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FRICTION COEFFICIENT AND WEAR VARIATION FOR GREASE WITH DIFFERENT ADDITIVES

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S u m m a r y

The paper present the studies made with some lubricating compositions based on lithium soap grease and a number of different additives. The friction, wear and EP properties are evaluated at variable loads and durations using a four-ball machine. The friction coefficient are evaluated at long durations (30…120 minutes) because show more exactly the comportment of lubricant compositions. The investigations regard the performance of different additive combinations and some synergetic effects.

Keywords: *friction; wear; synergetic effect*

1. INTRODUCTION

The wear and friction coefficient values are affected by a number of parameters depending upon the lubricant (type, viscosity, the content and the type of additives, etc.), the material of the friction couplings (their nature and composition, roughness, thermo-chemical treatments, etc.) and upon the physical and mechanical conditions (speed, temperature, loading, type of contact, etc.). Usually, the friction coefficient is measured at reduced values for load and duration and, in this conditions, the determined friction coefficient value is more for information, as during such a reduced duration, the wear of the metallic surfaces does not begin, especially at relatively low loading. At increased durations (30…120 minutes) of tests, the friction coefficient variations show more exactly the comportment of the lubricant, especially additivated.

2. RESULTS AND DISSCUTIONS

A four-ball machine was utilized to investigate the friction and wear comportment for all samples tested.

Different type and additives concentration was dispersed in a grease type lithium soap with following characteristics:

* *Penetration at 25^{0}C, mm/10 …… 275*
* *Dropping Point, ^{o}C ……………. 190*
* *Rolling test (4 h), mm/10 ……… 305*
* *Oil separation (30 h, 100^{0}C), % .. 1.9*

The tests were made with the grease sample including the following additive types:

* *AO – antioxidant (aromatic sulphur combination)*
* *SC – sulphur compound (≈ 33% wt. sulphur)*
* *FM – friction modifier (oxidized vegetable oil)*
* *ZnDTP – zinc ditiophosphate.*

The results obtained with different additive concentrations and combinations and efficacy of this are presented in table1.

2.1. Friction coefficient variation

For this parameter, most often, like in the case of tests made on four-ball machine, the testing duration is approximately 60 sec. The determined friction coefficient value, in these conditions is more for information, as during such reduced length of time for testing, the wear does not begin, especially at relatively low loading. At the same loading values, but at increased durations (30…120 min), the friction coefficient variation show more exactly the comportment of the lubricant, especially additivated. In these conditions, friction coefficient is influenced, in the same time, by the shear stress of the chemical compounds developed at the metal surfaces by the additives action, and exist possibility from decreasing the value of the friction coefficient in the testing period. In the figures 1…7, are presented the variation of friction coefficient at long duration for lithium grease (NLGI 2) free and with different additives content. The efficacy for reduction of the friction coefficient is presented in table1. For this was utilized the average values of the friction coefficient obtained for 120 minutes of testing duration. For samples prepared with more additives, the total concentration is 3% wt.

Table 1.

