American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-8, pp-121-135
www.ajer.org
Research Paper Open Access

Metalworking Fluids and Lubricants Offer Effective Protection for Processing and Shipment of Metal Based Products

Y.J.Aghazada, A.D.Quliyev, E.A.Samedov, S.E.Abdullayev, E.K.Hasanov
Institute of Petrochemical Processes named after acad. Yu.G. Mamedaliyev, Azerbaijan National Academy of Sciences, AZ1025, Azerbaijan, Baku,. Khojali ave., 30
Corresponding Author: Y.J.Aghazada

ABSTRACT: *In this proceeding, the compositions of the T-30 turbine oil with oxidized liquid rubber, Co, Ni, Zn, Mg and Ba salts of the natural petroleum acids (NPA) boiling in the range 220 – 340°C and nitro compounds which are produced on the basis of $C_{14}H_{28}$ α-olefins have been investigated in different ratio and contents as metalworking fluids (MWF). The physical and chemical properties of the produced compositions have been studied, and the morphology of inhibited carbon steel surface was analyzed and characterized by using Fourier transformer infrared (FTIR) and scanning electron microscopy (SEM) techniques. Effect of temperature on inhibition efficiency and thermodynamic parameters have also been reported. Thermal analyzer was used for the thermogravimetric analysis (TG/DTA) of the prepared MWF. The experiments have been operated with different concentrations of inhibitor on the steel plates in condensation and environment phases in the experiment chamber.*

Keywords*: metalworking fluids and lubricants, corrosion, oxidized liquid rubber, natural petroleum acids*

Date of Submission: 13-07-2017 Date of acceptance: 10-08-2017

I. INTRODUCTION

Corrosion is defined as the deterioration of a material due to reaction with its environment. Regardless of their operation conditions, metal constructions show thermodynamically unstable state as they react with the aggressive part of the environment and corrode. This harmful attack can cause defect in the mechanical, physical and chemical properties of metal [1-3]. Therefore, protection methods should be developed to reduce the damage effects of the metal. Inhibitors have very wide application in a variety of industrial applications such as cooling systems, refinery units, pipelines, chemicals, oil and gas production units, boilers and water processing, paints, pigments, lubricants, etc. [4-8]. Organic inhibitors are very effective way for the reducing of corrosion of metals and alloys due to generate a thin film that controls and prevents access of corrosive agents to the metal surface. The inhibitory effect of an organic inhibitor is reinforced by the presence of hetero adsorption active centre such as sulphur (S), nitrogen (N) and oxygen (O) atoms in its molecule [9-11]. In addition to the molecular electronic structure with a number of these active centres, the molecular size, the mode of adsorption, the formation of metallic complexes, and the projected area of the inhibitor on the metallic surface also effect the efficiency of inhibition [12-14].

In recent years, some experimental studies have been done to describe the corrosion and electrochemical behavior of stainless steel in concrete environment [15-18]. The widespread investigation of the inhibitors in the metalworking fluids is based on its economic efficiency and simple structure of application technology. The addition of a small amount of an inhibiting substance to the aggressive system is enough for protecting the metal without any changes to the current technical system [19-21]. In various manufacturing processes, metalworking fluids (MWF) are applied to ensure workpiece quality, to reduce tool wear, and to improve process productivity. The specific chemical composition of an applied MWF should be strongly dependent on the scope of application. Even small changes of the MWF-composition can influence the performance of MWF in manufacturing processes considerably. Besides defined variations of the composition, the MWF-chemistry furthermore changes over the service life of the fluid.

The purpose of the work is to synthesize multifunctional nitrogen containing corrosion inhibitors with different molecular masses on the basis of local feedstocks with enough reserves and to prepare high – performance MWF by using them as additives.

This paper presents, the solution of the composition of inhibitor that is obtained by complex of the Co, Ni, Zn, Mg və Ba metal salts of the natural petroleum acids with nitro compounds and oxidized liquid rubber in T-30 oil has been applied as a corrosion protector. The compounds those have inhibitor properties in the prepared MWF mainly consist of 3 components: metal salts of natural petroleum acid, aliphatic based nitro compunds and oxidized liquid rubber.

II. EXPERIMENTAL

The metal (Co, Ni, Zn, Mg, Ba) salts of technical petroleum acids which are separated from Azerbaijan kerosene and diesel fractions and is soluble in organic solvents have been synthesized by the general methods. The NPA which is used in the process has been obtained by the dearomatization of the diesel fraction with the boiling range of 220-340°C. The dearomatization process has been operated with the extraction method. N-methyl pyrrolidone has been used as an extract. The physical and chemical properties of the fraction which is obtained from the extraction process were studied and given in Table 1.

Table1. The physical and chemical properties of the fraction NPA

Density ρ_4^{20}	Refraction n_d^{20}	Molecular weight M_r	Freezing temp.	Boiling temp.	Kinematic viscosity at 20°C,	Total sulfur content	Aromatic hydrocarbos
0,8294 g/cm^3	1,4677	187 g/mol	-51 °C	220-340 °C	~5,52 mm^2/sec	~ 0,03 %	~1 % (by mass)

The composition of the solution which contains synthesized the metal salts of the NPA and nitro compound with the polybutadiene based liquid rubber has been prepared and tested on steel plates. The liquid rubber which is used in the process has been synthesized on the basis of stereo regular structured 1,4 cis – polybutadiene (low molecular weight, M_r ~1800-3000), which has a wide range of industrial application (microstructure: 1,4 cis-75~80% ; 1,4 trans-18~22% ; 1,2-units-2~7%, number of units~80). The cis- position of the methyl groups in liquid rubber facilitates the adsorption on the metal surface [22-23]. Nitro compound is synthesized by using treating $C_{14}H_{28}$ which is produced by the oligomerization of ethylene with nitro compound with nitric acid in optimum condition (sodium nitrite is used as an inisiator). The amount of the active components was 1:1:1 (in grams). “T-30” turbine oil has been used as a solvent. The physical and chemical properties of the composition of inhibitor have been investigated (Table 2.) and its content has been proved by IR spectrosopy method [24-25].

Table 2. Main physical properties of metalworking fluids

Name of the property	Name of the device	ASTM	Samples				
			I	II	III	IV	V
Freezing point °C	Stanhope Seta	ASTM D2386	-35	-30	-25	-25	-25
Viscosity mm^2/s, °C 40	TW4000	ASTM D445	60.88	56.47	61.96	66.93	53.99
Viscosity, mm^2/s, °C 100	TW4000	ASTM D445	8.31	7.98	8.12	7.54	7.63
Density, g/cm^3	DMA 4500 M	D5002	0.9072	0.9112	0.9136	0.9093	0.9090

Name of the samples

I. T-30 oil + Co salt of the NPA+ Nitro compound+ox.liquid rubber
II. T-30 oil + Ni salt of the NPA+ Nitro compound+ ox.liquid rubber
III. T-30 oil +Zn salt of the NPA+ Nitro compound+ ox.liquid rubber
IV. T-30 oil + Mg salt of the NPA+ Nitro compound+ ox.liquid rubber
V. T-30 oil + Ba salt of the NPA+ Nitro compound+ ox.liquid rubber

In order to determine the identity of the conservation liquid, 5 different points have been chosen on given sample and IR spectra have been evaluated [26]. The following wavelength has been obtained by the spectral analysis of the conservation content of the inhibitor (Co salt of NPA + Nitro compound + ox.liquid rubber) which shows the maximum efficiency:

Fig.1.1.The microscopic view of 5 selected points in sample.

