STUDIES REGARDING THE WEAR OF THE TOOLS USED IN RUBBER REFINEMENT

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Abstract: *The paper presents the results obtained in the study of tools wear that occurs when used in the refining of rubber and solutions to reduce the level of the wear. Thus the wear that occurs in this type of tool is a dimensional one, but also one of corrosion cracking which results in a rapid removal of this type of tool from use.*

Key words: tools, wear, rubber, refinement

1. Introduction

Most machine parts that have a functional role are taken out of service due to wear of the contact surfaces in relative motion (friction). For this reason, knowledge and choice of materials resistant to wear, respectively the design of numerous items of machinery and plant construction based on the wear resistance condition has great significance [1,2].

In order to analyze the wear of the tools used in grinding scrap rubber we must first of all establish the reasons why it occurs. Wear which appears in tools used in the refining process of scrap rubber is due to the dry rolling phenomena that occur between a metal and a nonmetal [3]. The evolution in time of wear for any friction hitch comprises three distinct stages (fig. 1). This development is also valid for a friction coupling which consists of a metal and rubber.

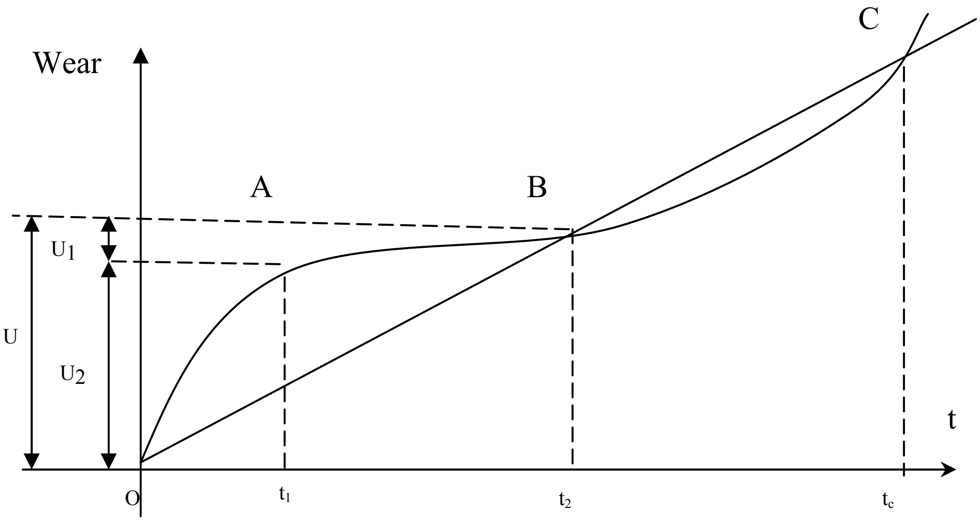


Fig. 1. *The evolution of wear in time.*

From the previous figure we can distinguish three areas:

1. $0 - t_1$ – the burn-in period, in which the wears grow rapidly until they are stabilized at normal work values.
2. $t_1 - t_2$ - the curve has an almost linear character, the development of wear is proportional to operating time.
3. $t_2 - t_c$ - the rapid growth tendency of wear.

U - the maximum value of wear allowed in service;

U_2 - the value of wear corresponding to the burn-in period;

U_1 - the value of normal wear in service.

Because the curve U is uncomfortable, in the calculations we use the line 0C, defined by the equation : U=k • t

$$k = tg\,\alpha = \frac{U_2}{t_2};\ k = tg\,\alpha = \frac{U - U_1}{t_c - t_1}$$

where:

k is an angular coefficient dependent on the type of construction of the part, the type of usage, maintenance, etc.

tgα – wear intensity, specific to every part;

t_2 – normal operating time of the part;

t_1 – burn-in period;

t_c – maximum operating time (not advisable to be achieved for machines which must meet special operating conditions).

To conclude, if α is low, t will be higher, and if t_2 is high, the wear after the burn-in U_2, has a low value, and the normal operating time will increase.

Burn-in wear is necessary in order to achieve the functional games between the parts and is controlled during the burn-in-period. Normal operating wear is almost constant for a long period of time and determines the lifetime of the tool. Accelerated wear prevents the normal operation of the subassembly and determines the disposal of tools. Rolling friction between the tools (rolls) and rubber causes the following types of wear: dimensional wear and the wear type cracking corrosion.

