Concentration Effect of Silicone Defoamer with Trade Name BYK-037 on Foam Destruction Rate for Water Solution of Polyacrylamide and Sodium Laureth Sulfate

Lyubov Polyuzhyn[1], Kateryna Bura[1],

Yosyf Shapoval[1], Igor Polyuzhyn[2]

[1]Chemical Technology of Plastic Processing Department, Lviv Polytechnic National University, UKRAINE, Lviv, S. Bandery street 12, E-mail: lyuba_polyuzhyn@ukr.net, bura_1993@mail.ua

[2]Department of Analytical Chemistry, Lviv Polytechnic National University, UKRAINE, Lviv, S. Bandery street 12, E-mail: igor_polyuzhyn@ukr.net

Abstract – The influence of the concentration silikone defoamer with trade name BYK-037 on rate of the foam destruction for water solution of polyacrylamide and sodium laureth sulfate as anionic surfactant. An optimal concentration of the defoamer when the system is remained as virtually homogenous and sufficient effect of defoaming is provided.

Key words – defoamer, polyacrylamide, sodium laureth sulfate, aqueous solutions.

I. Introduction

Lubricating and cooling technological fluids (LCTFs) water-based is important part in a range of products for metals tooling. The use of polymers in various technological processes of solids tooling, including as well as active components of LCTFs for cutting (in cutting fluids), is due to the polymers ability to activate the process of surface deformation and of solids dispergation [1,2].

It is known [3] that the main advantages of water-based LCTFs include their high cooling efficiency and environmental friendliness, and the shortcomings - relatively low lubricating ability, high corrosivity and lack of effectiveness in some specific conditions of cutting. Water-based LCTFs are divided into four main groups: 1)emulsions; 2) semi-synthetic; 3) synthetic; 4) electrolyte solutions [3]. Synthetic LCTFs are mixtures of water-soluble polymers, surfactants (SAC – surface active compound), additives and water. The concentration of polymer in these LCTFs is in the range of 1-10% by weight. Because synthetic water-based LCTFs not contain oils, so have low penetrating ability, which is increased by the addition of surfactants that reduce surface tension of an aqueous solution and thus increase its wetting and lubricating ability.

Among the water-soluble polymers, which can form true solutions in water, is polyacrylamide (PAA), which are widely used in various branches of engineering and also used for LCTFs. In paper [4] the possibility was described for creating LCTFs based water-soluble polymers such as polyvinylpyrrolidone and PAA. In paper [5] justification was conducted for LCTFs composition based on PAA using experimental data for surface tension and for contact angles.

In case of using aqueous solutions of PAA and surfactant the foaming is a problem in the system when LCTF is delivered to the place of cutting. The foam destruction can be performed by mechanical, hydraulic and aerodynamic ways, by vibrations of sound and ultrasonic frequencies, by thermal, electrical and other methods [6,7]. Since the use of these methods require any structural changes in LCTF supply system, so often defoamers (or antifoam agents) are used for foam destroying [7,8]. Combined defoaming methods are also offered [7-9]. In paper [10] research results are summarized for mechanisms of defoamers action. It is known that effective defoamers are silicone oils [6-10].

II. The purpose of the work

The aim of this work is to choose the optimal concentration of silicone defoamer with trade name BYK-037 on the basis of study of the concentration effect on foam destruction rate for water solution of PAA and sodium laureth sulfate as anionic surfactant.

III. Experiment

The objects of the study were aqueous solutions of PAA and SAC, and silicone defoamer with trade name BYK-037 (https://www.byk.com/en/additives/additives-by-name/byk-037.php, manufacturer - BYK-CHEMIE GMBH). According to information SDS and TDS [11] the defoamer with trade name BYK-037 is water emulsion of a paraffinic mineral oils (petroleum oils) and certain hydrophobic components, containing silicone and has a kinematic viscosity - 286 mm^2/s at 40 °C, density - 0.935 g/cm^3 at 20 °C and dry residue 53.5% when is heated to 150 °C during 10 minutes. The recommended concentration range of defoamer with trade name BYK-037 is 0.1-0.5% when it is used for emulsion paints and plasters [11].

