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# Antifriction and Antiwear Properties of Copper, Zinc and Manganese 8 – Hydroxyquinolinates in Lithium Grease

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In this work organo-metallic complexes of 8-hydroxyquinoline of copper, manganese and zinc were used as lubricant additives. The tribological tests were performed using four-ball machine. Test balls were chrome alloy bearing steel, with diameter 12.7 mm (0.5 in.). Dependence of friction coefficient and wear scar diameter on applied load was tested. Due to the obtained results one can conclude that addition of metal 8-hydroxyquinolinate improves anti-wear properties of the lubricant, because the wear scar diameter is significantly smaller for the composition containing organo-metallic complex than for lithium grease. Moreover, the results revealed that for high loads the wear scar diameter was smallest for the composition with the copper additive.

*Keywords*: friction, wear, friction coefficient, organo-metallic compounds, antiwear, antifriction properties.

## 1. INTRODUCTION

The main aim of applying additives to lubricants is reduction of wear, improvement of antiseizure properties and decrease in the frictional resistance. Organo-metallic complexes have been used as anti-wear and friction reduction lubricant additives for many years [1 – 4]. Organic rare earth complexes are also well-known lubricating additives. Some of them have good solubility in lubricating oils. These compounds improve lubricating ability of oils [5 – 8]. The majority of organometallic complexes, however, found limited applications in oils due to their poor solubility. The same rare earth complexes can be used as anti-wear grease additives [9 – 11].

Organo-metallic compounds have already been applied as oil additives [2 – 4], as well as grease additives [12 – 14]. Complexes of copper, zinc and manganese were tested as antiseizure additives [14]. The tests were performed on the four-ball machine. Dependence of friction torque on time for linearly increasing load was investigated. It turned out that all the complexes increase seizure load and for the copper-containing composition seizure had not occurred (for the maximal load 7200 N).

The next stage of the research was investigation of the influence of these complexes on motion resistance. The results are presented in this paper.

## 2. EXPERIMENTAL

### 2.1. Materials

#### 2.1.1. Lithium grease

Grease is a mixture of fluid lubricant (usually an oil) and a thickener dispersed in oil. The most popular thickeners are soaps of calcium, lithium, lead and aluminium. In order to change selected properties it is possible to apply some lubricant additives. Lithium soap greases are often called universal because they can be applied in a wide range of friction couples and temperatures. The lithium grease, manufactured by Refinery Czechowice-Dziedzice, “Racer”, was chosen as a base. It should be emphasized that this lithium grease does not contain any additives.

#### 2.1.2. 8-hydroxyquinoline

In the investigated organo-metallic complexes 8-hydroxyquinoline is a ligand. That is why its influence on friction process was tested. A mixture of 8-hydroxyquinoline with lithium grease with mass ratio 1 : 25 was applied. The structural formula of the ligand is presented in Fig. 1.

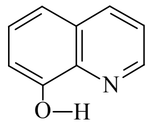

**Fig. 1.** Structural formula of the molecule of 8-hydroxyquinoline

#### 2.1.3. Copper, zinc and manganese 8-hydroxyquinolinates

The investigation of the influence of organo-metallic complexes applied as lubricant additives on friction processes was the aim of this paper. 8-hydroxyquinoline forms a series of complexes with ions of various metals. These complexes were obtained by adding the metal salt solution dropwise into 8-hydroxyquinoline alcoholic solution. The synthesis was performed at 50 °C. As a result, organo-metallic chelate compounds are formed. They belong to a class of coordination compounds having very polar ligands bonded with the metal through oxygen and nitrogen, as shown in Fig. 2.

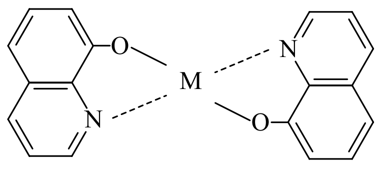

**Fig. 2.** Structural formula of the molecule of the complex of 8-hydroxyquinoline with metal M

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Complexes with three metals: copper, zinc and manganese were used in these investigations. A mixture of these complexes with lithium grease with mass ratio 1 : 25 was applied.