Sample	Additive content, % wt.				Efficacy, %				
	AO	FM	ZnDTP	SC	Friction coeff.		Wear		Weld Load
					300 N	600 N	300 N	600 N	
A	-	-	-	-	100	100	100	100	100
A 1	0.5	-	-	-	104	114.4	113.3	138.1	126.7
A 2	1.5	-	-	-	118.2	108.8	108	129.8	140
A 3	-	2	-	-	103.3	104.1	106.7	102.3	100
A 4	-	5	-	-	114.4	120.1	110.7	106.6	106.7
A 5	-	10	-	-	118.6	121	121	107.5	113.3
A 6	-	-	1	-	87.4	110	133.8	138.1	126.7
A 7	-	-	2	-	103.3	114	142.7	147	140
A 8	-	-	3	-	116.5	116.7	153.3	159.5	153.3
A 9	-	-	-	0.3	96	108.1	108.7	135.7	126.7
A 10	-	-	-	1.0	115.4	118.7	133.3	158	146.7
A 11	-	-	-	1.5	109.5	108	123	153.4	153.3
A 12	-	-	-	2.0	102.6	105.2	122	152.7	160
A 13	-	-	-	3.0	90	101.8	115	147.6	166.7
A 14	-	-	1.5	0.5	121.4	97.5	148	147.3	133.3
A 15	-	-	1.5	1.5	109.8	110.4	138.3	159.3	173.3
A 16	-	-	1.0	2.0	119.3	109.8	122	154	173.3
A 17	0.5	-	2.5	-	107.2	113.2	147.7	163.5	153.3
A 18	1.0	-	2.0	-	109.7	113.8	144	162.9	146.7
A 19	1.5	-	1.5	-	106.5	113.7	140.3	161.7	140
A 20	0.5	-	0.5	2.0	122	120.3	110	140.6	186.7
A 21	0.5	-	1.0	1.5	113.9	112	130	159.4	180

Test duration influence

* After 30 minutes from testing, the values of friction coefficient practically remain constants, for the majority of the samples. Therefore, for correct characterization of the lubricants, he must be not less than 30 minutes.
* Between the friction coefficient values after 1 minute and 30 minutes are great differences: 42% and 55% for grease with 1% wt. and 3% wt. ZnDTP, respectively.
* After the first minutes, the wear begin, but during the test, the variation of friction coefficient is small. This aspect is possible because the wear spot increase and, at the same load, the contact pressures decrease. The lubricant have in these conditions a great influence.

The load influence

* The results presented in table 1 and figure 1, show the decrease of the friction coefficient in presence of antioxidant (AO) additive at

reduced load (300 N) and relatively high (600 N). A reduction with 4…18.2% for friction coefficient are obtained at 300 N and with 14.4…8.8% at 600 N, for 0.5…1.5% wt. AO content. Therefore, the optimum content of this additive type is 0.5…1% wt.

* The friction coefficient decrease, especially at low load (table 1 and fig.2) if content of friction modifier (FM) increase. But, for 10% wt. FM content, obtain the decrease for dropping point (5…6^{0}C) and penetration (10…16 mm/10). Therefore, the maximum content of this additive is 5% wt.
* The friction coefficient decrease if ZnDTP content increase but, for 1% wt. at 300 N, the value of this parameter exceeds the value obtained for grease additive (fig.3, table 1). A possible explication consists in the fact that at low load, the temperature generated by friction is low and the additive remains inactive.
* For sulphur content, the very low values for friction coefficient is obtained for 1% wt. SC (≈ 0.33% wt. sulphur). At low load, for low (0.3% wt.) and high (3% wt.) content for SC, the friction coefficient values are high.

At reduced load, because the temperature generated by friction is low, the inactivity of sulphur is possible. For great sulphur content is possible to appear the corrosive wear (fig.4).

* For SC + ZnDTP combinations, the best results are obtained for samples with 2% wt. SC and 1% wt. ZnDTP (table 1 and fig.5).
* The comportment of samples with AO and ZnDTP additives are presented in table 1 and figure 6. For these samples, at higher loads, the friction coefficient values decrease and the best results is obtained for combination: 1% wt. AO + 2% wt. ZnDTP.
* In case of AO + ZnDTP + SC combinations, the best result is obtained for sample with 0.5% wt. AO + 0.5% wt. ZnDTP + 2% wt. SC (fig.7).
* The synergetic effects appear for following combinations:
  - at 300 N: 0.5% wt. SC + 1.5% wt. ZnDTP; 2% wt. SC + 1% wt. ZnDTP; 0.5% wt. AO + 0.5% wt. ZnDTP + 2% wt. SC; 0.5% wt. AO + 1% wt. ZnDTP + 1.5% wt. SC;
  - at 600 N: 1% wt. ZnDTP + 2% wt. SC; 1% wt. AO + 2% wt. ZnDTP; 1.5% wt. AO + 1.5% wt. ZnDTP; 0.5% wt. AO + 0.5% wt. ZnDTP + 2% wt. SC.

