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RESEARCHES ON THE CHEMICAL COMPOSITION AND HARDNESS MODIFICATIONS THAT APPEAR IN THE MATERIAL OF TOOLS USED FOR RUBBER WASTE ATTRITION

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This paper presents the results of the main changes in the chemical composition of the material, and changes in its hardness. The changes in terms of chemical composition refer primarily to changes in concentration of sulfur and carbon, and in terms of hardness material change there can be noticed a decrease in hardness of the material that is in direct contact with waste rubber.

Key words: tools, chemical composition, hardness, rubber waste, attrition

INTRODUCTION

Lately, materials researchers have gathered experimental information regarding the laws of plastic deformation, diffusion and mass exchange between the separation surfaces of certain microvolumes, enabling them to draw several principles related to the choice of the friction couples. In order to do this, they had to consider all geometrical, economical, technological, construction, and exploitation requirements imposed on materials. Special attention is required when considering the stress conditions on the rubbing aggregates (velocity, pressure, temperature) and the characteristics of the environment [1-3].

A similar situation can occur in the case of the tools used to shred rubber waste, when intense friction occurs between the waste and the material that was used in order to make the tool, under high pressure and temperature. Changes in the characteristics of the tool can also be triggered by the friction between two materials not sharing the same characteristics [4-5].

The tools that are used in order to shred rubber waste are striated cylinders, endowed with helicoid kennels, Figure 1. The cylinders are designed to be cooled in accordance with the requirements of the technological process [6].

Cylinders are generally obtained by molding, and the cylinder pane is placed inside a metallic chilling mould, in order for its quick chill to provide for a high-hardness superficial layer.

The tools that are used in order to shred rubber waste cyclically stressed by weariness, but, at the same time, they are used within a chemically aggressive environment. The aggressiveness of the working environment can be accounted for by the presence of various chemical elements (especially sulfur) in the chemical composition of rubber waste. Under certain pressure and temperature conditions, these chemical elements may generate certain corrosive compounds altering the metallic materials [7].

Figure 1 Striated cylinder tool used to shred rubber waste

Taking into account the fact that during the process of shredding waste there is a random effort distribution, we must consider any stress on the tools and any phenomena such as diffusion that may alter the inside or the outside of the material that was used in order to make the respective tool.

ANALYSIS OF THE CHEMICAL COMPOSITION MODIFICATIONS

The main material that is used in order to make the rubber waste shredding tools is the cast iron. Cast iron contains graphite and can be divided into the following types, according to its basic mass and to the proportion

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of the constituting material: iron-based, pearlite-based or iron/pearlite-based. According to its shape, size and distribution, cast iron can be divided into the following types: lamellar, worm-shaped, nest-shaped, spheroidal graphite, etc.

Rubber waste shredding tools have lately been made of carefully elaborated cast iron preferably containing neither sulfur nor phosphorus. A recommended material, containing neither sulfur nor phosphorus, is wooden coal (charcoal). They are obtained by top casting.

The chemical composition of the most frequent types of cast iron used in making cylinders is given in Table 1.

Table 1 **Chemical composition of the cast iron used to make the tools /%**

Board hardness BH	C/ %	Si/ %	Mn/ %	S+P max/ %
330-340	3-3,75	0,7-0,8	0,5-0,7	0,05

Preliminary researches on used rubber waste shredding tools have indicated an increase in the amount of sulfur, and a decrease in the amount of carbon.

These diffusion phenomena can be accounted for by the complexity of the physical and chemical processes which occur in the shredding of rubber waste. Both the increase in sulfur and the decrease in carbon in the tools material have got negative effects on their reliability in use.

In order to analyze the behavior of the tools materials concerning the diffusion of the two chemical elements (S and C) we drew two samples of the two parts of the broken tool (Figure 2), and analyzed the 1st and the 4th sample.

The device we used in order to perform the semi-quantitative chemical analysis was a German T.P. 1-02 SEPTOTRON of 0,001/ % accuracy.

In order to perform a conclusive analysis of the chemical composition we need to know the influence of each chemical element on the properties of the tools material. Because of the fact that preliminary research have shown modifications in the amounts of carbon and sulfur alone, we only performed an analysis of the effects of these two chemical elements, as follows:

- Carbon – the main alloying element. By the increase in its amount, there will be an increase in its resistance and hardness, and a decrease in its elongation, ductility, weldability and cutting workability. Its resistance to water, acid and hot gases corrosion is not influenced by the amount of carbon.

