

## Abrasive Treatment of Iron, Copper and Aluminum Alloys in Aqueous Binary Solutions of Polyethylene Glycol-Sodium Lauryl Sulfate

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**ABSTRACT:** The results of studies of dispersing, rheological, surfactant and conductometric properties of aqueous solutions of polyethylene glycols (PEG), sodium lauryl sulfate (LSNa) and aqueous binary solutions (WBS) of PEG-LSNa are presented. The synergism of the dispersing action of the WBS components has been established, the value of which is determined by the molecular weight (Mwt.) of PEG, the concentration of surfactants, and the nature of the alloys. A certain simbatism of changes in dispersing, surface-active, rheological properties and electrical conductivity was established, which is explained by the formation of intermolecular complexes (IMC) of PEG-LSNa. The lack of synergism in the dispersing properties of the WBS components during the dispersion of the aluminum alloy is explained by the abnormally high competitive adsorption of the lauryl sulfate ion on the freshly formed positively charged surface.

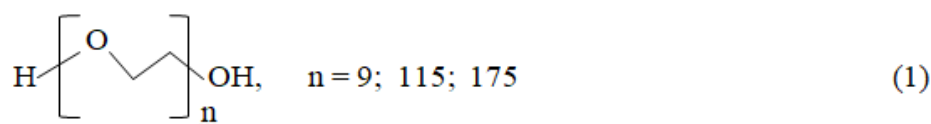
**KEYWORDS:** metal, abrasive, dispersion, polymer, surfactant, solution, intermolecular complex, synergism, antagonism.

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### I. INTRODUCTION

The efficiency of using polymer-surfactant WBS, polyelectrolyte-surfactant, oligomer-surfactant in the processes of abrasive processing of metals is shown in [1-5]. It is of scientific and practical interest to conduct comprehensive studies of dispersion media based on WBS using PEG, which is a weak nonionic surfactant of large-scale production, and a strong anionic surfactant LSNa. The chemical compounds used have the following structure: PEG (1) and LSNa (2):



## II. MATERIALS AND RESEARCH METHODS

The dispersing properties of aqueous solutions of PEG-9 (Mwt.=400), PEG-115 (Mwt.=4000), PEG-175 (Mwt.=6000), LSNa and WBS PEG-LSNa were studied by the gravimetric method during abrasive dispersion of disks made of iron alloys (St.45), brass (L59) and aluminum (D16T) on a friction machine [6] at a load of 0.1 mPa and a linear velocity of 0.12 m/s. Gray cast iron was used as a lap, silicon carbide (KZM20) was used as an abrasive. The dispersing effect of the components of the dispersion medium was determined by the increase in the removal rate  $\Delta Q^C$ , i.e. by the difference between the amount of metal removal in solution ( $Q^S$ ) and in water ( $Q^W$ ):  $\Delta Q^C = Q^S - Q^W$  [2]. Visual inspection of the samples shows that after the experiments, the surface of the disks becomes matte, of the corresponding color, and the absence of scratches and burns on it indicates the normal course of the microcutting process.

The rheological properties of the solutions were studied by the falling ball method (Lovis 2000M Anton PAAR viscometer, Austria) at a temperature of 20°C.

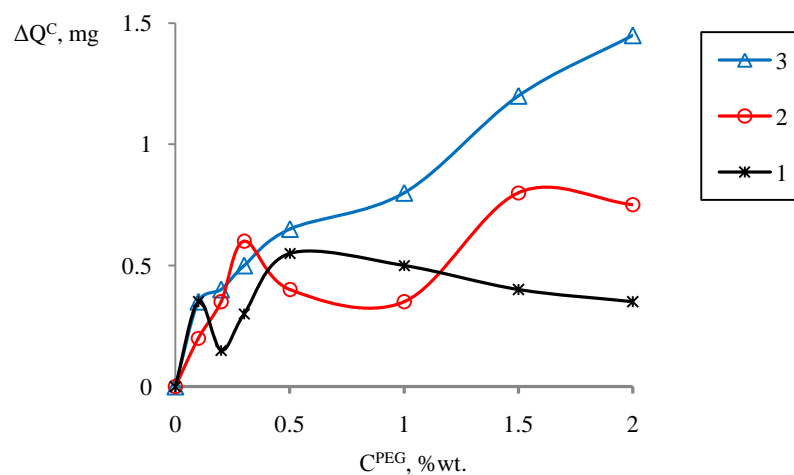
The surface tension of the solutions was determined by the Wilhelmy method (platinum plate) at  $T = 20^\circ\text{C}$ .

Studies of the specific electrical conductivity of aqueous solutions of PEG, LSNa and their binary solutions were carried out by conductometry (MPC227, METTLER TOLEDO).

## III. RESEARCH RESULTS AND DISCUSSION

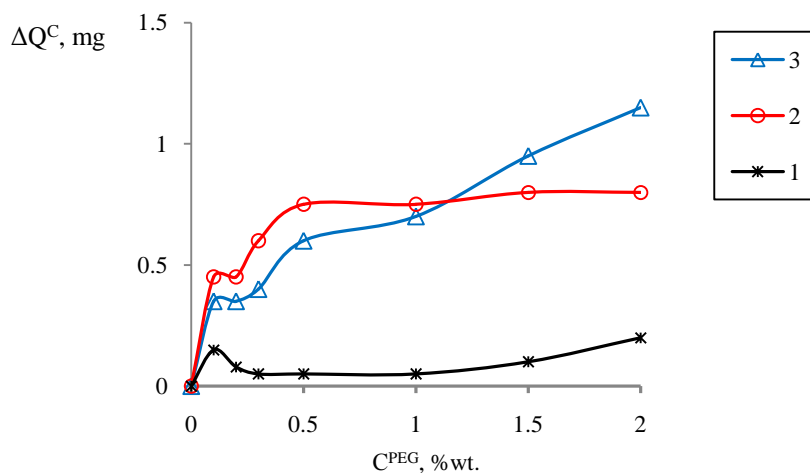
### 3.1. DISPERSING PROPERTIES

The results of the study of the concentration dependence of the dispersing properties of aqueous solutions of PEG-400, PEG-4000 and PEG-6000 during abrasive grinding of alloys are shown in fig. 1-3.



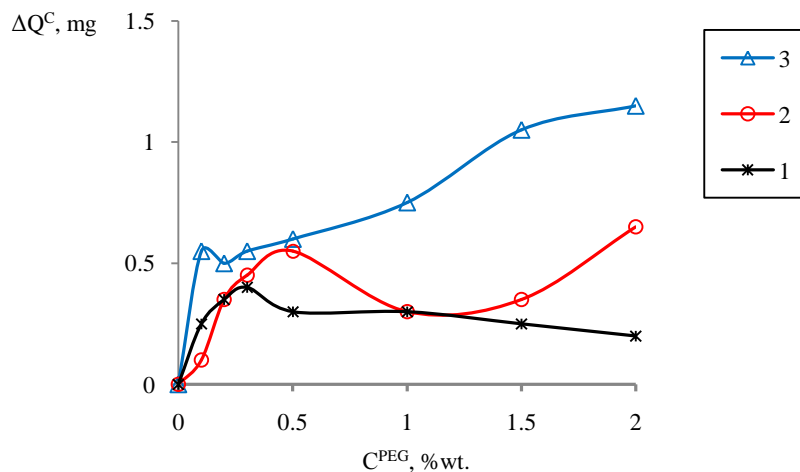
1 – St.45; 2 - brass L59; 3 - alloy D16T