## 2.1. Materials

Friction tests were performed using the modified four-ball machine (denoted t-02), designed and manufactured at Institute for Terotechnology (ITEE) in Radom, according to the Polish norm: pn-76/c-04147.

Operating conditions for the four-ball test are:

- balls with a diameter of ½’’ (12.7 mm), made of chrome alloy bearing steel,
- rotating speed 500 ± 50 rpm,
- load 1000 N, 2000 N, 3000 N, 4000 N,
- tests duration: 60 min, 180 min.

The balls were washed in extraction naphtha using an ultrasonic cleaner.

## 3. RESULTS

As described in Chapter 2, friction coefficient, temperature and wear scar diameter were measured using the four-ball machine. As the reference point lithium grease was chosen (Fig. 3 – 5) and its 8-hydroxyquinoline composition (Fig. 6 – 8).

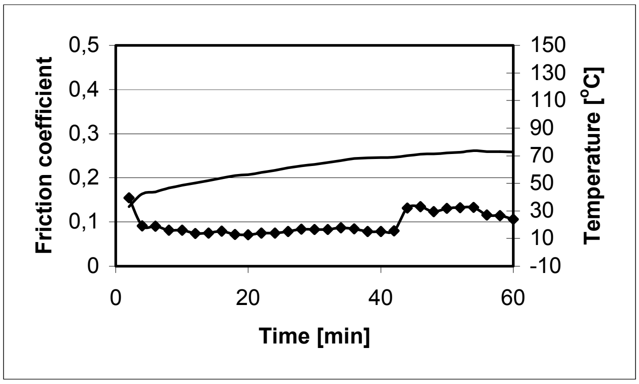


**Fig. 3.** Friction coefficient and temperature versus time, under 1000 N load, for lithium grease

For pure lithium grease (Fig. 3 – 5), under 1000 N load, friction coefficient increases from 0.07 to 0.13. For 2000 N and for 3000 N one can state that friction coefficient is constant, equal about 0.09. Under 4000 N load seizure occurred.