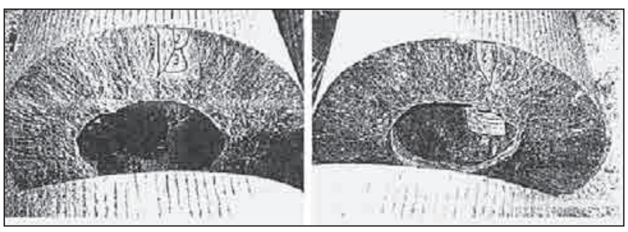

Figure 2 Worn tool and sampling areas

- Sulfur – noxious element, able to cause intense segregation and to make materials become breakable at high temperatures. The usual admissible content is 0,025 – 0,030 / %.

In order to perform the analysis of the chemical composition of the tools material we also needed to determine the chemical compositions of the materials in both the new and the shredding tools. This analysis is important because there is the possibility of damaging chemical elements building during the rubber waste shredding process, thus influencing their characteristics in a negative way. Table 2 shows the results of the analysis of the material in the new and in the shredding tool.

Table 2 **Chemical composition of the cast iron in the new and in the shredding tool /%**

Chem. comp.	C/ %	Mn/ %	Cr/ %	Ni/ %	Si/ %	S/ %
New tool	2,07	0,08	0,09	0,17	0,4	0,03
shredding tool	2	0,08	0,09	0,01	0,4	0,09

From the chemical analysis of the material in the rubber shredding tools we can notice a decrease in the amount of carbon, as well as a triple increase in the amount of sulfur, which goes well beyond the maximum admissible limit.

Due to the reduction of the amount of carbon, we can perceive a reduction of the hardness and of the mechanical and functional characteristics of the material. The increase in the amount of sulfur determines an intense segregation and a visible breakability at high temperatures. This breakability at high temperatures is very common in the case of rubber waste shredding tools, because their cooling system does not provide proper cooling, especially for the surface layer of the tools.

The existence of segregations determines the appearance of crack fuses, which, along with the mechanical stress on the tools make cracking very quick. These phenomena make the tools be disposed of after a very short while, and in this case there is no possibility of reconditioning then, as in the case of dimensional attrition.

The excessive amount of sulfur in the material of the shredding tool can be accounted for by its diffusion from the shredded rubber waste towards the surface of the tools. Also, sulfur can combine with the hydrogen in the working environment deriving in hydrogen sulfide, a very damaging compound for the structure of the metals.

The experimental analysis we have performed has enabled us to determine the fact that the maximum influence on the diffusion of the sulfur inside the materials is that of the hardness of the waste rubber, because of the fact that, the harder this waste is, the higher the amount of sulfur is.

The analysis of the chemical composition has also revealed a decrease in the amount of carbon. This has also made us decide to perform another analysis, regarding the evolution of the hardness in the cylinder material.

The experimental analysis we have performed has enabled us to determine the fact that the maximum influence on the diffusion of the carbon inside the materials is that of the hardness of the waste rubber, because of the fact that, the harder this waste is, the higher the amount of carbon is.

THE ANALYSIS OF THE HARDNESS MODIFICATIONS OF THE MATERIALS

The hardness of the materials in the tools is one of the properties that require the most careful examination, especially during their use. A significant decrease in the hardness of the material determines a quick dimensional deterioration and the appearance of cracking corrosion. Based on these considerations, it becomes important to keep the hardness of the material as high and as constant as possible.

The tools material is the gray cast iron on the inside, while white cast iron can be found in the superficial layer. This white cast iron comes from pouring the tools into metallic moulds in order to speed up the chilling of the surface layer and to slow down the chilling of the material inside. As a result of the application of various thermic treatments (chilling + reversion) the material hardness doe not normally exceeds 43-45 HRC. In order to perform the analysis of the modifications in the tool material hardness we used two samples we have taken from each of them (sample no 1 and sample no 4 in Figure 1).

The shape and analysis points for sample 1 are presented in Figure 3, and those for sample 4 are presented in Figure 4.

Several points close to the active part of the tool were used in order to determine the material hardness. This hardness determination method was used in order to prevent any measurement errors and to emphasis as accurately as possible the influence that the working conditions have on the tool material hardness.

The device we used in order to perform this analysis was an Italian NAMICON. This device was needed firstly because of its high accuracy.