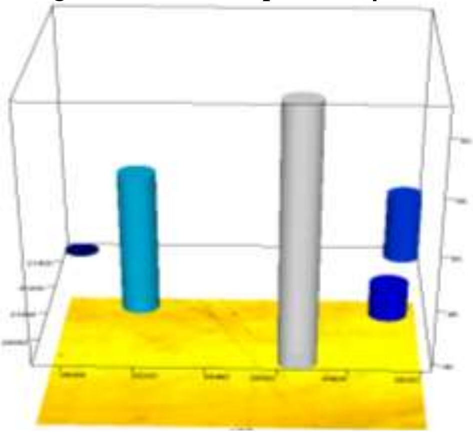


Fig. 1.2 IR spectra of the 1st point

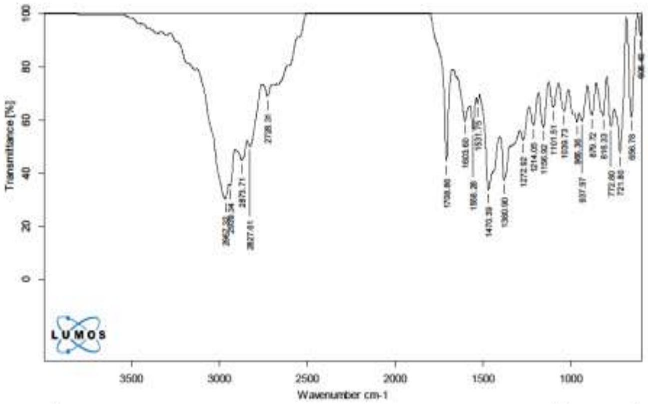


Figure 1.3 IR spectra of the 2nd point

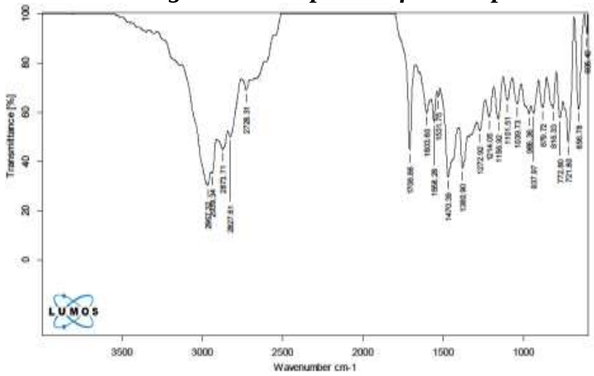


Figure 1.4 IR spectra of the 3rd point

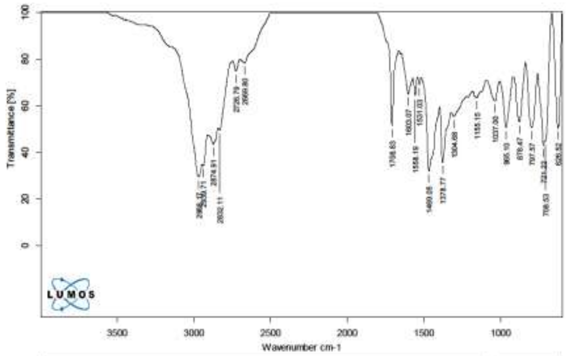


Figure 1.5 IR spectra of the 4th point.

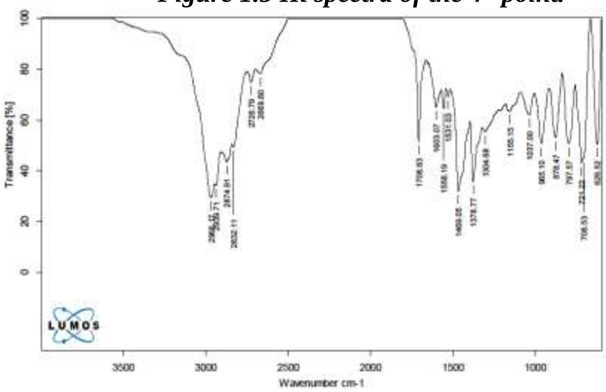
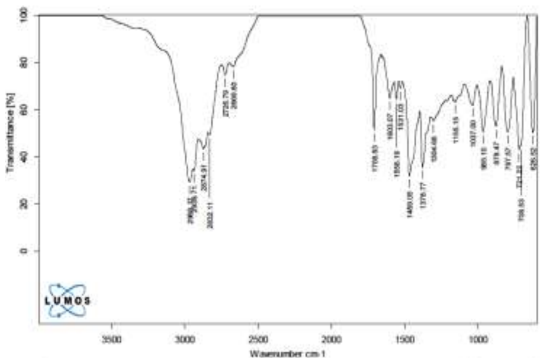


Figure 1.6 IR spectra of the 5 th point



The content of the composition has been tested by IR-Furye LUMOS (BRUKER) microscope in the range of 600-4000 cm^{-1} wavelength. The deformation (1376, 1457 cm^{-1}) and valence (2921, 2950 cm^{-1}) oscilations of structure groups (CH_3 and CH_2) which belong to NPA are observed in the spectrum of the approved sample. At the same time, the resonance signals for C – H bond and valence oscillations for $C – NO_2$ group are seen at 723 cm^{-1} and 1558 cm^{-1} wavelength, respectively. The comparison of the IR spectrum of all 5 points on the sample shows that they are practically the same which proves that the conservation materials are distributed on the metal surface homogeneously.

STA-449 F3, NETZSCH thermal analyzer was used for the thermogravimetric analysis (TG/DTA – change in mass depending on the temperature and differential thermal analysis) of the prepared conservative liquids. The processes has been operated by using nitrogen gas flow and by increasing the temperature by 20°C per minute. The evaluation of thermal analysis of the Sample 5 (table 1) shows that there is no chemical change in the STA (Simultaneous Thermal Analysis) curve, the peak at 360°C coincides with the complete disintegration of the compozition. The curve for the mass loss is observed in the TG (Thermogravimetry) curve which proves the homogeneity of the composition. The component that has less thermal stability in the studied MWF is nitro compound. Hence, nitro compounds are decomposed at temperatures above 600°C, then amido

amines and liquid rubber are decomposed respectively. The dependence of the change in the mass loss on the temperature is given in the Table 3.
Because of the uniform distribution of the components in the T-30 oil medium and thermostability property of the metal salts of the NPA, metalworking fluids can be utilized for a long time without losing quality.

Fig. 2. TG/DTA curves of the Sample 5.

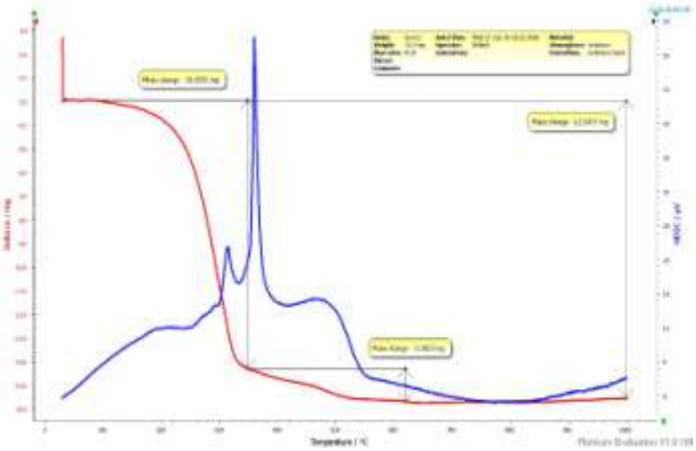


Table 3. Change in the mass loss

Temperature °C	Mass loss, mg	Mass loss, %
120	0	–
140	0.2	1.48
160	0.4	2.96
180	0.6	4.44
200	1.0	7.41
220	1.4	10.37
240	2.6	19.25
260	4.0	29.26
280	6.0	44.44
300	8.6	63.70
320	11.0	81.48
340	11.4	84.44
360	11.4	84.44
380	11.6	85.92
400	11.8	87.64
420	12.0	88.88
440	12.0	88.88
460	12.2	90.37

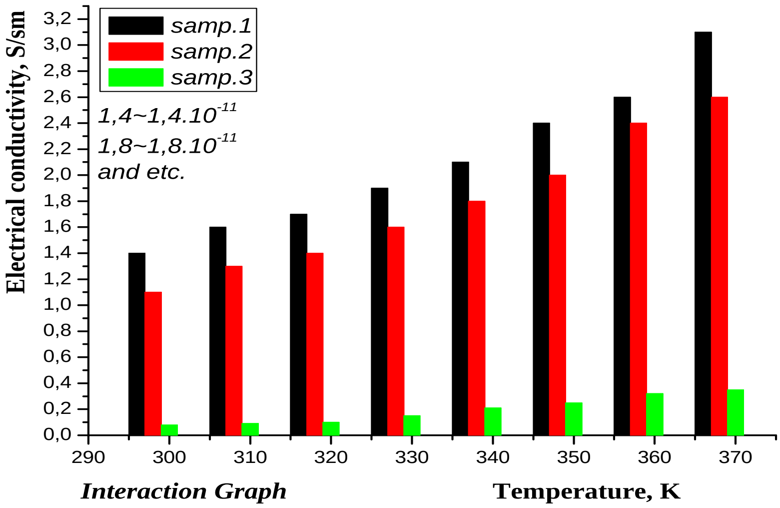
The specific contact method has been used in order to determine the resistivity (specific conductance) of the compositions. The measurement process has been operated by the E6-13A teraohmmeter. The measurement places are cleaned with alcohol before each process and the distance between electrodes is determined. Then, the substance is poured until the area between electrodes is filled and the resistivity is measured. The resistivity is calculated according to $\rho = \pi r^2/d$ equation and the conductance is determined with the following equation: $\sigma = 1/\rho$. The physical components in the formulae are following: ρ-resistance, π-constant, σ - conductance, r-radius of the measurement electrode, d-distance between electrodes. The determined electrical conductivity values of the samples are shown in the Table 4.