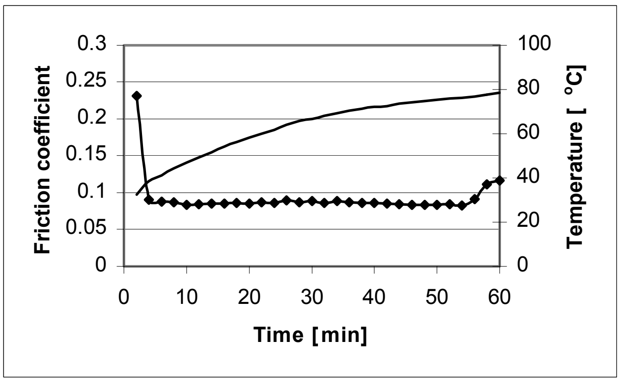


**Fig. 4.** Friction coefficient and temperature versus time, under 2000 N load, for lithium grease

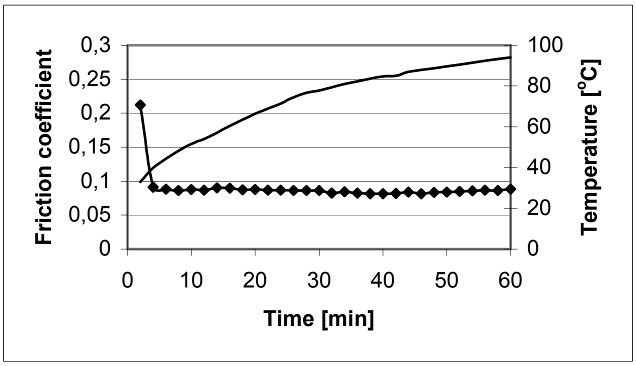


**Fig. 5.** Friction coefficient and temperature versus time, under 3000 N load, for lithium grease

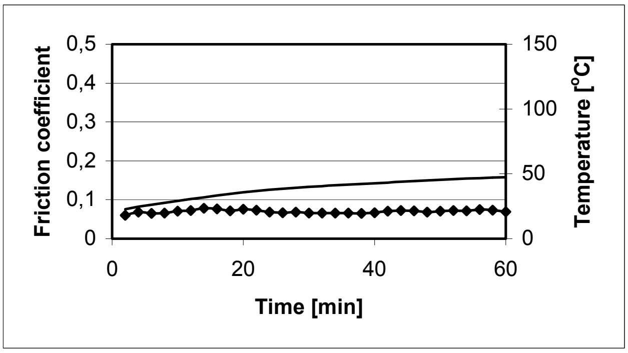


**Fig. 6.** Friction coefficient and temperature versus time, under 1000 N load, for lithium grease with 8-hydroxyquinoline as additive

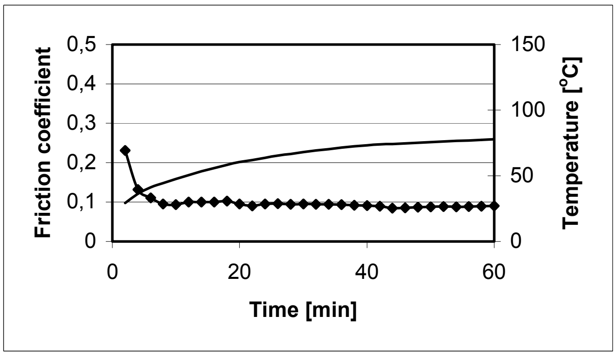


**Fig. 7.** Friction coefficient and temperature versus time under 2000 N load, for lithium grease with 8-hydroxyquinoline as additive

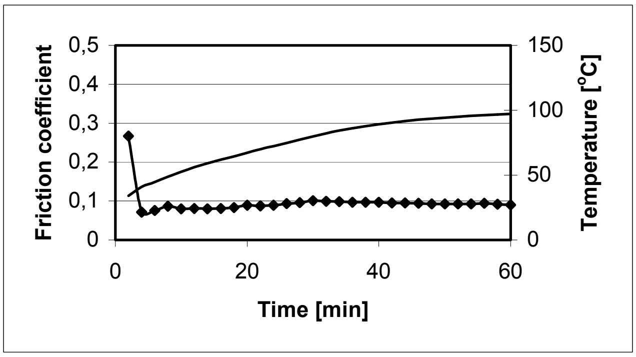


**Fig. 8.** Friction coefficient and temperature versus time, under 3000 N load, for lithium grease with 8-hydroxyquinoline as additive

For the mixture of 8-hydroxyquinoline and lithium grease no significant changes of friction coefficient were observed (Figs. 6 – 8). Under 1000 N load friction coefficient is almost constant, equal to 0.07, while under 2000 N and 3000 N it equals 0.1. Also in this case, under 4000 N, seizure occurred.

For the copper complex (Figs. 9 – 12) decrease of friction coefficient was observed. The friction coefficient, for the specified loads, is, respectively: 1000 N – 0.05, 2000 N – 0.08, 3000 N – 0.08, 4000 N – 0.08. At 5000 N seizure occurred.

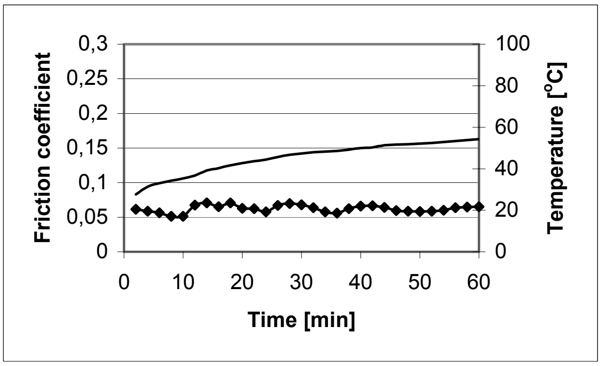


**Fig. 9.** Friction coefficient and temperature versus time, under 1000 N load, for grease with the complex of copper as additive