The paper used industrial sample of PAA with molecular weight $3 \cdot 10^5$ (TU 6 - 01 - 1049 - 92) as a gel with polymer contaning as 8% by weight. In paper [4] to assess the molecular weight of the industrial sample of PAA dependences were used on the intrinsic viscosity $[\eta]$ according to Kuhn–Mark–Houwink–Sakurada equation and PAA's molecular weight was determined as mean number $\overline{M}_n = 1609863$ and as mean weight $\overline{M}_z = 2577509$. As anionic surfactant is used industrial product with trade name Sulforokanol L270 / 1A (manufacturer - PCC EXOL SA, Poland, http://www.pcc-exol.eu). This product, for which some characteristics are given in [12], contains as an active ingredient sodium laureth sulfate (sodium lauryl ether sulfate) about 70% by weight. Sodium laureth sulfate (SLS) is a sodium salt of sulfated oxyethylated alcohol C_{12}-C_{16}. For product Sulforokanol L270 / 1A alcohol

radical is $R = C_{12}H_{25}...C_{16}H_{33}$, and n = 2 then general chemical formula is:

$$R-O-\left(CH_2-CH_2-O-\right)_2-SO_2-O^-Na^+$$
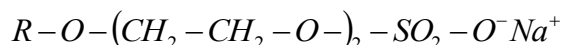
In the SAC the active substance content is determined by the method of flame photometry (methane-air burn mixture) by means of photometer Model FPL-1, equipped with interference filter for sodium yellow emission line with bandwidth of the light wavelength within (589±5) nm. Solution of the product Sulforokanol L270 / 1A (about 0.1% by weight) is diluted five times according to the calibration range 3-15 mg/dm^3 of sodium concentration in aqueous solutions. It was determined that the active substance content as SLS is 66.64% by weight, which is complies with the normative data (68-72% wt.) [12], given the assumptions made for molar mass (376 g/mole) per SLS containing 12 carbon atoms in the alcohol segment (passport data is 384 g/mole).

Initial solutions were prepared by weighing the substance and solvent. Weighing was made by means of electronic analytical balance of model XAS 220/C "Radwag" with increment from 0.1 mg. At dilution the solution volume was measured by burette with capacity of 50 cm^3 and with point value as 0.1 cm^3. The relative error of weight does not exceed 0.02%, and of measuring the volume - 0.2%.

The tested solution, which simulates a working LCTF, was prepared by ten times dilution of concentrated solution with tap water. The concentrated solution contains of 25% PAA gel and 1.5% SAC gel. To investigate the influence of the defoamer content the concentrated solutions were prepared with defoamer concentration as 0.01%, 0.05%, 0.1%, 0.5%, 1%, 5%, 10% by weight. Since the concentrated solution and defoamer BYK-037 are viscous liquids, so their mixtures were performed thorough mixing by shaking with glass beads. In the test solutions the defoamer concentration was in the range from 0.001 to 1% by weight.

To assess the defoaming effectiveness the rates were used for foam destruction and for growth in the liquid phase at room temperature (22-25°C). Kinetic curves were obtained using graded long glass tubes with a diameter as 12 mm and a height as 30 cm, in each of which 10 ml test solution was placed and then closed with rubber plugs. Foam was created intense shaking of the tubes in the vertical direction. After foam formation the tubes was installed quickly to supporting stand and the views of tubes were fixed at certain times by the digital camera of model Casio EXILIM EX-ZR 100. Taking photos was carried out on a green background for the proper foam image contrast. Control solution is not included the defoamer. Kinetic data obtained within 20-60 minutes, that is, until to the point when there are no significant changes in the height of foam and liquid phases. Mathematical data processing was performed using a spreadsheet program MS EXEL and MathCAD.