Fig. 1. Dependence of increase in removal rate  $\Delta Q^C$  of alloys on PEG-400 concentration during abrasive treatment of St.45, brass L59 and aluminum alloy D16T



1 – St.45; 2 - brass L59; 3 - alloy D16T

**Fig. 2. Dependence of increase in removal rate  $\Delta Q^C$  of alloys on PEG-4000 concentration during abrasive treatment of St.45, brass L59 and aluminum alloy D16T**

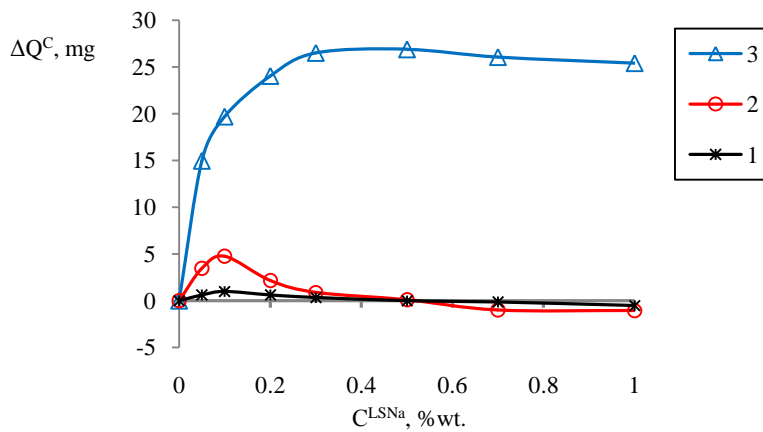


1 – St.45; 2 - brass L59; 3 - alloy D16T

**Fig. 3. Dependence of increase in removal rate  $\Delta Q^C$  of alloys on PEG-6000 concentration during abrasive treatment of St.45, brass L59 and aluminum alloy D16T**

As can be seen from the results shown in Fig. 1, Fig. 2 and Fig. 3, the nature of the curves of the concentration dependence of the dispersing action ( $\Delta Q^C$ ) of PEG-400, PEG-4000 and PEG-6000 differs significantly, and these differences are significantly affected by both the nature of the alloys, and the molecular weight of the polymers. The established differences in the concentration curves of the dispersing action can be explained [6] by counter processes of plasticization-embrittlement occurring in the zone of microcutting of alloys in accordance with the Rehbinder effect [7]. In the concentration range of 0.1-0.5%wt. rather clear maxima of  $\Delta Q^C$  values are observed (Figs. 1, 3), which indicates the classical version of the Rehbinder effect in aqueous PEG solutions belonging to the class of weak non-ionic high-molecular surfactants [8]. Differences in the nature of the concentration dependence of the dispersing action of PEG solutions can be largely due to the rheological properties determined by the molecular weight of the polymers.

The results of the study of the concentration dependence of the dispersing properties of aqueous solutions of LSNa during abrasive processing of alloys are shown in Fig.4.



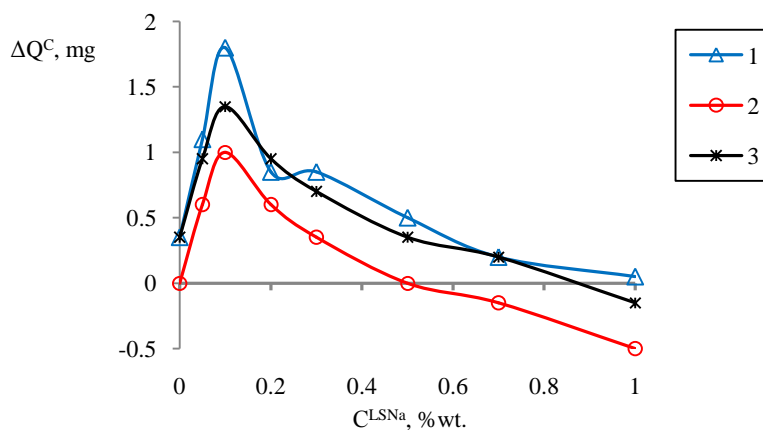
1 – St.45; 2 - brass L59; 3 - alloy D16T

Fig. 4. Dependence of increase in removal rate  $\Delta Q^C$  of alloys on concentration LSNa during abrasive treatment of St.45, brass L59 and aluminum alloy D16T

Analysis of the concentration dependence of the dispersing action shows that the value of  $\Delta Q^C$  is significantly affected by both the concentration of LSNa and the nature of the alloy. For iron and copper alloys, an extreme dependence of  $\Delta Q^C$  values on the surfactant content is observed, with the maxima lying in the region of 0.1–0.2% wt. which is optimal for the implementation of the Rehbinder effect [7]. When dispersing aluminum alloy D16T, anomalously high values of  $\Delta Q^C$  are observed already at an LSNa concentration of 0.05% wt. (Fig. 4, curve 3), and with a further increase in the surfactant content, the dispersing effect increases significantly with a weakly pronounced maximum at in the region of 0.4% wt.

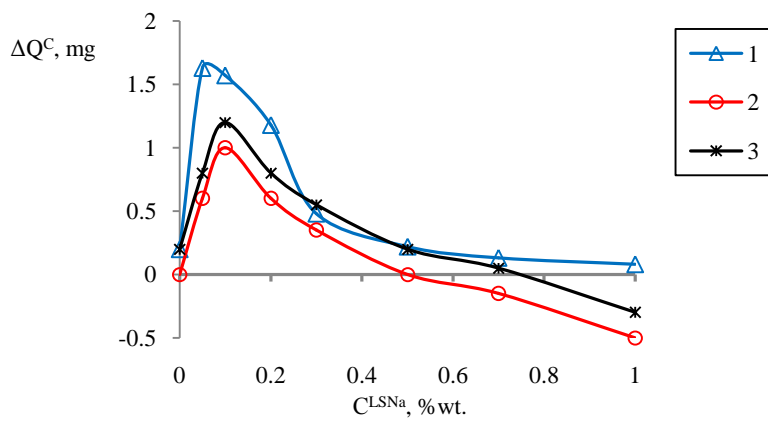
The concentration of PEG in aqueous binary solutions is 2% wt. and was chosen taking into account the results of studying the concentration dependence of the increase in removal  $\Delta Q^{PEG}$  of aqueous solutions of PEG-400, PEG-4000 and PEG-6000 during abrasive processing of alloys, which makes it possible to determine the values of  $\Delta Q^{BS}$  and compare them with the additive sum  $\Sigma \Delta Q^C$  of the  $\Delta Q^C$  values in solutions of LSNa and PEG, that is, to establish the presence of synergism or antagonism of the dispersing action of WBS components [2, 5].

The results of the study of the concentration dependence of the dispersing action of PEG-400-LSNa WBS during abrasive processing of alloys are shown in Fig. 5, Fig. 6 and Fig. 7.



