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DEVELOPMENT OF AQUEOUS PHASE FORMULATION FOR NON-TOXIC PAINTS

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Abstract. *The paper presents a well-proven formulation for the production of aqueous phase for non-toxic paints. The authors investigated the rheological properties of the aqueous phase depending on the ratio of the components. The authors studied the effect of a thickener (FLOGEL 700) on the rheological characteristics of the aqueous phase and estimated the best pH value of the aqueous phase.*

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Introduction

Nowadays modern art industry has a trend to replacing volatile organic solvents with water ones due to their high toxicity and fire and explosion hazards. Water-soluble paints are preferable, easy to use and, moreover, almost odourless.

Furthermore, the production of non-toxic, water-based paints which can contact with human skin is relevant. It is especially important in terms of the intensively developing cosmetics industry and creative activities involving the human contact with paints.

Human skin dye consists of pigments combined with an aqueous phase medium. The pigment particles are solid and insoluble in water. The most common substances used for the aqueous phase are purified distilled water, glycerin, alcohol, or gamma mellifera extract [1-4]. The main requirement for them is the safety of their application.

Main body

Therefore, the purpose of this study is to develop a method and formulation for the production of an aqueous phase for artistic paints which are safe for human skin.

We chose the following non-toxic substances for our research: glycerine (GOST 6259-75), propylene glycol (TU 2422-069-05766801-97), isopropyl alcohol (IPA) (GOST 9805-84),

polyethylene glycol PEG-400 (TU 2483-167-057587-2000), polyacrylic acid FLOGEL 700 was used as a thickening agent.

We mixed the components of the aqueous phase (distilled water, isopropyl alcohol, glycerine, propylene glycol, PEG-400) in the calculated ratios. We added FLOGEL 700 to the aqueous phase by dispersing it in the aqueous phase using a 250 cm^3 Homoge (Poland) laboratory dissolver with a 40 mm diameter disk stirrer with a maximum speed of 230 s^{-1} for 1 minute.

We calculated the solubility parameters of a mixture of water, isopropanol, glycerol and propylene glycol in relation to PEG-400 to obtain the aqueous phase formulation. As follows from references [2-7], the PEG-400 content in such materials should be within 10-12%. Thus, we calculated the formulation based on the solubility values for the aqueous phase (Table 1).

Table 1. Water phase component ratio. Recipe 1

Component	Mass content, mass %
Water	8.82
Glycerine	6.17
Propylene glycol	20.27
Isopropanol	52.89
PEG-400	11.85

We conducted rheological studies (Fig. 1) for the aqueous phase obtained from the formulation of Table 1. The pH of such a system is 6.015, which should ensure compatibility with pigments and human skin.

