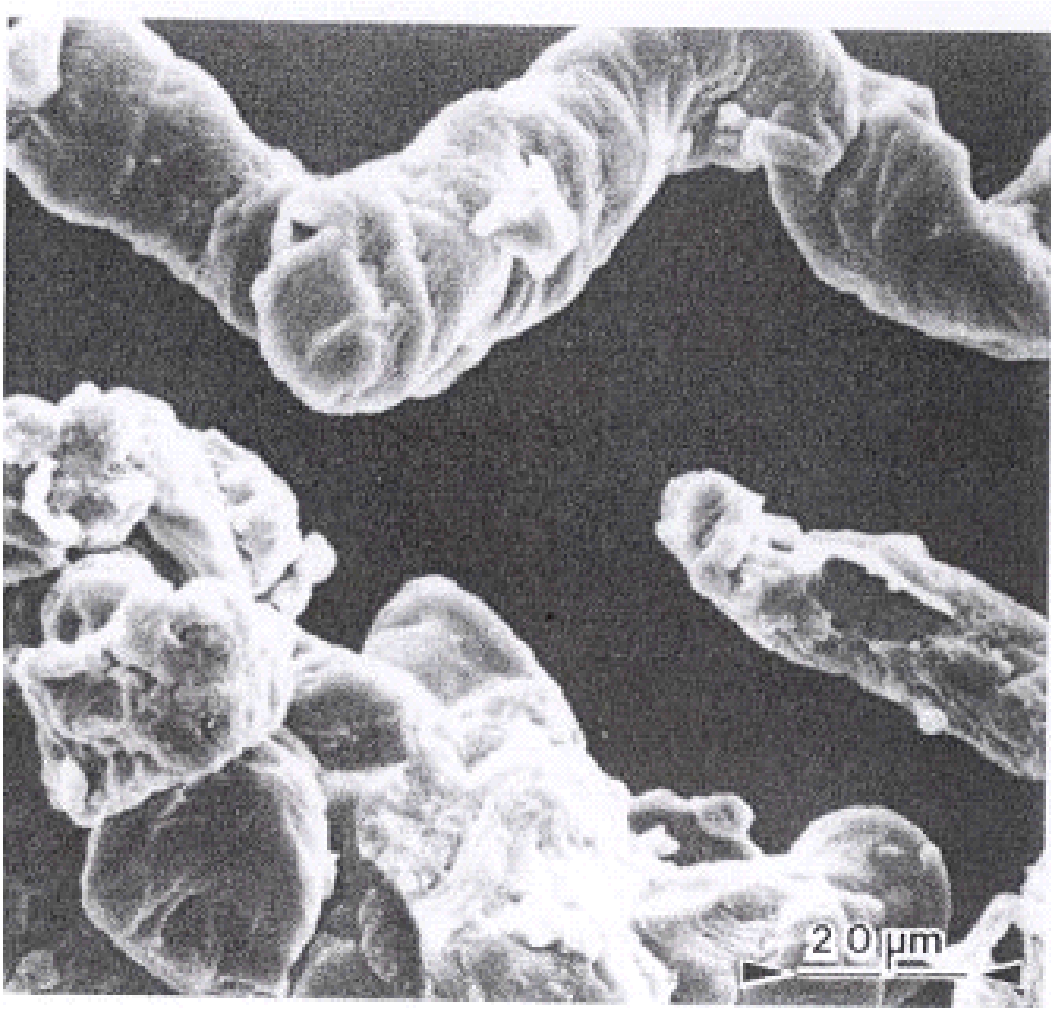