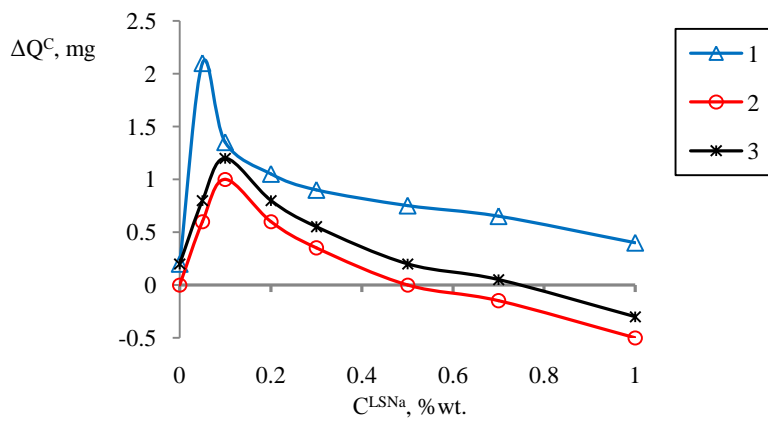
1 –WBS; 2 –LSNa; 3 –  $\Sigma$ PEG-400-LSNa

Fig. 5.a. Removal increase dependence  $\Delta Q^C$  St. 45 on the concentration of LSNa in WBS PEG-400-LSNa and the calculated values of the additive sum  $\Sigma \Delta Q^C$  for solutions of PEG-400 and LSNa



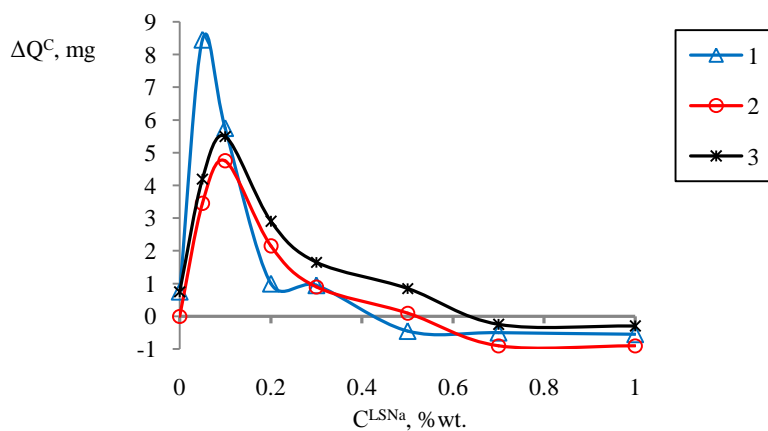
1 – WBS; 2 – LSNa; 3 –  $\Sigma$ PEG-4000-LSNa

Fig. 5,b. Removal increase dependence  $\Delta Q^C$  St. 45 on the concentration of LSNa in WBS PEG-4000-LSNa and the calculated values of the additive sum  $\Sigma \Delta Q^C$  for solutions of PEG-4000 and LSNa



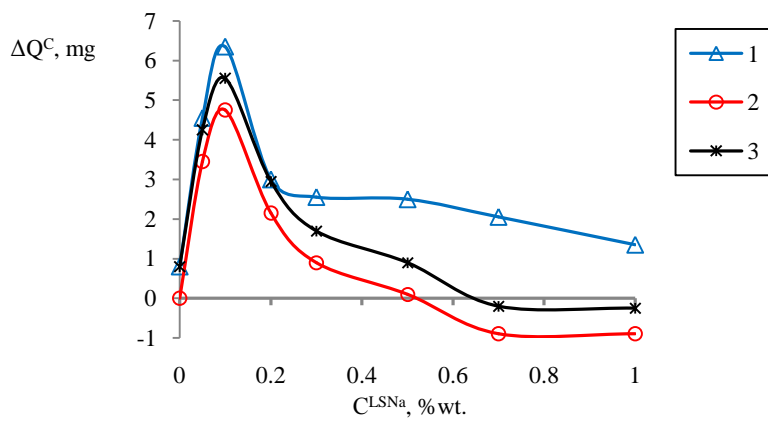
1 – WBS; 2 – LSNa; 3 –  $\Sigma$ PEG-6000-LSNa

Fig. 5,c. Removal increase dependence  $\Delta Q^C$  St. 45 on the concentration of LSNa in WBS PEG-6000-LSNa and the calculated values of the additive sum  $\Sigma \Delta Q^C$  for solutions of PEG-6000 and LSNa



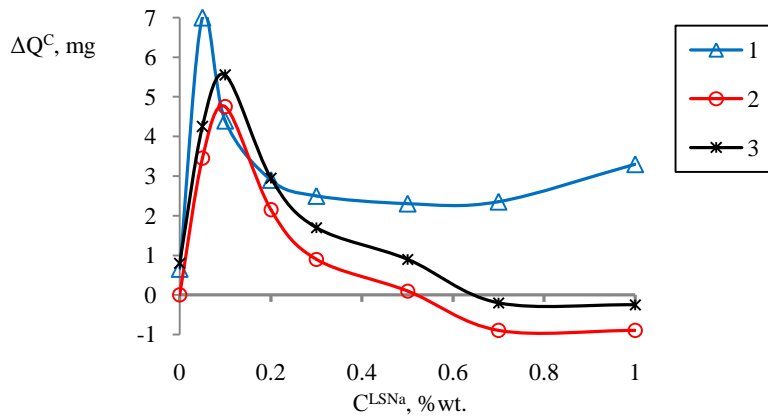
1 – WBS; 2 – LSNa; 3 –  $\Sigma$ PEG-400-LSNa

Fig. 6,a. Removal increase dependence  $\Delta Q^C$  brass L59 on the concentration of LSNa in WBS PEG-400-LSNa and the calculated values of the additive sum  $\Sigma \Delta Q^C$  for solutions of PEG-400 and LSNa



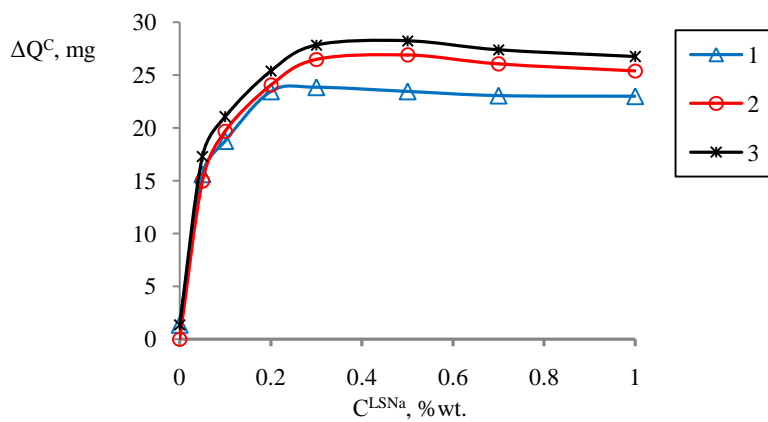
1 – WBS; 2 – LSNa; 3 –  $\Sigma$ PEG-4000-LSNa

Fig. 6,b. Removal increase dependence  $\Delta Q^C$  brass L59 on the concentration of LSNa in WBS PEG-4000-LSNa and the calculated values of the additive sum  $\Sigma \Delta Q^C$  for solutions of PEG-4000 and LSNa



