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LUBRICANT COMPOSITIONS BASED ON ORGANIC POLYMERS

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Abstract
The synthetic lubricants utilization, especially of those liquids, were developed in the last two decades because of the new fields development such as aerospace technique, nanotechnology, cryogenic technologies, medical technique a.s.o. In the same time the liquid lubricants based on the mineral oils showed theirs performance limits. This fact required new researches for theirs substitution.
Generally the synthetic lubricants have a good oxidation stability, a wide service temperature range, a high viscosity index and a good plastic compatibility, so that this type of products are possible alternatives for lubrication of machine elements a.s.o.
The paper presents a new type of synthetic lubricants, based on organic polymers. There are presented the researches made to determine the influence of the polymer characteristics on its tribological behavior. It has to be mentioned that this type of lubricants was not used until now, and the studies concerning its tribological behavior are at the beginning.

Key words: *lubricant solutions, organic polymer, polyacrylamide, ethylene alcohol, glycerin*

1. INTRODUCTION

Polyacrylamide (PAM) is one of the most widely used and technically important water-soluble organic polymers. Polyacrylamide (PAM) is usually obtained by free radical polymerization of acrylamide (AM) and in its partially hydrolyzed form is a synthetic straight-chain polymer of acrylamide monomers, some of which have been hydrolyzed (Figure 1) [1], [2].

The normally available PAM often contains about 1 to 3 mole % carboxilate groups as an impurity. Because of this fact, for the researches presented in this paper it was considered HPAM, with different hydrolysis levels [2], [3].

Some physical properties of HPAM such as polymer adsorption, shear stability and thermal stability are influenced by the hydrolysis degree (HD). However, although commercial polymers are supplied with a stated degree of hydrolysis, it is well known that at elevated temperatures the hydrolysis of the amide will continue [3], [4].

The structure of HPAM molecule is a flexible chain. This kind of structure is known as a random coil in polymer chemistry. Due of the hydrolyzed groups contained in its molecule, HPAM has multiple charges distributed along the chain, that make it a polyelectrolyte. Generally, the polyelectrolytes are distinguished from non-ionic polymers by the large effects, which change in salt concentration, and pH have on their viscosities. These changes in viscosity, respectively its decrease with salt concentration increase, appear due to the interactions between the fixed charges along the chain and the mobile ions in solution. Because the necessity of lubrication can occur in different conditions, we considered opportune to take into account this behavior. Also, the polyelectrolyte character of HPAM makes it to interact quite strongly with the metallic surfaces [4, 5].

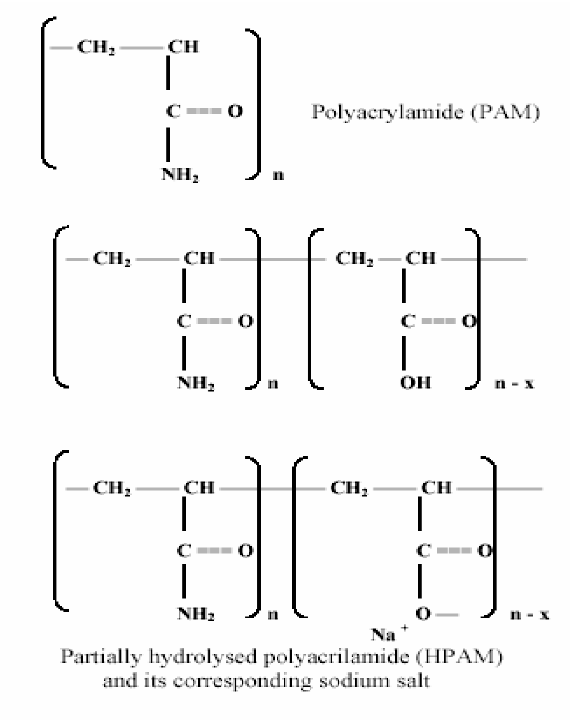

Figure 1: *The primary chain structure of polyacrylamide (PAM) and partially hydrolyzed polyacrylamide (HPAM).*

2. EXPERIMENTAL CONDITIONS

The polymers used to study their utilization as lubrication agents had the main characteristics presented in Table 1.

Table 1: The characteristics of the studied polymers

Polymer type	Characteristics	
	Molecular weight, MW_v [g/mol]	Hydrolyses degree, HD [%]
P1	$2 \cdot 10^6$	> 1
P2	$3.167 \cdot 10^6$	28

The polymer solutions were made with water and ethylene alcohol or glycerin (Table 2). It was studied the influence of temperature on the solution dynamic viscosity. The dynamic viscosity was determined with the Brookfield viscometer.