Table 4. Change in the electrical conductivity due to temperature

№	Tempe-rature, K	Special resistance ρ, Om·m	Electrical conductivity σ, S/sm	№	Special resistance ρ, Om·m	Electrical conductivity σ, S/sm	№	Special resistance ρ, Om·m	Electrical conductivity σ, S/sm
1	298	$6,9\cdot10^{8}$	$1,4\cdot10^{-11}$	2	$8,4\cdot10^{8}$	$1,1\cdot10^{-11}$	3	$1,08\cdot10^{10}$	$9,2\cdot10^{-13}$
	303	$6\cdot10^{8}$	$1,6\cdot10^{-11}$		$7,9\cdot10^{8}$	$1,3\cdot10^{-11}$		$1,04\cdot10^{10}$	$9,6\cdot10^{-13}$
	308	$6\cdot10^{8}$	$1,6\cdot10^{-11}$		$7,4\cdot10^{8}$	$1,4\cdot10^{-11}$		$1,04\cdot10^{10}$	$9,6\cdot10^{-13}$
	313	$5,6\cdot10^{8}$	$1,7\cdot10^{-11}$		$6,9\cdot10^{8}$	$1,4\cdot10^{-11}$		$1\cdot10^{10}$	$1\cdot10^{-12}$
	318	$5,6\cdot10^{8}$	$1,7\cdot10^{-11}$		$6,5\cdot10^{8}$	$1,5\cdot10^{-11}$		$9,2\cdot10^{9}$	$1,1\cdot10^{-12}$
	323	$5,2\cdot10^{8}$	$1,9\cdot10^{-11}$		$6,1\cdot10^{8}$	$1,6\cdot10^{-11}$		$8\cdot10^{9}$	$1,3\cdot10^{-12}$
	328	$5,2\cdot10^{8}$	$1,9\cdot10^{-11}$		$5,9\cdot10^{8}$	$1,7\cdot10^{-11}$		$6,8\cdot10^{9}$	$1,5\cdot10^{-12}$
	333	$4,8\cdot10^{8}$	$2,1\cdot10^{-11}$		$5,7\cdot10^{8}$	$1,8\cdot10^{-11}$		$6\cdot10^{9}$	$1,7\cdot10^{-12}$
	338	$4,6\cdot10^{8}$	$2,2\cdot10^{-11}$		$5,3\cdot10^{8}$	$1,9\cdot10^{-11}$		$5\cdot10^{9}$	$2\cdot10^{-12}$
	343	$4,2\cdot10^{8}$	$2,4\cdot10^{-11}$		$4,9\cdot10^{8}$	$2\cdot10^{-11}$		$4\cdot10^{9}$	$2,5\cdot10^{-12}$
	348	$3,8\cdot10^{8}$	$2,6\cdot10^{-11}$		$4,6\cdot10^{8}$	$2,2\cdot10^{-11}$		$3,6\cdot10^{9}$	$2,8\cdot10^{-12}$
	353	$3,8\cdot10^{8}$	$2,6\cdot10^{-11}$		$4,1\cdot10^{8}$	$2,4\cdot10^{-11}$		$3,2\cdot10^{9}$	$3,1\cdot10^{-12}$
	358	$3,2\cdot10^{8}$	$3,1\cdot10^{-11}$		$3,8\cdot10^{8}$	$2,6\cdot10^{-11}$		$2,8\cdot10^{9}$	$1,3\cdot10^{-12}$

The graph showing the change of the electrical conductivity of the metalworking fluids due to temperature is given below:

Figure 3. The graph of electrical conductivity against temperature.



As it is obvious from Table 4 and Table 5, there is a direct dependence between the electrical conductance and the corrosion protection effect of the metalworking fluids; the higher electrical conductance, the greater corrosion protection effect.

Obtained composition has been tested as MWF on steel plates by dissolving T-30 oil (5%, 7% and 10%). The experiments were carried out with DC01 (CR4) carbon steel specimens. The mainly chemical composition (wt%) of the carbon steel was listed as follows: C%~0.07; Si%~0,01; Mn%~0.2-0.35; Ni%~0.06; S%~0.025; P%~0.02; Cr%~0.03; Al%~0.02-0.07; Cu%~0.06; Fe balance. The test sample size was 150x100x1mm. The carbon steel plates were prepared, degreased and cleaned with deionized water and alcohol.

The experiment has been operated according to the current standards in the chamber called «CORROSİONBOX-1000E» which is considered as a modern technological device. The process has been carried out in two phases: condensation and atmospheric phase. Electronic appliances have been used in order to adjust the standard parameters for obtaining sustainable trials in the experiment chamber. For the condensation phase, these parameters are the temperature of the chamber and the duration of the trial, for the environmental phase, these are the temperature of the moisturizing agent and the chamber and the duration of the trial. The duration of the trial was in the interval of 1 minute – 9999 hours and the temperature of the chamber was 20 – 50°C for the condensation phase, whereas the temperature of the moisturizing agent was 20 – 80°C and the remaining parameters were the same for the environmental phase.

III. RESULTS and DISCUSSION

As can be clearly seen from the table, metal sheets were protected 31 and 56 days by using T-30 turbine oil and liquid rubber respectively, however, these pointers were higher when inhibitor was used. When 7 % concentration of the inhibitor (Co salt of NPA + Nitro compound + Oxidized liquid rubber) was used, in the condensation phase, the protection of the metal sheets from the corrosion lasted 301 days, however, in environmental phase, it was 384 days. In 10 % concentration, it was 322 and 401 days, respectively. At the same time, the corrosion protection efficiency of the conservative liquids those have been produced on the basis of the complex of the metal salts (Ni, Zn, Mg and Ba) of NPA with nitro compounds was high in comparison to current demand.

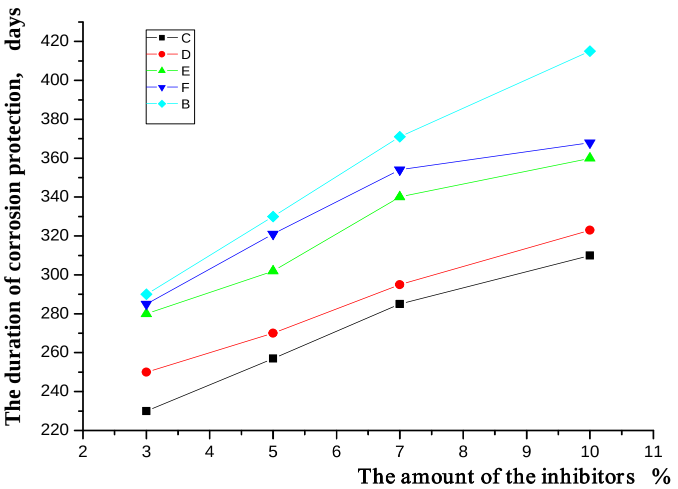
Table 5. The results of the trials of synthesized salts as metalworking fluids both individually and as compositions.