IV. Results and Discussion

The primary kinetic data were normalized for the heights of the phases at the foam destruction and the growth of liquid phase, according to initial foam height for control solution and the initial height of liquid in each of tubes before shaking. The normalized experimental kinetic data are shown on Figs. 1 and 2 for the foam destruction and for the growth in the liquid phase, respectively. From Figs. 1 and 2 one can see that the difference between kinetic data system without defoamer and with defoamer addition is more clearly observed for foam destroying (Fig. 1) already at a defoamer concentration of 0.001% by weight while the kinetics of quasi continuous liquid phase formation (Fig. 2) the similar difference is observed only at 0.05% by weight so for defoamer concentrations as 50 times greater. Thus, to evaluate the effectiveness of the process, depending on the defoamer concentration, based on defoaming rate that is more appropriate to use the foam destruction kinetic data.
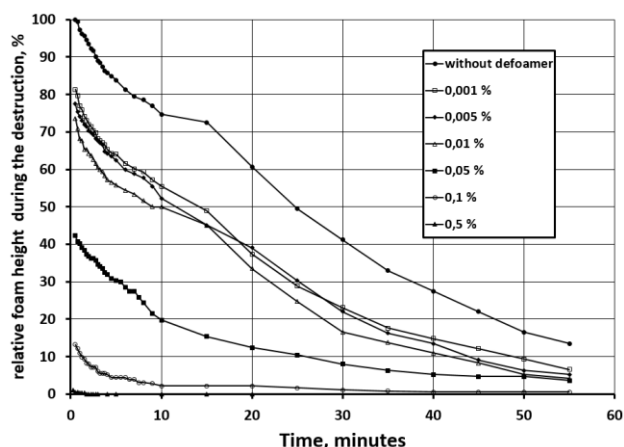

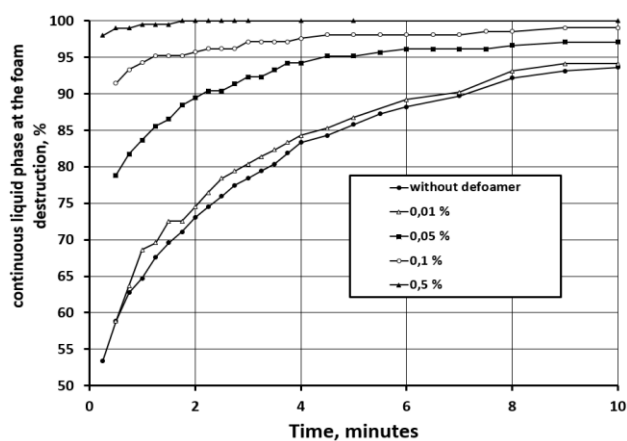Fig. 1. Kinetic curves for the destruction of foam

Fig. 2. Kinetic curves for continuous liquid phase increasing at the destruction of foam.

Based on the results of the first measurement of foam height (H_0) for a time of 15-30 seconds with Fig. 1 one can see that the defoamer addition in minimum quantities 0,001-0,01% reduces the relative height of foam about 20%, and almost foam is not formed at the defoamer concentration as 0.5%. As it is shown in Fig. 3 initial foam height decreases with increasing defoamer concentration. Based on this it is possible to estimate the defoamer ability to prevent the foam formation. The

dependence of the initial foam height on the defoamer concentration, that is presented in semi-logarithm coordinates (Fig. 3), is S-shaped.
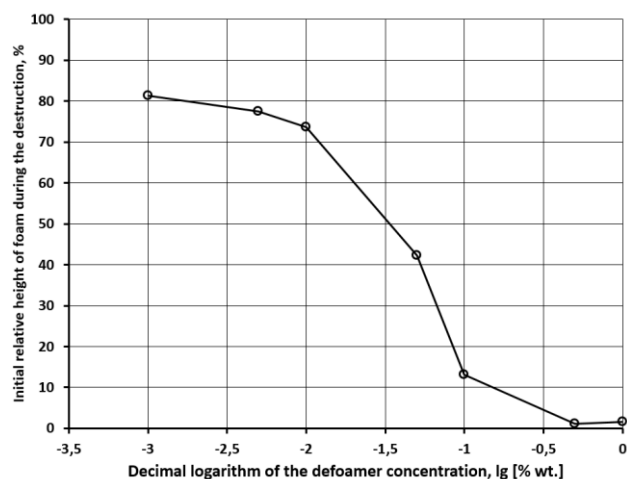