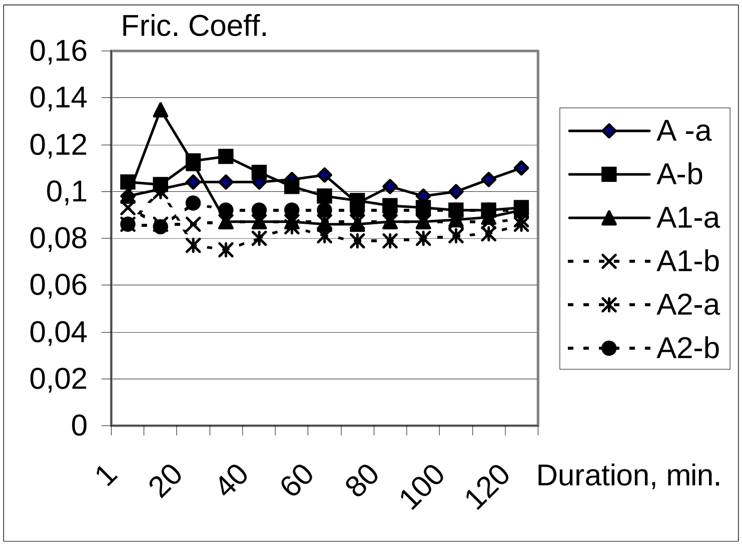

Fig.1. Friction coefficient variation with AO content: a) 300 N; b) 600 N

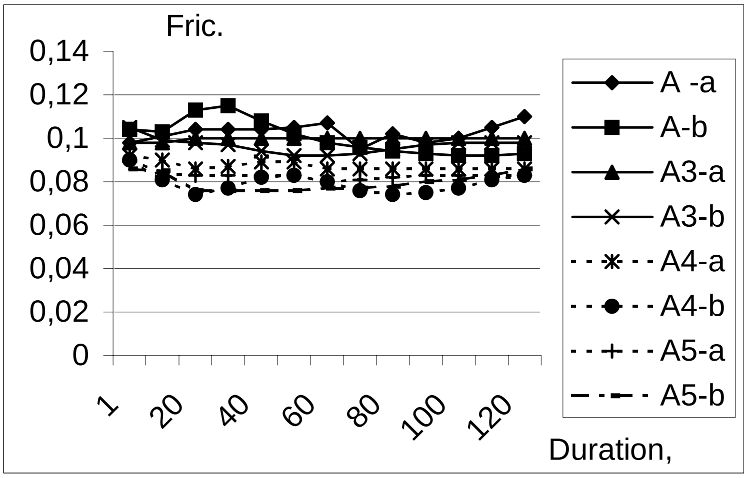

Fig.2. Friction coefficient variation with FM content: a) 300 N; b) 600 N

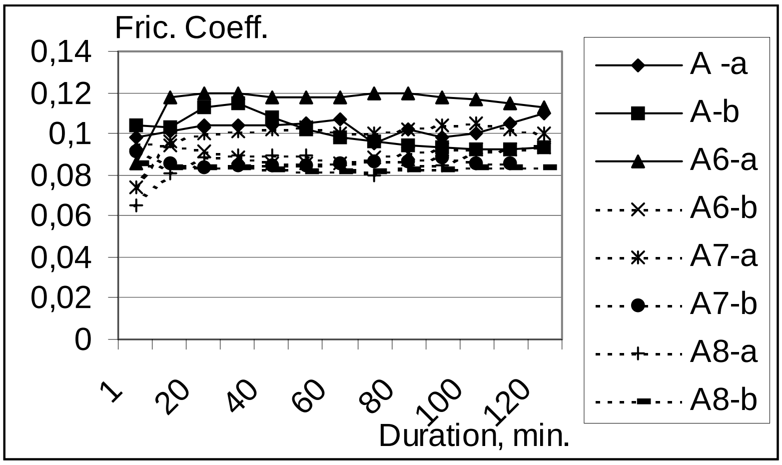