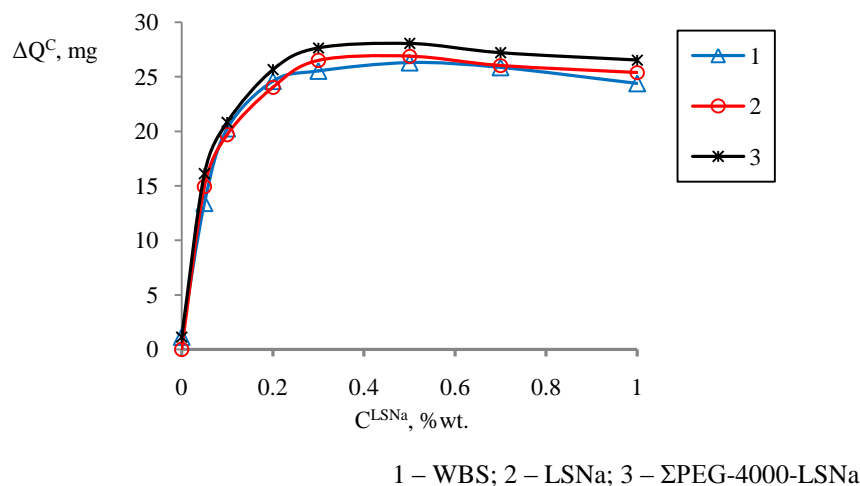
1 – WBS; 2 – LSNa; 3 –  $\Sigma$ PEG-6000-LSNa

Fig. 6,c. Removal increase dependence  $\Delta Q^C$  brass L59 on the concentration of LSNa in WBS PEG-6000-LSNa and the calculated values of the additive sum  $\Sigma \Delta Q^C$  for solutions of PEG-6000 and LSNa

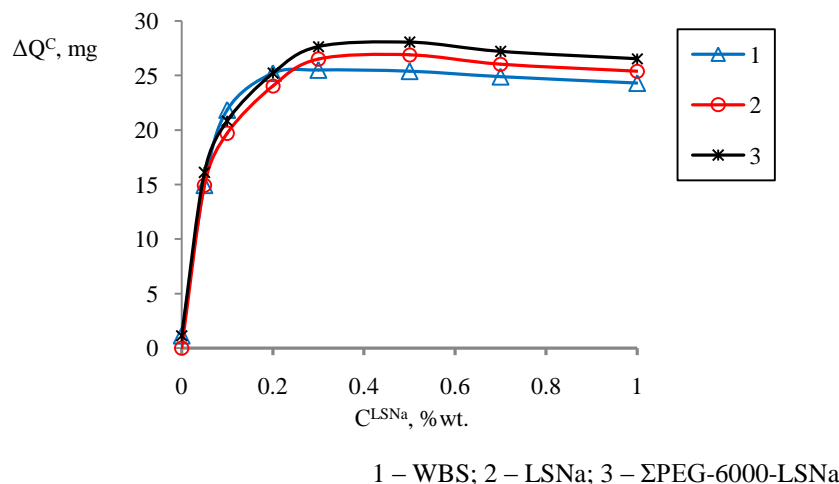


1 – WBS; 2 – LSNa; 3 –  $\Sigma$ PEG-400-LSNa

Fig. 7,a. Removal increase dependence  $\Delta Q^C$  alloy D16T on the concentration of LSNa in WBS PEG-400-LSNa and the calculated values of the additive sum  $\Sigma \Delta Q^C$  for solutions of PEG-400 and LSNa



**Fig. 7.b.**Removal increase dependence  $\Delta Q^C$  alloy D16T on the concentration of LSNa in WBS PEG-4000-LSNa and the calculated values of the additive sum  $\Sigma \Delta Q^C$  for solutions of PEG-4000 and LSNa



**Fig. 7.c.**Removal increase dependence  $\Delta Q^C$  alloy D16T on the concentration of LSNa in WBS PEG-6000-LSNa and the calculated values of the additive sum  $\Sigma \Delta Q^C$  for solutions of PEG-6000 and LSNa

As can be seen from the fig. 5-7 results, depending on the nature of the alloys, Mwt. PEG and LSNa concentration, synergism ( $S, \%$ ) is observed, i.e. mutual reinforcement of the dispersing action of WBS components ( $\Delta Q^{BS} > \Sigma \Delta Q^C$ ) or antagonism ( $\Delta Q^{BS} < \Sigma \Delta Q^C$ ). When abrasive processing St.45, according to the calculations carried out according to the method [1], the value of S reaches 33% for WBS PEG-400-LSNa, 36% for - WBS PEG-4000-LSNa and 75% for WBS PEG-6000-LSNa, therefore, with an increase in Mwt. PEG, the value of S increases by almost a factor of 2.

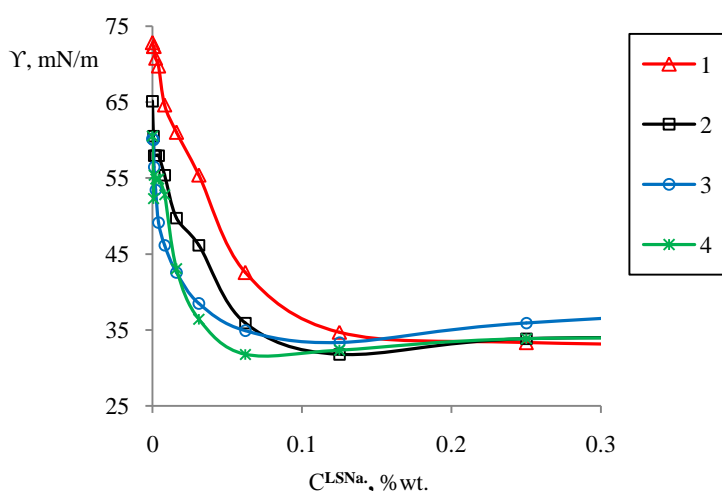
When dispersing brass L59 in WBS PEG-LSNa, the following S-row is set:  $S^{PEG-4000} = 14\%$ ;  $S^{PEG-6000} = 29\%$ ;  $S^{PEG-400} = 53\%$ , therefore, the maximum value of S is observed in WBS PEG-400-LSNa.

An analysis of the results of dispersion of aluminum alloy D16T in PEG-LSNaWBS (Fig. 7c) indicates an ambiguous effect of surfactant additives on the increase in  $\Delta Q$  in the concentration range of 0.05–0.15% wt. If in this range of LSNa concentrations, the value of  $\Delta Q$  of WBS of PEG-6000-LSNa somewhat exceeds  $\Delta Q$  LSNa and  $\Delta Q^C$ , then with an increase in the content of LSNa more than 0.2% wt., i.e. when going beyond the concentration limits in which the Reh binder effect is realized [7], the  $\Delta Q(WBS)$ ,  $\Delta Q( LSNa)$  and  $\Sigma \Delta Q^C$  curves diverge, while the WBS curves are located noticeably lower with respect to the  $\Delta Q^{LSNa}$  curves (Fig. 7). The high dispersing ability of LSNa solutions should be explained both by the high penetrating properties of LSNa molecules into the microcutting zone of the D16T alloy and the structural features of the thin surface layer, and by the electrostatic interaction of the lauryl sulfate ion with  $Al^{3+}$  cations of the freshly formed positively charged surface of the D16T alloy [9]. Consequently, the nature of the concentration dependences of the dispersing

action of the PEG-LSNaWBS during abrasive treatment of iron, copper, and aluminum alloys is the result of competitive adsorption of LSNa molecules, LSNa micelles, PEG macromolecules, and IMC PEG-LSNa on the freshly formed surface [4].