Fig. 3. Dependence of relative initial foam height (H_0) on the defoamer concentration

This S-shaped curve (Fig. 3) has three areas for defoamer ability to prevent the foam formation: 1) from 0.001% to 0.01% this ability appears limited to a so-called induction area; 2) from 0.01% to 0.1% - the maximum increasing of efficiency; 3) with increasing the defoamer concentration of more than 0.1% this ability gradually reaches the maximum level and at 0.5% the initial foam height is about 1% of the foam height in the system without defoamer. The third area in Fig. 3 indicates that inappropriate to increase the defoamer concentration above 0.5%, as it leads to defoamer overspending.

It is known [7] that at the absence of the process of foam formation the rate of foam destruction is proportional to the height of the foam accordinf by simple Eq. (1) (assuming that the height of the foam is the same for all the "foam-liquid" interface, so fof this foam the height and the volume are interchangeable):

$$-\frac{dH}{dt} = \frac{1}{s} \cdot H = k \cdot H \qquad (1)$$

In Eq. (1) the value of k is the rate constant of foam destruction that corresponds to the speed of foam destruction at the unit of the foam height. The value of s, which has the dimension of time and is inversely proportional to the rate constant of foam destruction, is a foam stability factor [7], thus the higher s-value is, then the lower value of the foam destruction rate and accordingly the foam is more stable. After separation of variables and integration one can obtaines the dependence for the foam layer height on the foam destruction time as Eq. (2).

$$H(t) = H_0 \cdot \exp(-k \cdot t) \qquad (2)$$

The foam destruction rate constant (k) corresponds to the slope of a straight line according to Eq. (3), that is obtained after logarithm of Eq. (2).

$$\ln\left(\frac{H_0}{H(t)}\right) = k \cdot t \qquad (3)$$

Since the rate of foam destruction for concentrations as 0.5 % and as 1% is large and at such concentrations the initial foam height is about 1% of the initial foam height without defoamer (in practice it is 1-2 divisions for scale graduation of the test tube, 1 division = 1 mm), so foam is practically not formed (Fig. 1), thus the data for these concentrations were not considered in within exponential model of foam destruction to determine the rate parameters of this process. All points in semi-logarithm coordinates and model straight lines for the rate of foam destruction shown on Fig. 4, where one can see that the kinetic curves for foam destruction have two areas with different rates of the foam destruction.
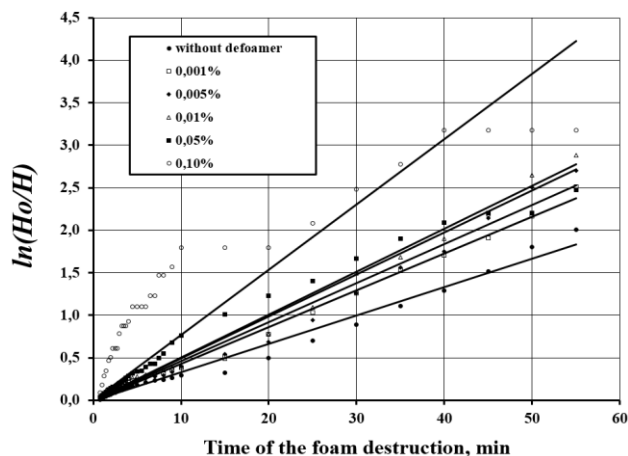

Fig. 4. Estimation of foam destruction rate constant according to the model Eq. (3) for various defoamer concentrations (all experimental points)

Table I shows the foam destruction rate constant which have been determined for all points and for initial time area up to 10 minutes (Fig.5), and the value of R^2, which are describing the reliability of experimental data approximation by straight logarithmic model dependency according to Eq. (3).