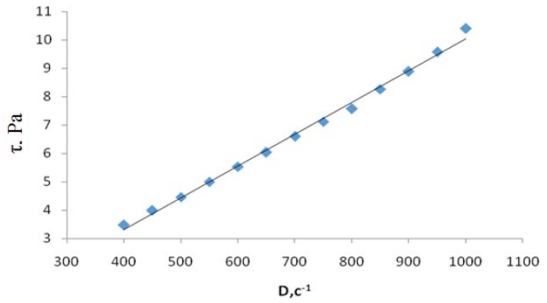


Fig. 1. Dependence of shear stress on shear rate for the aqueous phase

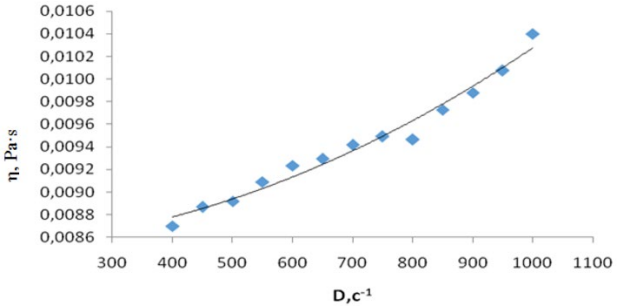
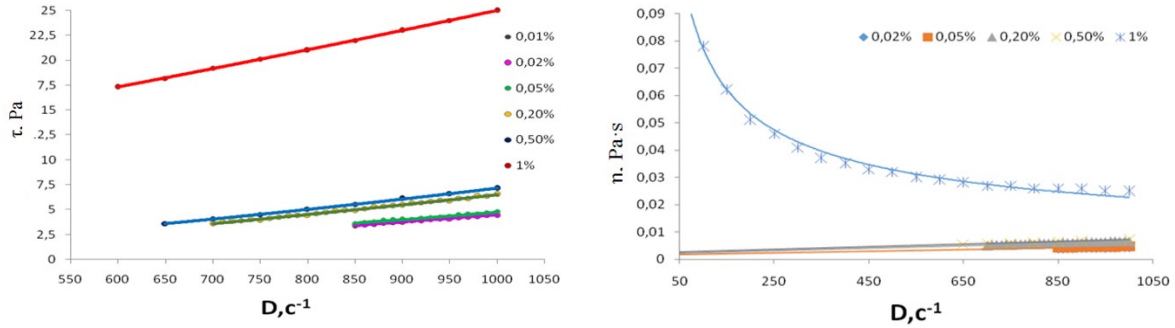


Fig. 2. Dependence of viscosity on shear rate for the aqueous phase

The graphs in Figures 1 and 2 show an increase of viscosity and shear stress with shear rate for the resulting aqueous phase, indicating a dilotant nature of the flow. The thixotropic nature of the flow is more preferable for the artwork associated with the application of paint to human skin. We therefore considered the possibility of introducing a thickening agent into the aqueous phase.

A polyacrylic polymer is suitable as a thickening agent for water-disperse paints for human skin applications. We have selected the powdered polyacrylic thickening agent ЫFLOGEL 700. It disperses rapidly and can be used in aqueous or non-aqueous systems. The maximum viscosity of FLOGEL 700 aqueous emulsion is reached at pH 5-11 [8], which allows obtaining transparent solutions with low foam formation. It is not biologically active, so it is compatible with all components and is not toxic.

We studied the rheological properties of FLOGEL 700 water emulsions of various concentrations in order to determine the optimum concentration of the emulsion (Fig. 3).



a *б*

Fig. 3. Dependence of rheology of FLOGEL 700 aqueous emulsions on concentration: *a* - is dependence of shear stress on shear rate; *b* - is dependence of viscosity on shear rate

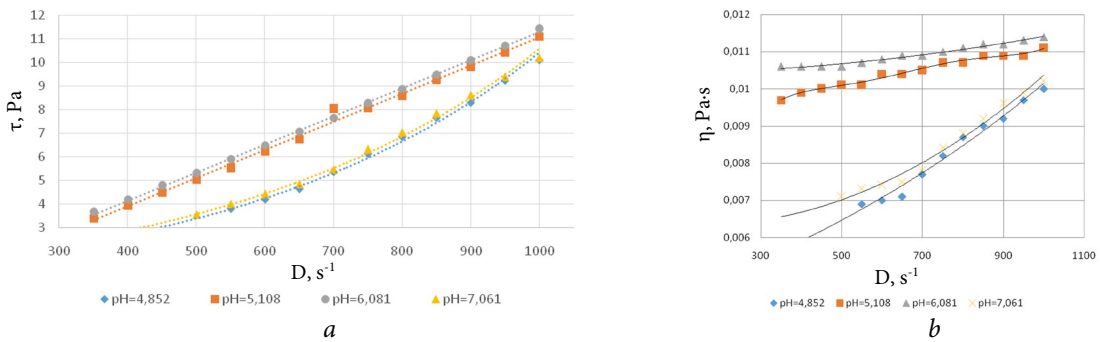
The presented concentration dependencies of rheological properties of FLOGEL 700 emulsions show the insignificant increasing of viscosity due to introducing FLOGEL 700 into a system up to 0.5 mass %. However, already at 1% of its content, the shear stress increases by almost 6 times. Moreover, a water emulsion containing 1% of FLOGEL 700 has a thixotropic flow character. For further studies we have selected aqueous solutions of FLOGEL 700 with a concentration of 0.5% and 1%, respectively.