### 3.2. SURFACTANT AND RHEOLOGICAL PROPERTIES

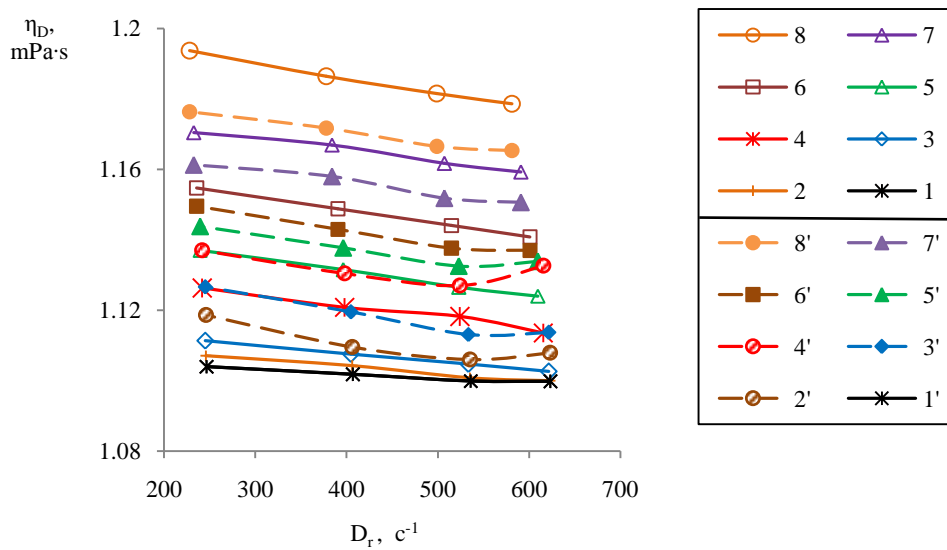
It is known that the synergism of the dispersing properties of the WBS components is due to the formation of IMC polymer-surfactant [1, 2], oligomer-surfactant [3], polyelectrolyte-surfactant [4], surface-active polymer-surfactant [5], the formation of which is detected when studying the surface tension, viscosity and electrical conductivity of WBS. The results of studies of the surface tension  $\gamma_{lg}$  of WBS PEG-LSNa depending on the concentration of the components, i.e. surface tension isotherms are shown in Fig. 8.



**Fig. 8. Dependence of surface tension LSNa (1), WBS: PEG-400-LSNa (2), PEG-4000-LSNa (3), PEG-6000-LSNa (4) on PEG  $M_m$  and surfactant concentration**

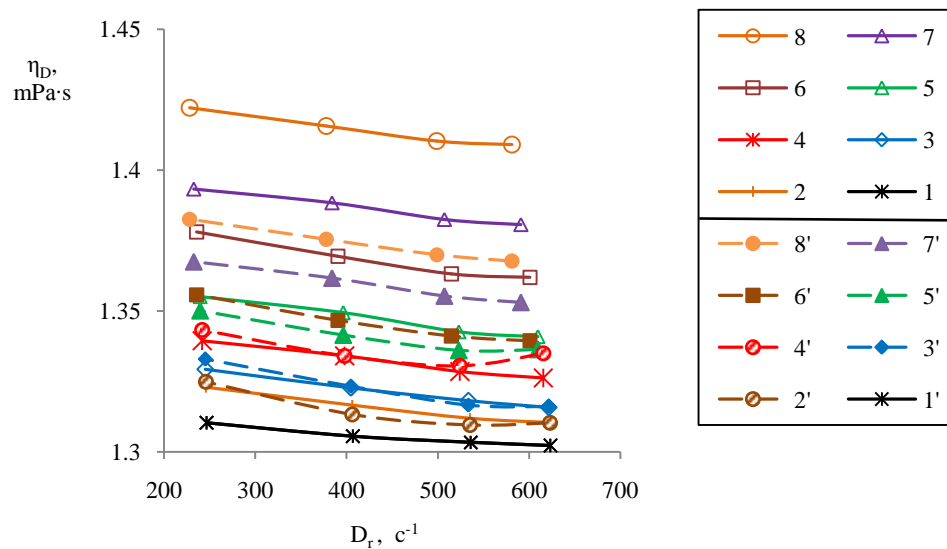
The character of isotherms  $\gamma_{lg}$  is significantly affected (Fig. 8, curves 1–4) by the Mwt. of the polymer, which can be explained by the formation of IMC PEG-LSNa, the stereochemistry and strength of which is determined by the interaction of PEG macromolecules of different Mwt. with LSNa molecules or micelles [8, 10, 11]. IMC PEG-LSNa is formed by the mechanism of coordination of fragments of PEG macromolecules around  $Na^+$  cations, with a decrease in  $\gamma$  values, i.e.  $\Delta\gamma$  compared to  $\gamma_{lg}$  of LSNa solution (Fig. 8, curves 1-4) noticeably increases with increasing Mwt. PEG. This indicates the formation of stronger IMC PEG-LSNa in WBS based on high molecular weight fractions of PEG. Attachment of LSNa molecules to the PEG chain, by analogy with WBS PEG-Na oleate [11], is accompanied by a decrease in the size of micelles and the number of aggregation, which initiates a rearrangement of the structure and manifests itself in the study of the rheological properties of WBS [1–5]. Considering these results, studies of the dynamic viscosity of WBS were carried out in a wide range of shear rate ( $D_r$ ) and LSNa concentration in a 2% solution of PEG-400, PEG-4000 and PEG-6000 (Fig. 9-11).





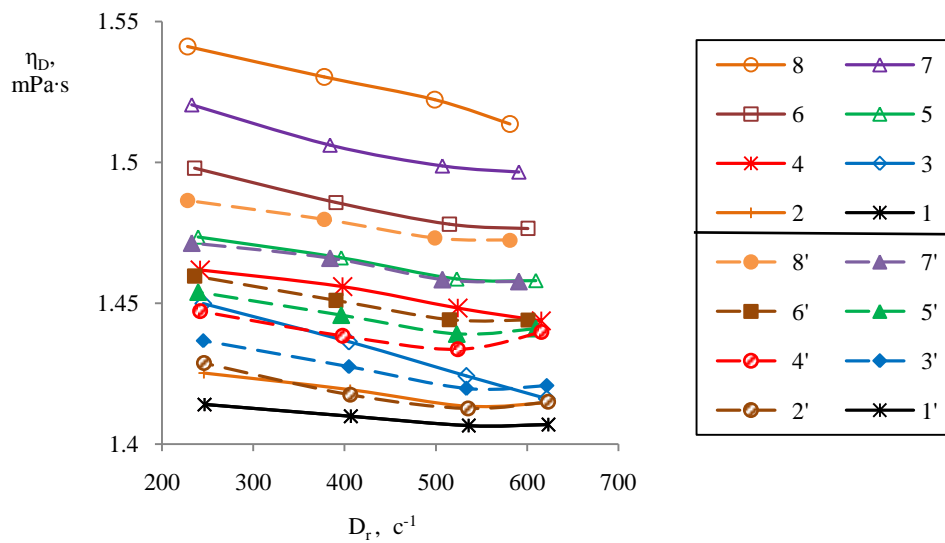
1,1' – 0,0%; 2,2' – 0,05%; 3,3' – 0,1%; 4,4' – 0,2%; 5,5' – 0,3%; 6,6' – 0,5%; 7,7' – 0,7%; 8,8' – 1,0%  
 1-8 -  $\eta_D$ WBS (2%PEG-400+LSNa), 1'-8' -  $\Sigma (\eta_D^{2\%PEG-400} + \eta_D^{x\%LSNa})$