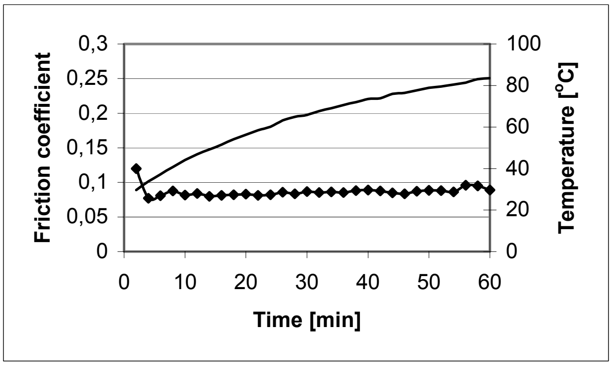


**Fig. 10.** Friction coefficient and temperature versus time, under 2000 N load, for grease with the complex of copper as additive

Dependence of friction coefficient on time for manganese and zinc complexes is similar, so it is not presented.

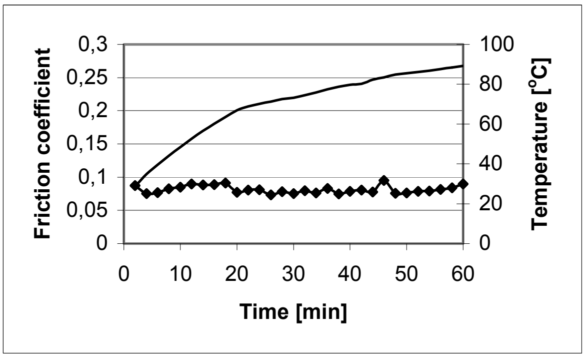


**Fig. 11.** Friction coefficient and temperature versus time, under 3000 N load, for grease with the complex of copper as additive

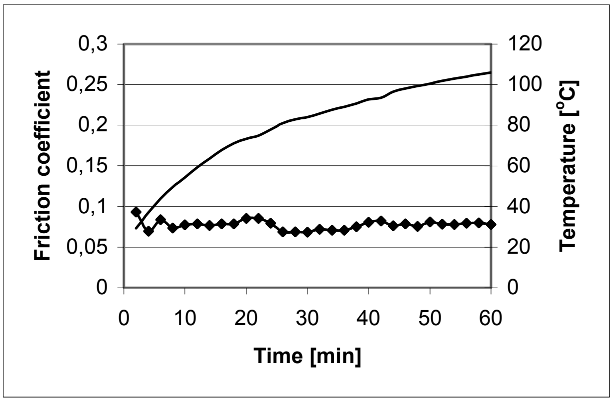


**Fig. 12.** Friction coefficient and temperature versus time, under 4000 N load, for grease with the complex of copper as additive

Motion resistance for all the investigated compositions does not depend on time. It was confirmed by 3-hours test. The averaged values of friction coefficient for the tested compositions are presented in Fig. 13.

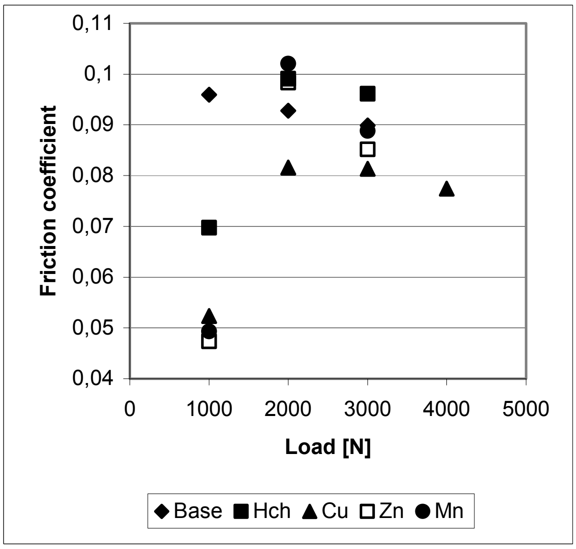


**Fig. 13.** Average friction coefficient vs. load for all lubricants. Notation: base – lithium grease, Hch – base with 8-hydroxyquinoline, Cu – base with copper complex, Zn – base with zinc complex, Mn – base with manganese complex

The additional parameter, which can be used to the results interpretation, is temperature. In all the investigated cases increment of temperature was noticed. As the start temperature was always the same (24 °C) and friction duration was always 1 hour, one can introduce one more parameter characterizing the results, that is, temperature at the end of each test (Table 1).