Dimensional wear is characterized by the fact that during the grinding process of the rubber, some of the material mass of the tool is lost resulting in a reduction in size. This dimensional wear process can be compensated by modifying the distance between the cylinders. In most cases dimensional wear also determines a geometry change in the cylinders [4,5]. Because the geometry of the cylinders changes the distance between the tools will be adjusted only after having first restored their geometry. Along with the recovery of the cylinder geometry, a considerable amount of material will be removed, which causes a reduction in the size of the cylinder with a much higher value than the size of their wear. This process of recovering the geometry can be done several times, but bear in mind that it should not exceed a dimension reduction of the tools in the radial direction more than 20 mm. Preponderant influence on the size of the dimensional wear have the efforts that accompany the process of refining rubber.

The process of normal dimensional wear may be replaced by a process of a very violent nature, but only for a short period of time, when an abrasive material is present between moving elements (metal inserts, rigid bodies of various materials). The characteristics of the material the tools are made of have a great deal of influence on the size of dimensional wear, but also of the material submitted to refinement. Appropriate choice of chemical composition, degree of alloying and heat treatment for the materials the tools are made of can have a favorable effect on increasing the wear resistance.

Wear of the type corrosion cracking is of great importance because its occurrence leads to cracking of the tools and taking them out of use before the scheduled date.

For a practitioner, knowledge of the susceptibility of materials to corrosion cracking has a special significance in terms of optimal design, ie the ratio of the mechanical charge, material consumption, investment costs, operation and maintenance, other influences (environment, human factors etc.). Traditionally in most cases, as a parameter for the susceptibility to corrosion cracking still serves the so-called durability of the appointed material, in an aggressive environment, in circumstances of ongoing mechanical stress.

2. Experimental research

With technological exploitation, tear or rupture disposals are due, in their vast majority, to the extension of the size of a crack type defect as a result of corrosion, respectively the action of an aggressive environment, the effect of cyclical variability in the intensity of mechanical stress (fatigue, etc..). This phenomenon is specific especially for lacerations which occur for low intensity mechanical stresses, without prior global deformation of the element affected (cracked).

The tear by cracking corrosion goes through the following three stages:

- stage 1 – the formation of primers, like light sticking points (fig. 2, a) on the metal surface;

- stage 2 – the primer becomes a crack (fig. 2, b) whose size continues to slowly extend from a macroscopic point of view;

- stage 3 – tear (fig. 2, c) when the crack, by expanding, reaches a certain size (length), big enough, called critical.

The evolution of a crack and the way in which it expands, respectively the way in which it is propagated, depends heavily on the state of the existing efforts in the area where the unit is placed.

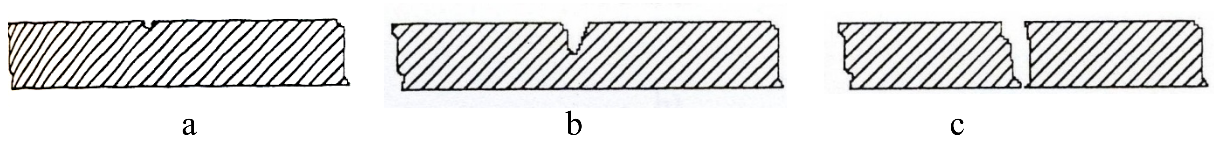
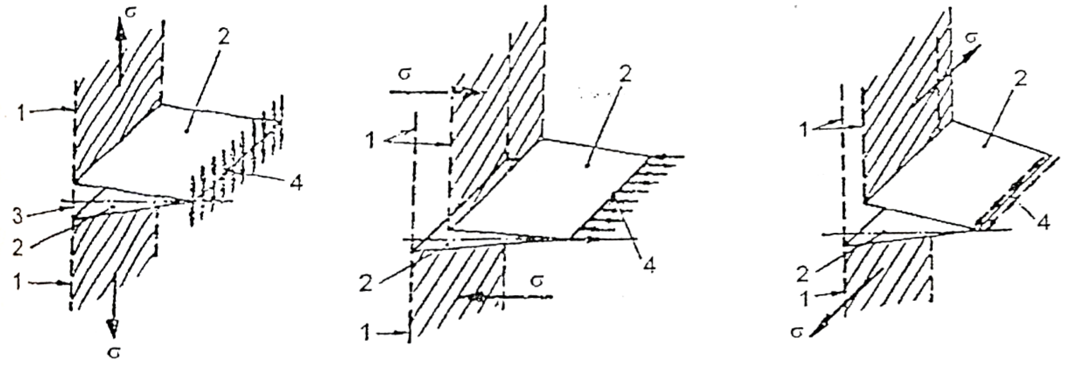


Fig. 2. Stages of corrosive tear: a – formation of primer (stage 1); b – cracking, respectively expansion of the crack, (stage 2); c – tear (stage 3).