Thus the results of the hardness on the 5 analysis points of each sample are shown in Table 3 (sample no 1) and Table 4 (sample no 4).

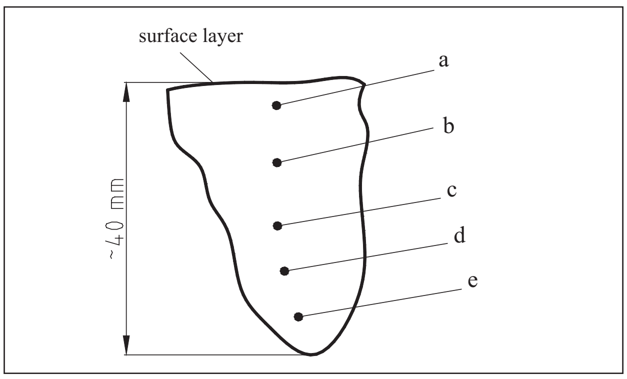

Figure 3 Analysis points for sample no 1.

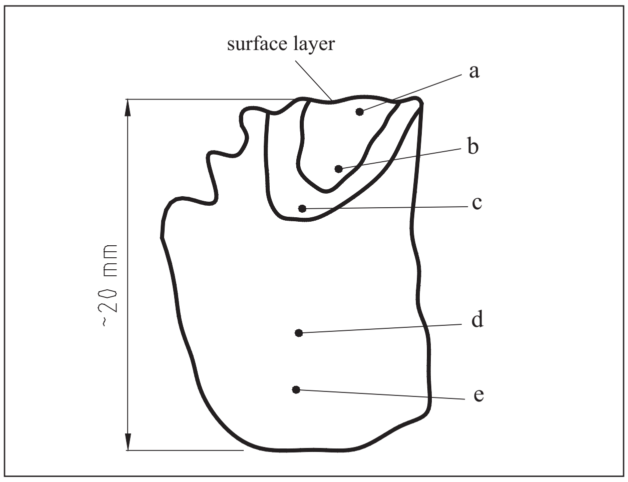

Figure 4 Analysis points for sample no 4

Table 3 **Hardness outputs for the 5 analysis points for sample no 1**

Analysis points	a	b	c	d	e
Measurement depth/ mm	4	6	10	20	30
Hardness / HRC	37	38	43	32	25

Table 4 **Hardness outputs for the 5 analysis points for sample no 4**

Analysis points	a	b	c	d	e
Measurement depth/ mm	2	4	6	12	14
Hardness / HRC	15	17	24	38	37

As for the measurement depth, it refers to the position of the analysis points as related to the surface layer of the shredding tool

The analysis of the material hardness shows a decrease in the hardness of the surface layer, when cylinders are used. This decrease occurs on a 5-10 mm depth, which is proof of the fact that in that area the cylinder material is affected by the various phenomena related to the rubber waste shredding.

At a 15 mm depth we can notice a high output for hardness. This can be accounted for by the fact that at this depth the cylinder material is not affected by any factors that may lead to a hardness decrease.

The hardness decrease can be accounted for by the reduction of the amount of carbon in the surface layer and by structural modifications. Due to these structural modifications of the cylinder material, structural constituents with much lower mechanical properties can appear in the surface layer. The hardness decrease in the surface layer causes a reduction in its strength to dimensional shredding, as well as a faster cracking corrosion.

CONCLUSIONS

After having analyzed the rubber waste shredding process and the modifications that occur in the material of a shredding tool, we have come to the following conclusions:

- the rubber waste shredding process determines a thermic, as well as a mechanic stress on the tool material;

- the attrition of the tools used for shredding rubber waste is both dimensional and cracking corrosion;
- in the case of the tools material we were able to notice a diffusion of the sulfur and a decrease in the amount of carbon;
- after the use of the tools their material also loses its hardness, especially in the contact area between the surface layer and the rubber waste.

In order to prevent diffusion and the hardness decrease in shredding tools, we suggest the following measures:

- proper thermic treatments of the tool material;
- the use of new tool materials which perform better when used, in order to avoid diffusion and hardness;
- constructive and geometrical modifications of the tools to put them to lower pressure during their use;
- improvement of the technological functional features according to the characteristics of the shredded materials.

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Note: The responsible translator for English language is S.C. PURTRAD S.R.L., Targu Jiu, Romania