After each one-hour test wear scar diameter was measured. The averaged results of at least 3 measurements are presented in Table 2 and in Fig. 14.

For all tested lubricants wear increase goes with load increase. The highest values of wear scar diameters were obtained for pure grease and for grease with 8-hydroxyquinoline, for all applied loads. Addition of organo-metallic complex most effectively reduces wear. Under 1000 N load, for all compositions, the results are

**Table 1.** Temperature at the end of the test. Base – lithium grease, Hch – base with 8-hydroxyquinoline, Cu – base with copper complex, Zn – base with zinc complex, Mn – base with manganese complex

| Lubricant | Temperature [$^{o}$C] | | | |
|---|---|---|---|---|
| | 1000 N | 2000 N | 3000 N | 4000 N |
| Base | 72 | 78 | 94 | – |
| Hch | 47 | 77 | 97 | – |
| Cu | 45 | 73 | 89 | 106 |
| Mn | 41 | 76 | 92 | – |
| Zn | 44 | 80 | 92 | – |

**Table 2.** Wear scar diameter vs. load for all lubricants. Base – lithium grease, Hch – base with 8-hydroxyquinoline, Cu – base with copper complex, Zn – base with zinc complex, Mn – base with manganese complex

| Lubricant | Wear scar diameter [mm] | | | |
|---|---|---|---|---|
| | 1000 N | 2000 N | 3000 N | 4000 N |
| Base | 0.9 | 2.5 | 2.9 | – |
| Hch | 0.8 | 2.9 | 4.0 | – |
| Cu | 0.9 | 1.4 | 2.25 | 2.7 |
| Mn | 0.7 | 2.5 | 3.5 | – |
| Zn | 0.8 | 2.8 | 3.5 | – |

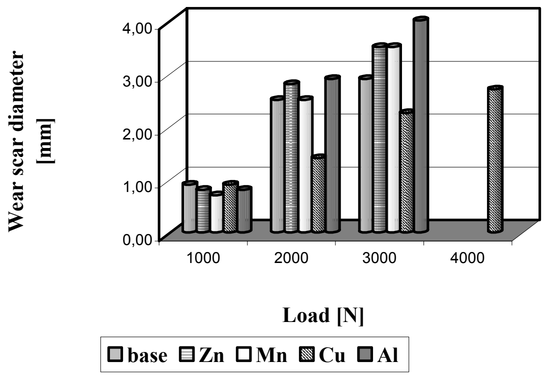


**Fig. 14.** Wear scar diameter vs. load for all lubricants. Base – lithium grease, Hch – base with 8-hydroxyquinoline, Cu – base with copper complex, Zn – base with zinc complex, Mn – base with manganese complex

comparable. For higher loads, however, this cannot be said. Under 2000 N complex of copper becomes the most effective anti-wear additive, while under 3000 N the difference in effectiveness becomes even more significant. For 4000 N load, tests could be performed only for lithium grease with copper complex. Wear, in this case, increased up to 2.7 mm.

Increasing of test duration to 3 hours did not change, for the copper complex (1000 N – 0.9 mm, 2000 N – 1.7 mm, 3000 N – 2.5 mm), wear scar diameter. One could even say that the measured quantity is, in limit of error, the same.

## 3. CONCLUSIONS

In this work copper, zinc and manganese 8-hydroxyquinolinates were used as lubricant additives. On the basis of the obtained results one can say that these additives significantly decrease movement resistance and wear. They also have very good antiseizure properties. The most important advantage of applying these compounds as lubricant additives is their destruction in the friction couple and creation of the metal layer which has a significant influence on motion resistance and wear reduction. The thin metal layer produced in this way is more durable than the one created, for instance, by electroplating, because presence of the organo-metallic compound in the friction couple guarantees its continuous renewing.