Fig.3. Friction coefficient variation with ZnDTP content: a) 300 N; b) 600 N

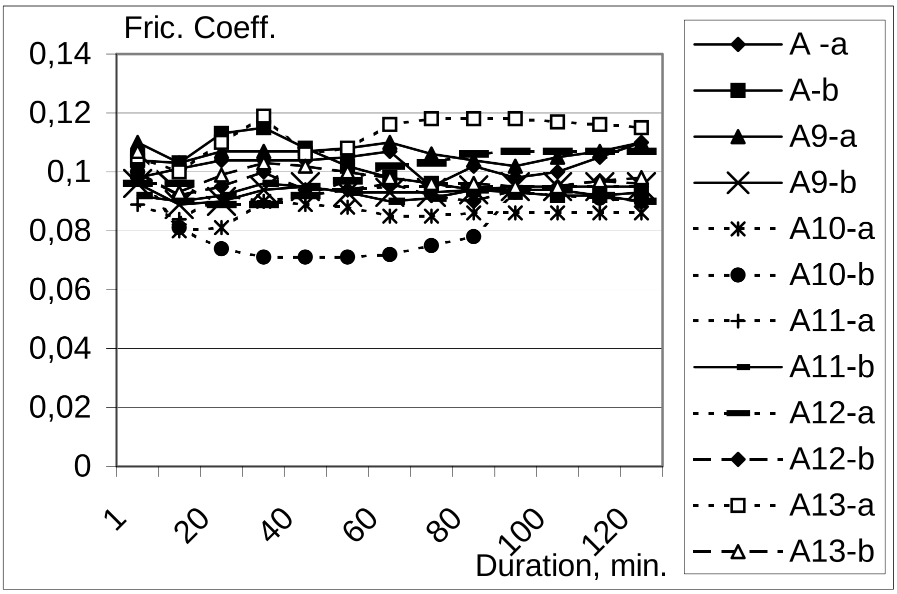

Fig.4. Friction coefficient variation with SC content: a) 300 N; b) 600 N

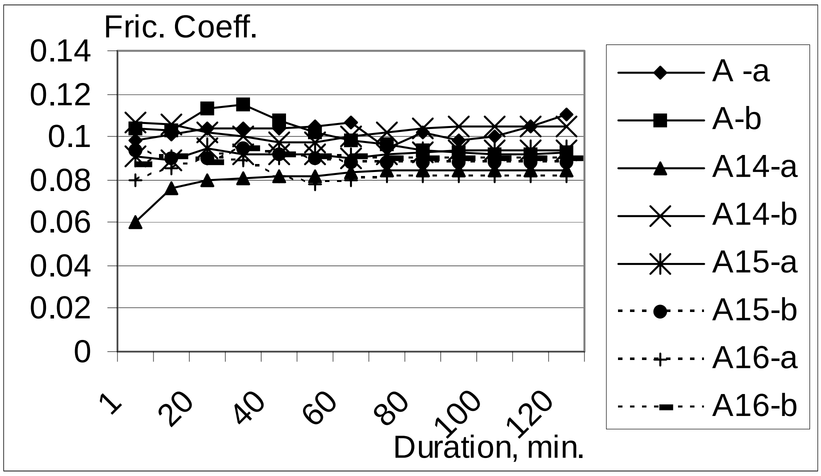

Fig.5. Friction coefficient variation with SC + ZnDTP combination: a) 300 N; b) 600 N