Therefore, we added FLOGEL 700 solution with different concentrations to the aqueous phase instead of distilled water. The ratio of components with high water content in the system based on solubility parameters, rheological characteristics, and previously obtained results [9] was chosen for further studies. Additionally, the aqueous phase formulation discussed above, the aqueous phase component ratios were also selected (Table 2).

Table 2. Water phase component ratio

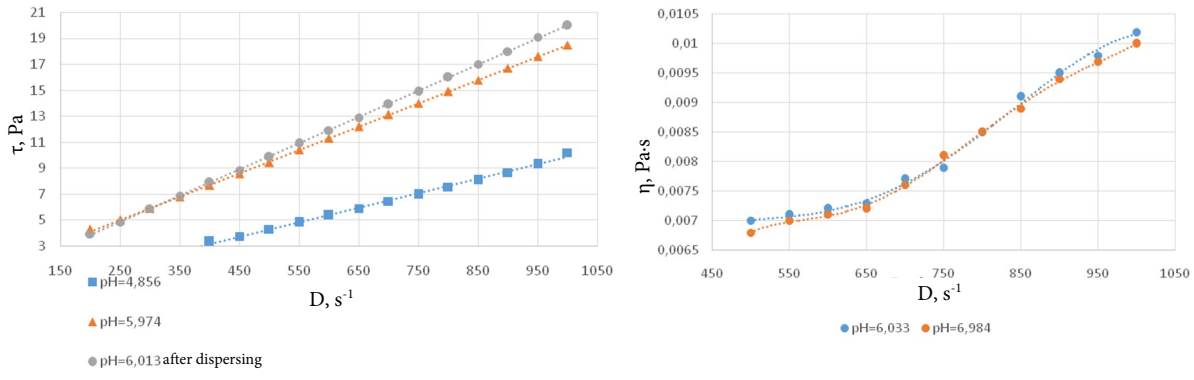
Components	Mass content, %			
	Recipe 2 0,5% FLOGEL 700	Recipe 3 1% FLOGEL 700	Recipe 4 0,5% FLOGEL 700	Recipe 5 1% FLOGEL 700
Flogel aqueous emulsion	8.82		20.83	
Glycerine	6.17		6.26	
Propylene glycol	20.27		20.83	
Isopropanol	52.89		41.49	
PEG-400	11.85		10.59	

The maximum viscosity and hence the operating pH values for its aqueous solutions are in the slightly alkaline range as follows from the FLOGEL 700 data sheet [3]. Therefore, we studied the rheological properties of the aqueous phase containing FLOGEL 700 emulsion of different concentrations as a function of pH (Fig. 4-7).