The probable mechanism of action of these compounds consists in creation of a tribofilm on the friction couple, as the result of chemical and physicochemical decomposition. The metal ions, arisen in the process of decomposition, react with active metal surface and cover the surface, especially in the areas of highest pressure.

The metal deposited on the surface is not strongly connected to the foundation and can be distributed over the whole surface, which results in improvement of the surface's properties.

Further research will be done to explain the mechanism of action of organo-metallic compounds in friction zone. Tests of composition of the outer layer of friction couple will be performed. Products of decomposition of the applied additives will be investigated.


### *Acknowledgements*

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### REFERENCES


1. **Zhang, J., Liu, W., Xue, Q., Wang, Q.** Investigation of the Friction and Wear Behaviours of Cu (I) and Cu (II) Dioctylditiophosphates as Additives in Liquid Paraffin *Wear* 216 1998: pp. 35 – 40.
2. **Sułek, M. W.** Tribological Properties of Organometallic Compounds in Glycerine *Tribologie und Schmirungstechnik* 4 1996: pp. 248 – 254 (in German).
3. **Sułek, M. W., Fąfara, Z., Karbownik, M., Wendt, U., Urbański, A.** Metabolism of Organometallic Compounds in the Friction Zone Tribologia 4 1995 pp. 383 – 390 (in Polish).
4. **Sułek, M., Kajdas, Cz.** The Influence of Organometallic Additives on Tribological Properties *Proceedings of III Symposium Intertribo'87* (in Polish).
5. **Lian,Y., Yu, L., Xue, Q.** The Anti-wear and Extreme Pressure Properties of Some Oil-water Soluble Rare Earth Complexes. Part 1: Their Tribological Behaviours in Water *Wear* 196 1996: pp. 188 – 192.
6. **Lian, Y., Yu, L., Xue, Q.** The Anti-wear and Extreme Pressure Properties of Some Oil-water Soluble Rare Earth Complexes. Part 2: Their Tribological Behaviours in Liquid Paraffin *Wear* 196 1996: pp. 193 – 196.

7. **Boshui, C., Junxiu, D., Guoxu, C.** Tribochemistry of Gadolinium Dialkylditiophosphate *Wear* 196 1996 pp. 16 – 20.

8. **Yu, L., Lian, Y., Xue, Q.** The Tribological Behaviours of Some Rare Earth Complexes as Lubricating Additives. Part 1: An Investigation of the Friction-reducing Behaviours and an XPS Study of the Tribochemical Characteristics *Wear* 214 1998: pp. 47 – 53.

9. **Yu, L., Lian, Y., Xue, Q.** The Tribological Behaviours of Some Rare Earth Complexes as Lubricating Additives. Part 2: The Anti-wear and Extreme Pressure Properties in Lithium Grease *Wear* 214 1998: pp. 151 – 155.

10. **Yu, L., Nie, M., Lian, Y.** The Tribological Behaviour and Application of Rare Earth Lubricants *Wear* 197 1996: pp. 206 – 210.

11. **Liu, W., Zhang, Z., Xue, Q.** Tribological Properties of Rare Earth Compounds/complexes as Anti-wear Additives in Lubricating Oils or Grease *Tribologia* 165 1999: pp. 257 – 271.

12. **Bocho-Janiszewska, A., Sułek, M. W.** Influence of 8-hydroxyquinoline Complexes with Metals as Lubricant Additives on Friction Process *Proceedings of the Third International Symposium on Tribology*, Kraków, 2001.

13. **Sułek. M. W., Bocho-Janiszewska, A.** Antiseizure Properties of Cadmium, Cobalt and Lead 8-hydroxyquinolinates in Lithium Grease *International Journal of Applied Mechanics and Engineering* 7 2002: pp. 177 – 182.

14. **Sułek, M. W., Bocho-Janiszewska, A.** Antiseizure Properties of Copper, Zinc and Manganese 8-hydroxyquinolinates in Lithium Grease *Tribologia* 2 2002: pp. 79 – 85.