№	The solutions of the compositions in the "T-30" oil			The duration of corrosion protection, days	
	Content	The amount of the components (%)		Condensation phase	Atmospheric phase
		Inhibitor	Solution		
1	T-30 oil+ Ox. liquid rubber	-	-	31	56
2	Co salt of the NPA Oxidized liquid rubber	5 5	10	138	219

3	Co salt of the NPA Nitro compound Oxidized liquid rubber	1,66 1,66 1,66	5	228	317
4	Co salt of the NPA Nitro compound Oxidized liquid rubber	2,33 2,33 2,34	7	301	384
5	Co salt of the NPA Nitro compound Oxidized liquid rubber	3,33 3,33 3,34	10	322	401
6	Ni salt of the NPA Oxidized liquid rubber	5 5	10	95	197
7	Ni salt of the NPA Nitro compound Oxidized liquid rubber	2,33 2,33 2,34	7	267	311
8	Ni salt of the NPA Nitro compound Oxidized liquid rubber	3,33 3,33 3,34	10	291	350
9	Zn salt of the NPA Nitro compound Oxidized liquid rubber	3,3,3 3,3,3 3,3,4	10	263	326
10	Mg salt of the NPA Nitro compound Oxidized liquid rubber	3,33 3,33 3,34	10	297	353
11	Ba salt of the NPA Nitro compound Oxidized liquid rubber	3,33 3,33 3,34	10	289	346

The dependence graph of the trial results of composition type conservation liquids on the concentration of the inhibitor is shown below:

Figure 4. The graphical illustration of the trial results of the metal salts of NPA as composition type metalworking fluids.



B - T-30 oil + Oxidized liquid rubber + Co salt of the NPA+ Nitro compound
F - T-30 oil + Oxidized liquid rubber + Ni salt of the NPA+ Nitro compound
E - T-30 oil + Oxidized liquid rubber + Zn salt of the NPA+ Nitro compound
D - T-30 oil + Oxidized liquid rubber + Mg salt of the NPA+ Nitro compound
C - T-30 oil + Oxidized liquid rubber + Ba salt of the NPA+ Nitro compound

As it is clear from the figure, the highest result was obtained from the conservation liquid which is synthesized by the composition of Co salt of the NPA (curve B). The long lasting influence of the aggressive environment on the metallic surface degrades the protective layer, as a consequence, the coating loses its function at the certain level of the experience.

As it is obvious from the Table 6, the lubricant which is produced when 10% of technical paraffin [27] is added to the MWF (Sample-I) which has the highest efficiency in "corrosionbox" protects metal plates for 356 and 423 days in condensation and environmental phase, respectively. At the same time, the lubricants which are prepared by other metalworking fluids show high anti – corrosion effect during the trial.

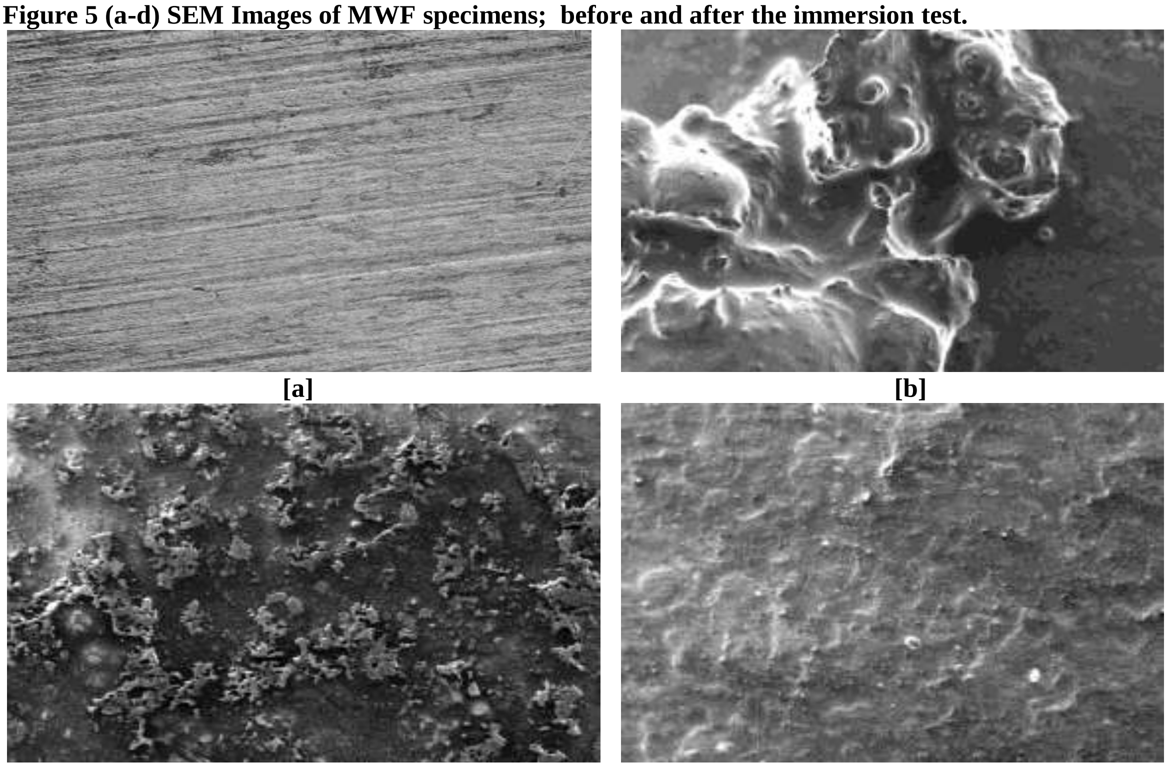
Table 6. The trial results of the lubricants

№	MWF 90%+ paraffin 10%	The total amount of the inhibitor in the sample (%)	The duration of corrosion protection, days	
			Condensation phase	Environmental phase
1	I+ paraffin	10	356	423
2	II+ paraffin	10	341	403
3	III+ paraffin	10	251	312
4	IV+ paraffin	10	332	378
5	V+ paraffin	10	304	352

Scanning Electron Microscopy Analysis (SEM)

Scanning Electron Microscope (SEM: S-3400N HITACHI) morphologies the steel plates in the corrosionbox in the absence and presence of MWF were shown in Figure 5 (a-d) respectively. Figure 5a shows the clean surface of steel sample before immersing in MWF. This figure reveals the homogeneity of the surface. Figure 5b shows the general appearance of mild steel without inhibitor (only T-30 oil). It can be seen from the figure that the surface of steel plates was extremely damaged in the absence of the inhibitor. Figure 5c & 5d reflect the SEM morphology of the steel specimen at lower concentration (5%) and higher concentration (10%) of the MWF. From the figures it is clear that at low concentration (5%) of the MWF only few constituents cover the surface which are not enough to afford a protective layer and hence dissolution of mild steel is observed to some extent whereas at higher concentration (10%) the constituents present are large enough to form a protective layer regarding the dissolution of steel plates.

Figure 5 (a-d) SEM Images of MWF specimens; before and after the immersion test.



[a] [b]

[c] [d]

As a result of the experiments, it has been revealed that, the inhibitor properties of the compositions of mineral oils with these kinds of mixture of complexes are more effective than the individual compositions with the same concentration those are prepared by adding salt and nitro compounds to the mineral oils separately. It can be explained by the superior ability of chemisorption on the metal surface and producing stronger coating for protection from corrosion of these complexes. On the other hand, these compounds are stronger ligands than the water that is why they can substitute water molecules from the surface of the metal and create strong protection layer.

IV. CONCLUSION

As can be seen from the table which indicates the results of the experiments, the manufactured MWF may be used in order to protect the metals from corrosion for industrial purposes. The components those have been used for producing MWF are cost effective and environmentally – friendly, on the other hand, they have simple manufacturing technology and rich feedstock. T-30 oil, additives which are used as inhibitors and oxidized liquid rubber which are used in the reaction medium are produced on the basis of the feedstock which have enough reserves. So, the comparative analysis of the results reveals that, the usage of the compositions of the metal salts of natural petroleum acids with nitro compounds as inhibitors have a practical importance for producing more effective MWF.

It has been revealed that the metalworking fluids that is produced by the composition of the synthesised inhibitor and nitro compound in the presence of oxidized liquid rubber has a great protection against corrosion than their individual usages, meets the requirements and has a great practical importance.

