

## THE INFLUENCE OF OIL QUALITY ON TRIBOCORROSION OF STEELS

H. Vermeşan, Dorina Jichişan Maticşan, G. Vermeşan, G. Negrea

Technical University of Cluj-Napoca

**ABSTRACT:** The first part of the paper presents the significance and importance of the tribocorrosion concept as well as some theoretical considerations related to the oxidation mechanism of hydrocarbons. The second part of the paper presents the experimental results obtained by using three oil types in a friction couple with the aim of assessing their influence on tribocorrosion processes. Experimental results showed that the lower the oxidation stability of the oil and the higher the temperature, the higher the degree of damage produced to the samples by tribocorrosion.

**KEYWORDS:** Corrosion, Tribocorrosion, Wear-corrosion

### 1. INTRODUCTION

The process of tribocorrosion implies simultaneous and interrelated action of both, chemical and mechanical factors in friction couples, in the presence of aggressive agents, aged lubricants or oils with inadequate additives. Within the frame of tribocorrosion, the following forms can be evidenced: stress corrosion, fatigue corrosion and tribochemical corrosion. In the case of stress corrosion, the protective layer is destroyed as a result of static mechanical stresses and therefore the corrosion process is intensified. Fatigue corrosion is the process of acceleration of fatigue caused by cyclic loading in the presence of a chemically active medium. The tribochemical corrosion is a consequence of the stresses caused by friction forces which make it possible or accelerate the chemical reactions between the friction surface of the material and the medium in which it works. It should be mentioned that mechanical forces do not initiate chemical reactions, but they generate modifications on the surface or to the internal structure of the material which then become favouring factors for chemical reactions.

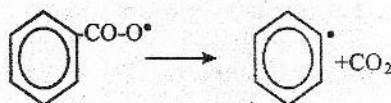
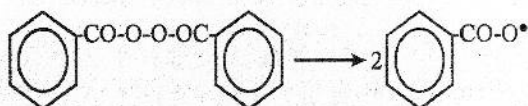
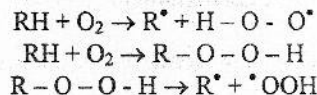
The corrosion process produce surface modifications by increasing the surface roughness, changing the chemical composition, selective dissolution of the components, accumulation of corrosion products etc.

The presence of oil in friction couples creates lubricant-metal interactions which may have favourable effects, such as the formation of tribo-chemical layers with protective and lubrication role, and also negative effects such as formation of deposits, corrosion effects and wear [1,2,3]. Insufficient refining, ageing products, chemical additives with opposite effects generate chemical reactions with the friction surfaces. Tribochemical reactions also have a negative effect on the stability of the lubricants and therefore their ageing rate increases during functioning time, depending on temperature and catalytic effects of the particles resulted from wear (Fe, Cu etc.). The presence of water increases the rate of corrosion wear under tribochemical conditions. In this context, the paper aims to present the influence of oil quality on the surface damage by tribocorrosion.

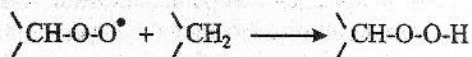
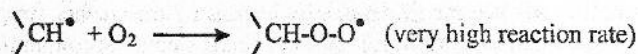
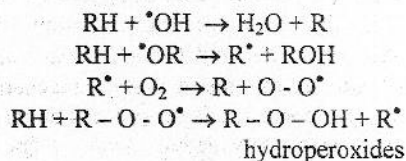
## 2. THEORETICAL CONSIDERATIONS

The most frequently used mineral oils are composed by a mixture of paraffinic, naphthenic and aromatic hydrocarbons with large molecular masses and very small amounts of unwanted sulphur, nitrogen and oxygen compounds.

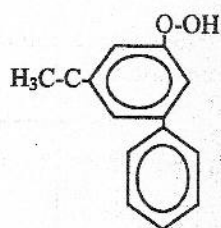
Oxidation of hydrocarbons (RH) from oils takes place through a radicalic mechanism, with radicals and free atoms, by reactions which pass through initiation, propagation, slowing down and interruption stages. In the initiation period, radicals, hydroperoxides and peroxides are formed.