**Fig.9.** Dependence of the dynamic viscosity of WBS of 2% PEG-400+LSNa on the shear rate  $D_r$  and LSNa concentration at a temperature of 20°C



1,1' – 0,0%; 2,2' – 0,05%; 3,3' – 0,1%; 4,4' – 0,2%; 5,5' – 0,3%; 6,6' – 0,5%; 7,7' – 0,7%; 8,8' – 1,0%  
 1-8 -  $\eta_D$ WBS (2%PEG-4000+LSNa), 1'-8' -  $\Sigma (\eta_D^{2\%PEG-4000} + \eta_D^{x\%LSNa})$

**Fig. 10.** Dependence of the dynamic viscosity of WBS of 2% PEG-4000+LSNa on the shear rate  $D_r$  and LSNa concentration at a temperature of 20°C



1,1' – 0,0%; 2,2' – 0,05%; 3,3' – 0,1%; 4,4' – 0,2%; 5,5' – 0,3%; 6,6' – 0,5%; 7,7' – 0,7%; 8,8' – 1,0%  
 1-8 -  $\eta_D$ WBS (2%PEG-6000+LSNa), 1'-8' -  $\Sigma (\eta_D^{2\%PEG-6000} + \eta_D^{x\%LSNa})$

**Fig. 11. Dependence of the dynamic viscosity of WBS of 2% PEG-6000+LSNa on the shear rate  $D_r$  and LSNa concentration at a temperature of 20°C**

Analysis of the effect of surfactant additives on the rheological properties of WBS PEG-LSNa shows (Fig. 9-11) that, depending on Mwt. PEG, LSNa concentration, and shear rate  $D_r$ , both synergism, i.e. increase in WBS viscosity ( $\eta_D^{WBS} > \eta_D^{\Sigma C}$ ), and antagonism, i.e. viscosity reduction ( $\eta_D^{WBS} < \eta_D^{\Sigma C}$ ) below the additive sum of the viscosity of the components. The prevalence of one of these options is determined by the nature of the interaction of PEG macromolecules with surfactant molecules, as a result of which the viscosity of WBS can either increase or decrease due to stretching or compression of polymer chains [10]. Influence of Mwt. PEG on the rheological properties of WBS can be explained by a change in the conformation of macromolecules and the size of coils, which determines the possibility and number of contacts of LSN-molecules or its micelles with the corresponding centers on the PEG chain [11].

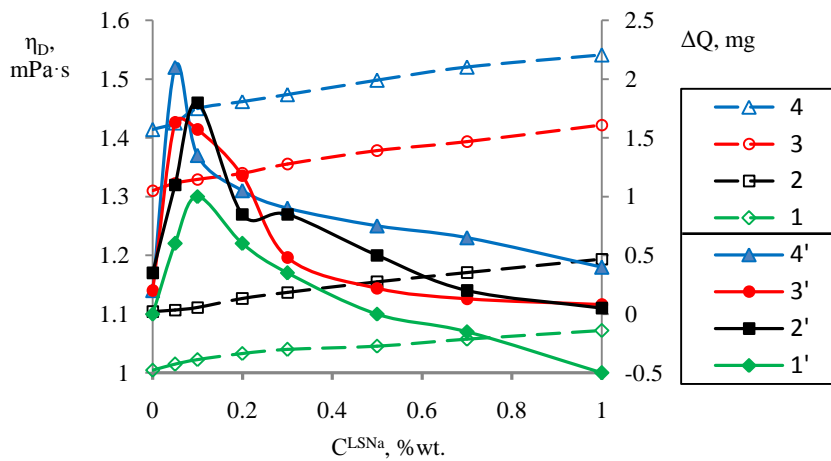
As can be seen from fig. 9-11, there is a surfactant concentration at which an inversion ( $C_{inv.}$ ) of the effect of LSNa on  $\eta_D^{WBS}$  is observed, that is, when  $\eta_D^{WBS} > \eta_D^{\Sigma C}$ :

inWBS 2% PEG-400-LSNa  $C_{inv.} \geq 0.5\% \text{ wt.}$

inWBS 2% PEG-4000-LSNa  $C_{inv.} \geq 0.5\% \text{ wt.}$

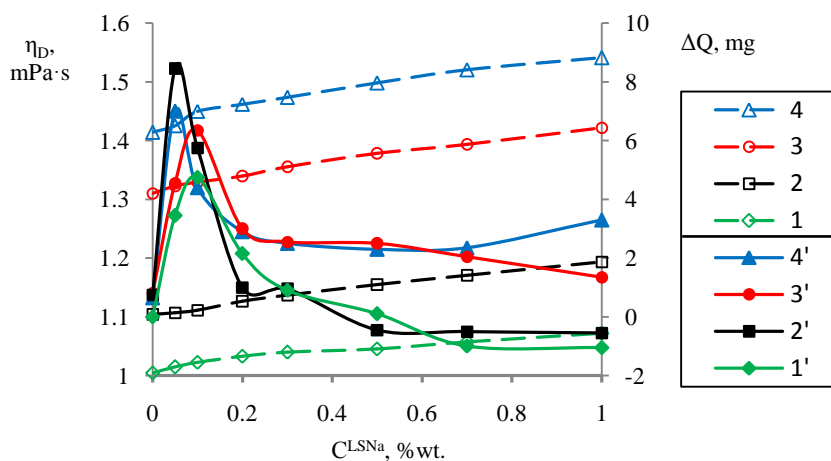
inWBS 2% PEG-6000-LSNa  $C_{inv.} \geq 0.1\% \text{ wt.}$

Taking into account that the dispersing action is a determining indicator of the quality of technological means for abrasive processing of metals, Figures 12-14 show for comparative analysis the curves of dependence of the increase in removal ( $\Delta Q$ ) and dynamic viscosity ( $\eta_D$ ) on the concentration of LSNa and Mwt. PEG.



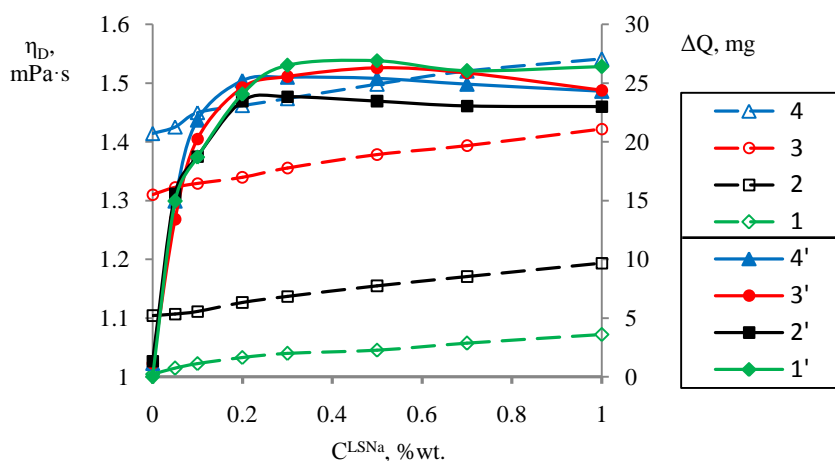
1,1' – LSNa; 2,2' – PEG-400; 3,3' – PEG-4000; 4,4' – PEG-6000  
 1-4 –dynamic viscosity ( $\eta_D$ ), 1'-4' –removal gain ( $\Delta Q$ )