REFERENCES

[1]. Rozenfeld I.L., *Corrosion Inhibitors*; McGraw-Hill. New York, 1981, p.182.
[2]. Roberge P.R. *Corrosion Engineering Principle and Practice*. McGraw-Hill. New York, 2008, 730 p.
[3]. McCoy, J.S., "*Introduction: Tracing the Historical Development of Metalworking Fluids", in Metalworking Fluids*; Byers, J. P., Ed.; 2nd edition, Taylor & Francis, New York, 2006, pp.1-18.
[4]. E.Brinksmeier, D.Meyer, A.G.Huesmann-Cordes, C.Herrmann. Metalworking fluids - Mechanisms and performance. *CIRP Annals-Manufacturing Technology* 64 (2015) 605–628 (http://creativecommons.org/ licenses/by-nc-nd/4.0/).
[5]. Hugh Spikes. Low- and zero-sulphated ash, phosphorus and Sulphur anti-wear additives for engine oils. *Lubrication Science* 2008; **20**:103–136 (www.interscience.wiley.com) DOI: 10.1002/ls.57
[6]. S. N. Smith, J. L. Pacheco: 'Prediction of corrosion in slightly sour environments', Paper 02241, *NACE Corrosion Conference 2002.*
[7]. Dharma R. Kodali, (2002),"High performance ester lubricants from natural oils", *Industrial Lubrication and Tribology*, Vol. 54 Iss: 4 pp. 165 – 170 http://dx.doi.org/10.1108/00368790210431718
[8]. Zvirko O. I., Mytsyk A. B., Tsyrulnyk O. T., Gabetta G., Nykyforchyn H. M. "Corrosion Degradation of Steel of an Elbow of Gas Pipeline with Large-Scale Delamination after Long-Term Operation./ *Mater Sci*, 2017, Volume 52, Issue 6, pp 861–865 https://doi.org/10.1007/s11003-017-0032-8
[9]. I Ghai, J Wentz, RE DeVor, SG Kapoor, J Samuel Droplet behavior on a rotating surface for atomization-based cutting fluid application in micromachining. /*J. Manuf. Sci. Eng* 132(1), 011017 (Feb 03, 2010) doi:10.1115/1.4000859
[10]. Myshkin N.K., Markova L.V. Methods and Instruments for Condition Monitoring of Lubricants. *In: On-line Condition Monitoring in Industrial Lubrication and Tribology*. *Applied Condition Monitoring*, vol 8. pp 1-29 Springer, Cham https://doi.org/10.1007/978-3-319-61134-1_1
[11]. Zhao, F., Urbance, M., & Skerlos, S. J. (2004). Mechanistic Model of Coaxial Microfiltration for Semi-Synthetic Metalworking Fluid Microemulsions. *Journal of Manufacturing Science and Engineering*, 126(3), 435. http://doi.org/10.1115/1.1763187
[12]. Kaesche H (1990) *Die Korrosion der Metalle*, third ed. Springer, Berlin, Germany.
[13]. Aiad, I., Riya, M.A., Tawfik, S.M., Abousehly A.M. Protection of carbon steel against corrosion in hydrochloric acid solution by some synthesized cationic surfactants. *Protection of Metals and Physical Chemistry of Surfaces*, (2016) 52: 339. https://doi.org/10.1134/S2070205116020027
[14]. Skerlos, S. J., Rajagopalan, N., DeVor, R. E., Kapoor, S. G., & Angspatt, V. D. (2001). Microfiltration of Polyoxyalkylene Metalworking Fluid Lubricant Additives Using Aluminum Oxide Membranes. *Journal of Manufacturing Science and Engineering*, 123(4), 692. http://doi.org/10.1115/1.1392993
[15]. Thomas Norrby, (2003) "Environmentally adapted lubricants – where are the opportu-nites?", *Industrial Lubrication and Tribology*, Vol. 55 Issue:6, pp.268-274, https://doi.org/10.1108/00368790310496400
[16]. Skerlos, S. J. (2011). Cutting Fluids and their Environmental Impact, *Chapter in Encyclopedia of Tribology*, Springer, http://doi.org/10.1007/978-0-387-92897-5.
[17]. MacLean, D., Hayes, K., Barnard, T., Hull, T., Park, Y.E., Skerlos, S.J., 2009 "Impact of Supercritical Carbon Dioxide Metalworking Fluids on Tool Life in turning of Sintered Steel and Milling of Compacted Graphite Iron", *Proceedings of the ASME International Manufacturing Science and Engineering Conference* 2009, MSEC2009, October 4-7, 2009, West Lafayette, Indiana, USA, pp. 43-48.
[18]. Iowa Waste Reduction Center, *Cutting Fluid Management for Small Machining Operations*: A Practical Pollution Prevention Guide, 3 rd edition, University of northern Iowa, 2003
[19]. Zimmerman, J. B., Hayes, K. F., & Skerlos, S. J. (2004). Influence of Ion Accumulation on the Emulsion Stability and Performance of Semi-Synthetic Metalworking Fluids. *Enviro-mental* Science and Technology, 38(8), 2482-2490. http://doi.org/10.1021/es0340477
[20]. Chang, S.-C., Rihana, A., Bahrman, S., Gruden, C. L., Khijniak, A. I., Skerlos, S. J., & Adriaens, P. (2004). Flow cytometric detection and quantification of mycobacteria in metalworking fluids. *International Biodeterioration & Biodegradation*, 54(2-3), 105–112. http://doi.org/10.1016/j.ibiod.2004.03.019
[21]. M. J. Hernández Gayosso, N. Nava & G. Zavala Olivares. Characterisation and comparison of corrosion products originated in steel pipelines transporting sour gas and crude oil. *The International Journal of Corrosion Processes and Corrosion Control.* 2016, 51(8) p. 626-634 http://dx.doi.org/10.1080/1478422X.2016.1173421
[22]. V.S.Aliyev, S.M.Aliyev, A.Q.Azizov, F.A.Nasirov, Q.A.Mamedaliyev, T.A.Ismaylov. Sposob polucheniya 1,4-cys-polibutadiyena. Avtorskoye svidetelstvo (A.s.)SSSR № 1066190, 1979.
[23]. Nasirov F.A. *Issledovaniye i razrabotca prochessa polucheniya nizcomolekulyarnoqo polibutadiyena v prisutstvii cataliticheskix sistem na osnove orqanichescix ditioproizvodnix nicelya (cobalta).* Diss... cand.xim.nauk., Baku, IPP ANAS 1983, 202 p.
[24]. ASTM C 613-14: 'Standard test method for constituent content of composite prepreg by Soxhlet Extraction'.

[25]. F.R. van de Voort, J. Sedman, D. Pinchuk, *An overview of progress and new developments in FTIR lubricant condition monitoring methodology*. J ASTM Int. **8**(5) (2011). ID: JAI103344Google Scholar
[26]. J. Chastain, in: R.C. King Jr. (Ed.), Handbook of X-ray Photoelectron Spectroscopy, *Physical Electronics*, Inc., 1995.
[27]. Parafini neftyanie tverdie. QOST 23683-89.