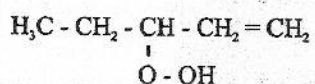
Free radicals extract a hydrogen atom from the most reactive group of  $-\text{OH}$ , or  $\text{>CH}_2$ , leading to the propagation of oxidation reaction and formation of oxygenated compounds and water.



Aromatic hydrocarbons with lateral catenary are oxidised easier than paraffinic hydrocarbons and naphthenes.



aromatic hydroperoxide



aliphatic hydroperoxide

Hydroperoxides react with the metallic surface which has a reduction role (the reaction is catalysed by some metals such as Fe, Pb, Cu) and forms resins, esters, aldehydes, ketone and acids with a corrosive action on the metal.

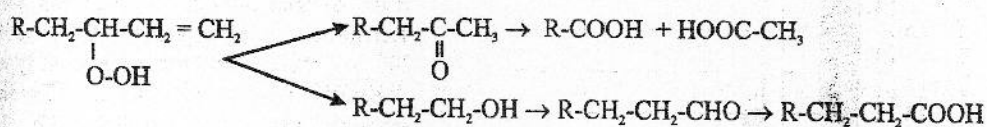
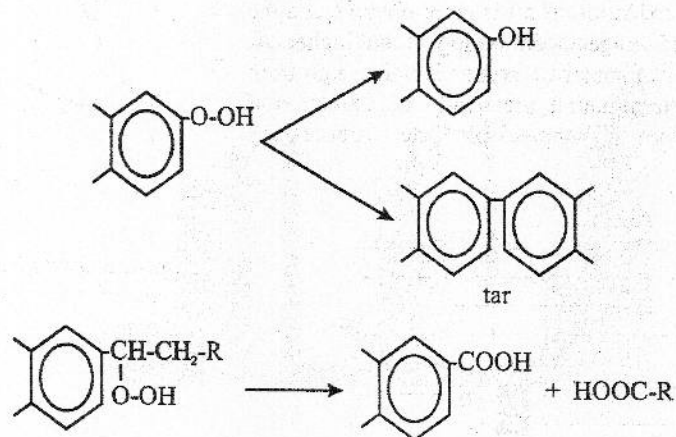


Table 1 shows the oxidation stability of a mineral oil in the presence of some metallic catalysts.

Table 1. The catalytic effect of metals on the oxidation rate of mineral oils.

Metal	Oxidation stability [mgO <sub>2</sub> abs. / 1 g oil]
Fe	11,3
Cu	9,3
Pb	8,6
Al	3,5
Ni	3,0

### 3. EXPERIMENTAL RESEARCH

The experiments were performed using three mineral oil types: paraffinic, naphthenic and aromatic. The friction couple consisted of two flat surfaces (OLC 45 steel grade) with linear relative motion.

The degradation of the oil and the action of degradation products on the metal surface have been investigated under friction conditions at the following temperatures: 100, 150, 200 and 250 °C.

The oxidation stability of the oil was estimated by measuring the quantity of oxygen consumed in the reaction of oil oxidation.

The diagram shows that at a temperature of 50 °C, the oil from the friction couple presents a rather long initiation period, of about 40 h hours, in which the oil is stable to oxidation, the quantity of absorbed oxygen being small. After 40 hours the oxidation of oil is more obvious and the quantity of absorbed oxygen becomes higher and higher. At 100 °C, the quantity of absorbed oxygen is rather high from the beginning of determination, practically, the oxidation of oil takes place with an appreciable rate without any initiation period.