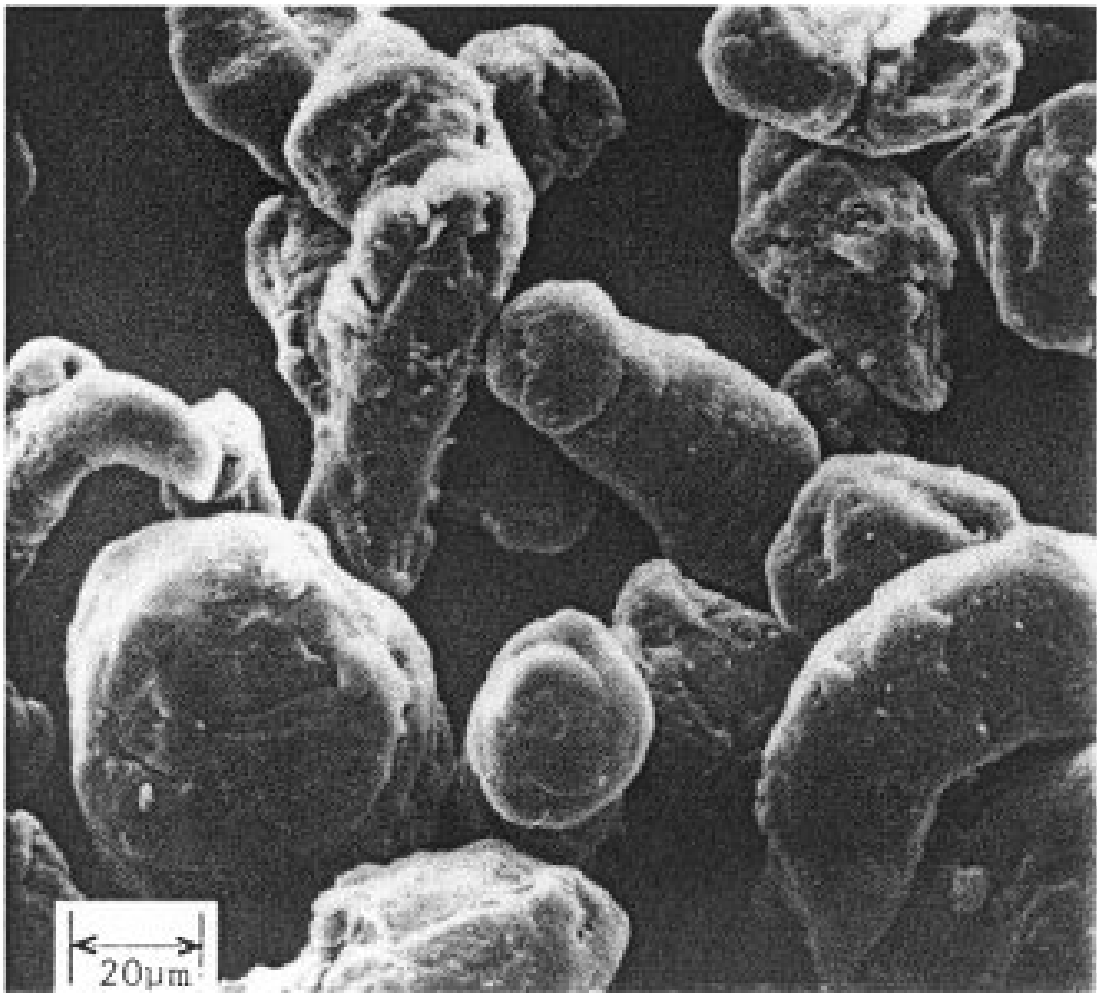