Fig.1.1.The microscopic view of 5 selected points in sample

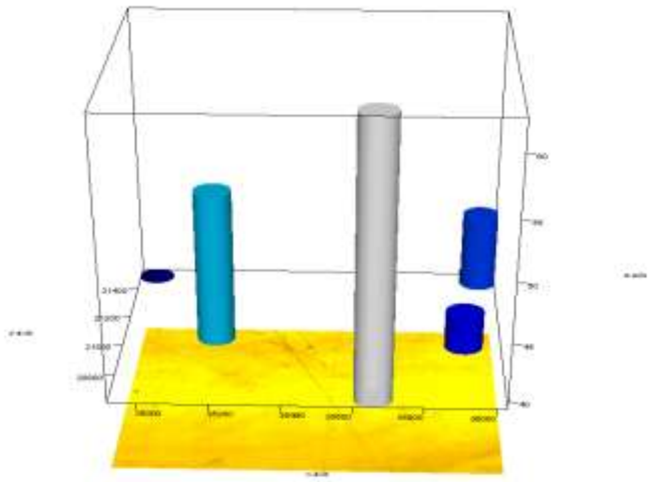


Fig. 1.2 IR spectra of the 1st point

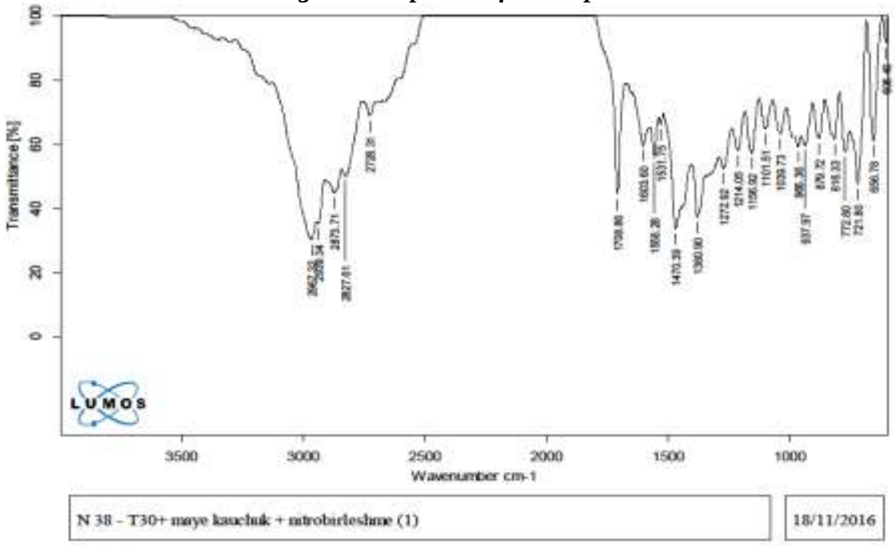


Figure 1.3 IR spectra of the 2nd point

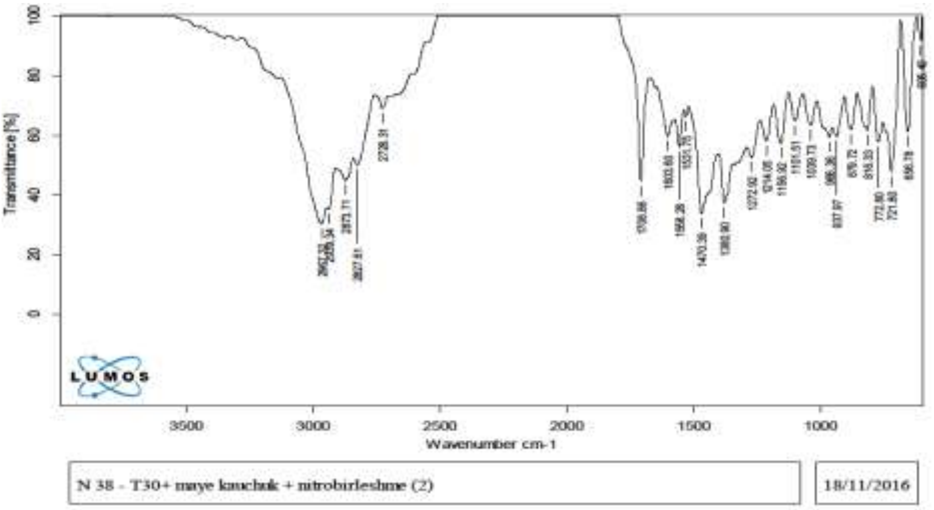


Figure 1.4 IR spectra of the 3rd point

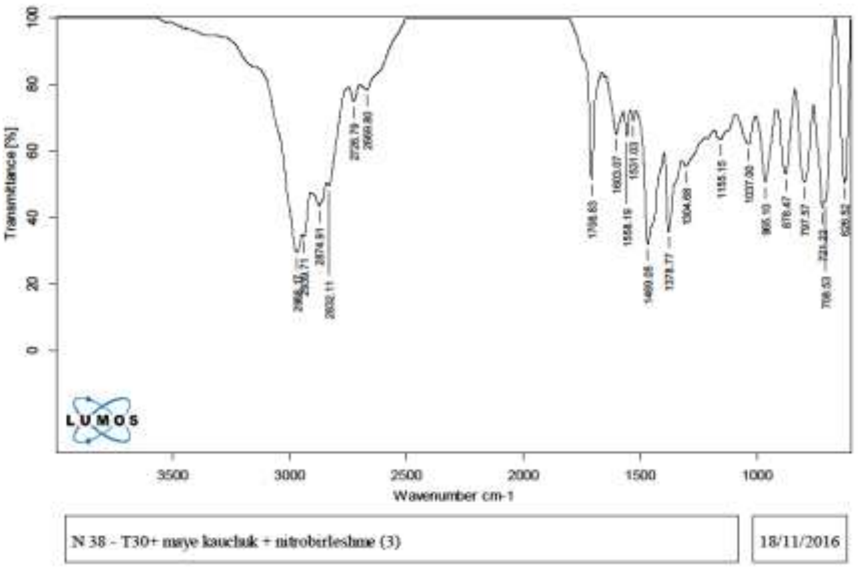


Figure 1.5 IR spectra of the 4th point

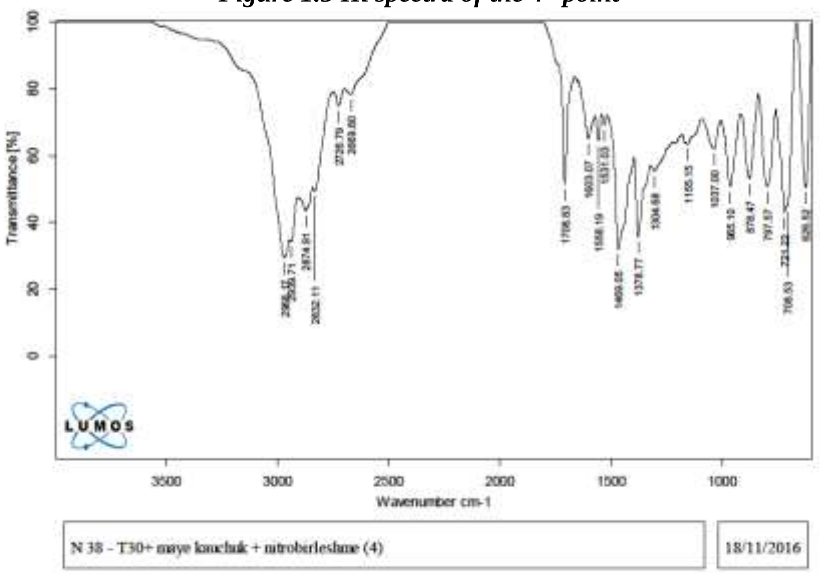


Figure 1.6 IR spectra of the 5 th point

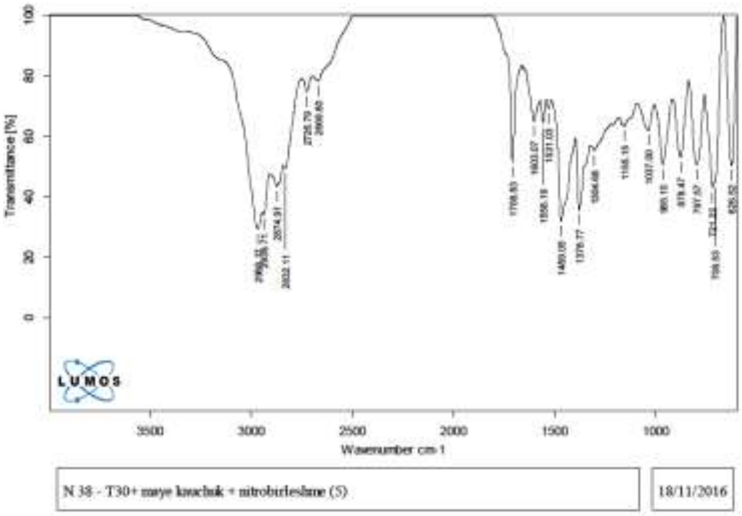


Fig. 2.TG/DTA curves of the Sample 5.