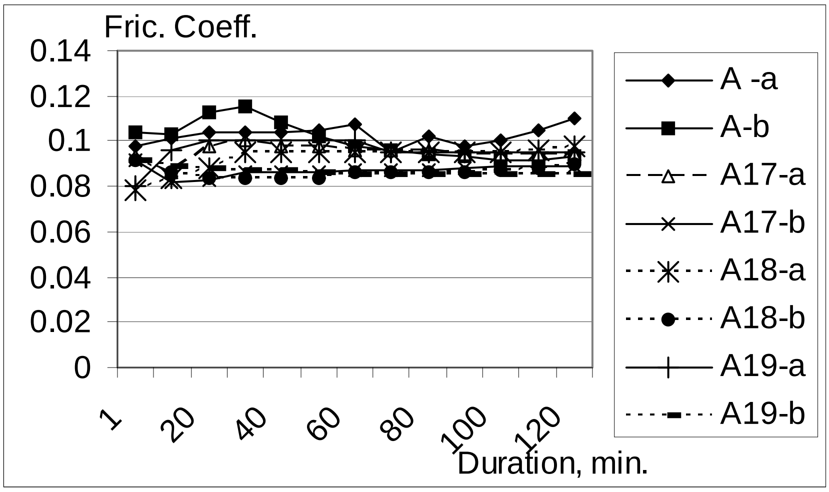

Fig.6. Friction coefficient variation with AO + ZnDTP combination: a) 300 N; b) 600 N

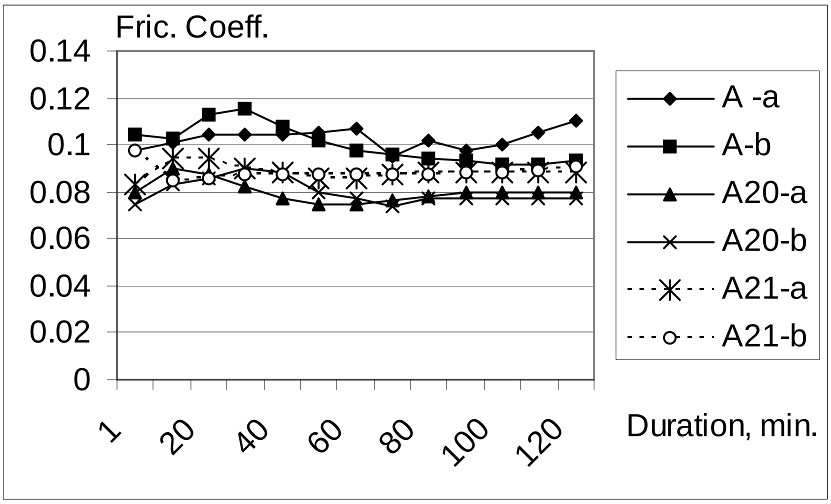

Fig.7. Friction coefficient variation with AO + ZnDTP + SC combination: a) 300 N; b) 600 N

2.2 Antiwear effects

The studies have been carried out on the four-ball machine at 300 N and 600 N for 120 minutes maximum duration.

The result are presented in table 1 (efficacy) and figures 8…14 (wear spot diameter).

* For the majority of samples containing one single additive type, the wear spot diameter ("d") value decrease when additive concen-

tration increase (fig.8…11), excepting the samples with contents over 0.5% wt. AO and 1% wt. SC. For great content of sulphur corrosive (chemical) wear appear.

* The samples with ZnDTP and SC, comportment differs with loading. For 600 N, maximum efficacy is obtained for 1.5% wt. SC + 1.5% wt. ZnDTP while at 300 N, minimum wear are obtained for 0.5% wt. SC + 1.5% wt. ZnDTP (fig.12 and table 1). The choice between these, another parameter is necessary; for example, weld load.
* For greases with AO + ZnDTP combinations obtain a great reduction of wear (fig.13, table 1). The better efficacy is obtained, in this case, for 600 N because AO additive contain sulphur. In the same time, with the increase of sulphur content (> 0.5% wt. AO), the antiwear efficacy decreases. The best result is obtained for the sample with 0.5% wt. AO + 2.5% wt. ZnDTP.
* The combinations containing AO, ZnDTP and SC decreased wear (fig.14, table 1). For 0.5% wt. AO + 1% wt. ZnDTP + 1.5% wt. SC content result the minimum value for wear.