Fig. 12. Dependence of dynamic viscosity  $\eta_D$  (1-4) and increase in removal  $\Delta Q$  (1'-4') St.45 in WBS PEG-LSNa on LSNa concentration



1,1' – LSNa; 2,2' – PEG-400; 3,3' – PEG-4000; 4,4' – PEG-6000  
 1-4 – dynamic viscosity ( $\eta_D$ ), 1'-4' – removal gain ( $\Delta Q$ )

Fig. 13. Dependence of dynamic viscosity  $\eta_D$  (1-4) and increase in removal  $\Delta Q$  (1'-4') brass L59 in WBS PEG-LSNa on LSNa concentration



1,1' – LSNa; 2,2' – PEG-400; 3,3' – PEG-4000; 4,4' – PEG-6000  
 1-4 – dynamic viscosity(η<sub>D</sub>), 1'-4' – removal gain(ΔQ)

**Fig. 14. Dependence of dynamic viscosity η<sub>D</sub> (1-4) and increase in removal ΔQ (1'-4') alloy D16Tin WBS PEG-LSNa on LSNa concentration**

As can be seen from Fig. 12-14 of the results, the effect of mm PEG on the value of ΔQ<sup>max</sup> for St.45 and brass L59 is not a determining factor, as evidenced by a comparative analysis of the results in ΔQ<sup>max</sup> and η<sub>D</sub>: ΔQ<sup>max</sup>(PEG-6000) > ΔQ<sup>max</sup>(PEG-400) > ΔQ<sup>max</sup>(PEG-4000); η<sub>D</sub>(PEG-6000) > η<sub>D</sub>(PEG-4000) > η<sub>D</sub>(PEG-400). For brass L59, the row ΔQ<sup>max</sup> changes: ΔQ<sup>max</sup>(PEG-400) > ΔQ<sup>max</sup>(PEG-6000) > ΔQ<sup>max</sup>(PEG-4000), and a number of η<sub>D</sub> does not change. Consequently, there is reason to believe that viscosity affects the dispersing capacity of WBS indirectly, that is, as a result of the appearance of a surface-active component (IMC) in a binary solution, which largely and depending on the alloy determines the dispersing properties of WBS.

The weak and ambiguous effect of η<sub>D</sub>, and hence Mwt. of PEG, on the dispersing ability of WBS PEG-LSNa during abrasive processing of D16T aluminum alloy (Fig. 14) can be explained by the anomalously high penetrating properties of LSNa molecules into the microcutting zone, which is due to the electrostatic interaction of the lauryl sulfate ion with freshly formed surface, which is positively charged [9].

### 3.3. ELECTROCONDUCTIVITY PROPERTIES

It is known that additions of anionic surfactants strongly affect both the surface-active and rheological properties, and the electrical conductivity of polymer-surfactant WBS [13–17].

On fig.15-18 shows the results of studies of the specific electrical conductivity χ of aqueous solutions of LSNa and WBS PEG-LSNa (Fig. 16-18) on the concentration of surfactants and Mwt. PEG. The value of the critical micelle concentration (CMC) of LSNa and PEG-LSNa WBS was determined from the graphic dependence of χ of solutions on the surfactant concentration by the Williams method [18].

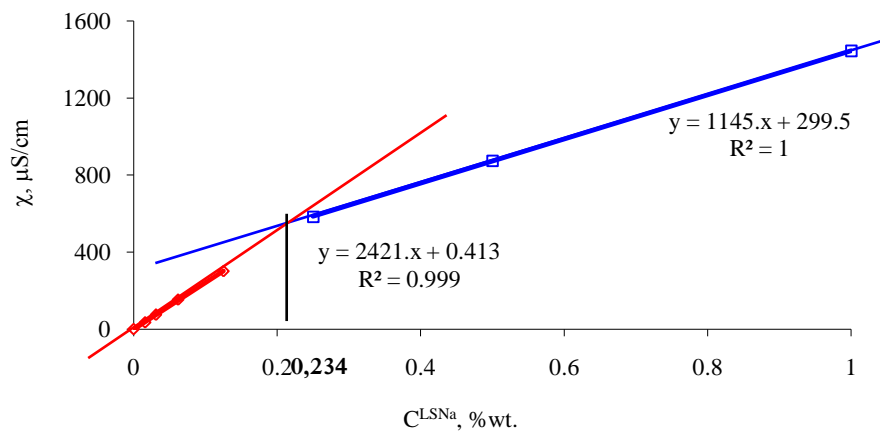


Fig. 15. Dependence of electrical conductivity  $\chi$  on the concentration of aqueous solutions of LSNa (T = 20 °C)

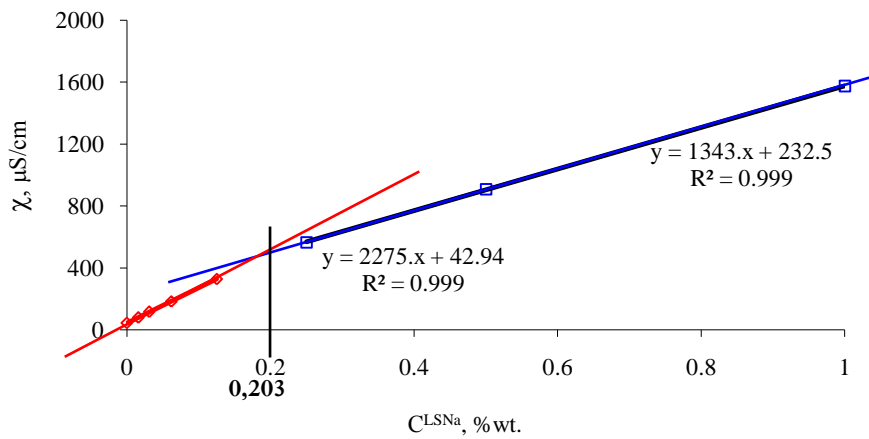


Fig. 16. Dependence of electrical conductivity  $\chi$  on the concentration of WBS 2%wt. PEG-400-LSNaon the concentration of LSNa (T = 20 °C)

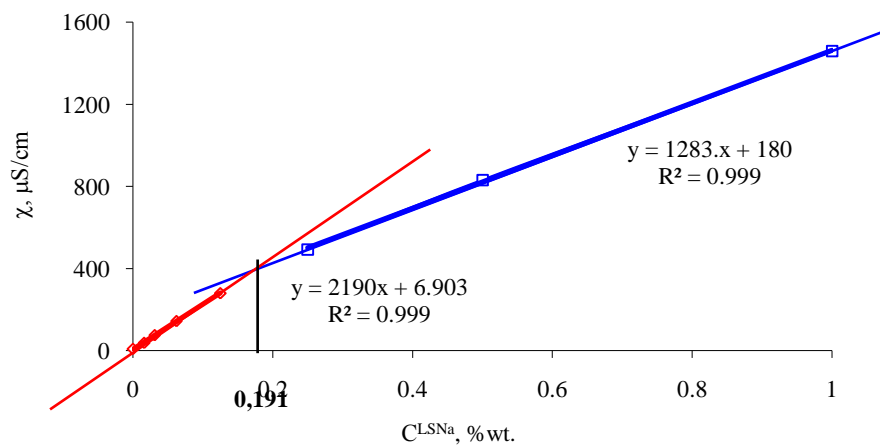
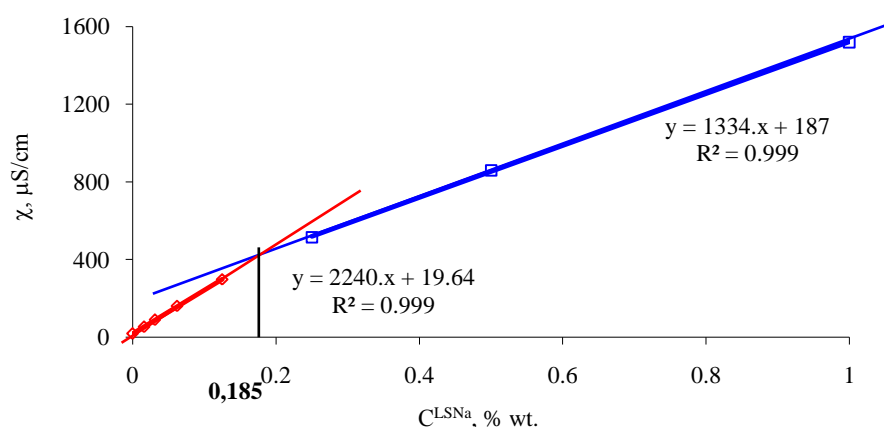