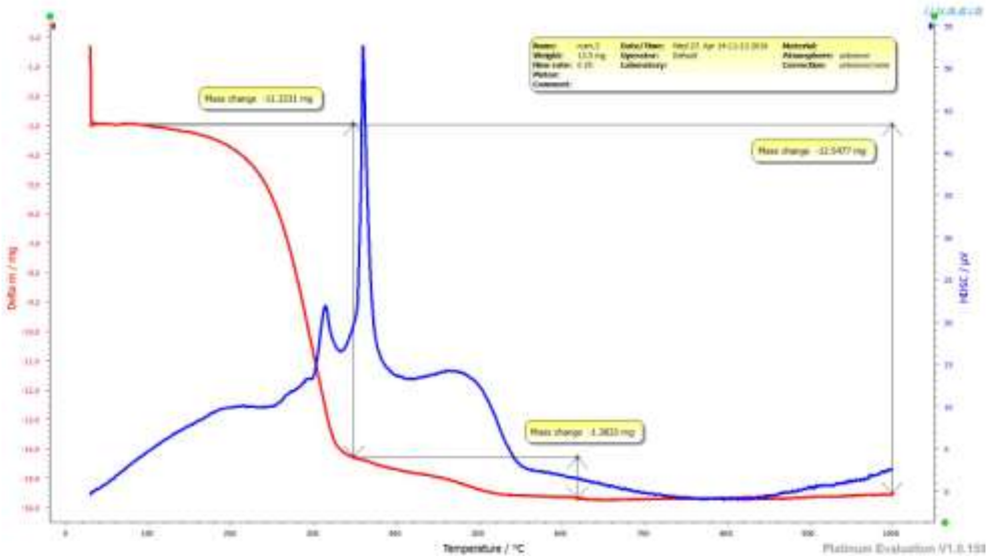


Figure 3. The graph of electrical conductivity against temperature.

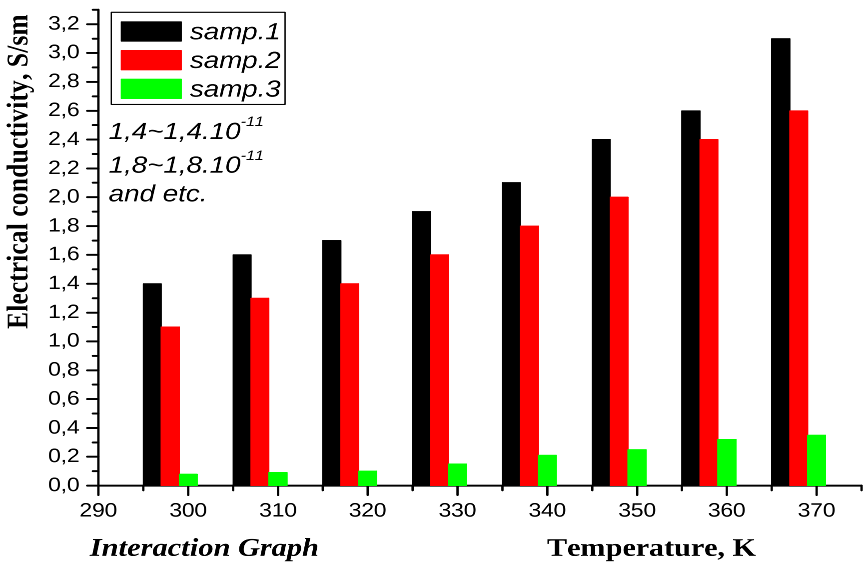


Figure 4. The graphical illustration of the trial results of the metal salts of NPA as composition type metalworking fluids.

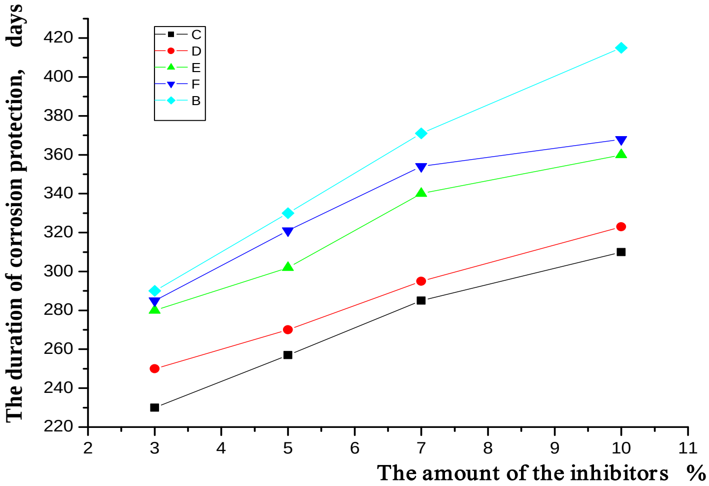
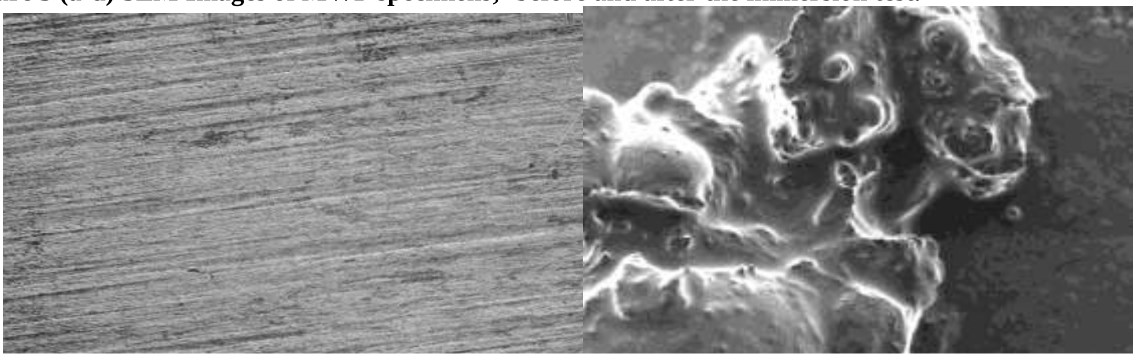
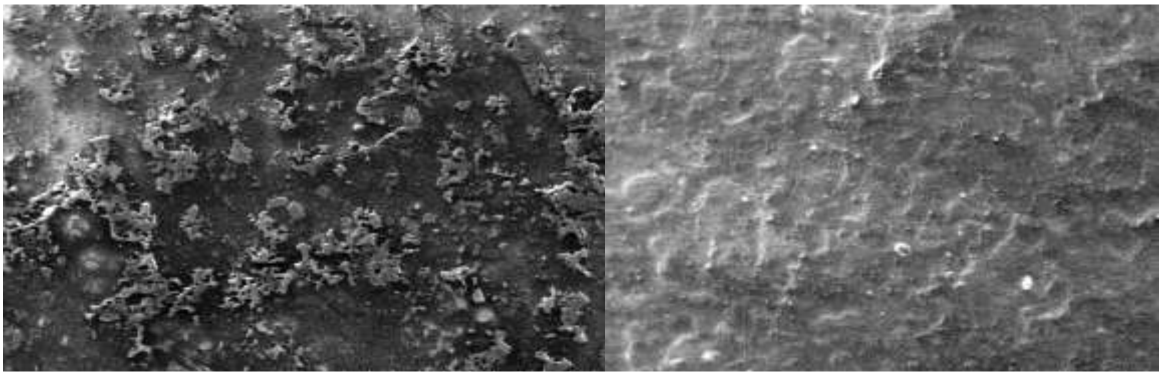


Figure 5 (a-d) SEM Images of MWF specimens; before and after the immersion test.

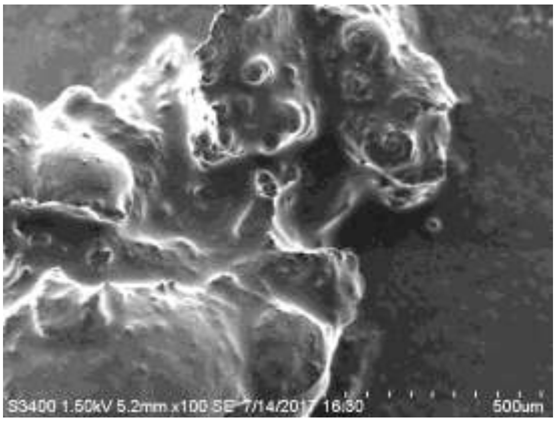


[a] **[b]**

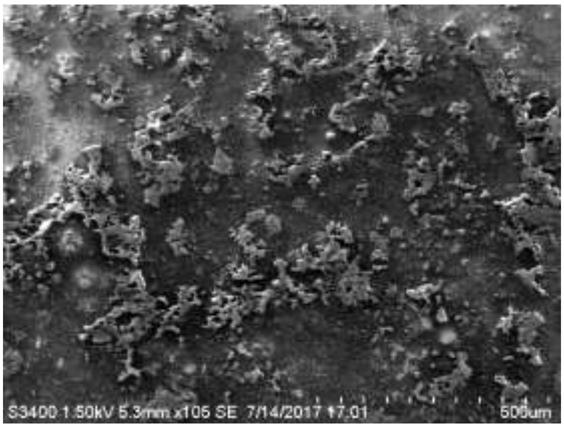


[c] **[d]**

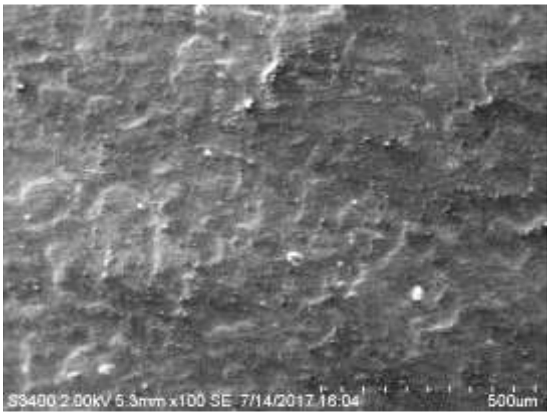
[a]