Figure. 2. Photograph of carboxymethylcellulose, magnification × 6oo[4]



Mathematical Modelling

Model 1

$$\sigma = k\gamma^{n} \qquad (1)$$

Model 2

$$\eta = \eta_{\infty} + \frac{\eta_0 - \eta_{\infty}}{[1 + (k\gamma)^{n}]} \qquad (2)$$

Figure 3 shows examples of experimental data described by the power-law *model 1*[1,2]:

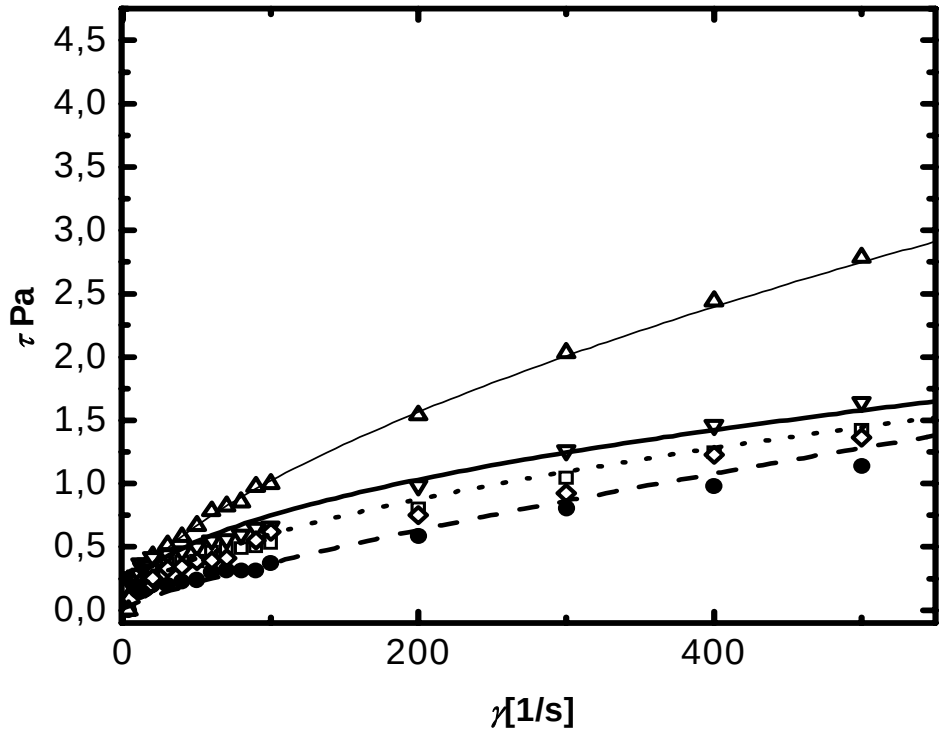


Figure. 3. Examples of flow curves, described by the power-law model, for the suspension of Sucralfat and basic magnesium carbonate in 0.1% xanthane gum solution (□ - 0,1% xanthan gum solution, ○ - 3g sucralfate suspension in 0,1% xanthan gum solution, Δ - 10g sucralfate suspension in 0,1% xanthan gum solution, ∇ - 10g basic magnesium carbonate suspension in 0,1% xanthan gum solution, ◊ **-** 3g basic magnesium carbonate in 0,1% xanthan gum solution)

RESULTS AND DISCUSION

Selection of the model resulted from properties of the tested fluids, their low viscosity which in certain cases changed almost linearly made it impossible to describe the data using other models available in the literature [1,2,3]. It is worth noting that on the basis of Fig. 3 a distinct dependence of viscosity on the amount of added solid substance can be observed. In the case of flow curves, the Sucralfat suspension and basic calcium carbonate with 3 g of continuous phase, viscosity of these systems is lower than the viscosity of 0.1% xanthane gum solution. The situation changes dramatically when the contribution of solid substance increases which is very well illustrated by flow curves for the suspensions with 10 g of solid phase. Both in the case of Sucralfat and basic magnesium carbonate, viscosity increases well above the viscosity of a 0.1% xanthane gum solution. This can be explained by a specific property of solid particles that cause destruction of the primary structure of the thickener solution. When added in a bigger amount they induce an increase of intraparticle friction inside the system which leads to an increase of viscosity. Rheological parameters of the power-law *model 1* are given in Table 1.

Table 1. Rheological parameters of the power-law model for the suspensions of Sucralfat and basic magnesium carbonate in 0.1% xanthane gum solution

Solid particles	g/100 ml H_2O	k [Pas^n]	n [-]
Sucralfat	3g	0.0107	0.770
	10g	0.0605	0.614
Basic magnesium carbonate	3	0.74036	0.4163
	10g	0.54381	0.3675

The Figure illustrates a change in the viscosity of a suspension with the same part of solid particles (10 g Sucralfat), the concentration of thickeners in particular cases was also constant, however, the applied thickeners were different. On the basis of the analysis of results it can be claimed that the highest viscosity was achieved when xanthane gum was used as a thickening substance, much worse results were in the case of hydroxyethylcellulose and carboxymethylcellulose. Rheological constants resulting from Cross' *model 1* i *model 2* are given in Table 2.

Table 2. Rheological parameters of Cross' model for the thickeners: xanthane gum and hydroxyethylcellulose, and power-law model for caboxymethylcellulose. Suspended substance – Sucralfat.