The aim of the tribological experiments was to determine the influence of the different polymer lubricant solutions on the friction coefficient and wear.

Table 2: The characteristics of the lubricant solutions

Solution type	Solution characteristics		
	Polymer	Polymer concentration [wt.%]	Solvent
S1	P1	0.2	water + ethylene alcohol
S2	P1	0.2	water + glycerin
S3	P2	0.5	water + ethylene alcohol

The tribological experiments were done on AMSLER tribometer using a SAE friction couple (linear contact, cylinder on cylinder like). The rolling motion was with sliding, the sliding speed being v=0.042 m/s, (Figure 2).

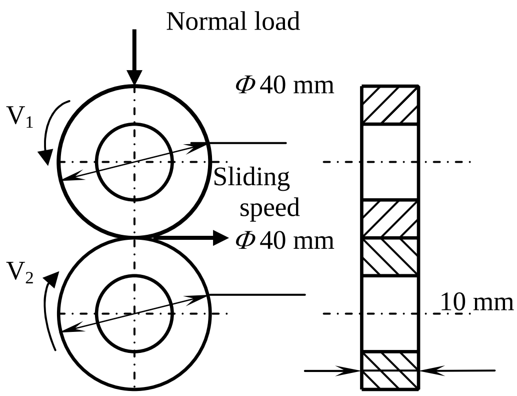

Figure 2: *The friction couple*

The metallic test pieces were made from construction alloy steel. The characteristics of the test pieces material and surfaces are presented in Table 3.

Table 3: The characteristics of the test pieces material and surfaces

Characteristics		Value
Main alloy elements [wt. %]	C	0.42
	Mo	0.25
	Cr	1.1
Thermal treatment and its corresponding hardness	Temper hardening	240 HB
	Hardening	63 HRC
Roughness R_a [μm]		0.8

3. RESULTS AND DISCUSSIONS

The characteristics concerning the dynamic viscosity of HPAM lubricant solutions were determined on the Brookfield viscometer. The main parameters, which influence the dynamic viscosity of HPAM lubricant solutions, are the molecular weight and the concentration (Figure 3) [4].

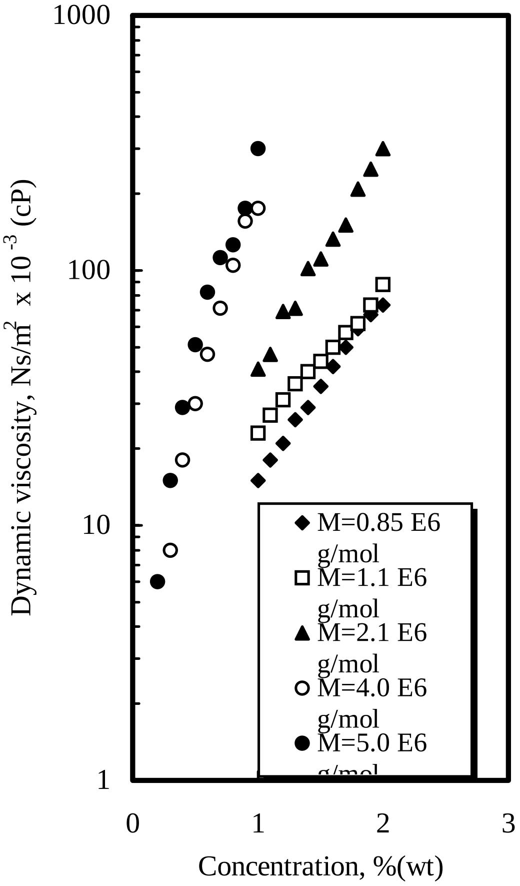

Figure 3: *The dependence between dynamic viscosity and concentration for different molecular weights [4]*

The influence of these parameters on the HPAM water solutions viscosity is presented in Figure 3. From this figure it can be deduced that for the molecular weight in the range of $0.85 \cdot 10^6 - 2.1 \cdot 10^6$ g/mol and concentrations between 1.0 – 2.0 %wt. the dynamic viscosity variation is smaller than for the other two types of HPAM water solutions which have higher molecular weights and lower concentrations.