TABLE I

THE FOAM DESTRUCTION RATE
CONSTANT ACCORDING TO MODEL EQ.(3)

Defoamer content, % wt.	All points		For initial time area up to 10 minutes	
	k, min^{-1}	R^2	k, min^{-1}	R^2
0 %	0,033	0,984	0,032	0,954
0,001 %	0,043	0,995	0,044	0,880
0,005 %	0,046	0,986	0,041	0,971
0,01 %	0,049	0,988	0,049	0,800
0,05 %	0,050	0,966	0,069	0,982
0,10 %	0,077	0,596	0,197	0,911

Table I shows that a significant differences between the values of foam destruction rate constants, which are obtained for all points and for points of the initial time area (10 min.), are observed for defoamer concentrations as 0.05 %. (up to 39%) and as 0.10 % (increasing in 2.56 times).

To assess the defoamer concentration effect on the foam destruction rate constant the dependence was obtained for the foam destruction rate constant on the

defoamer concentration in negative logarithmic coordinates for the initial part of the kinetic curve up to 10 minutes (Fig. 6) where one can see two regions.
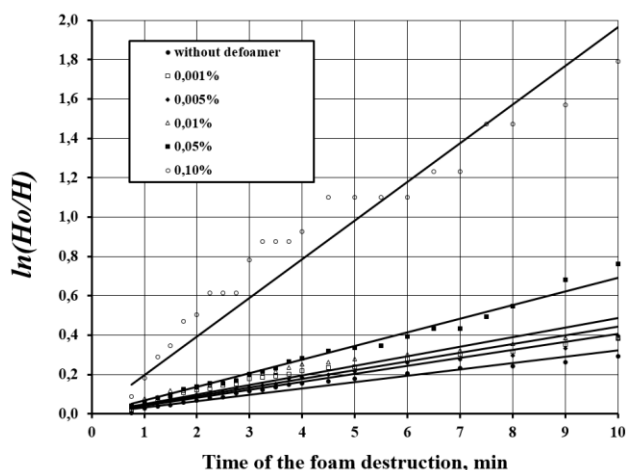

Fig. 5. Estimation of foam destruction rate constant for the initial part of the kinetic curve (10 minutes) according to the model Eq. (3) for various defoamer concentrations
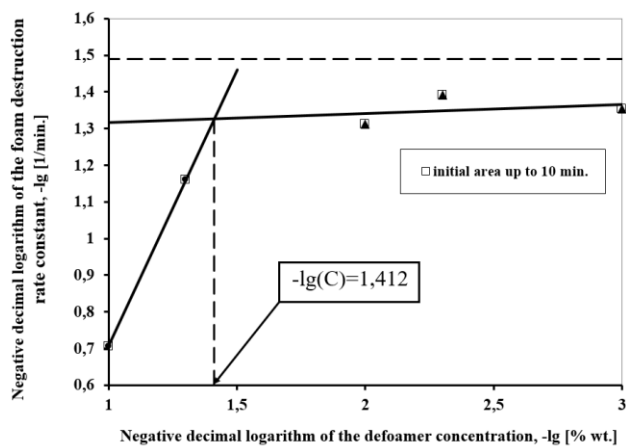

Fig. 6. The dependence of the foam destruction rate constant on the defoamer concentration in negative logarithmic coordinates for the initial part of the kinetic curve (10 minutes)

It should be noted that at the study of silicone defoamers trade name BYK-037 for an aqueous solution of PAA and the SAC the system turbidity is observed at the defoamer concentration as 0.05% and a marked separation is observed at 0.1%. Within defoamer concentrations 0.05-0.1% the preventing foam formation effect is observed significantly, and for this range an increase in sensitivity of foam destruction rate constant at concentration changes. Therefore, to ensure sufficient defoaming can be recommended value of 0.05% as the optimal concentration of antifoam BYK-037 for the tested aqueous solution of PAA and the SAC while maintaining the relative homogeneity of the system.