Thickeners	g/100 ml H_2O	η_0 [Pas]	η_∞ [Pas]	k [Pas^n]	n [-]
hydroxyethylcellulose	0.5g	168.8	4.814	0.0339	0.837
xanthane gum	0.5g	199.8	15.86	0.0246	0.769
carboxymethylcellulose	0.5g	-	-	773.7	0.489

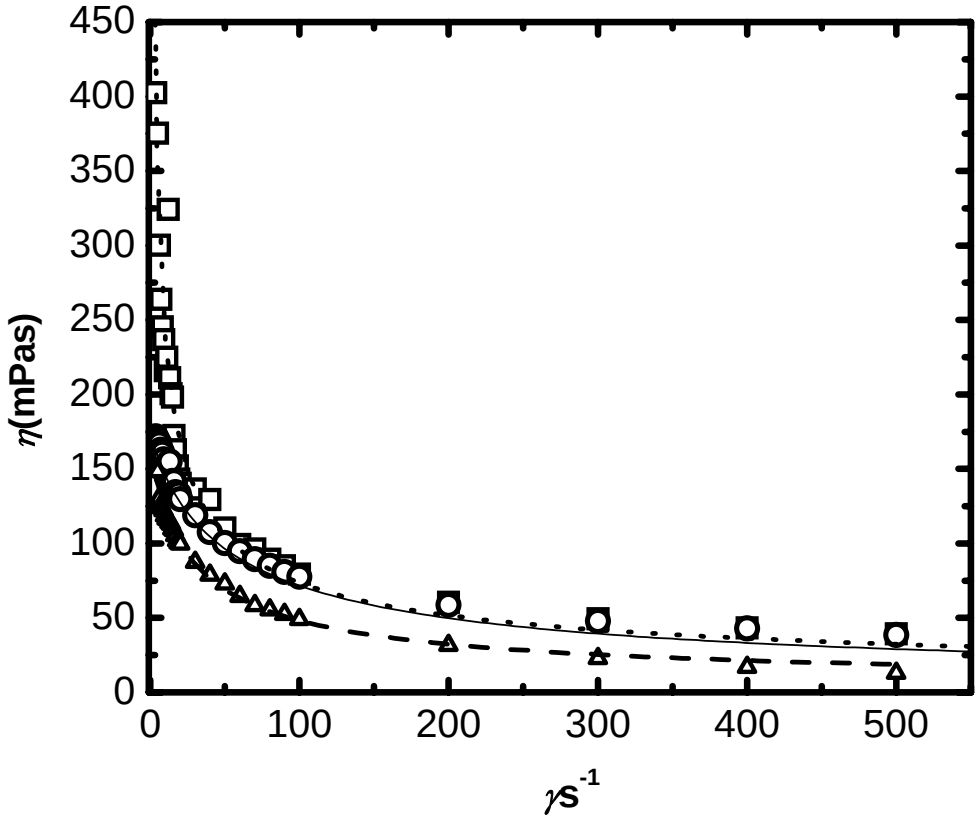


Figure. 4. Examples of flow curves described by the power-law model for the suspension of Sucralfat in different thickeners (□ - 10g sucralfate suspension in 0,6% xanthan gum solution,○ - 10g sucralfate suspension in 0,6% hydroxyethylcelullose solution, Δ - 10g sucralfate suspension in 0,6% karboxymethylcellulose solution)

Diagram in Figure 5 illustrates sedimentation of selected suspensions. It follows from it that for 10 g basic magnesium carbonate suspended in different thickeners, the best stability was provided by a 0.3% solution of xanthane gum. Next in this sequence was a 0.3% solution of hydroxyethylcellulose and 0.3% solution of carboxymethylcellulose. However, none of the thickeners applied in this concentration gives satisfying results because even in the best case the sedimentation reaches around 50%.