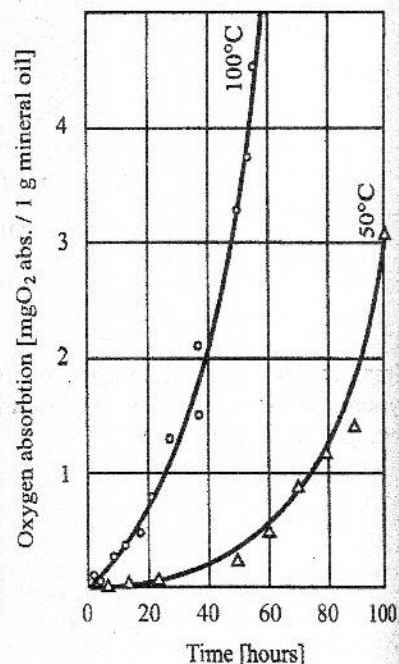


Figure 1 Oxidation stability of a mineral oil with substituted catenary.

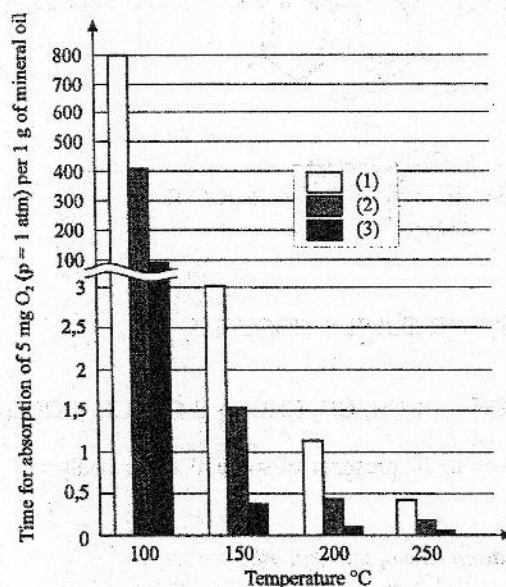


Figure 2. Time [min] for absorption of 5 mg O<sub>2</sub> (P = 1 atm) per 1 g of mineral oil at temperatures of 100, 150, 200 and 250 °C.

shortest for the aromatic oils (3). Absorption time is a measure of oil stability to oxidation. In conclusion, the oil stability to oxidation decreases in the following order: paraffinic > naphthenic > aromatic.

The time required for the absorption of a given oxygen quantity (5 mg) has been determined at temperatures of 100, 150, 200 and 250 °C for three mineral oil types - paraffinic (1), naphthenic (2) and aromatic (3) - in parallel with the evaluation of the tribocorrosion of the friction couple, fig. 2 and 3.

It can be seen from figure 2 that for all investigation temperatures, the paraffinic oils (1) showed the longest absorption time for a given oxygen quantity per one gram of oil. The absorption time decreases for naphthenic oils (2) and is

The effect of temperature on the oxidation rate of oils starts to play a role above 50 °C and becomes considerable above 150 °C as it can be seen in figure 2 and table 2.

Table 2. The influence of temperature on oxidation stability of a mineral oil.

Oil types with different resistance to oxidation	Time in minutes required for 1 g of oil to absorb 5 mg of oxygen at atmospheric pressure			
	100°C	150°C	200°C	250°C
Paraffinic oil (1)	48.000	180	55	23
Naphthenic oil (2)	24.000	95	25	9
Aromatic oil (3)	4.980	20	5	2

At higher thermal regimes (above 200 °C), the oxidation products (alkalis, aldehydes, ketones, acids) participate at polymerization and polycondensation reactions, forming resin deposits on the metal surfaces.