The molecular weight and concentration quantitative influence on the dynamic viscosity can be expressed, based on the experimental data, for the HPAM water solutions, by the following regression analysis [4]:

$$\eta = A_0 \cdot c^{a_1} \cdot \overline{M}_v^{a_2} \quad (1)$$

where:

η is the dynamic viscosity, cP;

c – HPAM water solution concentration, % (wt);

$\overline{M}_v$ – HPAM molecular weight, g/mol;

A_0, a_1, a_2 - constants of the regression analysis which have the values $A_0 = 7 \cdot 10^{-9}$, $a_1 = 2.242$, $a_2 = 1.565$.

The characteristics of the regression analysis (1) are:

- the molecular weight of HPAM in the range of $0,85 \cdot 10^6 \ldots 5 \cdot 10^6$ g/mol;
- the concentration of HPAM water solution in the range of 0.2 – 2.0 %(wt);
- the correlation coefficient R = 0.984.

The temperature influence on the dynamic viscosity was tested on the lubricant solutions S1 and S2 (Table 2). This dependence is presented in Figure 4 where it can be observed that the temperature increase implies the dynamic viscosity decrease, more strongly for the lubricant solution S2 than the S1.

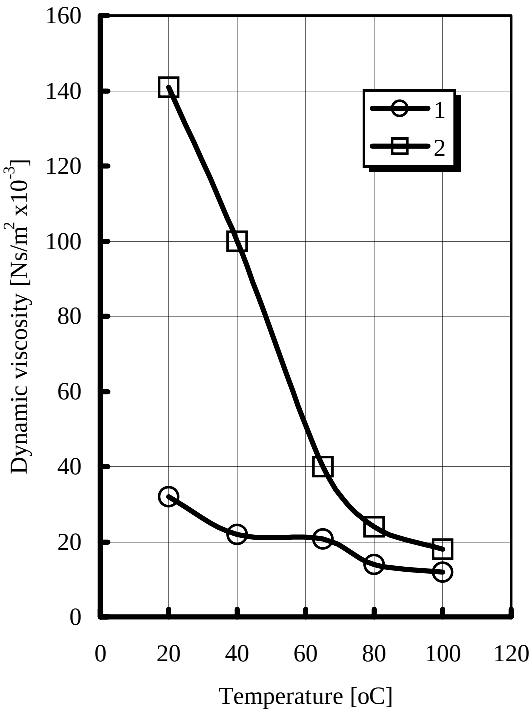

Figure 4: *The dependence between the dynamic viscosity and temperature for different lubricant solutions: 1 – S1; 2 – S2*

For emphasize the influence of lubricant solution on friction coefficient it were determined the dependencies between the friction coefficient and the normal load. Thus, in Figure 5 it is represented the dependence between the friction coefficient and normal load for different lubricant solutions.

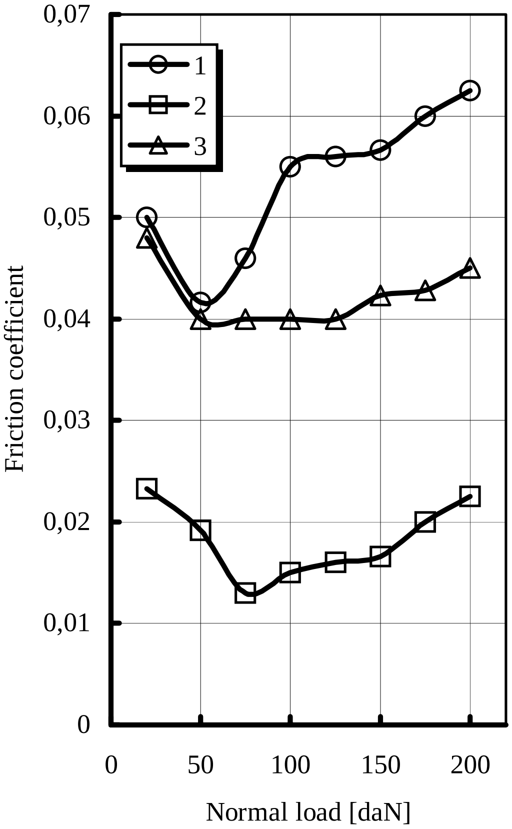

Figure 5: *The dependence between the friction coefficient and the normal load for different lubricant solutions: 1 – S1; 2 – S2; 3 – S3*

From Figure 5 it can be observed that the lubricant solution S2 utilization gives the lowest friction coefficient values. However, all the lubricant solutions utilization gives small values for the friction coefficient. It has to be remarked that for all studied cases the gripping state was not reached, for the normal loadings, which were used.