[b]



[c]



[d]

Table1. The physical and chemical properties of the fraction NPA

Density ρ_4^{20}	Refraction n_d^{20}	Molecular weight M_r	Freezing temp.	Boiling temp.	Kinematic viscosity at 20°C,	Total sulfur content	Aromatic hydrocarbos
0,8294 g/cm^3	1,4677	187 g/mol	-51 °C	220-340 °C	~5,52 mm^2/sec	~ 0,03 %	~1 % (by mass)

Table 2. Main physical properties of metalworking fluids

Name of the property	Name of the device	ASTM	Samples				
			I	II	III	IV	V
Freezing point ˚C	Stanhope Seta	ASTM D2386	-35	-30	-25	-25	-25
Viscosity mm^2/s, ˚C 40	TW4000	ASTM D445	60.88	56.47	61.96	66.93	53.99
Viscosity, mm^2/s, ˚C 100	TW4000	ASTM D445	8.31	7.98	8.12	7.54	7.63
Density, g/cm^3	DMA 4500 M	D5002	0.9072	0.9112	0.9136	0.9093	0.9090

Table 3. Change in the mass loss

Tempera-ture ,°C	Mass loss, mg	Mass loss,%
120	0	–
140	0.2	1.48
160	0.4	2.96
180	0.6	4.44
200	1.0	7.41
220	1.4	10.37
240	2.6	19.25
260	4.0	29.26
280	6.0	44.44
300	8.6	63.70

320	11.0	81.48
340	11.4	84.44
360	11.4	84.44
380	11.6	85.92
400	11.8	87.64
420	12.0	88.88
440	12.0	88.88
460	12.2	90.37

Table 4. Change in the electrical conductivity due to temperature

№	Tempe-rature, K	Special resistance ρ, Om·m	Electrical conductivity σ, S/sm	№	Special resistan. ρ,Om·m	Electr. cond. σ, S/sm	№	Special resistan. ρ,Om·m	Electr. cond. σ, S/sm
1	298	$6{,}9\cdot10^{8}$	$1{,}4\cdot10^{-11}$	2	$8{,}4\cdot10^{8}$	$1{,}1\cdot10^{-11}$	3	$1{,}08\cdot10^{10}$	$9{,}2\cdot10^{-13}$
	303	$6\cdot10^{8}$	$1{,}6\cdot10^{-11}$		$7{,}9\cdot10^{8}$	$1{,}3\cdot10^{-11}$		$1{,}04\cdot10^{10}$	$9{,}6\cdot10^{-13}$
	308	$6\cdot10^{8}$	$1{,}6\cdot10^{-11}$		$7{,}4\cdot10^{8}$	$1{,}4\cdot10^{-11}$		$1{,}04\cdot10^{10}$	$9{,}6\cdot10^{-13}$
	313	$5{,}6\cdot10^{8}$	$1{,}7\cdot10^{-11}$		$6{,}9\cdot10^{8}$	$1{,}4\cdot10^{-11}$		$1\cdot10^{10}$	$1\cdot10^{-12}$
	318	$5{,}6\cdot10^{8}$	$1{,}7\cdot10^{-11}$		$6{,}5\cdot10^{8}$	$1{,}5\cdot10^{-11}$		$9{,}2\cdot10^{9}$	$1{,}1\cdot10^{-12}$
	323	$5{,}2\cdot10^{8}$	$1{,}9\cdot10^{-11}$		$6{,}1\cdot10^{8}$	$1{,}6\cdot10^{-11}$		$8\cdot10^{9}$	$1{,}3\cdot10^{-12}$
	328	$5{,}2\cdot10^{8}$	$1{,}9\cdot10^{-11}$		$5{,}9\cdot10^{8}$	$1{,}7\cdot10^{-11}$		$6{,}8\cdot10^{9}$	$1{,}5\cdot10^{-12}$
	333	$4{,}8\cdot10^{8}$	$2{,}1\cdot10^{-11}$		$5{,}7\cdot10^{8}$	$1{,}8\cdot10^{-11}$		$6\cdot10^{9}$	$1{,}7\cdot10^{-12}$
	338	$4{,}6\cdot10^{8}$	$2{,}2\cdot10^{-11}$		$5{,}3\cdot10^{8}$	$1{,}9\cdot10^{-11}$		$5\cdot10^{9}$	$2\cdot10^{-12}$
	343	$4{,}2\cdot10^{8}$	$2{,}4\cdot10^{-11}$		$4{,}9\cdot10^{8}$	$2\cdot10^{-11}$		$4\cdot10^{9}$	$2{,}5\cdot10^{-12}$
	348	$3{,}8\cdot10^{8}$	$2{,}6\cdot10^{-11}$		$4{,}6\cdot10^{8}$	$2{,}2\cdot10^{-11}$		$3{,}6\cdot10^{9}$	$2{,}8\cdot10^{-12}$
	353	$3{,}8\cdot10^{8}$	$2{,}6\cdot10^{-11}$		$4{,}1\cdot10^{8}$	$2{,}4\cdot10^{-11}$		$3{,}2\cdot10^{9}$	$3{,}1\cdot10^{-12}$
	358	$3{,}2\cdot10^{8}$	$3{,}1\cdot10^{-11}$		$3{,}8\cdot10^{8}$	$2{,}6\cdot10^{-11}$		$2{,}8\cdot10^{9}$	$1{,}3\cdot10^{-12}$

Table 5. The results of the trials of synthesized salts as metalworking fluids both individually and as compositions.

№	The solutions of the compositions in the “T-30” oil			The duration of corrosion protection, days	
	Content	The amount of the components (%)		Condensation phase	Atmospheric phase
		Inhibitor	Solution		
1	T-30 oil+ Liquid rubber	-	-	31	56
2	Co salt of the NPA Liquid rubber	5 5	10	138	219
3	Co salt of the NPA Nitro compound Liquid rubber	1,66 1,66 1,66	5	228	317
4	Co salt of the NPA Nitro compound Liquid rubber	2,33 2,33 2,34	7	301	384
5	Co salt of the NPA Nitro compound Liquid rubber	3,33 3,33 3,34	10	322	401
6	Ni salt of the NPA Liquid rubber	5 5	10	95	197
7	Ni salt of the NPA Nitro compound Liquid rubber	2,33 2,33 2,34	7	267	311
8	Ni salt of the NPA Nitro compound Liquid rubber	3,33 3,33 3,34	10	291	350
9	Zn salt of the NPA Nitro compound Liquid rubber	3,3,3 3,3,3 3,3,4	10	263	326
10	Mg salt of the NPA Nitro compound	3,33 3,33	10	297	353

	Liquid rubber	3,34			
11	Ba salt of the NPA Nitro compound Liquid rubber	3,33 3,33 3,34	10	289	346

Table 6. The trial results of the lubricants

№	MWF 90%+ paraffin 10%	The total amount of the inhibitor in the sample (%)	The duration of corrosion protection, days	
			Condensation phase	Environmental phase
1	I+ paraffin	10	356	423
2	II+ paraffin	10	341	403
3	III+ paraffin	10	251	312
4	IV+ paraffin	10	332	378
5	V+ paraffin	10	304	352

Y.J.Aghazada " Metalworking Fluids and Lubricants Offer Effective Protection for Processing and Shipment of Metal Based Products." American Journal of Engineering Research (AJER) 6.8 (2017): 121-135