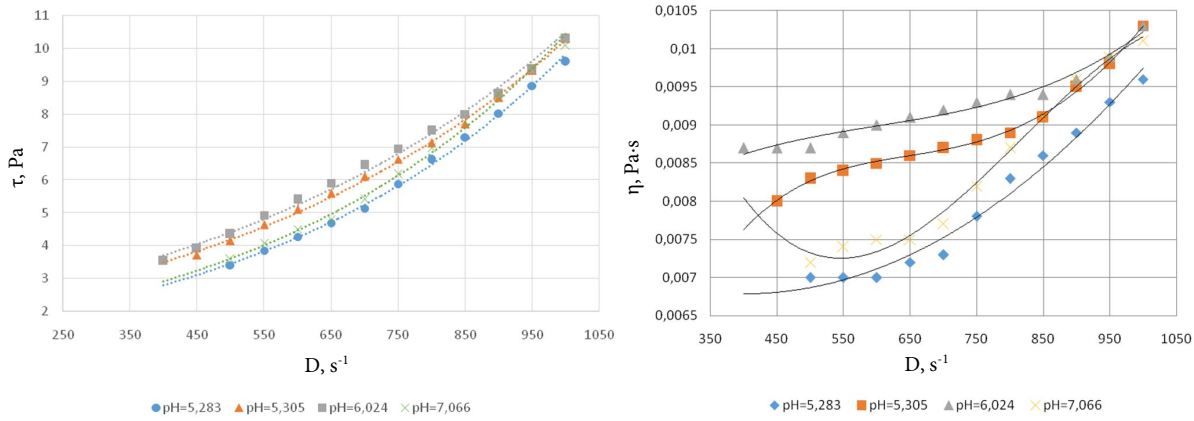
a *b*

Fig. 4. Dependence of rheological characteristics of the aqueous phase for formulation 2 (0.5% FLOGEL 700) on pH: *a* - dependence of shear stress on shear rate; *b* - dependence of viscosity on shear rate



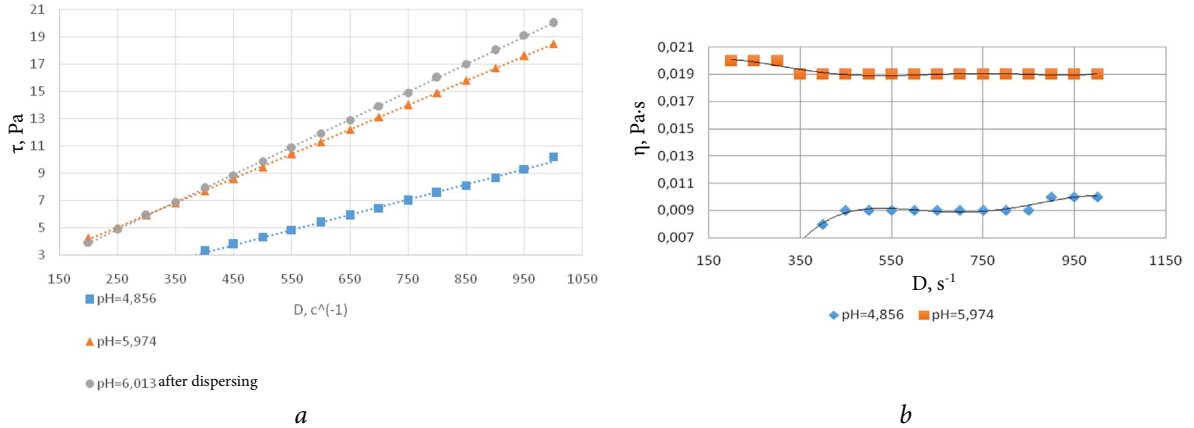
a *b*

Fig. 5. Dependence of rheological characteristics of the aqueous phase for formulation 3 (1% FLOGEL 700) on pH: *a* - dependence of shear stress on shear rate; *b* - dependence of viscosity on shear rate



a *b*

Fig. 6. Dependence of rheological characteristics of the aqueous phase for formulation 4 (0.5% FLOGEL 700) on pH: *a* - dependence of shear stress on shear rate; *b* - dependence of viscosity on shear rate



a *b*

Fig. 7. Dependence of rheological characteristics of the aqueous phase for formulation 5 (1% FLOGEL 700) on pH: *a* - dependence of shear stress on shear rate; *b* - dependence of viscosity on shear rate

According to the data of Fig. 4-7, after FLOGEL 700 is added into the system, the initial 6.015 pH of the aqueous phase becomes more acidic (pH=4.852). As the pH of the system increases, FLOGEL 700 is neutralized, and the conformation of its molecules changes: macromolecules change from collapsed conformation to linear, which contributes to an increase in

viscosity. The viscosity of all formulations peaks at a pH of approximately 6 and begins to decrease again as the pH is raised further.

Conclusions

Thus, the highest viscosity value can be achieved for recipe 3 at a pH value of 6.013. Recipes 3 and 4 with a higher content of FLOGEL 700 water emulsion have lower viscosity values. Consequently, for further research and the production of pigmented, non-toxic water-dispersion paints, it is advisable to use recipe 3 (with 1 mass % of FLOGEL 700) and set the pH value of this aqueous phase to approximately 6.

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