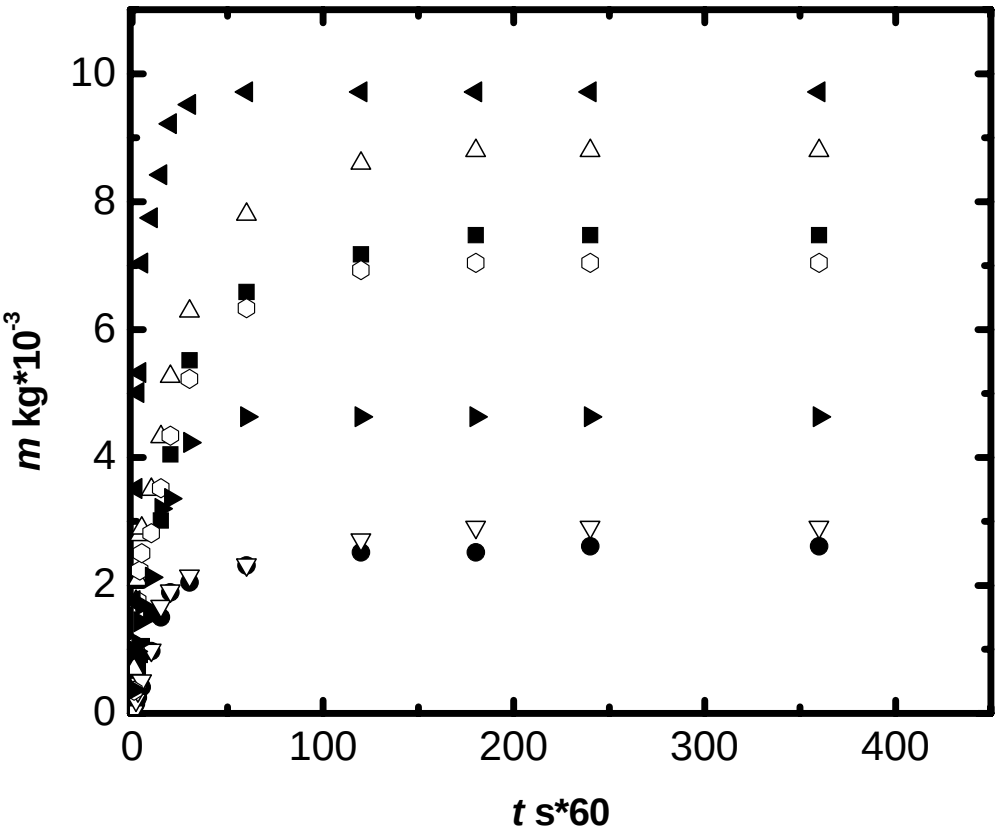


Figure 5. Experimental data of sedimentation for selected suspensions (■ - 10g sucralfate suspension in 0,1% xanthan gum solution, ● - 3g sucralfate suspension in 0,1% xanthan gum solusion, ∆ - 10g magnesium carbonate suspension in 0,1% xanthan gum solution, ∇ - 3g magnesium carbonate suspension in 0,1% xanthan gum solution, ○ - 10g magnesium carbonate suspension in 0,3% hydroxyethylcellulose solution, ◄ - 10g magnesium carbonate suspension in 0,3% carboxymethylcellulose solution, ► - 10g magnesium carbonate suspension in 0,3% xanthan gum solution)

Results obtained are only part of the preliminary studies aiming at the determination of rheological properties of suspensions. Knowledge of these values plays a key role in the subject of suspension stability.

On the basis of observations of the formed suspensions and results of rheological studies it can be stated that it is necessary to apply two models in the description of the experimental data presented above. From the point of view of approximation of the obtained results, the power-law model is very good, however, Cross' model can describe the results more precisely. This follows from the fact that this model provides more information on rheological properties of suspensions in a wide range of shear rates. It should be kept in mind, however, that it is not always possible to apply this model in the above cases.

From the point of view of desired rheological properties, i.e. high viscosity that ensures suspension stability, the most satisfying results were obtained when xanthane gum was used as a thickening substance. Suspensions formed on the basis of hydroxyethylcellulose and carboxymethylcellulose are characterised by lower viscosity and consequently, reduced stability.

Acknowledgements
The authors wish to thank Mr. Krzysztof T. Borkowski, the President of Pharmaceutical Plant "Polfa Lodz", for granting access to the Measurement Laboratory.

SYMBOLS

k – constant

n – constant

Greek Letters

γ	– shear rate	s^{-1}
η	– viscosity	Pa s
η_∞	– viscosity at shear rate tending to infinity	Pa s
η_0	– viscosity at shear rate tending to zero	Pa s
σ	– shear stress	Pa

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