Fig. 17. Dependence of electrical conductivity  $\chi$  on the concentration of WBS 2%wt. PEG-4000-LSNaon the concentration of LSNa (T = 20 °C)



**Fig. 18. Dependence of electrical conductivity  $\chi$  on the concentration of WBS 2%wt. PEG-6000-LSNa on the concentration of LSNa ( $T = 20\text{ }^{\circ}\text{C}$ )**

The results obtained are presented in table 1.

**Table 1**

Solutions	LSNa	PEG-400-LSNa	PEG-4000-LSNa	PEG-6000-LSNa
CMC, %	0,234	0,203	0,191	0,185

As can be seen from the results in the table, the CMC values gradually decrease with increasing PEG Mwt., which is consistent with the results of the study of surface tension isotherms (Fig. 8) and the effect of PEG macromolecules on the aggregation number and micelle size in WBS PEG-20-103-Oleate Na [11]. The results obtained make it possible to propose a mechanism for the immobilization of both individual LSNa molecules and its micelles in WBS with the formation of PEG-LSNa IMC responsible for the synergism and symbacy of changes in the surface-active, rheological, electrically conductive, and dispersive properties of WBS PEG-LSNa.

#### IV. CONCLUSION

The concentration dependences of dispersing, surface-active, rheological and conductometric properties of aqueous solutions of PEG, LSNa and aqueous binary solutions of PEG-LSNa have been studied. The synergy of the dispersing action of the WBS components was established, the value of which is determined by the molecular weight of PEG, the concentration of LSN and the nature of the alloys. The results of the studies suggest a mechanism for the immobilization of both individual LSNa molecules and their micelles in WBS with the formation of IMC PEG-LSNa responsible for the synergism and symbate changes in surface-active, rheological, conductometric, and dispersing properties.

#### REFERENCES

- [1]. Logvinenko P.N., Riabov S.V., Shevchenko V.V., Dmitrieva T.V., "Polymer-oligomer-containing dispersion media based on water in the processes of abrasive metal processing", Friction and wear, Vol. 20. 4. 439-445. 1999.
- [2]. Logvinenko P.N., Ryabov S.V., Karsim L.O., Glievaja G.E. Dispersion media for abrasive processing of metals based on aqueous binary composites PEG-nonionic surfactants // Friction and wear.-2015.-T.36, No. 2.-S.189-195.
- [3]. Lohvynenko P.N., Dmitrieva T.V., Boyko V.V., Karsim L.O., Glieva G.E., Nevmerdzitska G.F. and Riabov S.V. Dispersion Media Based on Aqueous Binary Compositions Modified by PEG-Stearox-6 for Abrasive Metalworking. Journal of Friction and Wear. 2018. Vol.39.No.6.pp.512-516
- [4]. Logvinenko P.N., Dmitrieva T.V., Boyko V.V., Karsim L.O., Nevmerzhitskaya G.F., Riabov S.V. " Abrasive Processing Steel in Aqueous Binary Compositions Polyelectrolyte-oligomer." American Journal of Engineering Research (AJER), vol.9(07), 2020, pp. 165-169.
- [5]. Logvinenko, P. N., Kobylinsky, S. N., Karsim, L. O., Glievaya, G. E., Ryabov, S. V. Abrasive Treatment of Iron, Copper and Aluminum Alloys in Aqueous Binary Solutions of Polyalkylene Glycol-Sodium Alkyl Sulfate. American Journal of Engineering Research (AJER). 2021, Vol.10, pp.356-365.
- [6]. Gorokhovskiy G.A. Polymers in metal processing technology. - K.: Naukova Dumka, 1975. - 224 p.

- [7]. Rebinder P.A., Shchukin E.V. Fav. Tr.: Surface phenomena in disperse systems//Under. Ed. P.A. Rebinder.-M.: Nauka,1989.-411 p.
- [8]. Schwager M.J. Mechanism of Interaction Between Ionic Surfactants and Polyglycol Ethers in Water. Journal of colloid and interface science, 1973, 43.2: 491-498.
- [9]. Rosenfeld I.L., Loskutov A.I., Alekseev V.N. Adsorption of sodium oleate and water on an oxidized aluminum surface. Proceedings of the Academy of Sciences of the USSR. Chemistry series. 1982. No. 2, pp. 254-259.
- [10]. Mohsenipour, A.A., Pal, R. Synergistic Effects on Anionic Surfactant and Nonionic Polymer Additives on Drag Reduction. Chem. Eng. Commun. 2013. 200. 935-958.
- [11]. A. P. Artikulny, V. I. Petrenko, L. A. Bulavin, L. Almashy, N. A. Grigoryeva, M. V. Avdeev, V. L. Aksenov. Influence of polyethylene glycol on the structure of micellar solutions of sodium oleate in water according to small-angle neutron scattering data. Surface. X-ray, synchrotron and neutron studies. 2018, No. 12, p.3-10.
- [12]. Jia Yang and Rajinder Pal. Investigation of Surfactant-Polymer Interactions Using Rheology and Surface Tension Measurements. Polymers. 2020, 12, 2302. pp.1-23.
- [13]. Carlsson A., Karlstrom G., Lindman B. Synergistic surfactant-electrolyte effect in polymer solutions. "Langmuir", 1986, 2, No.4, p.536-537.
- [14]. Kucher R.V., Lvov V.G., Serdyuk A.I. Interaction of ionic surfactants with polyethylene oxide in aqueous solutions. colloid magazine. 1984. V.46, No. 2, pp. 262-267.
- [15]. Baran Sh. Interaction of high-molecular flocculants with ionogenic surfactants. Colloid Journal.-2002.-T.64, No.5.-591-595.
- [16]. Germasheva I.I., Glukharev N.A., Prokhorova G.V. Interaction of L-lysine with sodium dodecyl sulfate. Scientificstatements. SeriesNaturalSciences. 2011. No. 3 (98). Issue 14.-p. 174-178.
- [17]. Williams R.J., Phillips J.N., Mysels K.J. The Critical Micelle Concentration of Sodium Lauryl Sulfate at 25°C. Trans Faraday Soc. 1995. 51: 728-7737.

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