The tools used in the refining of waste rubber are submitted cyclically to fatigue, but they also work well in a chemically aggressive environment. The aggressiveness of the environment in which these tools work can be explained by the presence in the chemical composition of the waste rubber of various chemicals (particularly sulfur). These chemical elements, under certain conditions of pressure and temperature, may form some compounds that can be corrosive on metallic materials.

If we take into account the fact that during the shred of the waste there is a random distribution of the efforts, all possibilities of application must be taken into account. Thus, after the relative motion of the fracture surfaces, located on either side of the plane in which the crack extends, change, and hence its propagation can be done in accordance with the following basic modes of travel (Fig. 3).



a b c

Fig. 3. *The fundamental ways of travel, respectively expansion (propagation) of the cracks.*
a – opening the crack (means I); b – the right sliding (means II); c – the curve sliding (means III). 1 – surface attacked by corrosion; 2 – surfaces (flanks) of the crack; 3 – front of the crack; 4 – root (tip of the crack).

means I – the crack is extended by opening, the points belonging to the crack surface shifting normally in the plane of the crack (fig. 3, a);

means II – the crack is extended by right sliding, frontal, the shifting of the points in the cracking surface being done in the plane of the crack, perpendicular to its edge and in the direction of its advancement (fig. 3, b);

means III – the crack is extended by curve sliding, lateral or spiral, the shifting of the points in the cracking surface also being done in the plane of the crack, but parallel to its front. (fig. 3, c).

Obviously, all other possible failure modes can be described by superposition, respectively by the proper combination of the three fundamental ways presented. With the advent of cracks, the unitary efforts σ change in value. The intensity factor of the mechanical tension, named K, is the measure of increase of unified efforts $\sigma_,$ generated by the presence of cracks, compared with the same nominal unit efforts, existing in an item in the absence of cracks. K's values are always over the unit, depending on the geometry of the structure or element or of the system studied and the crack length at one time.

Slow cracking in a corrosive environment can be fully described only by the intensity factor of the voltage, the method is, therefore, based on the K factor. For higher levels of intensity of mechanical stress, there isn't an unequivocal correlation between the K factor and the development speed of corrosion cracking. This correlation does not allow prediction of its future expansion for the cracks detected at one time. This time, the maximum utility only shows the results of the measurements under constant load of the crack extension speed.

For tools used to refine scrap rubber it is very important to avoid from the outset of the execution period the occasional hot spots or inclusions in these materials. The presence of these defects in the material of the tools can still be triggered as the main reasons for crack initiation and therefore corrosion cracking.

Regarding the wear of the type cracking corrosion, it results in the removal of the tools used to refine rubber and in that respect this type of wear should be avoided (Figure 4). The main cause of the occurrence of wear crack is represented by the working environment and conditions for applying the tools.

a.

b.

Fig. 4. *The refining cylinder and the way it breaks due to cracking corrosion*
a – presentation of the refining cylinder, b – cracking wear which occurs for the refining cylinders

3. Conclusions

Following the analysis of the process of rubber refining, a series of changes occur in the material of the used tools and the following conclusions can be drawn:

- the process of refining waste rubber causes both a heat stress and a and a very high mechanical one for the material of the rolling cylinders;
- the wear that appears to tools used in the refining of waste rubber is both a dimensional one and one of cracking corrosion (CORFIS);
- following the use of tools, in their material a series structural changes could be seen, due to thermal effects accompanying the process of refining rubber;
- in the material of spent cylinders a diffusion of sulfur in rubber was observed, but also a reduction of carbon concentration;
- after using cylinders, their material also suffers a loss of hardness and especially in the surface layer in direct contact with waste rubber.

To avoid diffusion phenomena, the structural changes, respectively the loss of toughness, that occur in the material of used cylinders the following measures are proposed:

- performing suitable heat treatments for the material of cylinders;
- using new materials for the cylinders so that they have a better behavior during operation;
- structural changes of the cylinders so that they may be required to make lesser efforts during use;
- optimization of the operating process parameters depending on the characteristics of the materials subjected to refining;
- ultrasonic activation of cylinders at different stages of the refining process.

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