The synergetic effects are obtained for the samples with following combinations:

- at 300 N: 1.5% wt. ZnDTP + 0.5% wt. SC; 1.5% wt. ZnDTP + 1.5% wt. SC; 0.5% wt. AO + 2.5% wt. ZnDTP; 1% wt. AO + 2% wt. ZnDTP; 1.5% wt. AO + 1.5% wt. ZnDTP; 0.5% wt. AO + 1% wt. ZnDTP + 1.5% wt. SC.
- at 600 N: all the samples excepting the combination with 0.5% wt. AO + 0.5% wt. ZnDTP + 2% wt. SC.

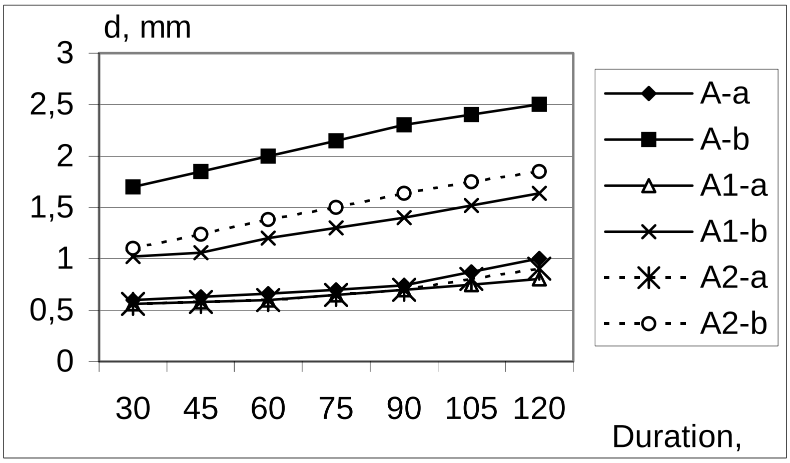

Fig.8. Wear spot variation for samples with AO: a) 300 N; b) 600 N

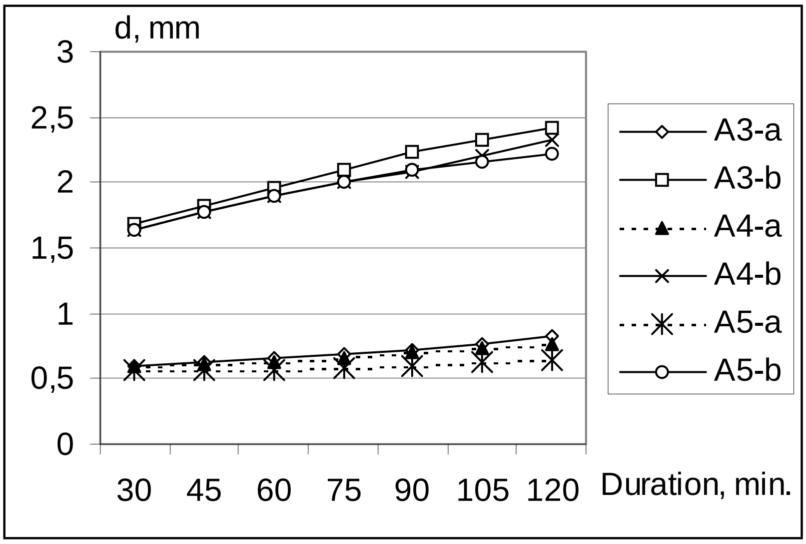

Fig.9. Wear spot variation for samples with FM: a) 300 N; b) 600 N

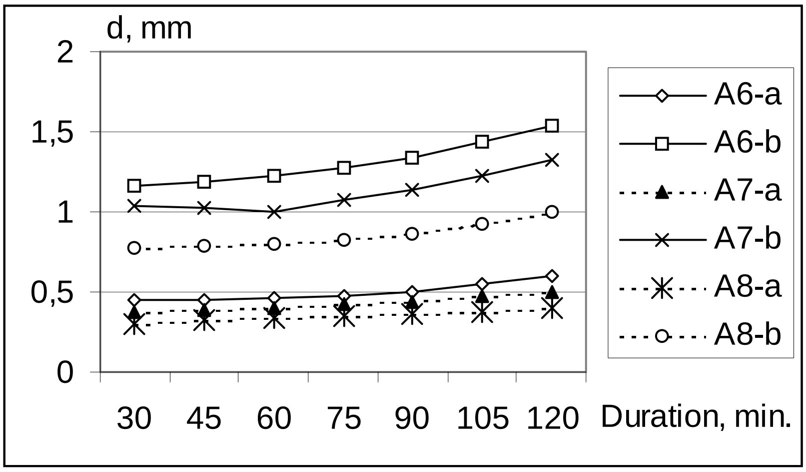