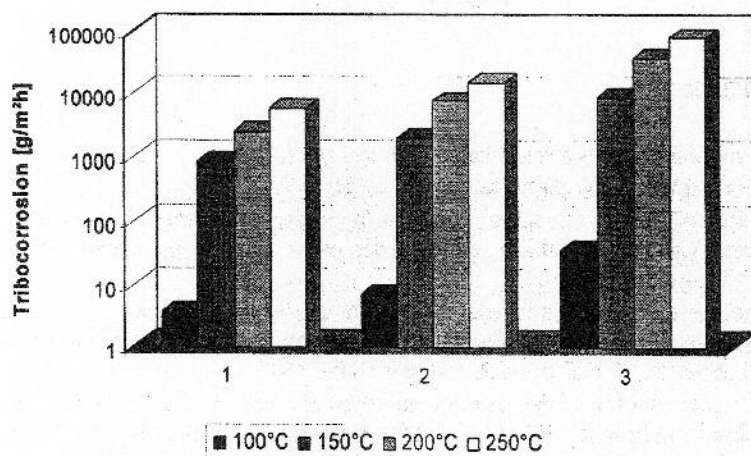


Figure 3. Tribocorrosion of metal in the presence of a mineral oil at 100, 150, 200 and 250 °C.

Tribocorrosion of metallic surfaces which represent the friction couple is presented in figure 3. The lower the oxidation stability of the mineral oil used (figure 2) the higher the damage produced to the metal by tribocorrosion (fig. 3). The raise of the temperature favours the degradation of the oil by oxidation (fig. 2) and leads to increased corrosion wear in the friction couple (fig. 3).

Tribocorrosion wear has a discontinuous character; it is initiated by the concentration of large energy quantities on the contact microzones or by accumulations of electrostatic potential which are statistically distributed over the friction surface. The wear of the friction couple as a function of time for aromatic oils with lateral substituted catenary is presented in figure 4. As seen in figure 4, the tribochemical phenomena accelerate the removal of material from the metallic surface ((1) - wear and corrosion in the same time) as compared to the case of corrosion without friction (2).

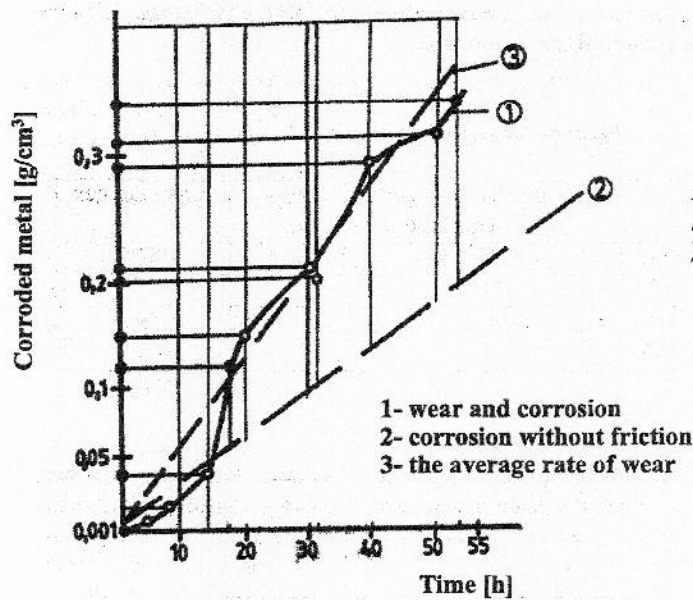


Figure 4. Tribocorrosion wear vs. time for aromatic oils with lateral substituted catenary

#### 4. CONCLUSIONS

- The tribocorrosion presents a remarkable practical interest due to its unfavourable consequences which, from economic view point, can not be neglected.
- The lower the stability of the oil to oxidation the higher the damage produced to the metal by tribocorrosion. Oxidation stability of oils decreases in the following sense: paraffinic > naphthenic > aromatic.
- The temperature raise favours the degradation of oil by oxidation and this leads to increased corrosion wear in the friction couple. The effect of temperature on the oxidation rate of oils can be observed above 50 °C and is much stronger above 150 °C.
- A thorough understanding of the phenomenon requires further investigations in order to create a databank which to allow the formulation of a mathematical model capable to predict the wear rate or the oxidation rate in the context of multiple influences on the process.
- The aspects outlined in the paper are also useful for designers, at the stage of oil, additive or metal selection for friction couples, in order to limit the damage produced by tribocorrosion.

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