The wear experiment was done for the same friction couple, which was made from construction alloy steel (Table 3). The normal load had the value N = 125 daN. The lubricant agent was the lubricant solution S2 (Table 2). The experimental results are presented in Figure 6 and Figure 7, where it is shown the dependence between the weight wear and the time.

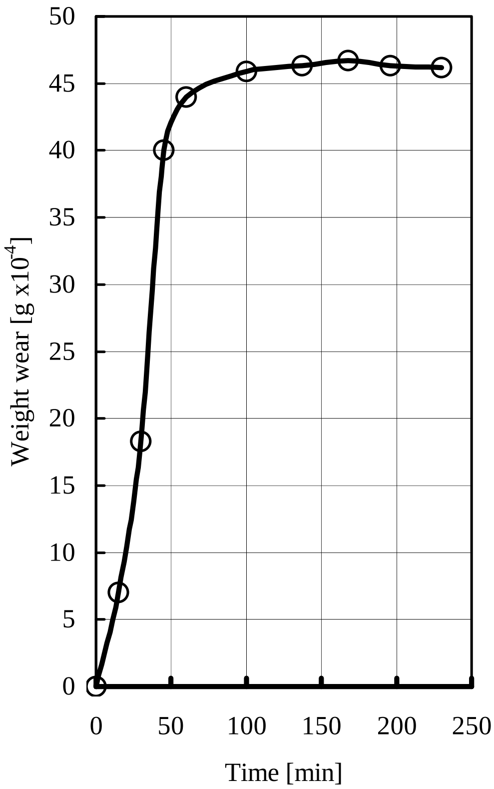

Figure 6: *Weight wear vs. Time for the tested steel (thermal treatment – temper hardening)*

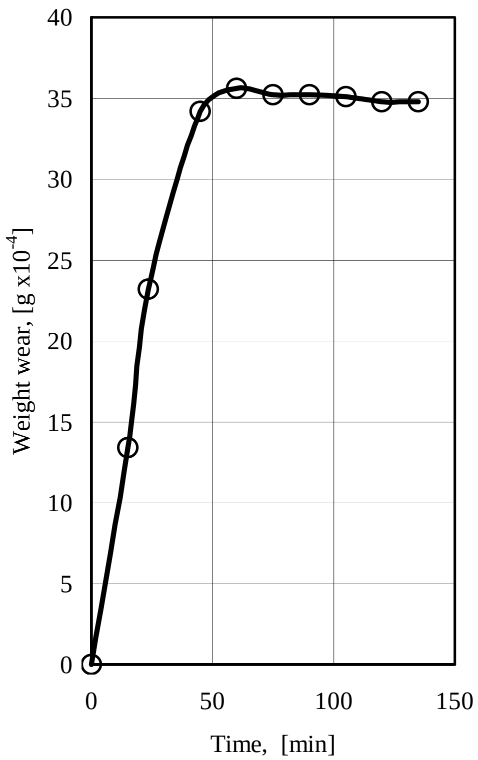

Figure 7: *Weight wear vs. Time for the tested steel (thermal treatment - hardening)*

For both cases it can be remarked that after the lapping time when the wear increases rapidly, the wear rate becomes almost null. Also, for the test pieces made from hardening steel the maximum value weight wear is smaller than for the test pieces made from temper-hardening steel. It can be seen that the friction surfaces after the wear test had a polish and bright state, with a roughness value less than R_a = 0.8 μm. About the lubrication regime it can be drawn the conclusion that it was a boundary one for the lapping time and an EHD one after this.

4. CONCLUSIONS

The lubricant solutions based on organic polymer HPAM like, consist a possible alternative in lubrication. Due to their properties, they can successfully remove other traditional sort of lubricants. The main conclusions, which result from this paper, are the following:

- the tested lubricant solutions assure, for the studied linear contact, low friction coefficient values;
- the tested lubricant solutions utilization implies low weight wear values for the alloy construction steel;
- due to their properties, the lubricant solution based on HPAM can be used in fields such as:
    - the industry lubrication (gears, bearings, rolling bearings, slideways, pumps etc);
    - the metal working fluids;
    - the drilling fluids;
    - the medicine;
    - the lubrication in special environments (sea water, brine etc).
- the obtained results presented in the paper lie at the basis of the next researches concerning the solutions based on HPAM and their utilization in lubrication.

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