Fig.10. Wear spot variation for samples with ZnDTP: a) 300 N; b) 600 N

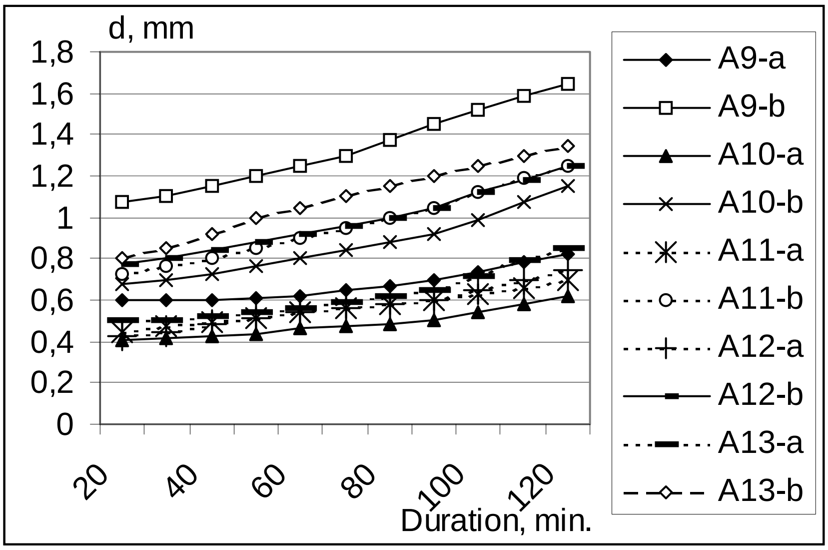

Fig.11. Wear spot variation for samples with SC: a) 300 N; b) 600 N

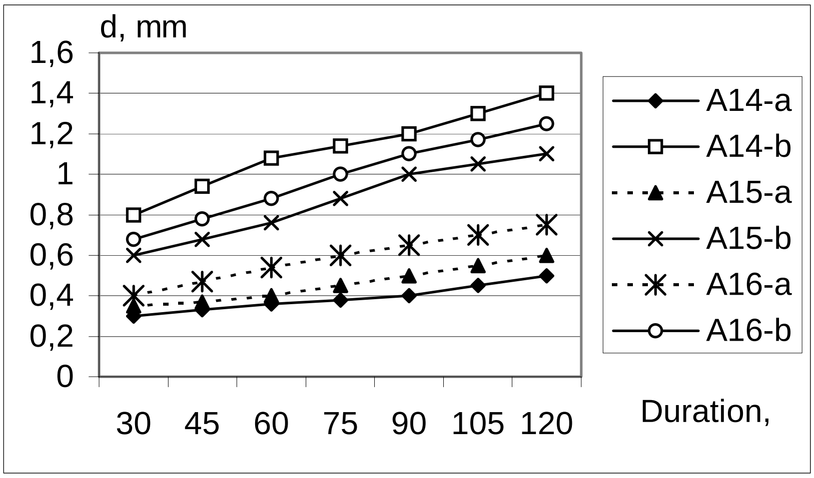

Fig.12. Wear spot variation for samples with ZnDTP + SC: a) 300 N; b) 600 N

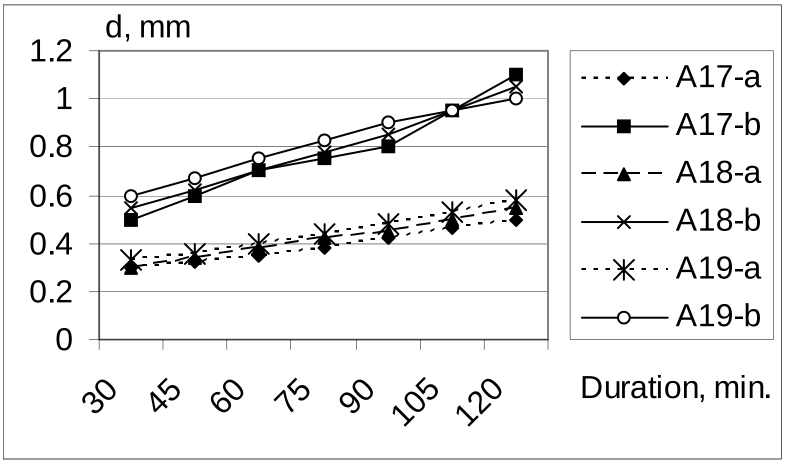

Fig.13. Wear spot variation for samples with AO + ZnDTP: a) 300 N; b) 600 N

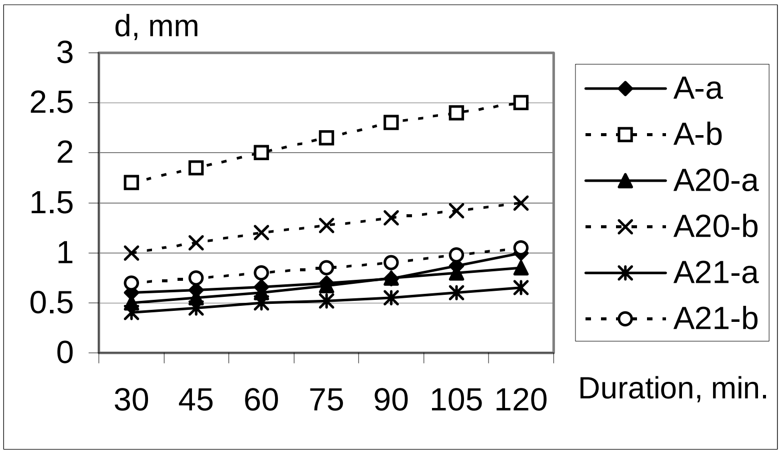

Fig.14. Wear spot variation for samples with AO + ZnDTP + SC: a) 300 N; b) 600 N

2.3. EP characteristics

For this, on utilized as parameter the weld load. The results obtained are presented in table 1 (efficacy) and figure 15 (values).

Based on these results can be draw:

* When the additive concentrations increase, the weld load increase.
* For the majority of EP greases, 2400 N is the value for weld load and thus, the samples containing following additives are accepted: > 2% wt. SC; 1.5% wt. ZnDTP + 1.5% wt. SC; 1% wt. ZnDTP + 2% wt. SC; 0.5% wt. AO + 0.5% wt. ZnDTP + 2% wt. SC and 0.5% wt. AO + 1% wt. ZnDTP + 1.5% wt. SC.

In this case, synergetic effects are put in evidence for all additive combinations.

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