Conclusion

In this paper the concentration influence of the silicone defoamer with trade name BYK-037 on the foam destruction rate for water mixture solution of polyacrylamide (PAA) and sodium laureth sulfate (SLS) as anionic surfactant.

The rate constants are determined for foam destruction and the dependence is obtained for their values on the defoamer concentration.

It was established that the optimal defoamer concentration is 0.05% wt., when the system remains virtually homogenous and provided sufficient defoaming effect.

References

[1] Smazochno-ohlazhdajushhie tehnologicheskie sredstva dlja obrabotki metallov rezaniem: Spravochnik / Pod red. S.G. Jentelisa, Je.M. Berlinera. - Moskva: Mashinostroenie, 1986. - 352 s.

[2] Soshko A.I. Fiziko-himicheskaja mehanika obrabotki tverdyh tel v polimersoderzhashhih smazochno-ohlazhdajushhih zhidkostjah – In book: Svojstva konstrukcionnyh materialov pri vozdejstvii rabochih sred. – Kiev: Naukova dumka, 1980. – P.332 – 339.

[3] Handbook of Lubrication and Tribology—Volume II: Theory and Design, Second Edition Edited by Robert W. Bruce, GE Aircraft Engines, Cincinnati, Ohio, USA Co-published by CRC Press (Taylor and Francis Group) and STLE, 2012, - 1160 p.

[4] Shapoval Y.M., Kochubei V.V., Suberliak O.V., Poliuzhyn I.P., Kozak M.B. Rozrobka ta doslidzhennia vlastyvostei mastylno-okholodzhuvalnykh ridyn na osnovi polivinilpirolidonu ta poliakrylamidu.– Visnyk Natsionalnoho universytetu "Lvivska politekhnika". Khimiia, tekhnolohiia rechovyn ta yikh zastosuvannia.- 2014.- № 787. - P.469-474.

[5] Shapoval Y.M., Poliuzhyn I.P., Kotsan M.P., Poliuzhyn L.I. Obhruntuvannia skladu tekhnolohichnykh mastylno-okholodzhuvalnykh ridyn na osnovi poliakrylamidu. – Visnyk Natsionalnoho universytetu "Lvivska politekh-nika". Khimiia, tekhnolohiia rechovyn ta yikh zastosuvannia.- 2015.- № 787. - P.23-35.

[6] Tihomirov V. K. Peny. Teorija i praktika ih poluchenija i razrushenija. 2-e izd., pererab. — Moskva: Himija, 1983. — 264 s.

[7] Fedoseev K.G. Processy i apparaty biotehnologii v himiko-farmacevticheskoj promyshlennosti . Uchebnoe posobie dlja studentov tehnologicheskih fakul'tetov himiko-farmacevticheskih institutov.- Moskva «Medicina» -1969. – 200 s.

[8] Foam and Foam Films. Theory, Experiment, Application / Dotchi Exerowa and Pyotr M. Kruglyakov (Eds.) – Elsevier, 1998 – 773 p.

[9] Penoobrazovanie i penogashenie. Sovremennoe sostojanie problemy. / Kotel'nikova M.N., Alykov N.M. - Lambert Academic Publishing's foundation (http://www.lap-publishing.com/), 2011. - 128 s.

[10] Abdolahi F., Moosavian M.A., Vatani A. The Mechanism Action Antifoams - Journal of Applied Sciences 5 (6), 2005. – P.1122-1129.

[11] Safety Data Sheet. BYK-037 Product code: 000000000000112484. - Version 4.0 SDB_GB Revision Date 26.02.2016. - Print Date 20.04.2016 (TDS_BYK-037_EN.pdf, SDS_BYK-037_GB_en.pdf)

[12] Sulforokanol L270.1A_ENG.pdf - http://www.pcc-exol.eu/bazy/exol.nsf/products/en/Sulforokanol_L270-1A